

Evaporative Loss from Closed-vent Internal Floating-roof Storage Tanks

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Measurement Coordination Department

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Evaporative Loss from Closed-vent Internal Floating-roof Storage Tanks

0. SUMMARY

There is presently no recognized methodology for estimating the impact of closed tank vents on emissions from an internal floating-roof tank (IFRT). When the vents in the fixed roof of an IFRT are closed, rather than open, estimation of emissions is shown to be highly complex.

Emissions reductions from adding closed vents to IFRTs were found to be significant only for small diameter tanks storing volatile liquids with infrequent turnovers. For low volatility stocks such as diesel, the emission reductions due to adding closed vents are generally less than 10% regardless of the tank diameter or frequency of turnovers. For IFRTs 60 ft in diameter and larger, experiencing 18 or more turnovers per year, the emission reductions due to adding closed vents are generally less than 10%, regardless of the liquid stored or the vent settings on the tank (assuming that the pressure setting is not so high as to require the tank to be anchored).

Given the high uncertainty associated with the methods evaluated, an assumption of a 5% reduction in emissions from an IFRT due to use of closed vents would be a reasonable approach for emissions estimating.

1. INTRODUCTION

This report addresses evaporative loss from internal floating-roof tanks (IFRTs) with closed vents, a subject not currently addressed by API. Nomenclature is provided in Appendix A.

The *API Manual of Petroleum Measurement Standards* Chapter 19, Section 1 (19.1)¹ addresses evaporative loss from fixed-roof tanks, and specifically excludes fixed-roof tanks that have an internal floating roof (19.1.1.1).

The *API Manual of Petroleum Measurement Standards* Chapter 19, Section 2 (19.2)² addresses evaporative loss from freely-vented internal floating-roof tanks, and specifically excludes “closed internal floating-roof tanks (that is, tanks vented only through a pressure-vacuum relief vent, blanketed with an inert gas, vented to a vapor processing unit, or otherwise restricted from being freely vented)” (1d).

2. CLOSED-VENT INTERNAL FLOATING-ROOF STORAGE TANKS

2.1 Venting

API 650, *Welded Steel Tanks for Oil Storage*³, H.5.2.2 addresses venting for internal floating-roof tanks. Two options are allowed: open circulation vents or closed pressure-vacuum vents. For closed pressure-vacuum vents, gas blanketing or another method to prevent the development of a combustible gas mixture within the tank is required.

2.2 Vacuum

Until the December 2005 Addendum, API 650 limited the design vacuum to 1 in. water column, which is 0.036 psi (API 650, 5.2.1b). (API 650 now allows up to 1.0 psi design vacuum, but the vast majority of existing storage tanks are not designed to withstand more than 0.036 psi vacuum.)

2.3 Pressure

API 650 limits the design pressure for tanks to 2.5 psi (API 650, 5.2.1c). Cone-roof tanks with pressure exceeding about 0.053 psi (the weight per unit area of typical ³/₁₆ in. thick roof plates) require special design (Appendix F), and anchoring the tank is required if the pressure exceeds the weight of the roof and the shell divided by the tank’s cross-sectional area. Also, if the design pressure exceeds a certain threshold, the shell-to-roof joint required to resist the pressure becomes too large to be considered frangible (i.e. a weak roof-to-shell joint as specified in API 650, 5.10.2.6), and the tank requires emergency vents. These pressure thresholds are shown in the API 650 Tank Design Pressures Table for 48 ft tall cone-roof tanks. Shell thicknesses are taken as the greatest of those required for the stored liquid (0.7 specific gravity), the hydrotest, and minimum thicknesses allowed in API 650. (Tanks are often designed with thicker shells in order to avoid

the need for an intermediate wind girder. A thicker tank shell would increase the maximum pressures shown below.)

API 650 Tank Design Pressures		
Tank Diameter (ft)	Maximum Pressure with Frangible Joint (psi)	Maximum Pressure without Anchors (psi)
48	0.199	0.285
60	0.205	0.294
90	0.178	0.251
120	0.175	0.247
150	0.169	0.238

The internal floating roof must also be capable of withstanding the internal pressure. API 650 describes several different types of floating roofs in H.2.2, including internal floating roofs that have their deck above the liquid and are supported by closed pontoons for buoyancy (H.2.2.e). These pontoons are typically 10 in. diameter, 0.050 in. thick aluminum and cannot withstand pressures above about 0.07 psi (unless special fabrication measures are taken to pressurize the pontoons).

2.4 European Practice

In Europe, pressure-vacuum vents are commonly used without gas blanketing the vapor space above the floating roof. The German standard DIN 4119 specifies that new tanks must be designed for a 0.29 psi relieving pressure (20 mbar) and a 0.145 psi (10 mbar) relieving vacuum⁶. The German design pressure is approximately the maximum pressure tanks can withstand without anchors.

3. EMISSION REDUCTIONS FROM FLOATING ROOFS VS EMISSION REDUCTIONS FROM CLOSED VENTS

Both internal floating roofs and closed vents reduce emissions from storage tanks. Let's first quantify the reduction each of these controls achieves separately before considering their combined effect.

3.1 Emission Reductions from Internal Floating Roofs

First, consider the emission reduction achieved by adding an internal floating roof to a tank with open vents. Consider tanks 48 ft tall storing RVP 10 gasoline or diesel at 14.5 psi atmospheric pressure, 60°F average liquid surface temperature, 20°F daily temperature range, and 25 turnovers per year. Their internal floating roof is welded steel with a vapor mounted primary and rim mounted secondary seal.

The evaporative loss without the floating roof is determined using API *MPMS* Ch. 19.1 with zero vent pressure/vacuum settings. The evaporative loss with the floating roof is determined using API *MPMS* Ch. 19.2.

Table 1—Evaporative Loss (lb/yr) for Open-vent Tanks with and without an Internal Floating Roof

Tank Diameter <i>D</i> (ft)	DIESEL			GASOLINE (RVP 10)		
	Loss without a Floating Roof $L_{T19.1}$	Loss with a Floating Roof $L_{T19.2}$	% Reduction	Loss without a Floating Roof $L_{T19.1}$	Loss with a Floating Roof $L_{T19.2}$	% Reduction
30	139	7	95.0%	51,154	1,567	96.9%
60	558	12	97.8%	204,614	2,410	98.8%
90	1,255	20	98.4%	460,382	4,168	99.1%
120	2,231	27	98.8%	818,457	5,481	99.3%

For the cases shown in the table above, adding a floating roof to an open-vent tank reduces emissions by approximately 95% to 99%, a fairly substantial reduction.

3.2 Emission Reductions from Closed Vents

Next, consider the emission reduction achieved by adding closed vents to a tank without a floating roof. The tank has the same parameters as in 3.1 above, except that only RVP 10 gasoline is stored, and the pressure/vacuum settings are as given in Table 2. The P/V settings range from the lowest to the highest usually encountered in unanchored storage tanks.

The lowest non-zero range used in the example is for ± 1 in. of water column (± 0.036 psi), which is slightly greater than the typical breather vent setting of $\pm \frac{1}{2}$ oz/in.² (± 0.031 psi). The pressure for the highest range is based on the approximate weight of the tank roof and shell, which is the limit above which anchorage is required. This is equivalent to approximately 0.3 psi for a 48-ft diameter tank and less for larger tanks. The API 650 tank design standard³ has historically limited the design vacuum to 1 in. water column (-0.036 psi) as noted in Section 2 above. This limitation has been removed in the most recent 650 edition, however, so larger vacuum settings are considered in this investigation. For the cases in which the pressure is greater than the minimum case, the vacuum setting is arbitrarily taken as one half of the pressure setting.

The Table 1 loss without a floating roof is the same as the Table 2 loss for a P/V setting of zero, since these are for the same case: an open-vent fixed-roof tank without an internal floating roof.

Table 2—Evaporative Loss (lb/yr) for Fixed-roof Tanks with Various Pressure/Vacuum Settings

Tank Diameter D (ft)	GASOLINE (RVP 10)							
	P/V	P/V	%	P/V	%	P/V	%	P/V
	+0	+0.036		0.100		0.200		0.300
	−0	−0.036	Red.	−0.050	Red.	−0.100	Red.	−0.150
30	51,154	50,617		50,037		48,928		47,826
60	204,614	202,467	1.0%	200,150	2.2%	195,713	4.4%	191,305
90	460,382	455,550		450,337		440,355		430,436
120	818,457	809,867		800,598		782,854		765,219

For the cases shown in the table above, adding closed vents to a tank without an internal floating roof reduces emissions by 1% to 6%. This is much less than the 95% to 99% emission reduction that results from adding an internal floating roof to a tank with open vents. Even relatively high vent settings do not reduce emissions by more than about 6% compared to open-vent tanks.

Therefore, closed-vent internal floating-roof tanks are not expected to have significantly less emissions than open-vent internal floating-roof tanks. Said another way, emissions from closed-vent IFRTs will be much closer to emissions from open-vent IFRTs than to emissions from closed-vent tanks without internal floating roofs.

4. THE ITERATIVE METHOD FOR ESTIMATING EMISSIONS FOR CLOSED-VENT IFRTs

To better understand closed-vent IFRT emissions, we constructed the model described below to determine the daily vapor content of the vapor space above the floating roof.

4.1 Daily Gain and Loss of Vapors in the Vapor Space

Consider a tank with an internal floating roof, closed vents, and a stationary product level. Each day:

- Vapors enter the vapor space: Product evaporates and moves from under the floating roof to the vapor space above the floating roof through deck seams, deck fittings, and rim seals. API MPMS Ch. 19.2 gives a method for estimating the amount of evaporative loss that occurs per year, assuming the vapor space above the floating roof is free of vapors (as is assumed to occur in an open-vent tank). This is expressed in terms of an average daily loss as follows:

$$L_{SD19.2} = L_{rd} + L_{dd} + L_{fd}$$

$L_{SD19.2}$ is the sum of the daily rim seal loss L_{rd} , daily deck seam loss L_{dd} , and daily deck fitting loss L_{fd} . The average daily loss is calculated by dividing the annual loss (from API MPMS Ch.19.2) by 365 days/yr. To determine the evaporative loss of product in a closed-vent IFRT, $L_{SD19.2}$ must be modified to account for the corresponding gain of vapors (and thus increase in saturation level) in the vapor space.

- **Vapors exit the vapor space:** Vapors in the vapor space expand due to the daytime increase in ambient temperature, and a portion of the vapors are expelled from the vents at the top of the tank if the resulting pressure exceeds the breather vent pressure setting. API MPMS Ch. 19.1 gives a method for estimating the amount of vapors that escape through the tank vents annually, assuming that there is a free liquid surface below the vapor space (i.e. no floating roof). This is expressed in terms of an average daily loss as follows:

$$L_{SD19.1} = V_V W_V K_E K_S \quad (2)$$

$L_{SD19.1}$ is the product of the vapor space volume V_V , the saturated vapor density W_V , the vapor space expansion factor K_E , and the saturation factor K_S . Both K_E and K_S are a function of the saturation of the vapor space, which changes over time.

All vapors in the vapor space will ultimately be exhausted through the vents when the tank is filled.

4.2 Saturation of the Vapor Space for Closed-vent IFRTs

To estimate the concentration of vapors above the floating roof in a closed-vent IFRT, modification is required of the equations for estimating emissions from both floating roof tanks and fixed roof tanks:

- The estimated gain (increase) of vapors in the headspace of a freely-vented IFRT [Equation (1)] must be modified to account for the retarding effect of the closed vents on the rate of evaporative loss past an internal floating roof. As the concentration of vapors above the floating roof increases, the expected rate of diffusion through openings in the floating roof decreases from that assumed by API MPMS Ch.19.2 for Equation (1) above.
- The estimated loss of vapors from the headspace of a fixed-roof tank by daily breathing [Equation (2)] must be modified to account for the retarding effect of the floating roof on the rate of evaporative loss from a fixed-roof tank. To the extent that the concentration of vapors in the vapor space is decreased, the saturation level of the vapors expelled through the fixed-roof vents will be less than that assumed by API MPMS Ch.19.1 for Equation (2) above.

In order to make these modifications, we need to know the actual saturation of the vapor space at any given time. API MPMS Ch. 19.1 gives an empirically-based method to determine the saturation of vapors at the top of the vapor space K_S as a function of the vapor space height:

$$K_S = \frac{1}{1 + 0.053 P_{VA} H_{VO}} \quad (3)$$

Although K_S as given by Equation (3) was determined empirically from various conditions of liquid level and number of days from emptying or filling, assume for simplicity that:

- K_S is the level of saturation at the top of a half full tank once equilibrium is reached.
- The saturation at the liquid surface is 1.0 once equilibrium is reached.

Equation (3) has saturation as a non-linear function of height. In order to determine the average saturation of the vapor space, Equation (3) is evaluated in Table 3 for various product vapor pressures P_{VA} and various outage heights H_{VO} (corresponding to various tank heights).