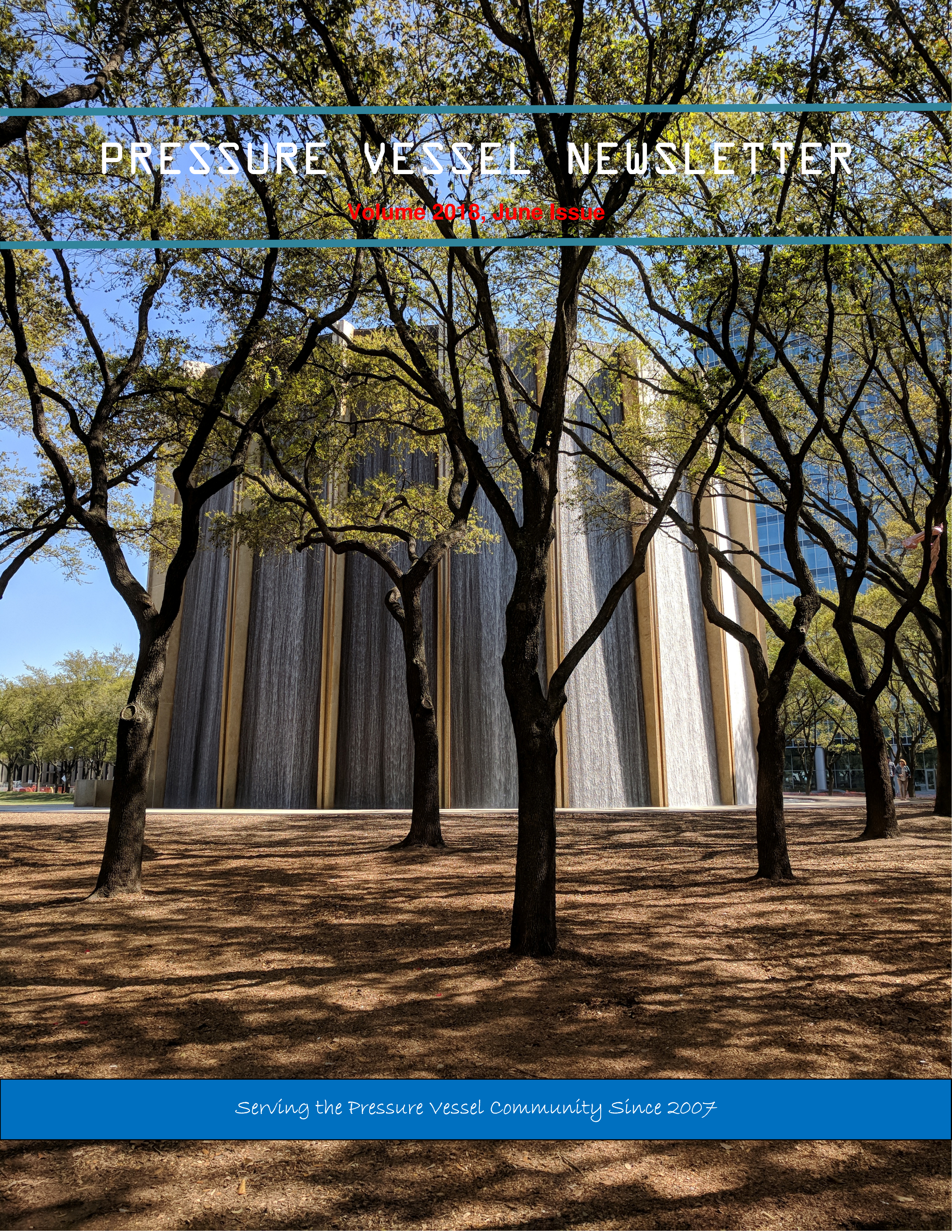
PRESSURE VESSEL NEWSLETTER

Volume 2018, June Issue



Serving the Pressure Vessel Community Since 2007

From The Editor's Desk:

Welding is an essential part of operating and maintaining assets in the petroleum and chemical processing industries. While it has many useful applications, the welding process can inadvertently weaken equipment by imparting residual stresses into the material, leading to reduced material properties.

To ensure that the material strength of a part is retained after welding, post weld heat treatment (PWHT) is regularly performed. PWHT can be used to reduce residual stresses, as a method of hardness control, or even to enhance material strength.

If PWHT is performed incorrectly, or neglected altogether, residual stresses can combine with load stresses to exceed a material's design limitations. This can lead to weld failures, higher cracking potential, and increased susceptibility to brittle fracture.

PWHT encompasses many different types of potential treatments; two of the most common types are post heating and stress relieving. In post heating, the material is heated to a certain temperature depending on the type and thickness of the material. It is then held at this temperature for a few hours depending on the thickness of the material. In stress relieving, the material is heated to a specific temperature and then gradually cooled.

Whether or not a material should undergo PWHT depends on several factors, including things like its alloying system or whether it has been subject to heat treatment previously. Certain materials can actually be damaged by PWHT, while others almost always require it.

In general, the higher the carbon content of a material, the more likely it needs PWHT after welding activities have been completed. Similarly, the higher the alloy content and cross-sectional thickness, the more likely that the material will need PWHT.

Ramesh K Tiwari

ramesh.tiwari@codesignengg.com

In this issue…

PRIMER: EXTERNAL FLOATING ROOFS

INTRODUCTION

The floating roof was developed in the 1920's to reduce product evaporation loss that occurred in the vapor space of fuels that were stored in fixed-roof tanks. The floating roof floats on the surface of the liquid product and rises or falls as product is added or withdrawn from the tank. It has not only proved effective for reducing emissions when compared to fixed-roof tanks, but has also helped to reduce the potential for vapor-space explosions that can occur in the fixed-roof tanks. The floating roof has virtually eliminated the possibility of a boilover phenomenon that occurs in fixed-roof tank fires where crude oils are stored. Because of these advantages, the floating roof is now extensively used throughout the industry to store petroleum and petrochemical substances in large quantities.

EPA REQUIREMENTS

When product vapor pressure is greater than 0.5 psia (more in some states) but less than 11.1 psia, the U.S. Environmental Protection Agency (EPA) permits the use of a floating-roof as the primary means of vapor control from the storage tank. Floating-roof tanks are not intended for all products. In general, they are not suitable for applications in which the products have not been stabilized (vapors removed). The goal with all floating-roof tanks is to provide safe, efficient storage of volatile products with minimum vapor loss to the environment.

FIXED ROOF TANKS

Fixed roof tanks are common in production facilities to store hydrocarbons with vapor pressures close to atmospheric pressure. In this use, they are equipped with pressure-vacuum valves and purged with natural gas to eliminate air intake into the vapor space. Product evaporative losses can be high especially when crude is added to the tank and vapors are expelled through the pressure vent valve. Figure 1 shows a fixed roof storage tank.

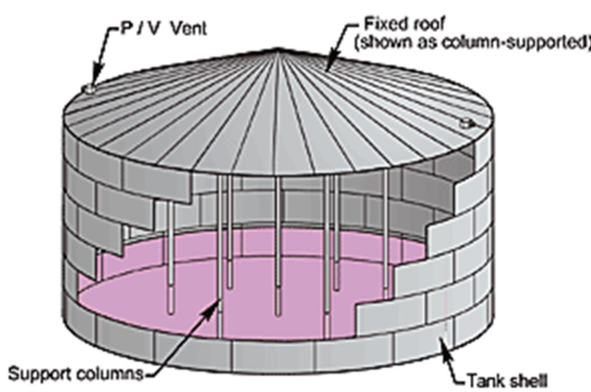


Figure 1: Fixed Roof Tank

EVAPORATIVE EMISSIONS

Evaporative emissions from a fixed-roof tank can be reduced by over 98% through the use of a properly designed and maintained floating roof tank, assuming the same product and ambient conditions.

Evaporative emissions, although greatly reduced, cannot be entirely eliminated. Normal practice is to use floating-roof tanks only to store products that are considered "stabilized" such that large quantities of vapor will not be introduced underneath the floating roof. In cases when the product entering the tank is at a condition that produces flashing conditions, vapors produced will be captured underneath the floating roof. Evaporation and associated product losses still occur from the rim space, standard roof deck fittings, product that remains on the tank shell, and tank operations that require the tank to be emptied and the floating roof landed on its supports.

FLOATING ROOFS

Floating roof tanks cost more to construct than fixed roof tanks for the same storage capacity. The floating roofs can be either external (i.e., with open top) or internal (i.e., inside fixed roof tanks). In general, the floating roof covers the entire liquid surface except for a small perimeter rim space. Under normal floating conditions, the roof floats essentially flat and is centered within the tank shell. There should be no vapor space underneath a welded-steel floating roof. Under normal conditions, the amount of product vapor that might become trapped beneath the floating roof should be insignificant. However, if large quantities of flash vapor or other noncondensable vapors become trapped, the floatation stability of the roof can be affected. These conditions should be avoided if possible.

It is important to understand how a floating roof works and why details are so important in the design of a floating-roof storage tank. The study of evaporative emissions from storage tanks and possible methods to control or eliminate these emissions has been the focus of an extensive series of analytical studies, field, and laboratory testing programs sponsored by the American Petroleum Institute.

EXTERNAL FLOATING ROOFS

Appendix C to API 650 covers the design of external floating roofs, but it recognizes that the design can involve many variations and proprietary details to which the designer and the purchaser must agree. Therefore, only minimum requirements are given that directly affect safety and durability. It is important for the purchaser of a tank with an external floating roof to provide the designer with supplementary requirements that are needed for the service conditions and operating procedures. See Figure 2 for external floating roof tank.

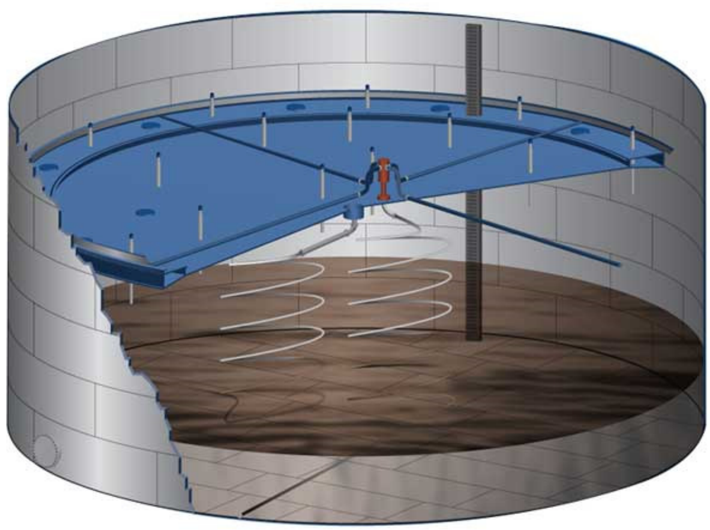


Figure 2: External Floating Roof Tank

<u>REQUIREMENTS OF API 650, APPENDIX C</u>: Maintaining buoyancy and draining rainwater are two primary concerns with the design of external floating roofs. API Standard 650 requires an external floating roof to have sufficient buoyancy to remain afloat on a liquid with a specific gravity of 0.7 under the following conditions (API 650, Appendix C, Paragraph C.3.4.1):

1. 10-inch rainfall in 24 hours with the primary drains inoperative, or
2. Two adjacent pontoons punctured with no water accumulation.

Furthermore, the pontoons must be strong enough to resist permanent distortions when the roof deck is covered with above-design rainfall (API 650, Appendix C, Paragraph C.3.4.2), and any penetration of the roof must not allow the contained liquid to flow onto the roof under the design conditions (API 650, Appendix C, Paragraph C.3.4.3).

The primary drain for an external floating roof is required to be 3-inch minimum for tanks up to 120 feet in diameter, and 4-inch minimum for larger diameters. Drains are required to have a check valve near the roof to prevent backflow of the liquid stored in the tank, in the event of leakage into the drain (API 650, Appendix C, Paragraph C.3.8).

The floating roof must be provided with “landing” legs that are designed to support the external floating roof under a uniform design load of at least 25 psf (API 650, Appendix C, 3.10). The length of the legs must be adjustable from the top of the roof, and the legs must be notched or perforated at the bottom to provide drainage. The leg attachments to the roof require special attention to prevent overstressing, and pads should be installed on the bottom plates with continuous fillet welds to distribute the design loads of the legs on the bottom of the tank.

Suitable devices must be provided to keep the roof centered and to prevent its rotation under all lateral loads that can be imposed on the roof, such as by wind and the roof ladder (API 650, Appendix C, Paragraph C.3.12).

The annular space between the outer periphery of the floating roof and the inside of the tank shell must be sealed with a flexible device (API 650, Appendix C, Paragraph C.3.13).

<u>TYPES OF EXTERNAL FLOATING ROOFS</u>: The two preferred configurations for external floating roofs are the double-deck, and the low single-deck with 30% minimum pontoon area. The low single-deck is the more efficient of the two for 30- to 200-foot diameter tanks. It is difficult to design pontoons for smaller diameters, and single-deck roofs with larger diameters can be too flexible. See Figure 2 for single-deck external floating roof, and Figure 3 for double-deck external floating roof.

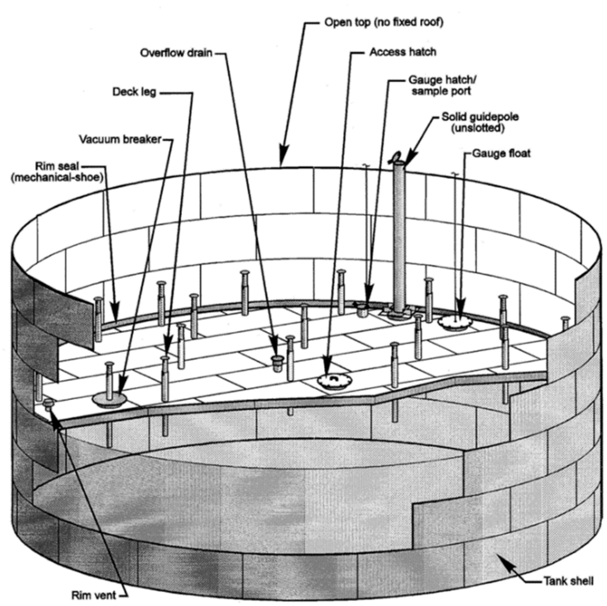


Figure 3: Double Deck Type External Floating Roof Tank

A double-deck roof is appreciably stronger than a single-deck roof. Therefore, a double-deck roof is superior 1) for heated tanks because it can support the weight of the insulation better, and 2) for tanks expected to accumulate a heavy buildup of bottom sediment that could result in uneven support when the roof is resting on legs. The double-deck roof can also handle heavy rainfall better and can be equipped with emergency drains to drain the roof without pumping if the primary drains are plugged.

The minimum acceptable thickness for deck and internal bulkhead plates is 3/16 inch. Plates for pontoons that are exposed to stockside corrosion should be 5/16 inch thick and thickness increased to 3/8 inch if corrosion is expected to be very severe.

Roof legs should be designed to support the roof in two positions. Fixed legs should be used to support the roof at the lowest position for operation, and removable legs should be used to support the roof at a higher position that permits maintenance workers to walk under the roof without bending over. The fixed roof legs should be made from galvanized 4-inch Schedule 80 pipe. Removable legs should be made from 3-inch Schedule 40 pipe, because the heavier legs are too difficult to handle and lighter legs are too easily bent by roof movements. Each leg should be designed to support at least twice the nominal load, because all the legs do not necessarily contact the bottom at the same time during emptying of the tank. Bottom settlement can further increase the loading on individual legs.

The pads on which the legs rest should be made from 3/8-inch thick plate that is 14 inches square and should be welded to the bottom plates with 1/4-inch continuous fillet welds. Leg loads above 10,000 pounds require specially designed pads. The pads should be designed to distribute the bearing load over a large enough area so that the maximum bearing strength of the foundation under the tank bottom is not exceeded.

Roof legs and their reinforcing pads are normally welded to only the topside surfaces of each deck. It is advisable to weld on the bottom side of each deck as well to prevent eventual cracking of the topside welds. This additional welding is especially important for large diameter roofs that are subjected to higher loads and greater flexing than are small diameter roofs, and for tanks in sour water service.

It is very important to make each pontoon compartment independently liquid and vapor tight, and to be sure each compartment can stay leak-tight through all foreseeable emergency conditions. The repair and refloating of a sunken roof is very costly, and the sinking of a roof while fighting a rim fire can have very serious consequences. Manways for access to pontoon interiors should be equipped with covers that are gasketed to be liquid tight and that are held in place with clamps. Each cover should be fitted with a goose-neck vent pipe to protect the pontoon chambers from bulkheads should be continuously fillet welded along all edges, including the top edge. API 650, Appendix C does not require welding of the top edge. The tank fabricator should be required to test each pontoon compartment during construction, to demonstrate that each is liquid and vapor tight.

INTERNAL FLOATING ROOFS

Appendix H to API Standard 650 covers the design and construction of internal floating roofs. As with Appendix C for external floating roofs, it is recognized that many variations and proprietary concepts can be involved in the design of an internal floating roof. Appendix H gives only minimum requirements that should be supplemented by the purchaser. See Figure 4 for internal floating roof tank.

Most of the above design requirements for external floating roofs apply to internal floating roofs as well. One significant difference is that drains are not needed for internal floating roofs. Also, these roofs need not be designed to float with the accumulation of rainwater on the deck, because their fixed roofs shield them from rainfall. However, they are required to be designed with sufficient buoyancy to support at least twice their dead weight and to remain afloat with any two pontoon compartments flooded (API Standard 650, Appendix H, Paragraph H.5.1.2).

Circulation vents are required in the shell or fixed roof above the seal of the floating roof at the maximum liquid level (API Standard 650, Appendix H, Paragraph H.6.2.2). The vents can be no more than 32 feet apart and must provide a total open area of at least 0.2 square foot per foot of tank diameter. In addition, an open vent of at least 50 square inches must be provided in the fixed roof at the highest elevation possible. All the vents must be equipped with weather shields to prevent the entry of rain water and screens to keep out birds.

Liquid overflow slots are required to indicate when a tank is filled to its design capacity. The slots must be sized to discharge at the maximum pump-in rate for the tank. The slots can contribute to the circulating venting requirements, but they must be sized such that no more than 50% of the vent area can be obstructed during overflow.

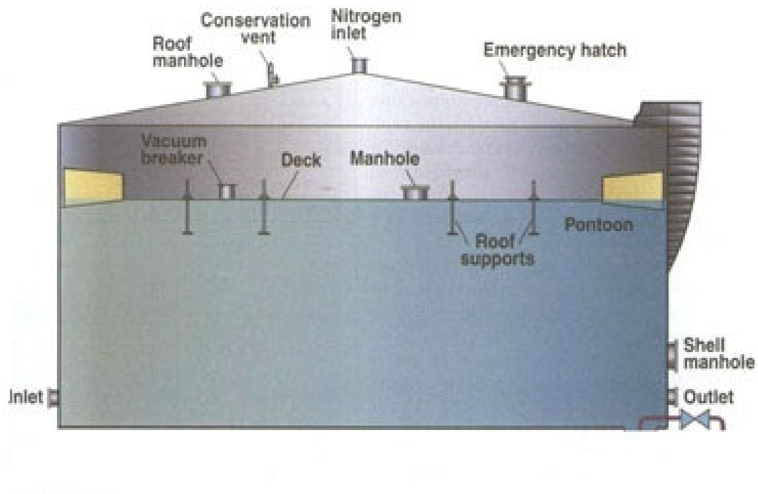


Figure 4: Internal Floating Roof Tank

DIFFERENCES BETWEEN IFR TANK AND EFR TANK

Tanks with floating roofs are used primarily to contain liquids with high vapor pressures, when the vapor emissions from fixed roof tanks would exceed the standards set by the local jurisdiction. External floating roof tanks are generally preferred to tanks with internal floating roofs, because they are more economical to construct and much easier to inspect and maintain.

Although external floating roofs are preferred, internal floating roofs are also useful:

- They permit use of an existing cone roof tank when the service requires a floating roof.
- Tanks with internal floating roofs are used when the stock contained in the tank is sensitive to water contamination (such as jet fuel), or if other factors such as very heavy snow loads would complicate the design of an external floating roof.

Air scoops are required to ventilate the space between an internal floating roof and the fixed roof above it, to prevent the accumulation of vapors in an explosive mixture with air. A disadvantage of internal floating roofs is that the seals cannot be maintained while the tank is in service.

As the diameter of a floating roof decreases, the buoyant force that floats the roof decreases in relation to the frictional resistance to vertical movement at the periphery of the roof. This loss of buoyancy can result in erratic roof movement during the filling or emptying of small-diameter (up to 30 feet) tanks. It is desirable to minimize this potential difficulty with small diameter floating roofs by avoiding roof ladders, swing lines, and closed-type roof drains whenever possible. This can be accomplished by using an internal floating roof, which normally does not require these accessories.

Figure 5 shows a single-deck pontoon type external floating roof tank with most of the components.

CALCULATING EVAPORATIVE LOSSES

API *Publications 2517 (EFRT)*, *2518 (FRT)*, and *2519 (IFRT)* summarized methods for calculating evaporative losses from the storage and handling of petroleum liquids. These were first published in 1962 and then updated in 1991. Most recently, *Publications 2517* and *2519* were consolidated in April 1997 in "Evaporative Loss from Floating-Roof Tanks," Chap. 19.2 of the API *Manual of Petroleum Measurement Standards*.

The new publication updates the evaporative loss estimation procedures for EFRTs, IFRTs, and CFRTs. The results continue to be used as the basis for the U.S. Environmental Protection Agency (U.S. EPA) publication on air pollution emission factors.

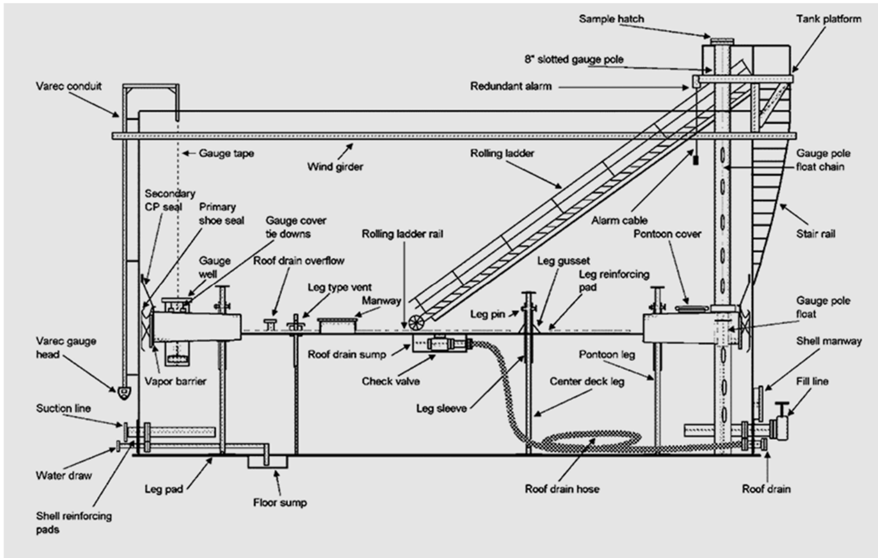


Figure 5: Pontoon Type External Floating Roof Tank

TYPES OF EXTERNAL FLOATING ROOFS

Roof Types

There are mainly three types of floating roofs:

PAN

The pan roof derives its buoyancy from the rim at the perimeter of the deck. Since it has pan configuration, it has no inherent buoyancy. A single pinhole anywhere below the liquid surface can cause this type of roof to sink or capsize. Although these roofs are allowed by the codes, they are not recommended due to safety problems they create, and they should be considered incident-prone. They are very seldom used.

PONTOON

The pontoon roof is the workhorse of the industry and the most commonly found type of the floating roof tank. It has inherent buoyancy which is derived from the outer pontoon compartments. Appendix C of API 650 gives specific design requirements for pontoon roof. The optimum economic diameter is from about 30 to 200 feet. Beyond this diameter, wind can cause ripples to form in the deck section of the roof, causing fatigue cracking of the welds. In addition, it is harder to maintain good drainage when the diameter exceeds 200 feet because the roof has excessive flexibility. Because of this flexibility, vapor bubbles can form in the center of large pontoon roofs which leads to vapor space corrosion problems and an excessive rise in the center deck. See Figure 2 for a single-deck pontoon type external floating roof.

DOUBLE DECK

This roof is the heaviest but most durable construction of all the roofs. It is most economical for small diameters up to about 30 feet and very large diameters from about 200 feet to over 300 feet. This roof maintains good rigidity under normal conditions, and therefore the drainage patterns can be adequately controlled for very large diameter tanks. Since the double deck roof has an air blanket between the upper and lower skins, it is much better insulated from solar heat gain, which tends to produce vapor under the roof in a pontoon-style roof. Because the roof is much heavier and less flexible than the pontoon-type roof, it is more suitable for a roof which needs to be insulated. See Figure 3 for a double-deck external floating roof.

EXTERNAL ROOF DESIGN CONSIDERATIONS

MATERIAL

External floating roofs are constructed of steel with deck plates a minimum of 3/16 in. thick. All deck plates should be seal welded on the top side and stich-welded below within 12 in. of any girders, support legs, or other rigid members. When crevice corrosion is anticipated, then seal welding of bottom side of the roof can be one design countermeasure.

LOAD CONDITIONS

When the roof is landed, API specifies that it shall be designed for a uniform load of 25 psf. When roof drains freeze or plug, loads higher than this can damage roofs or collapse them when they are in landed position. For floating condition, API specifies that the roofs shall maintain buoyancy under these conditions: 10 in. of rainfall in 24 hours with the primary drains inoperative or two adjacent pontoons punctured with no water accumulation. The pontoons must be designed so that permanent deformation does not occur when the roof is subjected to above design conditions. Any penetration of the floating roof should not allow product liquid to spill onto the roof.

BULKHEAD COMPARTMENTS

The top edge of all bulkhead compartments should be seal welded using a single fillet weld, providing a liquid-tight and vapor-tight compartment. There have been numerous cases where the compartments of a tipped roof allowed liquid to spill over the top of the bulkheads, leading to flooding of adjacent compartments and subsequent capsizing. Also a leak in one compartment can allow flammable vapors to get into adjacent compartments. This improves the inspection and identification of leaking compartments when gas testing is used. The roof legs support the roof in its landed position. They should be designed to support at least twice the dead load

FLOATING ROOF TANK NET WORKING CAPACITY

Determining what tank size is required for the desired net storage capacity must consider several factors. Internal or external floating-roof tank shell height must account for the space required by the floating roof as shown in Figure 6**.**

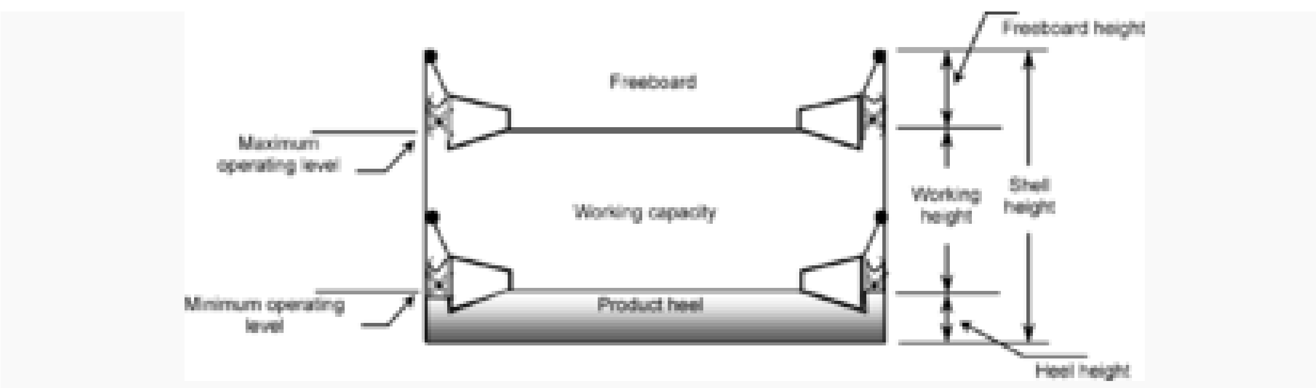


Figure 6: Tank Net Working Capacity.

The tank working capacity is obtained by operating a floating-roof tank between the maximum high gauge and recommended low landing position for the specific floating-roof tank design. A floating roof should be landed only if the tank is to be removed from service for routine inspection or maintenance activities. Landing the floating roof during normal tank operations should be avoided. Product losses increase whenever the roof is not in complete contact with the liquid surface.

In general, floating-roof tanks have been used only at terminal or refinery locations where larger storage capacities are needed. Increased emphasis on the control of evaporative emissions from storage tanks might change the roll of floating-roof tanks in the future with the increased use in smaller tanks. Internal floating roofs have been used in tanks as small as 15 ft in diameter to minimize product losses.

References:

Various sources from Internet.

API 510 PRESSURE VESSEL INSPECTOR

[*The following article has been taken from August 2010 publications from API. The changes in the codes since 2010 are not reflected in this article.*]

API Authorized Pressure Vessel Inspectors must have a broad knowledge base relating to maintenance, inspection, repair, and alteration of pressure vessels. The API Authorized Pressure Vessel Inspector Certification Examination is designed to determine if individuals have such knowledge. The following is a list of specific topics in which the API Authorized Pressure Vessel Inspector should be knowledgeable.

To determine whether the applicants have this broad base of inspection knowledge, a minimum of one question from each category listed within this Body of Knowledge will be included on the API certification examination. Only inspection information covered in one of the references outlined in this body of knowledge will be utilized for the examination questions.

The examination consists of two parts. The closed book part tests the candidate on knowledge and tasks requiring everyday working knowledge of API Standard 510 and the applicable reference documents. The open book portion of the examination requires the use of more detailed information that the inspector is expected to be able to find in the documents, but would not normally be committed to memory.

REFERENCE PUBLICATIONS

API publications and ASME codebooks must be brought to the examination site to be used as reference materials for the open-book part of the examination.

<u>API Publications:</u>

API 510	Pressure Vessel Inspection Code
API RP 571	Damage Mechanisms Affecting Equipment in Refining Industry
API RP 572	Inspection of Pressure Vessels (except Appendix B)
API RP 576	Inspection of Pressure-Relieving Devices
API RP 577	Welding Inspection and Metallurgy

<u>ASME Publications:</u>

Section V	Nondestructive Examination
Section VIII, Div. 1	Rules for Constructing Pressure Vessels
Section IX	Welding and Brazing Qualifications

THICKNESS MEASUREMENTS, INSPECTION INTERVALS AND VESSEL INTEGRITY

A. Code calculation questions will be oriented toward existing pressure vessels, not new pressure vessels. API Authorized Pressure Vessel Inspectors should be able to check and perform calculations relative to in-service deterioration, repairs, rerates, or alterations. Only internal and external pressure loadings will be considered for the API 510 examination.

Note: Dimensions, pressures and temperatures in exam items are supplied in SI units (metric) and the US customary units (inches, feet, psi, etc.) where applicable, to assist all candidates' understanding.

The following categories describe the minimum necessary knowledge and skills:

CORROSION RATES AND INSPECTION INTERVALS

The Inspector should be able to take inspection data and determine the internal and external inspection intervals.

The Inspector must be able to calculate:

a. Metal Loss (including corrosion averaging) [API-510, Para 7.4]

b. Corrosion Rates [API-510, Para 7.1]

c. Remaining Corrosion Allowance [API-510, Para 7.1]

d. Remaining Service Life [API-510, Para 7.2]

e. Inspection Interval [API-510, Section 6]

The formulas for performing the above calculations and rules for setting the inspection intervals may be "closed-book" during the examination.

JOINT EFFICIENCIES

The inspector must be able to determine the joint efficiency "E" of a vessel weld. Inspector should be able to determine:

a. Weld Joint Categories (ASME Section VIII, UW-3);

b. Type of radiography (full, spot, or none) performed basis the nameplate markings (RT-1, RT-2, etc.); [UW -11]

c. Joint efficiency by reading Table UW-12;

d. Joint efficiency for seamless heads and vessels Sections per UW-12 (d); and

e. Joint efficiency for welded pipe and tubing per UW-12 (e).

Determining joint efficiency may be part of the internal pressure problem since joint efficiency "E" is used in the formulas for determining required thickness or Vessel Part MAWP.

STATIC HEAD

The inspector must be able to compensate for the pressure resulting from static head. All static head will be based upon a Specific Gravity of 1.0. The inspector should be able to:

a) List the static head/pressure conversion factor (0.433 psi/ft);

b) Know the difference between vessel MAWP and vessel part MAWP [UG-98];

c) Calculate static head pressure on any vessel part;

d) Calculate total pressure (MAWP + static head) on any vessel part;

e) Calculate maximum vessel MAWP given vessel parts MAWP and elevations

Static head calculations may also be required during the internal pressure calculations if static head data is given in the examination problem.

INTERNAL PRESSURE

The inspector should be able to determine:

a) The required thickness of a cylindrical shell based on circumferential stress given a pressure [UG-27(c)(1)];
b) The vessel part MAWP for a cylindrical shell based on circumferential stress given a metal thickness [UG-27(c)(1)];
c) The required thickness of a head (ellipsoidal, and hemispherical) given a pressure. [UG-32 (d), and (f)]
d) The vessel part MAWP for a head (ellipsoidal, and hemispherical) given a metal thickness. [UG-32(d), and (f)].
e) Whether a head (ellipsoidal or hemispherical) meets Code requirements given both pressure and metal thickness [UG-32(d) and (g)].

The inspector should also be able to compensate for the corrosion allowance: add or subtract based on requirements of the examination problem. The Section VIII, Appendix 1 formula for cylinders, which is based on outside diameter, can be used. The Appendix 1 formulas for non-standard heads will not be required.

EXTERNAL PRESSURE

The inspector should be able to:

a) Calculate the maximum allowable external pressure; and
b) Calculate whether a cylindrical shell or tube meets Code design for external pressure given a wall thickness and a pressure [UG-28(c)(1)].

Note: Factors from the external pressure charts will be given in the wording of the question. Use of the actual charts is not required.

PRESSURE TESTING

The inspector should be able to:

a) Calculate a test pressure compensating for temperature. [UG-99 & UG-100]
b) Be familiar with the precautions associated with hydrostatic and pneumatic testing, such as minimum test temperatures, protection against overpressure etc.
c) Be familiar with all steps in a hydro-test procedure [UG-99 and UG-100]
d) Be familiar with all steps in a pneumatic test procedure [UG-100 and UG-102]

IMPACT TESTING

a) The inspector should understand impact testing requirements and impact testing procedure [UG-84]
b) The inspector should be able to determine the minimum metal temperature of a material which is exempt from impact testing [UG-20 (f), UCS-66, UCS-68(c)]

WELD SIZE FOR ATTACHMENT WELDS AT OPENINGS

The inspector must be able to determine if weld sizes meet Code requirements. The inspector should be able to:

a) Convert a fillet weld throat dimension to leg dimension or visa versa, using conversion factor (0.707); and
b) Determine the required size of welds at openings [UW-16]

NOZZLE REINFORCEMENT

The inspector should:

a) Understand the key concepts of reinforcement, such as replacement of strength removed and limits of reinforcement. Credit can be taken for extra metal in shell and nozzle

b) Be able to calculate the required areas for reinforcement or check to ensure that a designed pad is large enough. To simplify the problem:

   All fr = 1.0

   All F = 1.0

   All E = 1.0

   All required thicknesses are given

c) There will be no nozzle projecting inside the shell

d) Be able to compensate for corrosion allowances.

e) Weld strength calculations are excluded.

B. The following are typical ASME code engineering requirements that API certification candidates will NOT be expected to know for purposes of the certification examination.

1. Required thickness calculations for wind, earthquake, and other secondary stress loadings;
2. Supplementary design formulas and calculations for non-cylindrical shell components;
3. Most external pressure calculations (except as shown in A.5, above);
4. Nozzle calculations for external loads;
5. Flange calculations;
6. Brazing requirements;
7. Ligament calculations;
8. Stayed flat heads and sizing of stays;
9. Tubesheet calculations (stayed or unstayed) and tube to tubesheet joints and loads;
10. Relief valve sizing;
11. Lifting lug and other structural type calculations;
12. Proof testing requirements;
13. Required inspections for new construction, except as they apply to alterations and repairs;
14. Zick analysis;
15. Integrally forged pressure components;
16. Cryogenic vessels (below –50^{o}F);
17. Dimpled, embossed, jacketed, and non-metallic vessels and assemblies;
18. NDE requirements for acoustic emission, eddy current, and motion radiography;
19. ASME Sections UF, UB, UNF, UHA, UCI, UCL, UCD, UHT (except UHT-6), ULW, and ULT;
20. Code Cases and interpretations;
21. Welding process requirements other than shielded metal arc welding (SMAW), gas tungsten arc welding (GTAW), gas-metal arc welding (GMAW), or submerged arc welding (SAW);

22. Requirements for pressure vessels for human occupancy; and
23. Rules for natural resource vessels, API-510, Section 9.

WELDING PROCEDURE AND QUALIFICATION EVALUATION BASED ON ASME BOILER AND PRESSURE VESSEL CODE, SECTION IX

A. WELD PROCEDURE REVIEW

The inspector should have the knowledge and skills required to review a Procedure Qualification Record and a Welding Procedure Specification and to be able to determine the following:

a) Determine if procedure and qualification records are in compliance with applicable ASME Boiler and Pressure Vessel Code and any additional requirements of API- 510. The weld procedure review will include:
   - One Weld Procedure Specification (WPS); and
   - One Procedure Qualification Record.

b) Determine if all required essential and non-essential variables have been properly addressed. (Supplemental essential variables will not be a part of the WPS/PQR)

c) Determine that the number and type of mechanical tests that are listed on PQR are the proper tests, and whether the results are acceptable.

WELD PROCEDURE REVIEW MAY INCLUDE SMAW, GTAW, GMAW, OR SAW, WITH THE FOLLOWING LIMITATIONS:

a) No more than one process will be included on a single WPS or PQR and the WPS to be reviewed will be supported by a single PQR.

b) Filler metals will be limited to one-per-process for SMAW, GTAW, GMAW, or SAW

c) The PQR will be the supporting PQR for the WPS.

d) Base metals will be limited to P1, P3, P4, P5, and P8.

e) Dissimilar base metal joints, and dissimilar thicknesses of base metals will be excluded.

f) Special weld processes such as corrosion-resistant weld metal overlay, hard-facing overlay, and dissimilar metal welds with buttering of ferritic member will be excluded.

g) For P1, P3, P4, and P5, for the purpose of the examination the lower transition temperature will be 1330°F and the upper transformation temperature will be 1600°F.

B. ASME Section VIII, Div. 1 and API-510: GENERAL WELDING REQUIREMENTS:

1. ASME Section VIII, Div. 1

   The inspector should be familiar with and understand the general rules for welding in ASME Section VIII, Div. 1, Parts UW and UCS such as:

   a) Typical joints and definitions
   b) Weld sizes
   c) Restrictions on joints
   d) Maximum allowable reinforcement

e) Inspection requirements

f) Heat treatment

2. API 510: The inspector should be familiar with and understand any rules for welding in API-510. Any rules for welding given in API-510 shall take precedence over those covering the same areas in ASME, Section VIII, Div. 1.
3. "Editorial" and non-technical requirements for the welding subject matter, the candidate is to be tested on, are excluded. This includes items such as the revision level of the WPS, company name, WPS number and date, and name of testing lab. However, the API 510 applicants shall know that the PQR must be certified by signing and dating.

C. The inspector shall be familiar with all the requirements of and information in API RP 577.

NONDESTRUCTIVE EXAMINATION

ASME Section V, Nondestructive Examination

NOTE: The examination will cover ONLY the main body of each referenced Article, except as noted.

A. Article 1, General Requirements

The inspector should be familiar with and understand:

1. The Scope of Section V,
2. Rules for use of Section V as a referenced Code,
3. Responsibilities of the Owner / User, and of subcontractors,
4. Calibration,
5. Definitions of "Inspection" and Examination",
6. Record keeping requirements.

B. Article 2, Radiographic Examination

The inspector should be familiar with and understand:

1. The Scope of Article 2 and general requirements,
2. The rules for radiography as typically applied on pressure vessels such as, but not limited to:
   a. Required marking
   b. Type, selection, number, and placement of IQI's
   c. Allowable density
   d. Control of backscatter radiation
   e. Location markers
3. Records

C. Article 6, Liquid Penetrant Examination, including Mandatory Appendices II and III

The inspector should be familiar with and understand:

1. The Scope of Article 6,

2. The general rules for applying and using the liquid penetrant method such as, but not limited to;
    a) Procedures
    b) Contaminants
    c) Techniques
    d) Examination
    e) Interpretation
    f) Documentation and
    g) Record keeping.

D. Article 7, Magnetic Particle Examination (Yoke and Prod techniques only)

   The inspector should be familiar with and understand the general rules for applying and using the magnetic particle method such as, but not limited to:

   1. The Scope of Article 7,
   2. General requirements such as but not limited to requirements for:
      a. Procedures
      b. Techniques (Yoke and Prod only)
      c. Calibration
      d. Examination
      e. Interpretation
      f. Documentation and record keeping

E. Article 23, Ultrasonic Standards, Section SE–797 only – Standard practice for measuring thickness by manual ultrasonic pulse-echo contact method:

   The inspector should be familiar with and understand;

   1) The Scope of Article 23, Section SE-797,
   2) The general rules for applying and using the Ultrasonic method
   3) The specific procedures for Ultrasonic thickness measurement as contained in paragraph 7.

ASME Section VIII, Div. 1 and API-510.

General nondestructive examination requirements:

1. ASME Section VIII, Div. 1: The inspector should be familiar with and understand the general rules for NDE (UG, UW, Appendices 4, 6, 8, and 12)
2. API 510: The inspector should be familiar with and understand the general rules for NDE in API-510.

PRACTICAL KNOWLEDGE – GENERAL

The following topics may be covered in the examination:

1. Organization and Certification Requirements.
2. Types and Definitions of Maintenance Inspections.

3. Types of Process Corrosion and Deterioration.
4. Modes of Mechanical, Thermal, and High Temperature Deterioration.
5. Pressure Vessel Materials and Fabrication Problems.
6. Welding on Pressure Vessels.
7. Nondestructive Examination (NDE) Methods.
8. Corrosion and Minimum Thickness Evaluation.
9. Estimated Remaining Life.
10. Inspection Interval Determination and Issues Affecting Intervals.
11. Relief Devices.
12. Maintenance Inspection Safety Practices.
13. Inspection Records and Reports.
14. Repairs/Alterations to Pressure Vessels.
15. Rerating Pressure Vessels.
16. Pressure Testing After Repairs, Alterations, or Rerating

PRACTICAL KNOWLEDGE - SPECIFIC

API-510, Pressure Vessel Inspection Code

All of API 510 is applicable to the examination unless specifically excluded. For example: Section 9 and Appendix E are excluded.

API RP 571, Damage Mechanisms Affecting Fixed equipment in the Refining Industry

ATTN: Test questions will be based on the following mechanisms only:

Par. 3. Definitions (included as a frame of reference only)

4.2.3 Temper Embrittlement

4.2.7 Brittle Fracture

4.2.9 Thermal Fatigue

4.2.14 Erosion/Erosion-Corrosion

4.2.16 Mechanical Failure

4.3.2 Atmospheric Corrosion

4.3.3 Corrosion under Insulation (CUI)

4.3.4 Cooling Water Corrosion

4.3.5 Boiler Water Condensate Corrosion

4.3.10 Caustic Corrosion

4.4.2 Sulfidation

4.5.1 Chloride Stress Corrosion Cracking (Cl-SCC)

4.5.2 Corrosion Fatigue

4.5.3 Caustic Stress Corrosion Cracking (Caustic Embrittlement)

5.1.2.3 Wet H_2S Damage (Blistering/HIC/SOHIC/SCC)

5.1.3.1 High Temperature Hydrogen Attack (HTHA)

API RP-572, Inspection of Pressure Vessels

Entire document is subject to testing with the exception of Appendix B.

API RP 576, Inspection of Pressure-Relieving Devices

Entire document is subject to testing with the exception for appendices

API RP 577, Welding Inspection and Metallurgy

Entire document is subject to testing

References:

Body of Knowledge – API 510 Pressure Vessel Inspector (API Publications)

This page intentionally left blank.

DETERMINATION OF JOINT EFFICIENCIES IN SHELL AND HEADS

The rules for determining joint efficiencies of shell and heads of a pressure vessel designed and constructed to ASME Section VIII, Division 1 are provided in the Nonmandatory Appendix L. These efficiencies are used in design formulas for the required design thickness or for the maximum allowable working pressure for a given thickness.

When is radiography mandatory for pressure vessels?

Full radiography (radiography for the full length of the joint) is mandatory for the following welded joints in a pressure vessel:

1. All butt welds in the shell and heads of pressure vessels used to contain lethal substances. The term "lethal substance" refers to poisonous gases or liquids of such a nature that a very small amount of gas or of the vapor of the liquid mixed or unmixed with air is dangerous to life when inhaled.
2. All butt welds in the shell and heads of pressure vessels in which the nominal thickness at the welded joint exceeds 1½ in. Lesser thicknesses may be applicable depending on the class of material used. Nominal thickness at the welded joint is defined as the nominal thickness of the thinner of the two parts joined. Nominal thickness is the thickness selected as commercially available and supplied to the Manufacturer of the pressure vessel.
3. All butt welds in the shell and heads of unfired steam boilers having design pressures a) exceeding 50 psi, or b) not exceeding 50 psi but with the nominal thickness at the welded joint exceeding the thickness specified in 2) above.
4. All butt welds in nozzles with the nominal thickness at the welded joint that exceeds the thickness specified in 2) above or attached to the shell or heads of vessels that are required to be fully radiographed. Category B and C butt welds in nozzles that neither exceed NPS 10 nor 1⅛" wall thickness do not require any radiographic examination. Category B welds are between two shells, or a shell and a 2:1 ellipsoidal head, or a shell and a torispherical head. Category C welds are between nozzle and the flange.
5. All category A and category D butt welds in shell and heads of pressure vessels where the joint efficiency is taken from column (a) of Table UW-12 AND category B or C butt welds which intersect category A butt welds or connect to seamless vessel shell or heads are examined by spot radiography as a minimum. The spot radiographs required to satisfy this requirement cannot be used to satisfy the spot radiography requirement for any other weld increment.

Categories of welded joints are shown in Figure 1.

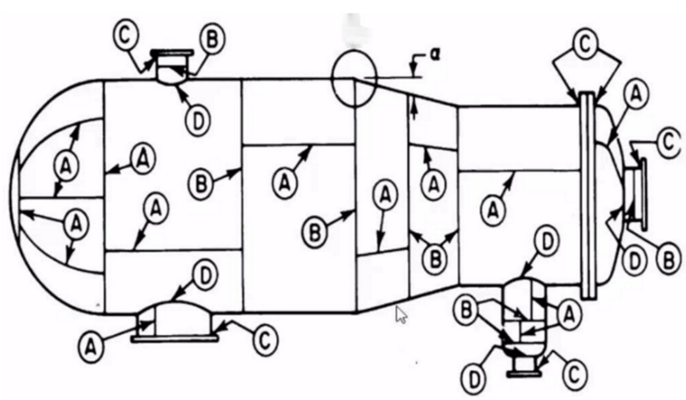


Figure 1: Categories of Welded Joints

What factors determine the joint efficiency to be applied in various design formulas?

Except as specified in 5) above, the joint efficiency of a joint depends only on the type of joint and on the extent of examination of the joint; and does not depend on the extent of examination of the other joint. The value of joint efficiency, E for various joint categories and for joint types are shown in Table 1.

Table 1: Joint Efficiencies for Welded Joints

JOINT TYPE	JOINT DESCRIPTION	DEGREE OF RADIOGRAPHIC EXAMINATION		
		FULL	SPOT	NONE
(1)	Double-welded butt joint	1.00	0.85	0.70
(2)	Single-welded butt joint with backing strip	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip	NA	NA	0.60
(4)	Double full-fillet lap joint	NA	NA	0.55
(5)	Single full-fillet lap joint with plug welds	NA	NA	0.50
(6)	Single full-fillet lap joint without plug welds	NA	NA	0.45
(7)	Corner joints, full penetration, partial penetration, and/or fillet welded	NA	NA	NA
(8)	Angle joints	NA	NA	NA

Joints types (4), (5), (6), (7) and (8) are rarely used in code construction.

- A value of efficiency, E not greater than that given in the column "FULL" is used for those joints where radiography is performed for the entire length of the weld. An exception to this rule is when the requirements of paragraph UW-11(a)(5) are met.
- A value of efficiency, E not greater than that given in the column "SPOT" is used for those joints where spot radiography is performed for the length of the weld. This value of efficiency is also used when the requirements of paragraph UW-11(a)(5) are not met. To meet the requirements of spot radiography, one spot is examined for each 50 ft increment of weld.
- A value of efficiency, E not greater than that given in the column "NONE" is used for those joints where no radiography is performed on the weld.

Seamless vessel sections or heads are considered equivalent to welded parts of the same geometry in which all Category A welds are Type No. 1 and are examined for their entire length by radiography.

Flowcharts

Figures 2 and 3 provide step-by-step guidelines for determining required joint efficiencies for various components. Generally, following points should be considered:

a. Is radiography mandatory due to service or material thickness?

b. Are weld types mandated? For example, UW-2 restricts weld types to Types 1 or 2 for weld categories A and B. If not, select types appropriate.

c. If radiography is not mandatory, the amount of radiography performed is optional.

d. Does the degree of radiography performed on the Category B weld joints in a cylindrical shell affect the joint efficiency used on Category A weld joints?

e. Minimum required thickness for a cylindrical shell is calculated separately for the circumferential and longitudinal directions and the larger of these two thicknesses calculated selected.

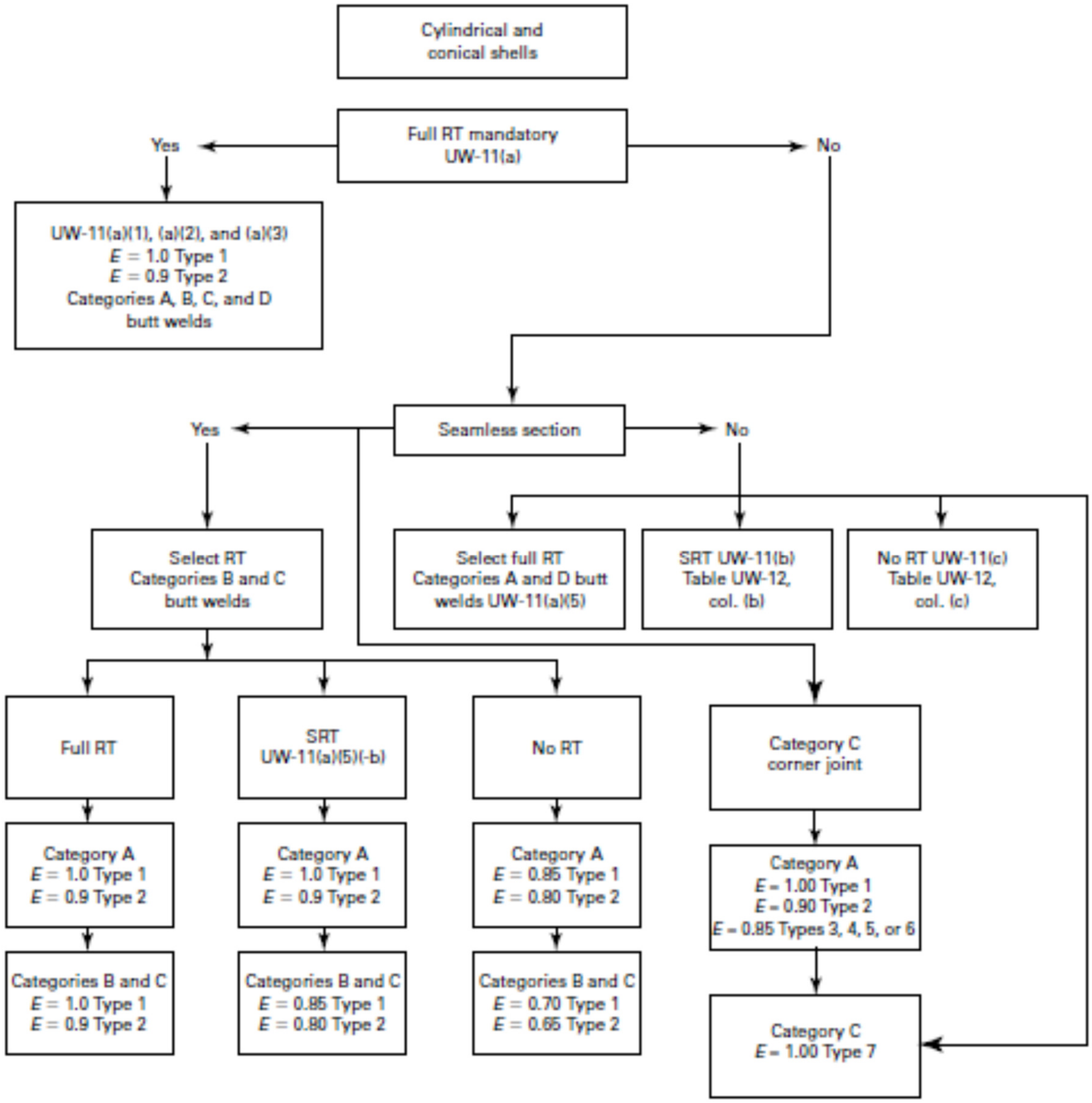


Figure 2: Flowchart for Determining Joint Efficiencies for Cylinders

How are RT markings applied under the Certification Mark when radiographic examination has been performed on a vessel?

- **"RT 1"** when all pressure-retaining butt welds, other than Category B and C butt welds for nozzles that do not exceed NPS 10 or 1⅛" wall thickness, are examined by radiography for their entire length.
- **"RT 2"** when the complete vessel satisfies the requirements of UW-11(a)(5) and when the spot radiography requirements of UW-(11)(a)(5)(b) have been applied.
- **"RT 3"** when the complete vessel satisfies the spot radiography requirements of UW-11(b).
- **"RT 4"** when only part of the complete vessel has satisfied the radiography requirements of UW-11(a) or where none of the markings "RT 1", "RT 2", or "RT 3" are applicable.

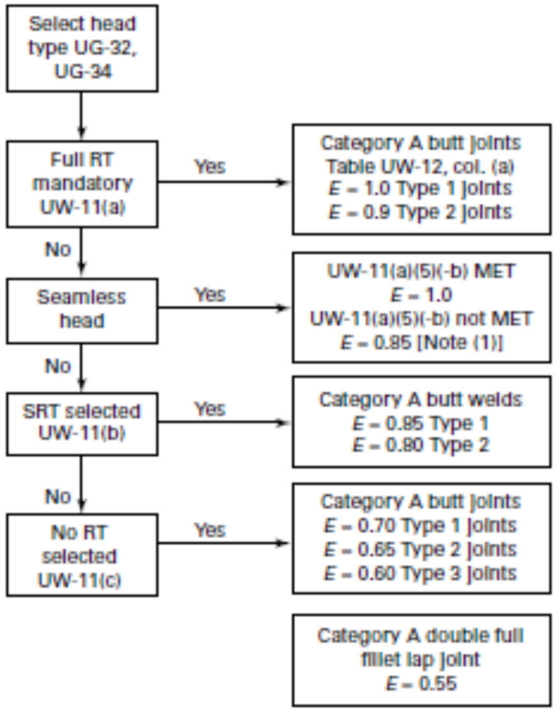


Figure 3: Flowchart for Determining Joint Efficiencies for Heads

---

References:

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1

CRITICAL THINKING IN EVERYDAY LIFE

Most of us are not what we could be. We are less. We have great capacity – however, most of it is dormant and undeveloped. Improvement in thinking is unlikely to take place in the absence of a conscious commitment to learn. If we take our thinking for granted, we don't do the work required for improvement. Development in thinking requires a gradual process; changing one's habit of thought is a long-range, happening over years, not weeks or months.

There are stages required for development as a critical thinker from the Unreflective Thinker where we are unaware of significant problems in our thinking TO the Challenged Thinker where we become aware of problems in our thinking TO the Beginning Thinker where we try to improve but without regular practice TO the Practicing Thinker where recognize the necessity of regular practice TO the Advanced Thinker where we advance in accordance with our practice TO finally Master Thinker where skilled & insightful thinking become second nature to us.

This article explains nine (9) strategies that any motivated person can use to develop as a thinker. These strategies are:

1. **Use "Wasted" time**

   All humans fail to use all their time productively. So why not take advantage of the time you normally waste by practicing critical thinking. This could involve thinking back over your day, evaluating your strengths and weaknesses, or simply asking yourself a lot of probing questions. It would be useful to record your observations so that you are forced to spell out details and be explicit in what you recognize and see. As time passes, you will notice patterns in your thinking.

2. **A Problem A Day**

   At the beginning of each day, choose a problem to work on when you have free moments. Figure out the logic of the problem by identifying its elements. Systematically think through the questions: What exactly is the problem? How does it relate to my goals, purpose and needs? Figure out the information you need and actively seek that information. Analyze and interpret the information, drawing reasonable inferences. Figure out your options for action for the short term and the long term. Evaluate the options and adopt a strategic approach to the problem and follow through on this strategy. Finally, monitor the implications of your action as they begin to emerge. Be prepared to shift your strategy as more information about the problem becomes available to you.

3. **Internalize Intellectual Standards**

   Each week, develop a heightened awareness of one of the universal intellectual standards (clarity, precision, accuracy, relevance, depth, breadth, logicalness, significance). Focus one week on clarity, the next week on accuracy etc. If you are focusing on clarity for the week, try to notice when you are being unclear in communicating with others. Notice when others are unclear in what they are saying.

   When you orally express or write out your views, ask yourself whether you are clear about what you are trying to say. In doing this focus on four techniques of clarification:

   - Stating what you are saying explicitly and precisely (with careful consideration given to your choice of words)
   - Elaborating on your meaning in other words
   - Giving examples of what you mean from experiences you have had, and
   - Using analogies**,** metaphors, pictures or diagrams to illustrate what you mean.

4. **Keep an Intellectual Journal**

   Each week write out a certain number of journal entries. Use the following format (keeping each numbered stage separate):

   - Wherever possible, take problems one by one. State the problem as clearly and precisely as you can.
   - Study the problem to make clear the "kind" of problem you are dealing with. Distinguish problems over which you have some control from problems over which you have no control. Set aside the problems over which you have no control and concentrate your efforts on those problems you can potentially solve.
   - Figure out the information you need and actively seek that information.
   - Carefully analyze and interpret the information you collect, drawing what reasonable inferences you can.
   - Figure out your options for action – both for the short term and the long term. Distinguish problems from under your control from problems beyond your control. Recognize explicitly your limitations as far as money, time and power.
   - Evaluate your options, considering their advantages and disadvantages in the situation you are in.
   - Adopt a strategic approach to the problem and follow through on that strategy. This may involve direct action or a carefully thought-through wait-and-see strategy.
   - When you act, monitor the implications of your actions as they begin to emerge. Be prepared to shift your strategy or your analysis or statement of the problem, or all three, as more information about the problem becomes available to you.

5. **Reshape Your Character**

   Choose one intellectual trait – intellectual perseverance, autonomy, empathy, courage, humility, etc. – to strive for each month, focusing on how you can develop that trait I yourself. For example, concentrating on intellectual humility, notice when you admit you are wrong. Notice when you refuse to admit you are wrong, even in the face of glaring evidence that you are in fact wrong. Notice when you become defensive when another person tries to point out a deficiency in your work, or your thinking. Notice when your intellectual arrogance keeps you from learning, for example, when you say to yourself "I already know everything I need to know about this subject". By owning your "ignorance", you can begin to deal with it.

6. **Deal with Your Egocentrism**

   Egocentric thinking is found in the disposition in human nature to think with an automatic subconscious bias in favor of oneself. You can observe your egocentric thinking in action by contemplating questions like: Did I ever become irritable over small things? Did I do or say something "Irrational" to get my way? Did I impose my will upon others? Did I ever fail to speak my mind when I felt strongly about something, and then later feel resentment? Once you identify egocentric thinking in operation, you can then work to replace it with more rational thought through systematic self-reflection and thinking along the lines of: What would a rational person think in this or that situation? What would a rational person do? (Hint: If you continually conclude that a rational person would behave just as you behaved you are probably engaging in self-deception.

7. **Redefine the Way You See Things**

   We live in a world, both personal and social, in which every situation is "defined", that is, given a meaning. How a situation is defined determines not only how we feel about it, but also how we act in it, and what implications it has for us. However, virtually every situation can be defined in more than one way. This fact carries with it tremendous opportunities.

   In this strategy, we practice redefining the way we see things, turning negatives into positives, dead-ends into new beginnings, mistakes into opportunities to learn.

   Let's look at an example. You do not have to define your initial approach to a member of the opposite sex in terms of the definition "his/her response will determine whether or not I am an attractive person." Alternatively, you could define it in terms of the definition "let me test to see if this person is initially drawn to me – given the way they perceive me." With the first definition in mind, you feel personally put down if the person is not "interested" in you; with the second definition you explicitly recognize that people respond not to the way a stranger is, but the way they look to them subjectively. You therefore do not take a failure to show interest in you (on the part of another) as a "defect" in you.

8. **Get in Touch with your Emotions**

   Whenever you feel negative emotions, systematically try to identify the thinking that led to that emotion. Try to solve the problem at hand through another thought process. You will find that as you change the though process, your emotions will (eventually) shift to match it.

9. **Analyze Group Influences on Your Life**

   Closely analyze the behavior that is encouraged, and discouraged, in the groups to which you belong. Every group enforces some level of conformity. Most people live too much within the view of themselves projected by others. Discover what pressures you are bowing to and think explicitly about whether to reject that pressure.

The key point to keep in mind when devising strategies is that you are engaged in a personal experiment and that you are testing ideas in everyday life. You are becoming a "Practicing Thinker". Your practice will bring advancement. And with advancement, skilled and insightful thinking may become more and more natural to you.

References:

Critical Thinking in Everyday Life: 9 Strategies – Paul, R. & Elder, L.

BUILDING A BETTER TOMMORROW

It is becoming less practical for many companies to maintain in-house engineering staff. That is where we come in – whenever you need us, either for one-time projects, or for recurring engineering services. We understand the codes and standards, and can offer a range of services related to pressure vessels, tanks and heat exchangers.

Training & Development
Engineering and Design Services

CoDesign Engineering

Pressure Vessels ● Heat Exchangers ● Tanks ● Piping

Petroleum ● Petrochemical ● Chemical ● Power ● Fertilizer