Venting Aboveground Tanks: Part 1 - Tank Types and the API Standards

Venting of aboveground storage tanks is one of the most difficult aspects of tank engineering to understand. Proper venting of tanks and vessels is essential to conserve product, reduce emissions and minimize hazards to people and equipment.

Continuing Education
This is the first of a two-part article on venting of aboveground storage tanks. Part 1 describes the different types of tanks and how the API’s venting standards relate to each type. Part 2 will discuss how venting devices work, how to inspect them and how to deal with some special issues and misconceptions. Part 2 will culminate in specific recommendations for specifying venting for aboveground tanks. To aid in the understanding of this article, a glossary of technical terms is presented in a side bar. Also, the bracketed numbers in the text refer to the references at the end of the text.

Venting of aboveground storage tanks is one of the most difficult aspects of tank engineering to understand and apply. Proper venting of tanks and vessels is essential to conserve product, reduce emissions and minimize hazards to people and equipment. How does proper venting accomplish these objectives?

In the early days of oil storage, tanks were simply vented to the atmosphere through open vents. Liquids of relatively high volatility, such as motor fuels, degraded by “weathering” to the point that the more volatile components simply got blown away through the open vents. The loss of product through such emissions also presented hazards of fire from outside ignition sources. As this article will explain, a simple device called a pressure-vacuum (PV) vent valve was invented to reduce the frequency and volume of vapor releases and prevent flames outside a tank from propagating to the vapor space inside.

Because of the importance of proper venting, API has published standards for determining whether and how aboveground tanks should be vented. This article covers venting standards for tanks designed to API 650 [1]. Some basic factors that should always be considered are the tank’s design pressure, the stored product’s flash point, and whether or not the tank has an internal floating roof. Other factors to consider are not so easy. For example, storing liquids that are subject to rapid chemical reaction within the liquid or ignition of combustible vapors above the liquid are not within the standards’ scope. This article should help clarify some of the “unwritten,” but important, issues for
anyone working with tank venting.

**API standards**

API 650 specifies venting requirements for certain scenarios and, for other scenarios, refers to API 2000 [2]. In some cases, venting requirements are not readily apparent from the standards. In fact, API 2000 acknowledges that API 650 is not as definitive as it might be in presenting venting requirements. Yet, it is incumbent upon the tank purchaser to understand venting sufficiently to specify the intended service conditions and venting requirements.

To understand the requirements, you need to understand some basic features of tanks and the different types of, or reasons for, venting. The next sections will provide some of these basics, after which the standards for certain types of tanks and venting will be summarized.

**Floating or fixed roof?**

The first step in assessing venting requirements is to identify the kind of tank involved and whether it has a floating roof. The venting requirements for API 650 tanks may be segregated into rules for tanks with floating roofs and tanks with fixed roofs. Do not be confused by the fact that some tanks with floating roofs also have fixed roofs; in other words, the floating roof is internal. So, floating-roof tanks are said to have either external or internal floating roofs. Tanks with only a fixed roof are referred to as just that: fixed-roof tanks. Figures 1, 2 and 3 illustrate the three types of roofs.

- External floating-roof tank
- Internal floating-roof tank
- Fixed-roof tank

As implied above, the space above a floating roof is either open (external floating roof) or covered with a fixed roof that is vented to the atmosphere (internal floating roof). However, when a floating roof is landed—i.e., the roof is resting on the tank bottom—the space under the floating roof can be thought of as similar to the vapor space of a fixed-roof tank. Therefore, API 650 requires that both external and internal floating roofs have venting to accommodate liquid filling and withdrawal rates.

This requirement, specified in API 650 (C.3.9) for external floating roofs and in API 650 (H.6.2.1) for internal floating roofs, prevents damage to the floating roof. Devices are installed in the floating roof to ventilate this vapor space while the roof is landed. These devices may be “leg-actuated vents” which open a port through the deck of the floating roof when it comes to rest on the tank bottom. A typical leg-actuated vent is shown in Figure 4. Sometimes a pressure-vacuum (PV) vent valve is installed on the floating roof.

In fixed-roof tanks (with no internal floating roof), the vapor space is above a free liquid surface. API 2000 covers the venting requirements for such tanks, but only for the following:

- Displacement of air or vapor caused by transferring fluid into or out of the tank.
• Expansion or contraction of the vapor in the tank caused by thermal changes.

• External events, such as nearby tank fires. These effects are discussed later as the conditions addressed by normal venting or emergency venting requirements.

API 2000 does not provide guidance on polymerization or chemical reactions that release heat and vapor; boiling liquids; ignition of vapor in the tank’s ullage; decomposition or detonation of the liquid in the tank; or failure of the valves controlling the flow of liquid into or out of the tank.

**With or without gas blanket?**

Another important consideration in assessing venting requirements is whether or not the tank is equipped with a gas blanket. A gas blanket is, as the name implies, a blanket made of inert gas (e.g., nitrogen) that occupies the vapor space of a fixed-roof or internal floating-roof tank. The inert gas keeps the oxygen level in the space so low that combustion is impossible. While the floating roof is the simplest, most reliable and most widely-used practice for venting tanks, the blanketed tank is another often-used approach.

In gas-blanketed tanks, the inbreathing of the blanket is controlled by a gas pressure regulation system. It is important to control both the in and out pressures resulting from the breathing of the inert gas, so that gas is not wasted and, to ensure that inert gas (rather than air) is filling the vapor space. Proper maintenance of these systems is critical to ensure safe operation.

Petroleum facilities often have excess fuel gas (fuel vapor that is richer and less flammable than the stored product vapor). If fuel gas is used to replace all of the “demand” in the vapor space of a tank, the space can be kept well above the upper flammable limit and, therefore, safer than having air in the vapor space.

**Typical leg-actuated vent (top) with vacuum breaker closed (left) and open (right)**

**Venting types and flash points**

The three types of venting are: normal, emergency and deflagration venting. Venting requirements are affected significantly by the stored liquid’s flash point.

**Normal venting** relieves both internal and external pressure (i.e., partial vacuum) that may result from normal operations. Such pressure arises from liquid movement and thermal breathing. Liquid movement involves the flow of product, either into or out of the tank, and the associated flow of displaced gases. Thermal breathing refers to the flow of gases into or out of the tank as a result of the expansion or contraction of the gases in the vapor space due to changes in ambient temperature.

Photos of a typical pressure/vacuum vent (A) and two cutaway views (B) and (C). Courtesy of Protectoseal.

The provisions in API 2000 for normal venting depend on the product’s flash point and temperature.
The flash point of a liquid is the minimum temperature at which the liquid generates sufficient vapors to form an ignitable mixture with air, and thus is a measure of combustibility. The lower the flash point, the more easily ignited are the vapors.

If the product flash point is below 100°F, or if the fluid temperature exceeds the flash point, the means of venting may be either pressure/vacuum (PV) valves (see Figure 5) without flame arresters, or open vents with flame arresters [3].

If the product flash point is 100°F or more, and the fluid temperature remains below the flash point, the means of venting may include open vents without flame arresters [3].

Whereas open vents remain fixed in an open position, PV valves remain closed until the pressure or vacuum at the inlet reaches the set pressure, at which point the valve begins to open. When the pressure at the inlet increases to the relieving pressure, the flow through the vent is at the valve’s full rated relieving capacity. Tanks that are to be operated with an internal pressure should have their operating pressure maintained below the set pressure so the valve does not open under static operating conditions. Vents should be sized so that their relieving pressure does not exceed the tank’s design pressure.

**Emergency venting** addresses the effects of an external fire in the vicinity of the tank. Heat from fire exposure causes an increase in the internal pressure of the tank that may not be adequately relieved by normal venting. API 2000 (4.4.3) specifies that emergency venting may be accomplished either by additional venting (see Figure 6) or by a frangible roof-to-shell joint.

**NOTE:** Vertical cone-roof tanks built to UL or API specifications may have a weak roof-to-shell seam, if the seam is built with weak angle iron and the roof does not slope more than two inches per foot. The roof is attached to the top angle iron, with only a three-eighths-inch weld on top of the angle. On the bottom-to-shell seam, both sides of the joint are secured by a three-fourths-inch or larger weld, making it much stronger than the top-to-shell seam. Thus, any pressure that develops in the tank during fire exposure will be relieved by the roof tearing loose from the shell on part of the tank. In some cases an internal explosion of vapor space will completely blow the roof from the tank. Not all tanks built to UL or API specifications employ a weak roof-to-shell design.

**Frangible roofs have weak roof-to-shell seams**

A frangible roof-to-shell attachment is designed to be weaker than either the weakest vertical joint in the shell or the shell-to-bottom connection (see Figure 7). The requirements for frangible attachments of roofs, as specified in API 650, can only be met for supported cone roofs that meet the requirements of API 2000 (3.10.2.5.1), which references details in Appendix F of the standard.

Photo of a typical emergency vent hatch. Courtesy of Protectoseal.
It is important to recognize the circumstances under which a frangible roof cannot be used. They are as follows:

- When the tank is small, there usually is not enough weight in the shell and framing to meet the requirements of frangibility. The tank fabricator can advise whether or not a tank is “too small” to be frangible. The minimum size is usually around 20 to 40 feet in diameter, depending on the tank’s construction.

- When the design pressure is high enough to require the tank to be anchored, it also tends to require a steeper pitch to the cone roof. The angle is usually too steep for the roof to be frangible.

- When the fixed roof is self-supporting (i.e., supported only at its periphery), the roof-to-shell attachment must be adequate to support the roof. The strength of the joint prevents it from being frangible.

Emergency venting options other than frangible roofs are specified in API 2000 (4.4.2) as: open vents (with flame arresters if the flash point is below 100° F); PV valves, gauge hatches or manholes with covers that lift when exposed to abnormal internal pressure; rupture disk devices; or other forms of construction that can be proven to be comparable to these devices.

**Deflagration venting** addresses the effects of an internal fire. It is important to note that emergency venting provisions under API rules only apply to vapor expansion in the vapor space due to heating loads that might be caused by an external fire. The API rules do not cover possible burning (deflagration) of flammable air-vapor mixtures inside the tank.

Neither API 650 nor the documents it references require venting of deflagrations, because deflagrations in petroleum storage tanks are rare. However, in the petroleum business, deflagrations occur most often in asphalt or sour crude services where scaly iron sulfide deposits (pyrophoric substances) provide a ready ignition source when contacted by oxygen. Fortunately, most tanks used in such services are constructed with frangible roofs that will adequately vent these deflagrations.

In fact, the frangible-roof design fulfills the venting requirements due to deflagrations inside tanks for most tank sizes greater than about 35 feet in diameter. That is, of course, if the tanks are built according to the rules for frangible roofs. See Figures 7 and 8.

For small tanks which do not have frangible roofs—i.e., those with dome roofs and other roofs not constructed in accordance with frangible roof rules—the user must turn to such documents as NFPA 68 [4] and NFPA 69 [5].

For reasons discussed above, many tank owners prefer to satisfy emergency venting requirements with a frangible roof, particularly for tanks without a floating roof, because of the frangible roof’s potential to vent deflagrations without substantial damage to the shell or bottom. Even when using a frangible roof, however, some owners still equip the tank with emergency vents to avoid rupturing the roof-to-shell attachment unnecessarily. The emergency vents accommodate such conditions as a
pressure rise due to a nearby fire, and the frangible roof joint provides an additional margin of protection in the event of pressure conditions that the emergency vents cannot adequately relieve, such as a deflagration.

How a frangible roof-to-shell joint works

Applying the API standards

Up to this point, we have made several references to the two API standards that specify venting requirements. The principal standard is API 650. For certain scenarios, API 650 refers to API 2000. To see how this works, let’s summarize what they require when applied to some different types of tanks and venting.

(A). For a tank with a fixed roof and internal floating roof, but without a gas blanket:

- **For normal venting**, API 650 (G.8.3 and H.6.2) specifies vents in the fixed roof, tank shell and internal floating roof. The vents in the floating roof protect the roof and rim seal and accommodate liquid movement and thermal breathing.

- **Emergency venting** is not specified for either the fixed roof, shell or internal floating roof. In case of fire, the seal material on the floating roof would melt and likely provide sufficient venting. More problematic would be the potential for fire or explosion due to heat entering the shell.

(B). For a tank the same as described in (A) above (fixed roof and internal floating roof) but with a gas blanket:

- The normal and emergency venting provisions with regard to the internal floating roof would be the same as stated above.

- However, for both normal and emergency venting, API 650 (H.6.2), by reference to API 2000, requires PV vents on the fixed roof.

(C). For a tank with a fixed roof and no internal floating roof, the normal venting and emergency venting requirements are complicated by such factors as the tank’s internal and design pressure; the weight of the tank roof, framing and shell; the use of flame arresters and frangible roofs; and the product’s flash point. Following are summaries of how the requirements are applied to different scenarios:

- **If a tank’s internal pressure is less than the fixed roof’s weight**, API 650 does not specify any normal venting requirements. Even so, normal venting is necessary for liquid movement and thermal breathing [1 and 2]. If this tank does not have a frangible roof, it shall meet the emergency venting requirements of API 2000 (4.3.3.2). Although not specified, the relieving pressure should not exceed the tank’s design pressure. Also, if open vents are used and the stored product has a flash point below 100° F, API 2000 requires flame arresters. Finally, if this tank has an aluminum dome roof, API 650 (G.8.3) specifies that the vent area be adequate for pump-in and pump-out rates. Aluminum dome eave vents usually provide the necessary open area for normal and emergency venting. If not,
additional venting devices must be provided.

**If a tank’s internal pressure is more than the weight of the roof plates but less than the combined weight of the roof, tank framing and shell**, API 650 (Appendix F.2.1) requires normal venting designed to prevent exceeding the design pressure as calculated per Appendix F.

If this tank does not have a frangible roof, API 650 (F.2.2) says that it must meet API 2000 (4.3.3.2) for emergency venting. Again, although not specified, the relieving pressure should not exceed the tank’s design pressure.

If this tank has an aluminum dome, API 650 (G.4.3) says that normal venting shall be sized to not exceed the design pressure, which shall not be greater than 9 inches water column. Also, G.8.3 says that emergency venting, if required, shall be according to API 2000.

**If a tank’s internal pressure is more than the combined weight of the roof, framing and shell but less than 2.5 psig**, API 650 (F.2.1) requires vents for normal venting that are sized to prevent exceeding the design pressure. API 650 (F.7) requires tank anchorage and emergency venting in accordance with API 2000. Regardless of the venting, tanks designed in accordance with API 650 must not exceed the specified limits on design pressure and vacuum. The standard limits partial vacuum to one inch of water column. Design pressures, on the other hand, may be specified up to 2.5 pounds per square inch gauge (69 inches of water column), provided that the tank is designed accordingly. As indicated in the previous scenarios (under item (C) above), the API 650 provisions for venting a fixed roof are based on the internal pressure for which the tank is designed.

**Venting and the building codes**

While API 650 does not specify venting requirements for certain scenarios, new construction is often subject to building codes.

Building codes in the United States commonly require compliance with NFPA 30 [6], which has requirements similar to those of API 2000 for venting aboveground tanks storing flammable and combustible liquids. Even when API 650 is silent, the venting requirements of API 2000 may be invoked if the construction specification requires compliance with NFPA 30.

It is not common, however, for building codes to specify compliance with either NFPA 68 or NFPA 69, which address deflagrations.

**Stay tuned for part 2**

The preceding information introduced you to the different types of aboveground tanks and their characteristics, and how different tank scenarios affect the application of tank venting standards. You should also know that certain fixed-roof tank scenarios are not subject to the standards unless so specified by the purchaser.

The purchaser should specify compliance with API 2000 venting requirements, and should supply sufficient information to allow proper vent selection and tank design. Given the required set pressure,
design pressure, and flow capacity for normal venting conditions (as well as for emergency conditions due to fire exposure, if required), venting can be properly sized for API 650 fixed-roof tanks.

Part 2 of this article, slated for the June issue of PE&T, will describe how pressure and vacuum vents work and how to inspect them. It will also get into some common errors, special concerns and some misconceptions sometimes fostered by regulators or manufacturers. And, as a grand finale, Part 2 will culminate in detailed recommendations on what tank owners should specify for tank venting.

REFERENCES


GLOSSARY

Accumulation: A pressure increase above the tank’s design pressure or maximum allowable working pressure (MAWP).

Blanketed tank: A tank having a blanket of inert gas (e.g., nitrogen) that occupies the vapor space of a fixed-roof tank or an internal floating-roof tank.

Breaking or buckling pin: A thin bar or rod that holds the seat of the vent cover tightly closed against the opening until the internal pressure causes it to buckle, allowing the cover to move away from the opening.

Deflagration: Combustion that propagates at a velocity less than the speed of sound in the vapor space inside a tank.

Design pressure: Maximum allowable working pressure (MAWP) of a tank.

Emergency venting: Venting to relieve the internal tank pressure caused by a fire.

External floating roof: Roof that floats on the surface of the liquid in a tank, with no fixed roof above it.

Failure pressure: The pressure at which a frangible roof will fail by buckling of the shell-to-roof junction.

Fixed-roof tank: A tank with a fixed roof above a free liquid surface (i.e., the tank has a fixed roof but no floating roof).

Flame arrester: A screen-like device designed to prevent the passage of a flame—burning outside the tank—from propagating into the tank’s vapor space.

Flash point: The minimum temperature at which liquid generates sufficient vapor to form an ignitable mixture with air; thus a measure of the liquid’s combustibility.

Flow capacity: The capacity of a relief device to relieve pressure. Required flow capacity is the capacity required to prevent overpressure or vacuum in a tank under the most severe operating conditions.

Frangible roof: A tank roof with a weak roof-to-shell connection that fails more easily than the rest of the tank under excessive internal pressure.

Gas blanket: See blanketed tank.

Gravity-operated vent: A vent that uses the weight of the pallet or cover to close.

Internal floating roof: Roof that floats on the surface of the liquid in a tank, but is covered by a fixed roof that is vented freely to the atmosphere.

Landed floating roof: A floating roof that has come to rest on the tank bottom.

Leg-actuated vent: Vent through the deck of a floating roof that opens when the roof is landed, allowing free flow of air into or out of the space under the floating roof.

Liquid movement: The flow of product into or out of a tank.

Maximum allowable working pressure: The design pressure of a tank (MAWP).

Normal venting: Venting that relieves pressure caused by movement of liquid into or out of a tank or by thermal breathing.

Operating pressure: The normal limits of pressure inside the tank below the setting of any pressure-vacuum vent settings.

Overpressure: The difference between the set pressure and the higher relieving pressure.

Pressure/vacuum vent valve: Either a weight-loaded valve, a pilot-operated valve or a spring-loaded valve used to relieve excess pressure or vacuum that has developed in a tank.

Rated relieving capacity: The flow capacity of a relief device, expressed in terms of airflow at standard conditions (SCFH) when flowing air at a designated pressure or vacuum.

Relief device: Any device, such as a P/V valve, rupture disk or open vent, used to relieve excess pressure or vacuum in a tank.

Relieving pressure: The pressure at the inlet of a relief device when it is flowing at the required relieving capacity, i.e., the pressure at which the vent is sufficiently open to accommodate the specified flow rate.

SCFH: Standard cubic feet of air or gas per hour (same as free air or free gas) at a temperature of 60°F and a pressure of 14.7 pounds per square inch absolute (1.014 bar).

Set pressure: The point at which a pressure/vacuum valve is set to start opening under service conditions.

Steam jacketed vent valve: A P/V vent valve constructed of an inner and outer wall in which steam flows to keep the inner wall hot, thus preventing freezing of sulfur or other vapor inside the valve and clogging it.

Thermal breathing: The flow of air or vapor into or out of a tank as a result of expansion and contraction of vapor in the vapor space caused by ambient temperature changes.

Weight-loaded direct acting vent: Same as gravity-operated vent.
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