

Pressure Vessel Newsletter

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Serving the Pressure Vessel Community Since 2007

From The Editor's Desk:



Mechanical groups in most engineering department of EPC companies that serve oil & gas industry have people that can be characterized as experts in either static equipment or rotating equipment. Very seldom do

we have any crossovers, i.e. someone from static group performing functions of a rotating equipment engineer.

Yet, engineering departments can more effectively work when mechanical engineers in these companies are adequately trained to perform both functions while retaining technical expertise in one. I have worked as pressure vessel engineer for very long time and claim expertise in that field. But at the same time, I have provided training for process equipment and piping systems for a number of years, and have accumulated sufficient knowledge with respect to pumps, compressors, fans, blowers etc,

and have also become familiar with various piping codes especially process piping and power piping.

That doesn't mean that I can troubleshoot a pump or a compressor; however, it does make me qualified to prepare most documents an EPC company needs to produce for a typical project. So, if the rotating equipment engineer on the project is unavailable for an extended time (for whatever reason), I can temporarily fill in.

And in any case, none of the equipment - static or rotating - works in isolation; so it always helps to understand the bigger picture. This is only possible when the engineer is provided an opportunity to work with different types of equipment. Such an engineer would be more valuable to an EPC company in the long run, and the companies should encourage their engineers to acquire knowledge outside of their main expertise.

The engineers would appreciate such opportunities as well.

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TANK EMISSION MECHANISMS AND CONTROL

ORGANIC LIQUID STORAGE TANKS

Organic liquids in the petroleum industry are mixtures of hydrocarbons having dissimilar true vapor pressures (for example, gasoline and crude oil). Organic liquids in the chemical industry, usually called volatile organic liquids, are composed of pure chemicals or mixtures of chemicals with similar true vapor pressures (for example, benzene or a mixture of isopropyl and butyl alcohols). Various tank designs are used for storage of organic liquids. They are:

Fixed Roof Tanks

This type of tank (Figure 1) consists of a cylindrical steel shell with a permanently affixed roof which may be cone- or dome-shaped, or flat. Losses from fixed roof tanks are caused by changes in temperature, pressure and liquid level. Fixed roof tanks are either freely vented or equipped with pressure/vacuum vent. The latter allows the tanks to operate at a slight internal pressure or vacuum to prevent the release of vapors during very small changes in pressure, temperature or liquid level. Of the tanks designs discussed here, the fixed roof tank is the least expensive to construct and is generally considered the minimum acceptable equipment for storing organic liquids.

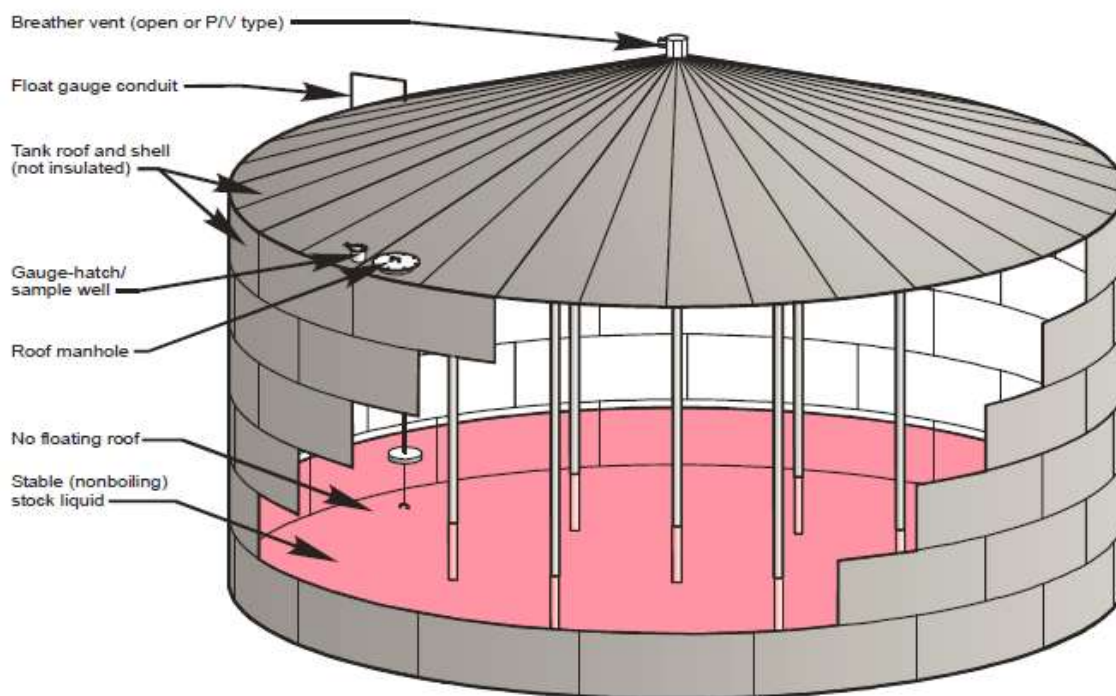


Figure 1: Typical Fixed-Roof Tank

External Floating Roof Tanks

A typical external floating roof tank (EFRT) consists of an open-topped cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid. The floating roof consists of a deck, fittings and rim seal system.

Floating decks that are currently in use are constructed of welded steel plate and are of two general types: pontoon or double-deck. Pontoon-type and double-deck-type external floating roof tanks are shown in Figures 2 and 3. With all types of external floating roof tanks, the roof rises and falls with the liquid level in the tank. The external floating roof design is such that evaporative losses from the stored liquid are limited to losses from the rim seal system and deck fittings (standing storage loss) and any exposed liquid on the tank walls (withdrawal loss).

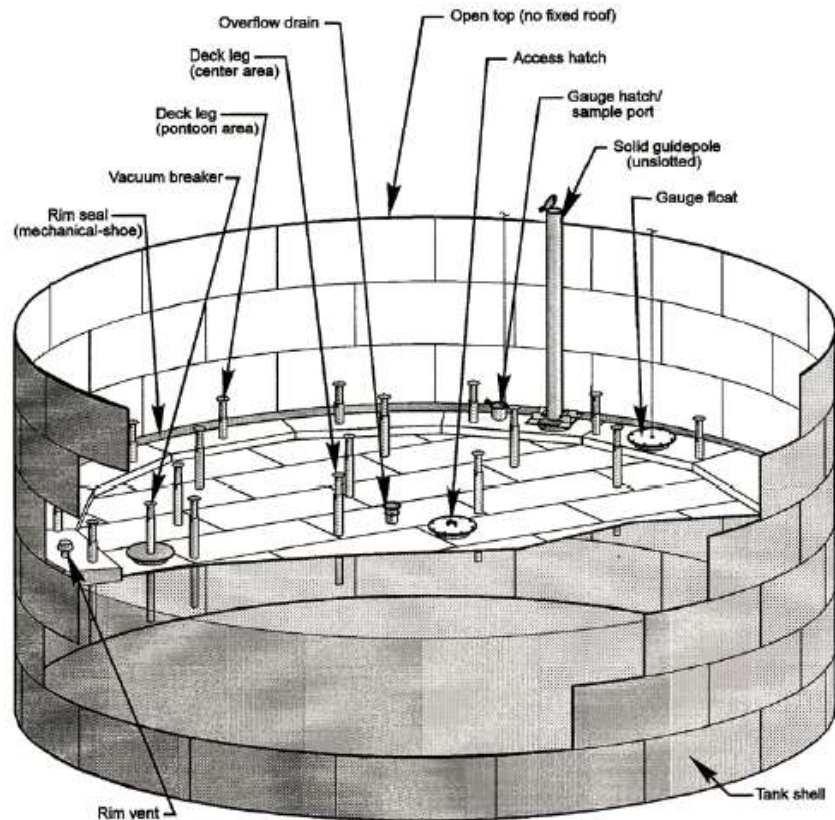


Figure 2: External Floating Roof (Pontoon Type)

Domed External Floating Roof Tanks

Domed external (or covered) floating roof tanks have the heavier type of deck used in external floating roof tanks as well as a fixed roof at the top of the shell like internal floating roof tanks. Domed external floating roof tanks usually result from retrofitting an external floating roof tank with a fixed roof. This type of tank is very similar to an internal floating roof tank with a welded deck and a self-supporting fixed roof. A typical domed external floating roof tank is shown in Figure 4.

The function of the fixed roof is not to act as a vapor barrier but to block the wind. The type of fixed roof most commonly used is a self-supporting aluminum dome roof. The deck fittings and rim seals are identical to those on external floating roof tanks. In the event that the floating deck is replaced with the lighter internal floating roof-type deck, the tank would then be considered an internal floating roof tank.

Internal Floating Roof

An internal floating roof tank (IFRT) has both a permanent fixed roof and a floating roof inside. There are two basic types of internal floating roof tanks: tanks in which the fixed roof is supported by vertical columns within the tank, and

tanks with a self-supporting fixed roof and no internal support columns. Fixed roof tanks that have been retrofitted to use a floating roof are typically of the first type. External floating roof tanks that have been converted to internal floating roof tanks typically have a self-supporting roof. Newly constructed internal floating roof tanks may be of either type.

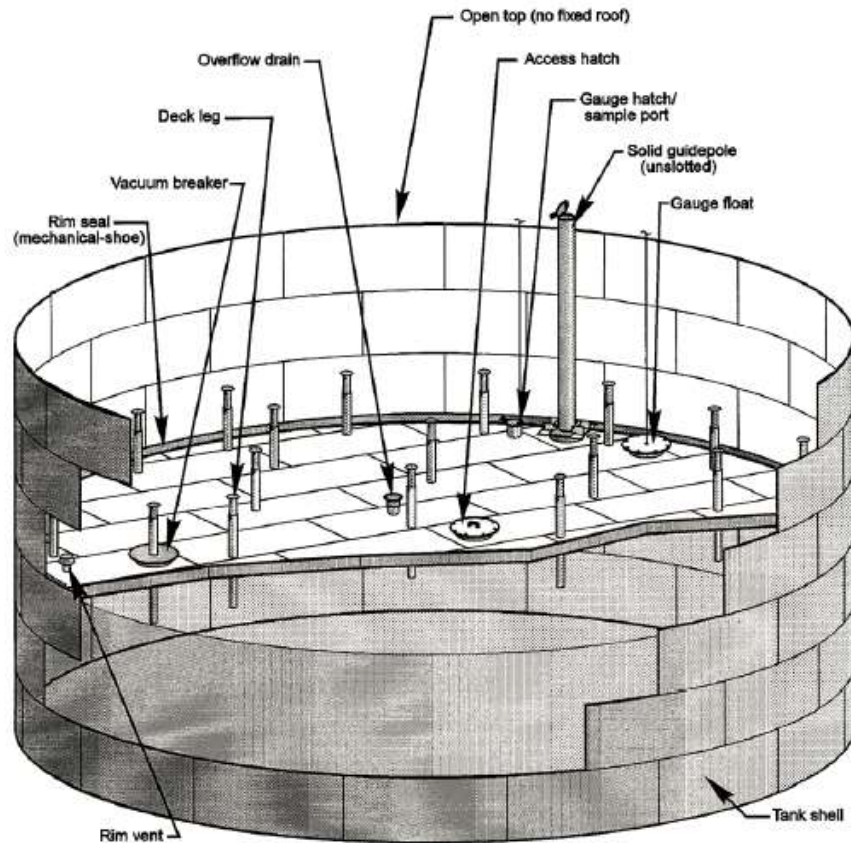


Figure 3: External Floating Roof (Double Deck)

The deck in the internal floating roof tanks rises and falls with the liquid level and either floats directly on the liquid surface (contact deck) or rests on pontoons several inches above the liquid surface (noncontact deck). The majority of aluminum internal floating roofs currently in service have noncontact decks. A typical internal floating roof tank is shown in Figure 5.

EMISSION MECHANISMS AND CONTROL

Emissions from organic liquids in storage occur because of evaporative loss of the liquid during its storage and as a result of changes in the liquid level. The emission sources vary with tank design, as does the relative contribution of each type of emission source. Emission from fixed roof tanks are a result of evaporative losses during storage (known as breathing losses or standing storage losses) and evaporative losses during filling and emptying operations (known as working losses). External and internal floating roof tanks are emission sources because of evaporative losses that occur during standing storage and withdrawal of liquid from the tank. Standing storage losses are a result of evaporative losses through rim seals, deck fittings, and/or deck seams.

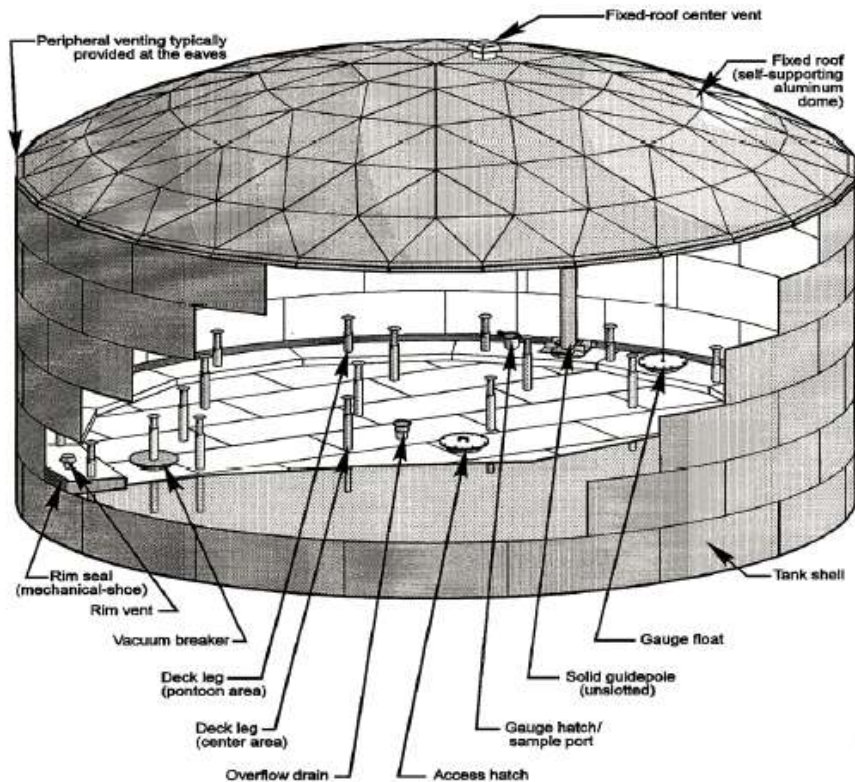


Figure 4: Domed External Floating Roof Tank

Fixed Roof Tanks

The two significant types of emissions from fixed roof tanks are storage and working losses. Storage loss is the expulsion of vapor from a tank through vapor expansion and contraction, which are the results of changes in temperature and barometric pressure. This loss occurs without any liquid level change in the tank. The combined loss from filling and emptying is called working loss. Evaporation during filling operations is a result of an increase in the liquid level in the tank. As the liquid level increases, the pressure inside the tank exceeds the relief pressure and vapors are expelled from the tank. Evaporative loss during emptying occurs when air drawn into the tank during liquid removal becomes saturated with organic vapor and expands, thus exceeding the capacity of the vapor space.

Fixed roof tank emissions vary as a function of vessel capacity, vapor pressure of the stored liquid, utilization rate of the tank, and atmospheric conditions at the tank location.

Several methods are used to control emissions from fixed roof tanks. Emissions from fixed roof tanks can be controlled by installing an internal floating roof and seals to minimize evaporation of the product being stored. The control efficiency of this method ranges from 60 to 99 percent, depending on the type of roof and seals installed and on the type of organic liquid stored.

Vapor balancing is another means of emission control. Vapor balancing is probably most common in the filling of tanks at gasoline stations. As the storage tank is filled, the vapors expelled from the storage tank are directed to the emptying gasoline tanker truck. The truck then transports the vapors to a centralized station where a vapor recovery or control system is used to control emissions. Vapor balancing can have control efficiencies as high as 90 to 98 percent if the vapors are subjected to vapor recovery or control. If the truck vents the vapor to the atmosphere instead of to a recovery or control system, no control is achieved.

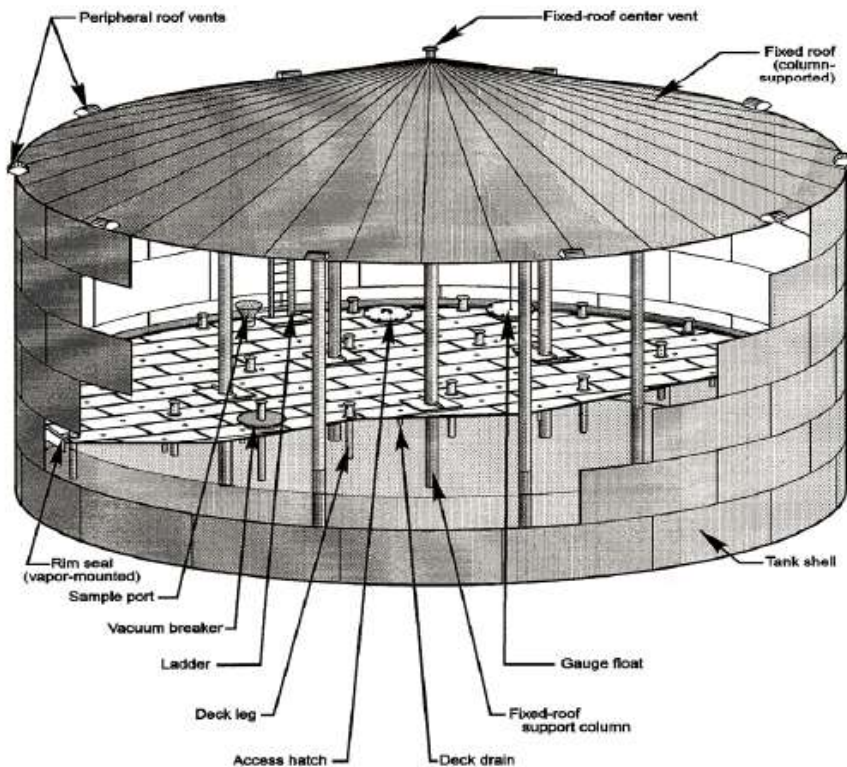


Figure 5: Internal Floating Roof Tank

Vapor recovery systems collect emissions from storage vessels and convert them to liquid product. Several vapor recovery procedures may be used, including vapor/liquid absorption, vapor compression, vapor cooling, vapor/solid adsorption, or a combination of these. The overall control efficiencies of vapor recovery systems are as high as 90 to 98 percent, depending on the methods used, the design of the unit, the composition of vapors recovered, and the mechanical condition of the system.

In a typical thermal oxidation system, the air/vapor mixture is injected through a burner manifold into the combustion area of an incinerator. Control efficiencies for this system can range from 96 to 99 percent.

Floating Roof Tanks

Total emissions from floating roof tanks are the sum of withdrawal losses and standing storage losses. Withdrawal losses occur as the liquid level, and thus the floating roof, is lowered. Some liquid remains on the inner tank wall surface and evaporates. For an internal floating roof tank that has a column supported fixed roof, some liquid also clings to the columns and evaporates. Evaporative loss occurs until the tank is filled and the exposed surfaces are again covered. Standing storage losses from floating roof tanks include rim seal and deck fitting losses, and for internal floating roof tanks also include deck seam losses for constructions other than welded decks. Other potential standing storage loss mechanisms include breathing losses as a result of temperature and pressure changes.

Rim seal losses can occur through many complex mechanisms, but for external floating roof tanks, the majority of rim seal vapor losses have been found to be wind induced. No dominant wind loss mechanism has been identified for internal floating roof or domed external floating roof tank rim seal losses. Losses can also occur due to permeation of the rim seal material by the vapor or via a wicking effect of the liquid, but permeation of the rim seal material generally does not occur if the correct seal fabric is used. Testing has indicated that breathing, solubility,

and wicking loss mechanisms are small in comparison to the wind-induced loss. The rim seal factors presented in this section incorporate all types of losses.

The rim seal system is used to allow the floating roof to rise and fall within the tank as the liquid level changes. The rim seal system also helps to fill the annular space between the rim and the tank shell and therefore minimize evaporative losses from this area. A rim seal system may consist of just a primary seal or a primary and a secondary seal, which is mounted above the primary seal. Examples of primary and secondary seal configurations are shown in Figures 6, 7, and 8.

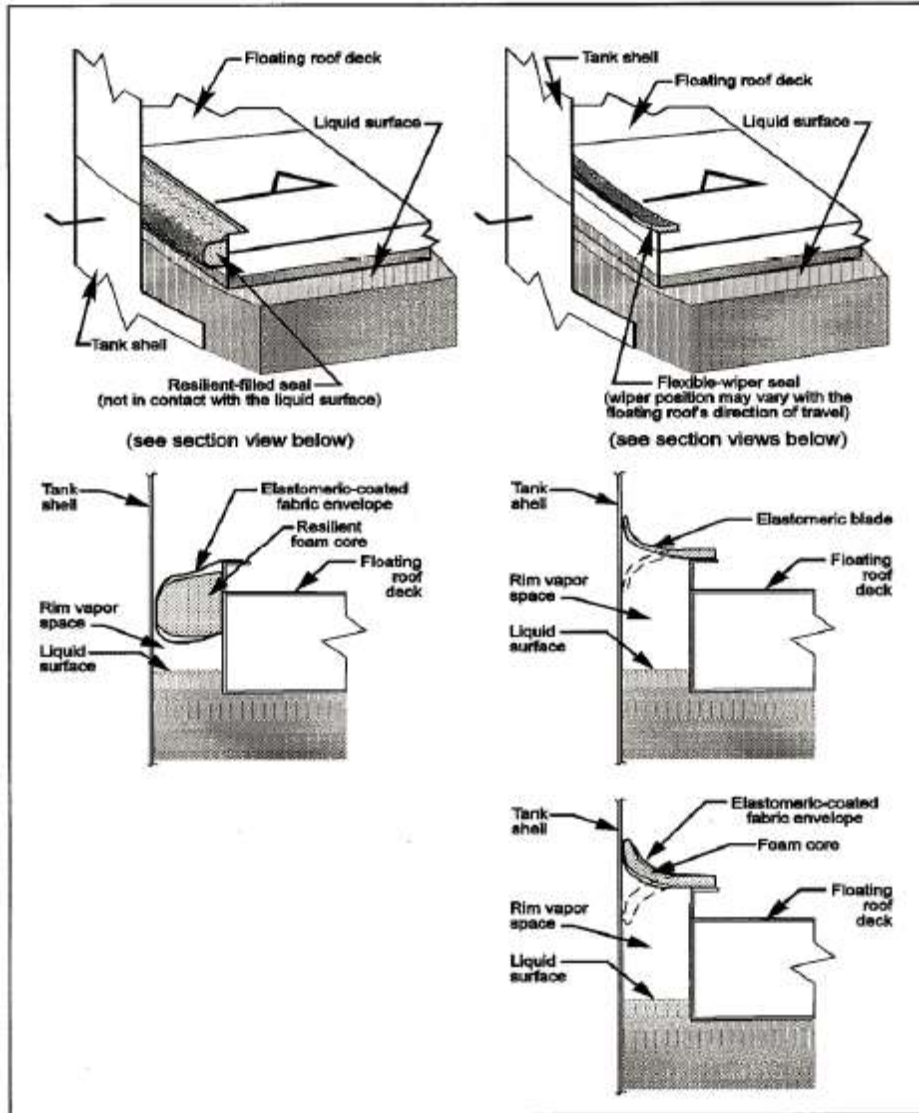


Figure 6: Vapor Mounted Primary Seals

The primary seal serves as a vapor conservation device by closing the annular space between the edge of the floating deck and the tank wall. Three basic types of primary seals are used on external floating roofs: mechanical (metallic) shoe, resilient filled (nonmetallic), and flexible wiper seals. Some primary seals on external floating roof tanks are protected by a weather shield. Weather shields may be of metallic, elastomeric, or composite construction and provide the primary seal with longer life by protecting the primary seal fabric from deterioration due to exposure to weather, debris, and sunlight.

Internal floating roofs typically incorporate one of two types of flexible, product-resistant seals: resilient foam-filled seals or wiper seals. Mechanical shoe seals, resilient filled seals, and wiper seals are discussed below.

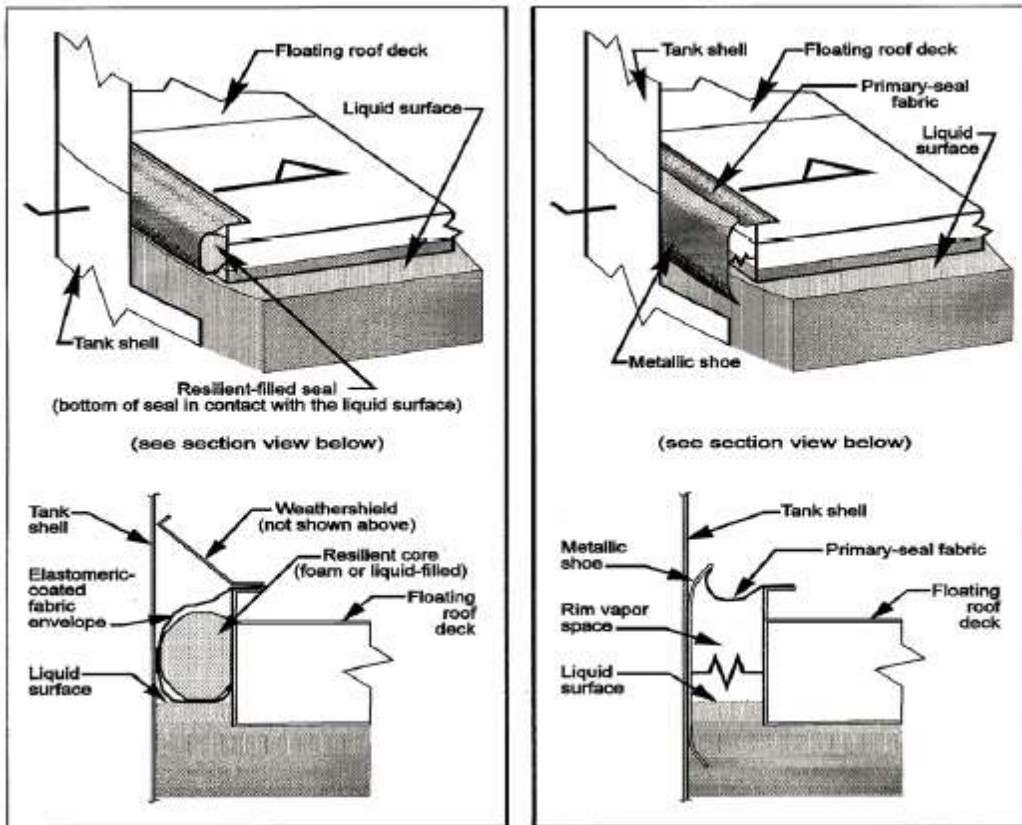


Figure 7: Liquid-Mounted and Mechanical Shoe Primary Seals

A mechanical shoe seal uses a light-gauge metallic band as the sliding contact with the shell of the tank, as shown in Figure 7. The band is formed as a series of sheets (shoes) which are joined together to form a ring, and are held against the tank shell by a mechanical device. The shoes are normally 3 to 5 feet deep, providing a potentially large contact area with the tank shell. Expansion and contraction of the ring can be provided for as the ring passes over shell irregularities or rivets by jointing narrow pieces of fabric into the ring or by crimping the shoes at intervals. The bottoms of the shoes extend below the liquid surface to confine the rim vapor space between the shoe and the floating deck.

The rim vapor space, which is bounded by the shoe, the rim of the floating deck, and the liquid surface, is sealed from the atmosphere by bolting or clamping a coated fabric, called the primary seal fabric, which extends from the shoe to the rim to form an "envelope". Two locations are used for attaching the primary seal fabric. The fabric is most commonly attached to the top of the shoe and the rim of the floating deck. To reduce the rim vapor space, the fabric can be attached to the shoe and the floating deck rim near the liquid surface. Rim vents can be used to relieve any excess pressure or vacuum in the vapor space.

A resilient filled seal can be mounted to eliminate the vapor space between the rim seal and liquid surface (liquid mounted) or to allow a vapor space between the rim seal and the liquid surface (vapor mounted). Both configurations are shown in Figures 6 and 7. Resilient filled seals work because of the expansion and contraction of a resilient material to maintain contact with the tank shell while accommodating varying annular rim space widths. These rim seals allow the roof to move up and down freely, without binding.

Resilient filled seals typically consist of a core of open-cell foam encapsulated in a coated fabric. The seals are attached to a mounting on the deck perimeter and extend around the deck circumference. Polyurethane-coated nylon fabric and polyurethane foam are commonly used materials. For emission control, it is important that the attachment of the seal to the deck and the radial seal joints be vapor-tight and that the seal be in substantial contact with the tank shell.

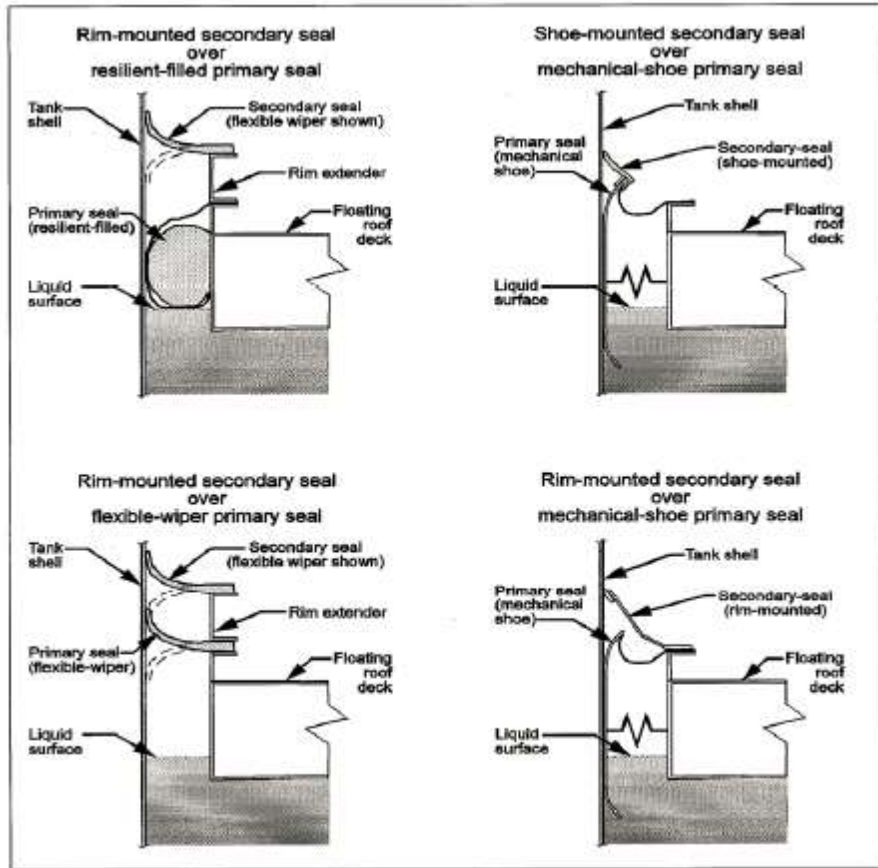


Figure 8: Secondary Rim Seals

Wiper seals generally consist of a continuous annular blade of flexible material fastened to a mounting bracket on the deck perimeter that spans the annular rim space and contacts the tank shell. This type of seal is depicted in Figure 6. New tanks with wiper seals may have dual wipers, one mounted above the other. The mounting is such that the blade is flexed, and its elasticity provides a sealing pressure against the tank shell.

Wiper seals are vapor mounted; a vapor space exists between the liquid stock and the bottom of the seal. For emission control, it is important that the mounting be vapor-tight, that the seal extend around the circumference of the deck and that the blade be in substantial contact with the tank shell. Two types of materials are commonly used to make the wipers. One type consists of a cellular, elastomeric material tapered in cross section with the thicker portion at the mounting. Rubber is a commonly used material; urethane and cellular plastic are also available. All radial joints in the blade are joined. The second type of material that can be used is a foam core wrapped with a coated fabric. Polyurethane on nylon fabric and polyurethane foam are common materials. The core provides the flexibility and support, while the fabric provides the vapor barrier and wear surface.

A secondary seal may be used to provide some additional evaporative loss control over that achieved by the primary seal. Secondary seals can be either flexible wiper seals or resilient filled seals. For external floating roof tanks, two configurations of secondary seals are available: shoe mounted and rim mounted, as shown in Figure

8. Rim mounted secondary seals are more effective in reducing losses than shoe mounted secondary seals because they cover the entire rim vapor space. For internal floating roof tanks, the secondary seal is mounted to an extended vertical rim plate, above the primary seal, as shown in Figure 8. However, for some floating roof tanks, using a secondary seal further limits the tank's operating capacity due to the need to keep the seal from interfering with fixed roof rafters or to keep the secondary seal in contact with the tank shell when the tank is filled.

The deck fitting losses from floating roof tanks can be explained by the same mechanisms as the rim seal losses. However, the relative contribution of each mechanism is not known. The deck fitting losses identified in this section account for the combined effect of all of the mechanisms.

Numerous fittings pass through or are attached to floating roof decks to accommodate structural support components or allow for operational functions. Internal floating roof deck fittings are typically of different configuration than those for external floating roof decks. Rather than having tall housings to avoid rainwater entry, internal floating roof deck fittings tend to have lower profile housings to minimize the potential for the fitting to contact the fixed roof when the tank is filled. Deck fittings can be a source of evaporative loss when they require openings in the deck. The most common components that require openings in the deck are described below.

1. Access hatches. An access hatch is an opening in the deck with a peripheral vertical well that is large enough to provide passage for workers and materials through the deck for construction or servicing. Attached to the opening is a removable cover that may be bolted and/or gasketed to reduce evaporative loss. On internal floating roof tanks with noncontact decks, the well should extend down into the liquid to seal off the vapor space below the noncontact deck. A typical access hatch is shown in Figure 9.
2. Gauge-floats. A gauge-float is used to indicate the level of liquid within the tank. The float rests on the liquid surface and is housed inside a well that is closed by a cover. The cover may be bolted and/or gasketed to reduce evaporation loss. As with other similar deck penetrations, the well extends down into the liquid on noncontact decks in internal floating roof tanks. A typical gauge-float and well are shown in Figure 9.
3. Gauge-hatch/sample ports. A gauge-hatch/sample port consists of a pipe sleeve equipped with a self-closing gasketed cover (to reduce evaporative losses) and allows hand-gauging or sampling of the stored liquid. The gauge-hatch/sample port is usually located beneath the gauger's platform, which is mounted on top of the tank shell. A cord may be attached to the self-closing gasketed cover so that the cover can be opened from the platform. A typical gauge-hatch/sample port is shown in Figure 9.
4. Rim vents. Rim vents are used on tanks equipped with a seal design that creates a vapor pocket in the seal and rim area, such as a mechanical shoe seal. A typical rim vent is shown in Figure 10. The vent is used to release any excess pressure or vacuum that is present in the vapor space bounded by the primary-seal shoe and the floating roof rim and the primary seal fabric and the liquid level. Rim vents usually consist of weighted pallets that rest on a gasketed cover.
5. Deck drains. Currently two types of deck drains are in use (closed and open deck drains) to remove rainwater from the floating deck. Open deck drains can be either flush or overflow drains. Both types consist of a pipe that extends below the deck to allow the rainwater to drain into the stored liquid. Only open deck drains are subject to evaporative loss. Flush drains are flush with the deck surface. Overflow drains are elevated above the deck surface. Typical overflow and flush deck drains are shown in Figure 10. Overflow drains are used to limit the maximum amount of rainwater that can accumulate on the floating deck, providing emergency drainage of rainwater if necessary. Closed deck drains carry rainwater from the surface of the deck through a flexible hose or some other type of piping system that runs through the stored liquid prior to exiting the tank. The rainwater does not come in contact with the liquid, so no evaporative losses result. Overflow drains are usually used in conjunction with a closed drain system to carry rainwater outside the tank.

6. Deck legs. Deck legs are used to prevent damage to fittings underneath the deck and to allow for tank cleaning or repair, by holding the deck at a predetermined distance off the tank bottom. These supports consist of adjustable or fixed legs attached to the floating deck or hangers suspended from the fixed roof. For adjustable legs or hangers, the load-carrying element passes through a well or sleeve into the deck. With noncontact decks, the well should extend into the liquid. Evaporative losses may occur in the annulus between the deck leg and its sleeve. A typical deck leg is shown in Figure 10.

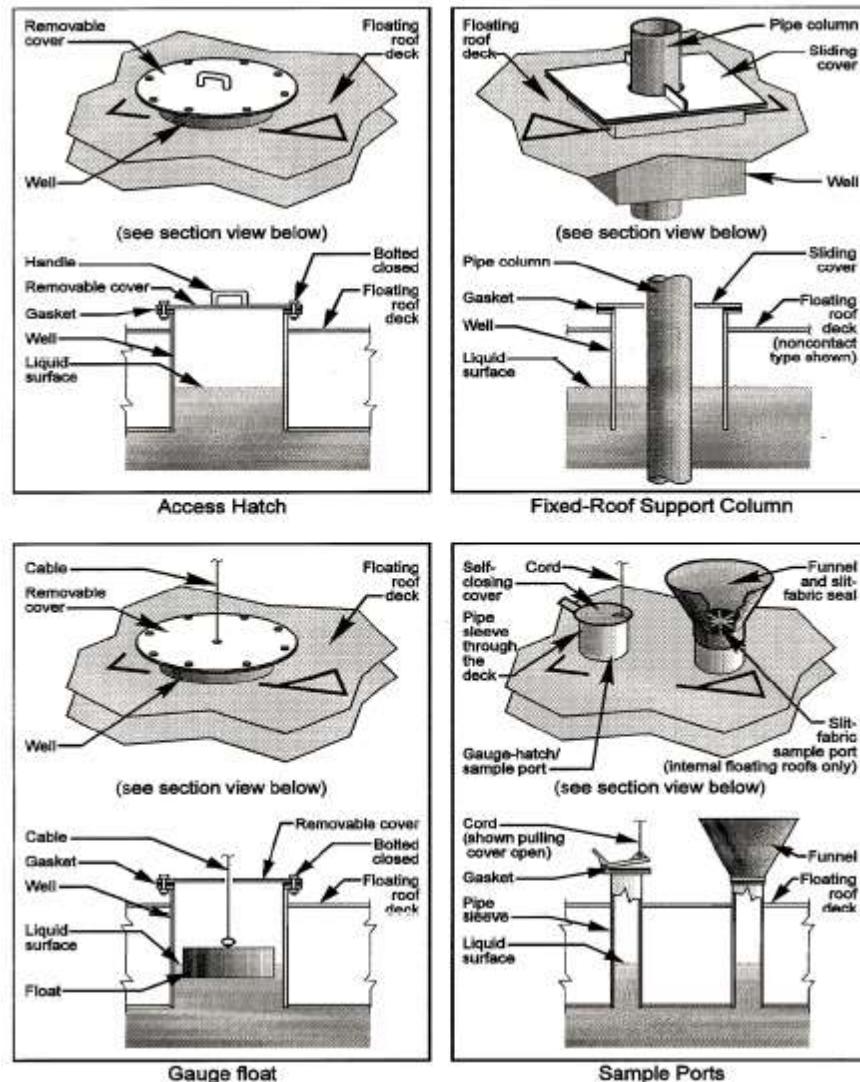


Figure 9: Deck Fittings for Floating Roof Tanks

7. Unslotted guidepoles and wells. A guidepole is an antirotational device that is fixed to the top and bottom of the tank, passing through a well in the floating roof. The guidepole is used to prevent adverse movement of the roof and thus damage to deck fittings and the rim seal system. In some cases, an unslotted guidepole is used for gauging purposes, but there is a potential for differences in the pressure, level, and composition of the liquid inside and outside of the guidepole. A typical guidepole and well are shown in Figure 11.
8. Slotted (perforated) guidepoles and wells. The function of the slotted guidepole is similar to the unslotted guidepole but also has additional features. Perforated guidepoles can be either slotted or drilled hole guidepoles. A typical slotted guidepole and well are shown in Figure 11. As shown in this figure, the guide

pole is slotted to allow stored liquid to enter. The same can be accomplished with drilled holes. The liquid entering the guidepole is well mixed, having the same composition as the remainder of the stored liquid, and is at the same liquid level as the liquid in the tank. Representative samples can therefore be collected from the slotted or drilled hole guidepole. However, evaporative loss from the guidepole can be reduced by modifying the guidepole or well or by placing a float inside the guidepole. Guidepoles are also referred to as gauge poles, gauge pipes, or stilling wells.

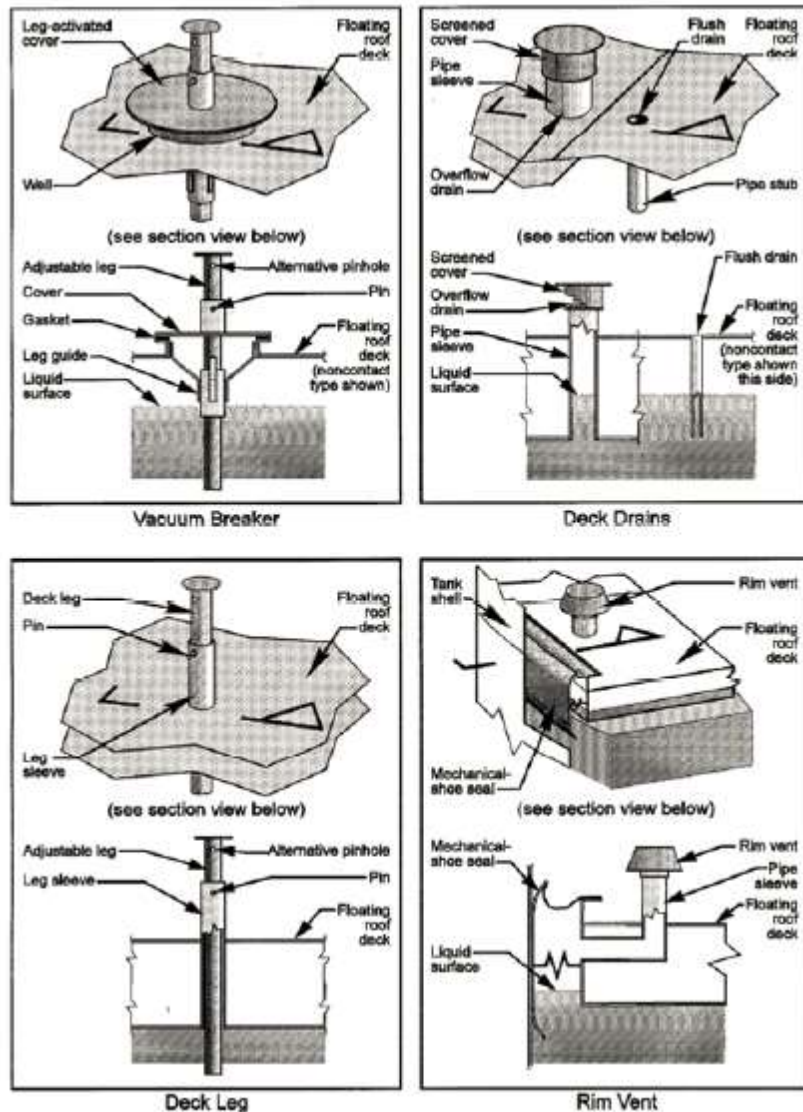


Figure 10: Deck Fittings for Floating Roof Tanks

9. Vacuum breakers. A vacuum breaker equalizes the pressure of the vapor space across the deck as the deck is either being landed on or floated off its legs. A typical vacuum breaker is shown in Figure 10. As depicted in this figure, the vacuum breaker consists of a well with a cover. Attached to the underside of the cover is a guided leg long enough to contact the tank bottom as the floating deck approaches. When in contact with the tank bottom, the guided leg mechanically opens the breaker by lifting the cover off the well; otherwise, the cover closes the well. The closure may be gasketed or ungasketed. Because the purpose of the vacuum breaker is to allow the free exchange of air and/or vapor, the well does not extend appreciably below the deck.

Fittings used only on internal floating roof tanks include column wells, ladder wells, and stub drains.

1. Columns and wells. The most common fixed-roof designs are normally supported from inside the tank by means of vertical columns, which necessarily penetrate an internal floating deck. (Some fixed roofs are entirely self-supporting and, therefore, have no support columns.) Column wells are similar to unslotted guide pole wells on external floating roofs. Columns are made of pipe with circular cross sections or of structural shapes with irregular cross sections (built-up). The number of columns varies with tank diameter, from a minimum of 1 to over 50 for very large diameter tanks. A typical fixed roof support column and well are shown in Figure 9.

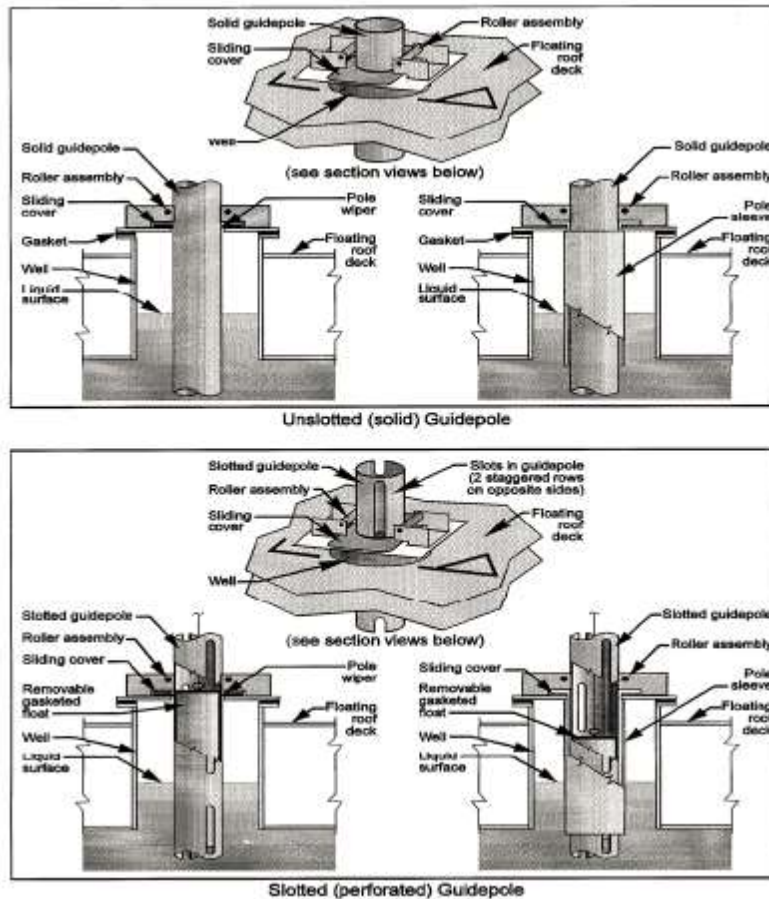


Figure 11: Slotted and Unslotted Guidepoles

The columns pass through deck openings via peripheral vertical wells. With noncontact decks, the well should extend down into the liquid stock. Generally, a closure device exists between the top of the well and the column. Several proprietary designs exist for this closure, including sliding covers and fabric sleeves, which must accommodate the movements of the deck relative to the column as the liquid level changes. A sliding cover rests on the upper rim of the column well (which is normally fixed to the deck) and bridges the gap or space between the column well and the column. The cover, which has a cutout, or opening, around the column slides vertically relative to the column as the deck raises and lowers. At the same time, the cover slides horizontally relative to the rim of the well. A gasket around the rim of the well reduces emissions from this fitting. A flexible fabric sleeve seal between the rim of the well and the column (with a cutout or opening, to allow vertical motion of the seal relative to the columns) similarly accommodates limited horizontal motion of the deck relative to the column.

- Ladders and wells. Some tanks are equipped with internal ladders that extend from a manhole in the fixed roof to the tank bottom. The deck opening through which the ladder passes is constructed with similar design details and considerations to deck openings for column wells, as previously discussed. A typical ladder well is shown in Figure 12.

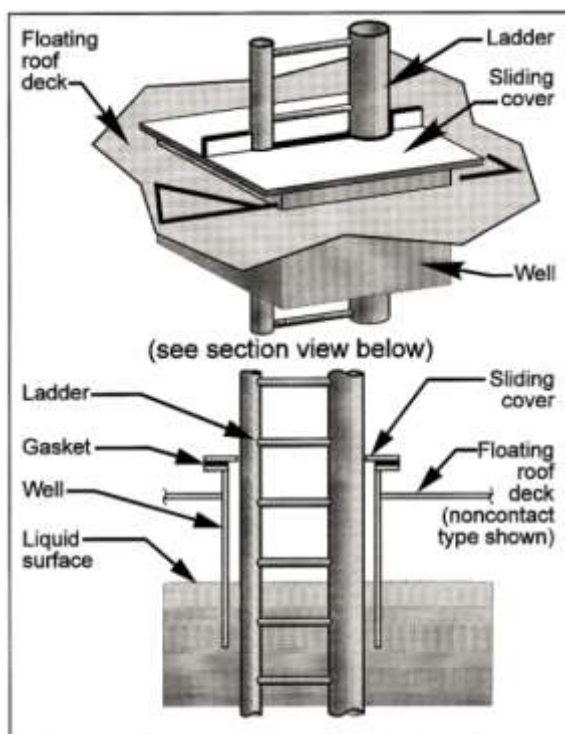


Figure 12: Ladder Well

- Stub drains. Bolted internal floating roof decks are typically equipped with stub drains to allow any stored product that may be on the deck surface to drain back to the underside of the deck. The drains are attached so that they are flush with the upper deck. Stub drains are approximately 1 inch in diameter and extend down into the product on noncontact decks.

Deck seams in internal floating roof tanks are a source of emissions to the extent that these seams may not be completely vapor tight if the deck is not welded. Generally, the same loss mechanisms for fittings apply to deck seams. The predominant mechanism depends on whether or not the deck is in contact with the stored liquid. The deck seam loss equation accounts for the effects of all contributing loss mechanisms.

References:

United States EPA's Guidance for Estimating Emissions from Storage Tanks

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DISHED END MANUFACTURING FOR BEGINNERS

An Introduction to the dishing and flanging process

Tanks, pressure vessels, silos, truck tanks, and more all require dished ends. Fabricators make these ends using various processes. One popular method is dishing and flanging.



Figure 1: Completed Head after Flanging Operation

There are hundreds of manufacturers of tanks, silos, pressure vessels, truck tanks, and metal rolls components all over the world. Most of these companies need to produce or source dished ends of various types, sizes, and specifications to complete their products.

However, there are only a few dished end manufacturers that can supply this kind of product, a significant reason dished end production has become a very profitable business and a craft that companies are carrying on and conserving generation after generation.

Many types and sizes of dished ends are used in the industry today. These dished ends are produced in different ways, and every method has its pros and cons. These methods include hot and cold forming, deep drawing, spinning, as well as the forming of heads in crown and petal segments.

Another common method is called dishing and flanging, a technique that provides manufacturers with the flexibility, high productivity, and quality of the end product required in today's competitive market. A dishing and flanging line can form heads of any shape, be it flat, conical, standard, torispherical, semielliptical, or ellipsoidal. Material thicknesses range from 3/16 to 2-3/8 inches in the cold condition and up to 3-1/4 inches in the hot condition; diameters range from less than 3 ft 3-3/8 inches up to more than 26 ft. This shows how versatile the production with a dishing and flanging line can be.

The dishing and flanging occurs in two sequential operations that each require specific machinery: the dishing of the blank and the forming of the plate edge.

THE DISHING PROCESS

Once the plate has been cut to size in a circular shape (using a circular shear, laser, plasma, or other method), the resulting dish is formed under a press that, with multiple hits distributed over the entire surface, will crown the plate.

To make different types of dished ends and different diameters, a dishing press must be equipped with a set of dies shaped with different radii. The dishing process is rather slow. It generally requires several hours depending on the plate dimensions and the material. This procedure can be automated with the use of a numerically controlled manipulator. It is possible to find presses with CNCs that can handle more than 10 axes and run automatically for hours.

Besides the automation, another important factor in the dishing process is speed. A double-speed press can greatly increase the production output.

A dishing press makes continual hits to the workpiece. This means that the structure of a dishing press is subject to material fatigue; therefore, a cost-saving designed press may have a short life, showing the first cracks in the structure in a short time. Presses with an “HPT design” can resist fatigue better. The design comprises a structure made by four main parts: top beam, bottom beam, and two uprights. The two beams are connected to the uprights with the use of hydraulic pretension tie rods. These tie rods better resist the continuous stress, in comparison to seam welding or bolts, by giving more elasticity to the structure.

THE DISHING OF POLYCENTRIC ENDS

A particular kind of dished end is widely used by the manufacturers of truck tanks: the polycentric dished end. These dished ends, often made of aluminum or stainless steel, are normally made with thin plates up to a maximum of 6 mm. This thickness allows the forming of polycentric dished ends using a technique called hydroforming.



Figure 2: Dishing Press

A hydroforming press uses high-pressure water against the sheet to form the dished end, which will take the shape of the holding die. Hydroforming has several advantages:

- **The speed of production.** A dished end can be dished in a few minutes instead of a few hours.
- **The quality of the surface finishing.** It is much higher because the forming occurs with water pressure, not steel dies.
- **The ease of manufacturing.** There is no need for manipulators or die changes.
- **Flexibility to form other shapes.** By using the same press, and by quickly changing the die, elliptical, circular, oval, and complex shapes can be formed as well.

A hydroforming press, together with a precise CNC measuring laser for dished-end depth control and an efficient plate handling system, is the most productive technique for manufacturing oval and polycentric dished ends for truck tanks.

THE FLANGING PROCESS

The operation that follows dishing is the forming of the edge, which will allow the dished end to be welded to the tank body to support the pressure inside. During the flanging operation, the plate edge is formed with a flanging roll moving against and with the radius of the shaping roll. The two rolls turn and bend the material at the desired radius. This operation may cause lamination of the plate. The best-quality machines should be powerful enough to do the flanging in a minimum number of passes, causing a minimum thinning of the dished end.

The minimization of thinning is one of the biggest challenges for flanging operators, because there are very strict tolerances with respect to the dished end, especially when the tanks have high pressures inside. Less thinning of the plate means a more profitable production for producers, because they do not need to use thicker plates to guarantee the minimum thicknesses.

To reduce the lamination, it is important to have a machine with the correct geometry, enough power in the rotation, and good control of the movements of the flanging roll. Modern machines should be equipped with a pressure control that helps the operator by preventing the squeezing of the plate. With an efficient gap control CNC, such machines allow even inexperienced operators to execute the flanging with the minimum number of passes.

A good flanging machine also should feature controls that always allow for the best contact of the rolls with the plate. This includes the ability to tilt the flanging and shaping rolls. The electric and hydraulic units make the difference between a good-quality and a low-quality flanging machine. The hydraulic unit must allow the movements to be proportional and simultaneous; it is of major importance, for example, to have simultaneous, fast movement of the carriage that holds the dished end to the rest of the axis.

Dished ends can be flanged with or without a center hole. Depending on this, the flanging machine can have a different configuration: with or without a closed structure. A flanging machine for dished ends without a center hole has a closed structure that permits the blocking of the disc with two clamping cylinders. For these flanging machines to have a smooth movement of the carriage, no matter how high the clamping force is, they must be equipped with the latest generation of friction-free technology that consists of ball rails for the carriage movement and ball screws for the precise positioning.

Once the dished end is formed, manufacturers must match tolerances for circumference and depth. Flanging machines can be equipped with machining arms to chamfer the edge of the plate and adjust the dished end height. The most advanced machines have a sophisticated system for measuring the dished end circumference to make it easier for the operator to deliver a perfect product.

Dishing and flanging machines are machines with many important technical aspects that should be properly evaluated. Selecting the right machine can make the difference between a successful and unsuccessful business.



Figure 3: Flanging Operation

The above article appeared in the July 2018 edition of "The Fabricator". The author of the article is Andrea Comparin.

PSV SIZING AND SELECTION: ENGINEERING TIPS

How understanding API and ASME standards can help prevent over-sizing PSVs and their respective piping systems:

NOTE: this article is written to an audience that is familiar with PSVs, PSV sizing, and API and ASME standards at a basic level. The author initially wrote this article in early 2017, and due to some great input and questions, made significant revisions to increase clarity in mid-2018. We hope it is helpful to you, please send us a message with any comments/questions!

The Conundrum

If you have ever sized/selected a pressure safety-relief valve (PSV) using vendor sizing programs or good-old hand calculations, you've probably run into a strange anomaly: Why does a PSV orifice size change between American Petroleum Institute (API) and American Society of Mechanical Engineers (ASME) data sets? What is an "effective" orifice area? How do I know which standard to use when selecting a PSV?

Usually this issue is one of curiosity and doesn't affect the end result of what valve is chosen. Common practice is to default to API sizing equations and parameters, and only use ASME data sets for situations outside of the API-letter designations. But what if I told you that approach is likely causing you to oversize about 10% of your PSVs and their respective piping systems?

Standards referenced in this article:

- ASME Boiler & Pressure Vessel Code (BPVC), Section VIII
- API Recommended Practice (RP) 520
- API Recommended Practice (RP) 526

ASME and API: To Size or Not to Size

Most of the time simply using API data sets is fine. And I should note that this is a conservative approach, so you won't make a mistake doing this. But did you know that PSVs are certified to ASME capacities, not API? And did you know those ASME capacities are nearly always higher than the API ones? I'm guessing you don't, because there are very few resources available that speak to this topic. I've found it common for engineers to understand API 520 quite well, but have a very limited working knowledge of how the ASME BPVC comes into play.

First, let's clarify the main roles API and ASME play on this subject, and how the standards are intended to be used:

1. API 526 provides basic design criteria for PSVs, and is aimed at manufacturers.
2. API 520 provides detailed methods to a) determine specific required relief loads, and b) select preliminary, generic valve sizes.
3. ASME BPVC governs testing and certification of valves.

Too often, we leave that third part out of the process, and simply calculate relief loads and select valves using API techniques, without ever checking our selection against certified ASME data. Proper application of these standards is the first key point of this article:

Initial sizing and valve selection is done using API equations, and final valve selection and certification is done using ASME-certified coefficients and capacities.

When sizing a PSV, the sizing equations are always API 520. When a PSV is certified, it is always certified to ASME BPVC (whether one "selects" ASME certification or not!) It's important to remember that the ASME BPVC is the "code", the standard to which we must design. API 520/526 are "recommended practices" which were developed to give engineers a tool to meet the ASME requirements. Another way to look at it: ASME BPVC sets the goal, API 520/526 provide the instructions, and ASME has the final say.

ASME BPVC: What are the Rules?

The BPVC is an enormous code, and not reviewed in detail here. On the subject of PSVs, it basically says that a PSV must be capable of relieving the required load, and it must be tested in a specific manner to be certified to do so. If a valve is tested per the specific directions in the BPVC, it will be ASME certified and receive an ASME UV stamp.

NOTE: when specifying a PSV for a pressure vessel, it's important to always specify that the UV stamp is required. There are times when a non-code PSV is acceptable, but that is outside the scope of this article.

API 526: Standardized Valve Design

The first thing API does is attempt to standardize physical PSV sizes and design, and it does so in API RP 526, which is targeted at PSV manufacturers. API provides pre-defined valve sizes, with letter designations D through T (API 526). It also defines other details directed toward valve manufacturers (such as temperature ratings). All of this is intended as minimum design standards, and manufacturers are free to exceed these parameters as they wish.

API 520: PSV Sizing Equations

The second thing API does is provide standardized equations and parameters to use when trying to figure out just what size of a PSV one needs for a particular scenario. The equations account for design parameters that ASME doesn't speak to, such as specific fluid properties, backpressures, critical flow, two-phase flow, and many other aspects of fluid dynamics that will affect the ability of a particular valve to relieve a required load.

API sizing equations are by nature theoretical, standardized, and use default or "dummy" values for several sizing parameters that may or may not reflect the actual values for any specific valve.

API RP 520 very clearly talks about this, and emphasizes that the intended use of its equations is to determine a preliminary valve size, which should be verified with actual data. API intends PSV sizing to be a two-step process, but we are often unaware of this because we (gasp) don't read the full standard, and/or rely solely on vendor sizing software that hides the iteration from us. See API 520, part 1, section 5.2 for further explanation.

The Intersection

When valves are built, they are built to the API RP 526 standard, however, as one might imagine, when valves are actually tested and certified, the results don't match up identically to the theoretical values that were calculated. This is where API and ASME intersect; we switch from calculations (API) which were used as a basis to design the valve, to actual empirical data (ASME) to certify the valve. When a valve manufacturer gets the UV code stamp that certifies the valve orifice size and capacity, it is based on actual test results, not API sizing standards. And ASME (which came first) does not have tiered letter designations. The typical D, E, F, etc. sizes we refer to are strictly an API tool, and ASME's capacity certifications are completely independent of them!

An Example

Here is an example scenario where all of this comes to a confusing head:

1. ABC Valve Company builds a valve, aiming at the design specs for an API N orifice, which API says is an effective area of 4.34 in².
2. They test the final product according to ASME BPVC, and get a result that equates to an effective orifice area of 4.90 in². This is its ASME effective area.
3. A third-party Engineer (you), trying to select a PSV, runs a sizing calculation using API 520 equations on ABC Valve Company's sizing software, gets a result that requires 4.66 in² to relieve the load, and is now thoroughly confused on what size valve to select.

If one selects the API data set on the sizing software in this example, it will automatically eliminate N-orifice valves as an option, and bump the user up to a P-orifice. However, if one simply selects the ASME data set, the N-orifice valve magically reappears as an option. How can this be? Will the N-orifice work or not?

The short answer is yes, it is certified to an actual area of 4.90 in². So the “N” orifice for this specific PSV will work, and is certified to do so, in this application. Remember: use API to get you close, and ASME to confirm the final answer.

Digest that for a moment. If you've sized and purchased more than a dozen PSVs, chances are you have inadvertently selected a PSV a full size larger than you needed to, in a situation much like our example, simply because you chose a PSV based on its API “rating” rather than its real, certified, stamped ASME rating. If that was a small valve, impact was probably nil. But what if this happened on a valve that resulted in selecting a 8x10 PSV when you could have used a 6x8?

A More Detailed Explanation

If you're like me, that answer isn't very satisfying. Why on earth is this so confusing? How can you simply hit a button on the sizing program and a different size of valve is suddenly acceptable? The key lies how the main coefficient of discharge, K_d , is handled, and how capacities are determined.

There are several K values used in API calculations, all of which have generic values defined in API 520 that can be used for preliminary sizing. These are the numbers used in initial sizing calculations to get us close, then (if we do this correctly) replaced with the actual/tested/empirical/ASME values when we get a certified valve. Remember, anytime you hear “certified” or “stamped”, think ASME.

Let's take the numbers from the example above, which came from an attempt to size a valve for liquid relief. API says to use a value of $K_d=0.65$ for liquid relief. If one uses the API data set on the vendor software, then the calculation stops here, and you get a required area of 4.66 in². When you select a valve, you're comparing that to the API effective (actual) area of an N orifice, which is 4.34 in², which is obviously too small and you'd logically step up to a P orifice. **However....**

Remember that the API N-orifice area is just the benchmark, a minimum requirement, and may or may not (most likely not) reflect the actual area of a real-life PSV. Once a valve is selected, all of those K values and capacities should be replaced with actual ASME-certified K values, also determined by testing, that are specific to each valve model, and the calculations performed again.

Normally, ASME-certified K-values are smaller than the API dummy values, driving up the required orifice area. So valve manufacturers have to over-design their valves to make up for it, resulting in ASME-certified areas and capacities that typically exceed the benchmark API ones. The end result of all this?

The ASME-certified capacity of any given valve will nearly always exceed its API capacity.

It (almost) all boils down to one sneaky little sentence in the ASME BPVC which mandates a 10% safety factor on the empirically-determined K_d that “de-rates” the valve (see ASME BPVC Section VIII, UG-131.e.2). This tidbit seems to be a little-known fact that is key to proper PSV sizing and selection, because as engineers we often pile safety factors upon each other and oversize our equipment. I cannot highlight this enough:

...by selecting an ASME data set at the final iteration of valve selection, you automatically include a 10% safety factor in your design!

I mentioned above that ASME K values are nearly always lower than API values, due to this 10% de-rating. The PSV in our example scenario has a determined K_d of 0.73, which is adjusted down by 10% for a final ASME K_d of 0.66, slightly higher than the dummy API value (that just means that this particular valve proved it could do about 11% better than the minimum theoretical flow calculated by API when it was tested). So, for our valve in question, the Required ASME area is slightly less than the API area. This is atypical, but not unheard of, and again points to the importance of checking the ASME ratings of any valve you select, and comparing against the API benchmarks.

But that's not the whole picture. For our example, the net effect of the ASME K_d is basically nothing. So how is it the ASME capacity is higher? This brings us to the last key concept:

When you choose to use the ASME data on a specific valve, it's not just the K_d sizing factor that changes; the actual orifice area and therefore the capacity of the valve also adjusts to empirical, certified values. You can generally expect both values to increase over the API values.

Why is this? Simply that any given real-world valve is usually over-designed so that it will meet and exceed the required minimum capacity of its corresponding API size. What a simple concept, but so often overlooked by engineers!

Back to our example scenario: even though the ASME K_d , and hence required area, adjustment had a negligible effect, the actual ASME orifice area, and hence capacity, is significantly higher than the listed API area and capacity for an N-orifice. Below is a summary:

- API N Orifice: **4.340 in²**
- API Calculated Required Area: 4.667 in²
- ASME Calculated Required Area: 4.624 in²
- ASME Certification for Brand X* 4N6: **4.900 in²**

**Note: this is data from a real case; the specific PSV make/model is omitted. Did you catch the result? The actual, certified capacity of this valve is nearly 13% higher than the generic N-orifice valve, and that includes its 10% safety factor!*

With this adjusted orifice area, we can compare to the ASME certified area (which is always going to be larger than the API area), and we have our final answer for the valve size. Often this will not result in a different choice of valve, but sometimes, as in the example case, it will allow us to use a valve with an API letter designation that did not appear large enough based on its API effective area. This can save time and money for our plants by preventing over-sizing valves, leading to smaller piping systems to support them. And remember, the ASME values are empirical and have a 10% safety factor built in, so we don't need to worry about cutting the design too close; the conservatism is already built in to the method. We can choose the Brand X N-orifice valve and sleep well at night!

Summary

Avoid simply defaulting to the API data set for the final "rating" or data sheet when selecting a PSV. Use API sizing calculations as they are intended: for preliminary valve selection. Then switch to the ASME data set. This will often (but not always, remember, it's valve-specific) result in two differences:

1. An actual orifice area that is greater than the standard API letter-designated orifice area. This is ok; it just means the PSV selected performs slightly better, or is slightly larger, than the minimum design conditions for its API letter designation.

2. A required orifice area that is greater than the one calculated by API. This is also ok, and is usually due to the 10% de-rating on Kd that ASME requires.

Closing notes: PSV sizing and selection is a big topic, and this article only addresses one issue. I have chosen to omit specific code references and quotations in an attempt to make this a general guideline that is useful for most engineers, not an interpretation of the codes. Many tangent issues can spin off from this article; I will be happy to help with any questions it may generate. Please email me any comments or suggestions, I welcome all input.

Anytime you are selecting a PSV that is near its API capacity limits, a flag should go off in your head: remember to check the ASME capacity!

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METALLIC STRUCTURES

This article describes the structure of metals, and relates that structure to the physical properties of the metal.

THE STRUCTURE OF METALS

The Arrangement of Atoms

Metals are giant structures of atoms held together by metallic bonds. "Giant" implies that large but variable numbers of atoms are involved - depending on the size of the bit of metal.

12-Coordination

Most metals are *close packed* - that is, they fit as many atoms as possible into the available volume. Each atom in the structure has 12 touching neighbors. Such a metal is described as 12-co-ordinated. Each atom has 6 other atoms touching it in each layer.

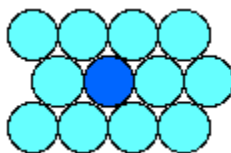


Figure 1: 12-Coordinated Atom – Middle Layer

There are also 3 atoms touching any particular atom in the layer above and another 3 in the layer underneath.

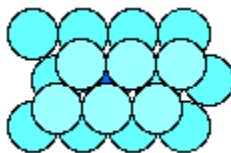


Figure 2: 12-Coordinated Atom – Layer above Middle Layer

This second diagram shows the layer immediately above the first layer. There will be a corresponding layer underneath.

8-Coordination

Some metals (notably those in Group 1 of the Periodic Table) are packed less efficiently, having only 8 touching neighbors. These are 8-co-ordinated.

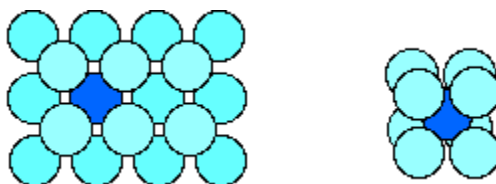


Figure 3: 8-Coordinated Atom

The left hand diagram shows that no atoms are touching each other within a particular layer. They are only touched by the atoms in the layers above and below. The right hand diagram shows the 8 atoms (4 above and 4 below) touching the darker colored one.

Crystal Grains

It would be misleading to suppose that all the atoms in a piece of metal are arranged in a regular way. Any piece of metal is made up of a large number of "crystal grains", which are regions of regularity. At the grain boundaries atoms have become misaligned.

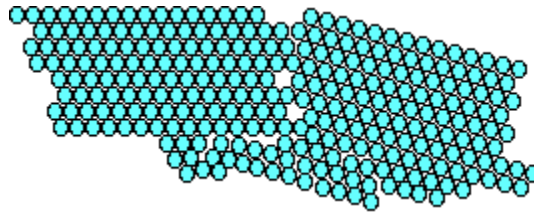


Figure 4: Crystal Grains

THE PHYSICAL PROPERTIES OF METALS

Melting Points and Boiling Points

Metals are giant structures of atoms held together by metallic bonds. "Giant" implies that large but variable numbers of atoms are involved - depending on the size of the bit of metal.

Metals tend to have high melting and boiling points because of the strength of the metallic bond. The strength of the bond varies from metal to metal and depends on the number of electrons which each atom delocalizes into the sea of electrons, and on the packing.

Group 1 metals like sodium and potassium have relatively low melting and boiling points mainly because each atom only has one electron to contribute to the bond - but there are other problems as well:

- Group 1 elements are also inefficiently packed (8-co-ordinated), so that they aren't forming as many bonds as most metals.
- They have relatively large atoms (meaning that the nuclei are some distance from the delocalised electrons) which also weakens the bond.

Electrical Conductivity

Metals conduct electricity. The delocalized electrons are free to move throughout the structure in 3-dimensions. They can cross grain boundaries. Even though the pattern may be disrupted at the boundary, as long as atoms are touching each other, the metallic bond is still present.

Liquid metals also conduct electricity, showing that although the metal atoms may be free to move, the delocalization remains in force until the metal boils.

Thermal conductivity

Metals are good conductors of heat. Heat energy is picked up by the electrons as additional kinetic energy (it makes them move faster). The energy is transferred throughout the rest of the metal by the moving electrons.

Strength and workability

Malleability and ductility

Metals are described as malleable (can be beaten into sheets) and ductile (can be pulled out into wires). This is because of the ability of the atoms to roll over each other into new positions without breaking the metallic bond.

If a small stress is put onto the metal, the layers of atoms will start to roll over each other. If the stress is released again, they will fall back to their original positions. Under these circumstances, the metal is said to be elastic.

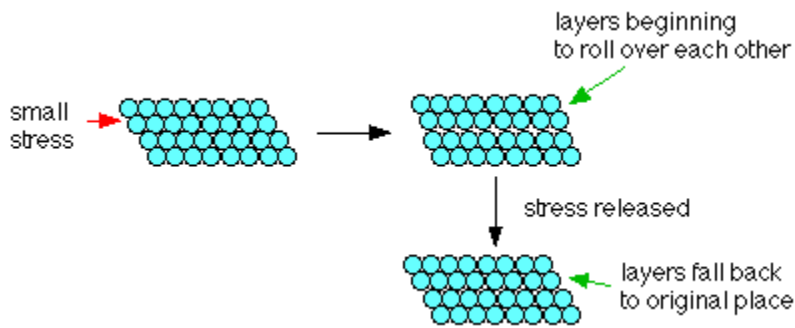


Figure 5: Elastic Phase in Metals



Figure 6: Plastic Phase in Metals

The hardness of metals

This rolling of layers of atoms over each other is hindered by grain boundaries because the rows of atoms don't line up properly. It follows that the more grain boundaries there are (the smaller the individual crystal grains), the harder the metal becomes.

Offsetting this, because the grain boundaries are areas where the atoms aren't in such good contact with each other, metals tend to fracture at grain boundaries. Increasing the number of grain boundaries not only makes the metal harder, but also makes it more brittle.

Controlling the size of the crystal grains

If you have a pure piece of metal, you can control the size of the grains by heat treatment or by working the metal.

Heating a metal tends to shake the atoms into a more regular arrangement - decreasing the number of grain boundaries, and so making the metal softer. Banging the metal around when it is cold tends to produce lots of small grains. Cold working therefore makes a metal harder. To restore its workability, you would need to reheat it.

You can also break up the regular arrangement of the atoms by inserting atoms of a slightly different size into the structure. Alloys such as brass (a mixture of copper and zinc) are harder than the original metals because the irregularity in the structure helps to stop rows of atoms from slipping over each other.

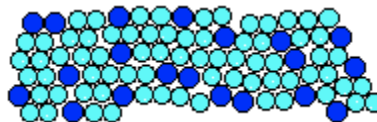


Figure 7: Working the Metal

References:

Internet Sources



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