BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LIX No. 3/2007	41 - 46	Seria Tehnică

Diminishing The Losses Of Petroleum Products Stored In Fixed - Roof Tanks

Liviu Toader, Costin Ilinca

Universitatea Petrol-Gaze din Ploieşti, Bd. Bucureşti, 39, Ploieşti
e-mail: toader.liviu@yahoo.com

Abstract

The paper was intended to be a study on ways of reducing the evaporation losses of petroleum products stored in atmospheric storage tanks and is concentrated on the rational operation and proper processing of the stored petroleum products, that help reduce the atmospheric emissions and the risk of pollution from the point of view of the technical/ technological safety.

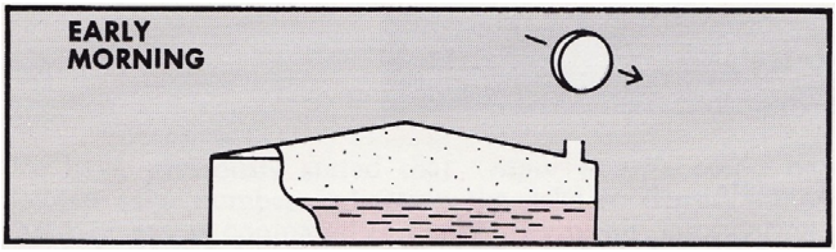
Keywords: *evaporation losses of petroleum products, atmospheric storage tanks, internal floating roof system in a fixed roof tank.*

Sources and factors that determine the evaporation losses

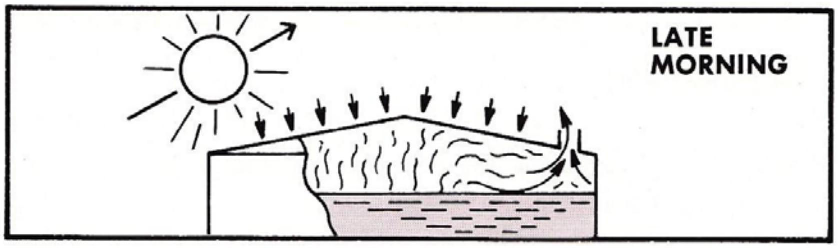
Evaporation losses are one of the most important areas of concern to operating and top management men in the chemical, petrochemical and petroleum industries. Authorities in the field have said that if total evaporation losses were known or could be fairly accurately estimated, the figure would stagger the imagination. It has been estimated, that in one day, approximately a million gallons of gasoline are vaporized in storage or in handling at refineries. When one adds to this the probable losses through evaporation in the chemical industry, one can't help but agree with a statement made by a cost control engineer that "evaporation losses are one of the most costly operating factors affecting the profitability of the chemical and petrochemical industries."

Though engineers have been aware of evaporation losses for many years, it has been within the past twenty-five to thirty years that any considerable notice has been given to the subject by organized bodies in the industries affected by the losses. Since that time, a great deal of information has been gathered, sifted, and published in an effort to guide and assist those responsible for conserving their company's assets. Manufacturers of tanks, processing equipment and related hardware have been especially active in researching the subject of evaporation losses, and their contribution to the fund of practical knowledge has been most significant.

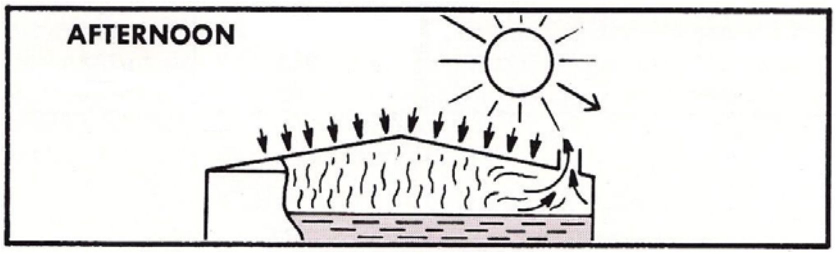
Though there are many factors which can contribute to evaporation losses from liquids in storage, temperature is the most important variable directly influencing such losses. It is well known that evaporation — the process through which a substance passes from a liquid to a gaseous state — increases as the temperature increases. The rate of increase varies with the characteristics of the liquid. Evaporation occurs at the surface of the liquid in the tank. Studies indicate that the temperature of the body of a stored liquid is approximately 6 degrees F. above the mean atmospheric temperature, and surface temperatures are approximately 10 degrees F. above the mean atmospheric temperature. This means an overall yearly average differential of approximately four degrees F. between the surface temperature and the liquid body temperature. However, reference to the drawings on the following page will show that the surface temperature can, during certain times of the day, increase considerably over liquid body temperatures due to solar radiation alone. Other temperature-inducing or decreasing factors which must be considered of course are color and material of the tank itself, wind, absorption efficiency of the tank, etc [1].



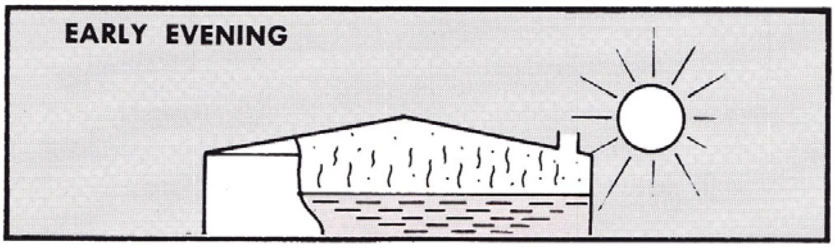
1. Sun has not come up. Temperature of gas in tank vapor space is near atmospheric temperature.
2. Condensed vapor on underside of roof reduces hydrocarbon content and density of top vapor layer.
3. Convection (see sketch above) is reduced due to decreased density in top vapor layer.



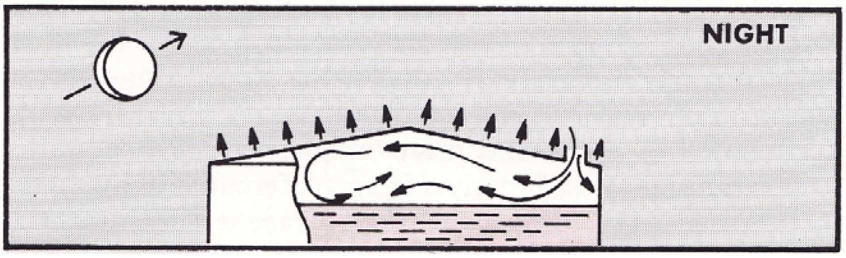
4. Rising sun increases atmospheric temperature.
5. Vapor space absorbs sun's heat and liquid surface temperature rises.
6. Expanding air-vapor mixture increases evaporation at liquid surface.
7. Thermal expansion causes air-vapor mixture to vent to atmosphere, thus increasing evaporation at liquid surface.



8. Increasing heat of sun raises temperature of vapor space, causing air-vapor mixture to expand while surface temperature rises.
9. Venting reaches peak during early afternoon due to expansion of air-vapor mixture and increased surface evaporation.



10. Venting rate decreases in late afternoon and ceases as temperature declines.



11. Vapor space temperature decreases because of heat loss through tank roof and shell.
12. Contracting air-vapor mixture draws air into tank through vent.
13. Cooler incoming air rests momentarily on heavier vapors, then descends along tank shell to liquid surface as its density is increased by cooling.
14. Warm vapors rise at center, creating convection currents in vapor space.

The drawings illustrate the effect of solar radiation on a fixed roof atmospheric tank used for storing a volatile product during a normal 24 hour breathing cycle.

The breathing cycle of a tank plus differential temperatures in the vapor space and in the body of the liquid itself, create an interesting chain reaction of liquid and vapor movement in the tank. When the vapor space temperature approximates atmospheric temperature in the early morning hours (1) the liquid temperature is slightly higher due to heat stored from the previous day. As this heat tends to move through the tank walls to cooler atmosphere, the layer of liquid nearer the wall will be cooler and tend to move toward the bottom of the tank, causing mild convection currents inside the liquid body.

Similarly, temperature differentials in the vapor space causes convection currents in the air-vapor mass. As the sun rises and atmospheric temperatures increase, the tank begins to vent an air-vapor mixture.

During the morning, as solar radiation increases, heat is absorbed by the liquid nearest the tank shell, raising its temperature above that of the liquid mass, causing this outer belt of liquid to rise and spread over the top surface. This in turn, causes an increase in the rate of evaporation and emission of vapors to the atmosphere.

This cycle continues with the rising and setting of the sun each day. In effect, the air-vapor mixture and the liquid itself is in a constant state of movement which — however small — continues the cycle of vapor loss through open vents.

Knowing the extent of these losses is important to the operating management of any company.

The measured loss "L" in barrels per year is correlated with the following factors:

True vapor pressure of the stored liquid in pounds per square inch absolute.

Tank diameter in feet.

Average outage in feet. (This is the height of the vapor space, including an allowance for the tank roof,)

Average daily ambient temperature change in degrees, Fahrenheit.

The paint factor, based on 1.00 for an all-white tank with paint in good condition.

Previous experience with manual correlations of breathing loss information, indicated that an exponential relation with each variable might yield a reasonable result. For example, the variable "D" should yield a loss of zero when "D" is zero. An exponent of "2" would make the loss vary with the liquid surface area and pass through zero at zero area. By varying the exponent from “2”, the curvature of a loss versus a diameter curve can be adjusted in a very flexible manner to best fit a number of data points. This general handling of each variable factor appeared reasonable except for the paint factor "Fp" which should have no exponent, for obvious reasons, and the variable "P" where $\left(\frac{P}{14,7-P}\right)^a$ was used as the correlating parameter.

The model equation finally selected for correlation was [4, 5]:

$$L = K\left(\frac{P}{14,7-P}\right)^a \times D^b \times H^c \times T^d \times F_P \tag{1}$$

where:

L = measured loss in barrels per year

K = a constant

P = vapor pressure at bulk liquid temperature, in pounds per square inch absolute

D = tank diameter in feet

H = average outage in feet, including a correction for the roof volume

T = average daily ambient temperature change in degrees Fahrenheit

Fp = paint factor

a, b, c and d = constant exponents

During the correlation attempts, it soon became apparent that the model equation was not adequate for the complete range of tank diameters. In particular, small tanks (less than approximately 20 ft. in diameter) did not fit a correlation based on the complete range of diameters. For this reason it was decided to develop a correlation based only on the large tanks.

A multiple correlation for tanks 20 feet in diameter or larger, based on the model equation, derived from. the tests on the tanks, yielded in the case of gasoline:

$$L_V = \frac{24}{1,000}\left(\frac{P}{14,7-P}\right)^{0,68} \times D^{1,73} \times H^{0,51} \times T^{0,50} \times F_P \tag{2}$$

where:

L = the breathing loss in barrels per year

P = the true vapor pressure at bulk liquid temperature in pounds per square inch absolute

D = tank diameter in feet

H = the average outage in feet

T = average daily ambient temperature change

Fp = the paint factor.

A modification of the above equation (2) was then required which would accommodate small-diameter tanks.

$$L_V = \frac{24}{1{,}000}\left(\frac{P}{14{,}7-P}\right)^{0{,}68} \times D^{1{,}73} \times H^{0{,}51} \times T^{0{,}50} \times F_P \times C \quad ; \qquad (3)$$

Chart 1.1. shows an adjustment factor which, if applied to the calculated loss from equation (2) markedly improves the fit of the theoretical to the experimental data. This adjustment factor may be applied to equation (2) to estimate the breathing loss of gasoline from fixed roof tanks. These methods are also applicable to all finished and intermediate refinery stocks derived from petroleum.

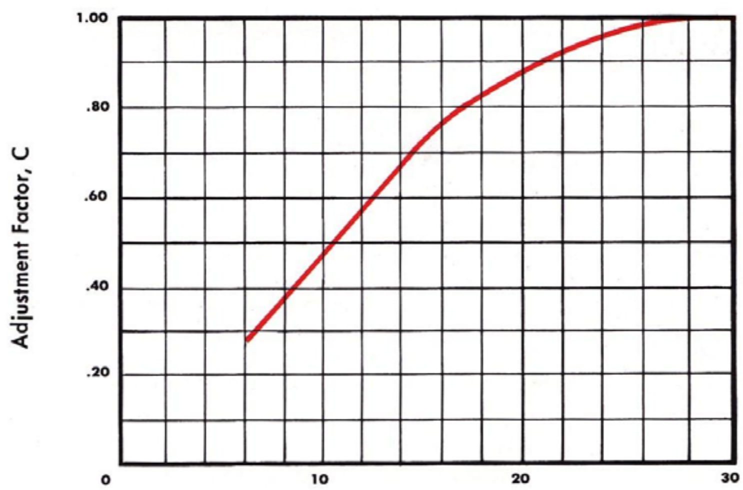


Fig.1.1. - Adjustment Factor for Small-Diameter Tanks.

Means of diminishing the evaporation losses

There are two commonly used unpressurised storage methods for hydrocarbon products and chemicals [2, 3]:

- Fixed roof storage tanks
- Open tot storage tank with a floating roof.

Both methods give-off a certain amount of emission and pollute the environment. The emissions are caused by atmospheric conditions (sun and wind) and the high vapor pressure of the stored products.

Apart from the damaging effect on the environment this also results in the permanent loss of expensive stored product.

To protect the environment, it is important to control and minimize these emissions.

In most cases these emissions can be controlled by one of the following precautions:

- Installation of an internal floating roof system in a fixed roof tank
- Fitting a secondary tank seal on external floating roof tanks

Both cases are effective and result in a considerable reduction of volatile product emissions.

The following examples give an accurate indication of the effectiveness of both methods in reducing emissions [1, 4, 5]:

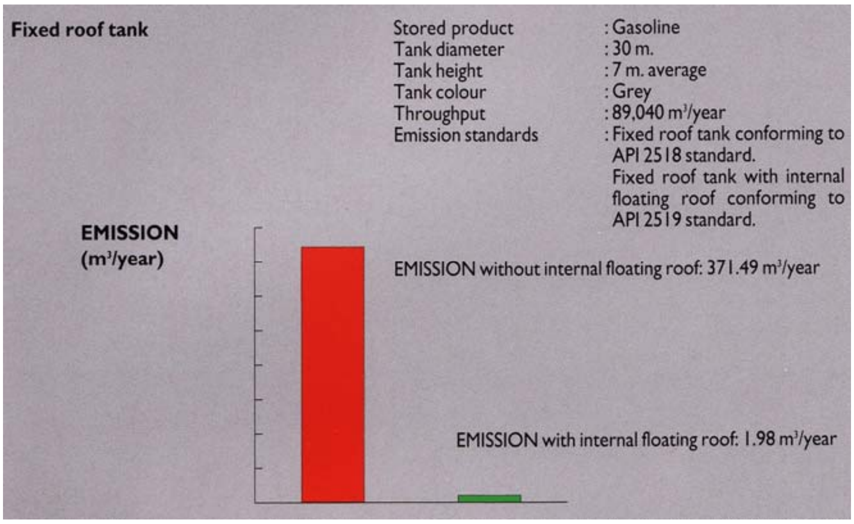


Fig. 1.2. Emission (m^3/year) for Fixed Roof Tank

Observations

As a conclusion based on this comparison, the obvious solution is to use tanks that are provided with an internal floating roof for which we have an estimated emission value of only 1.98 m3/year. This means a reduction by at least 90% of the emission rate as compared to the tanks that are not provided with an internal floating roof for which it was estimated a value of 371.49 m3/year.

The practical studies have shown that this amount of 371.49 m3/year is caused by the vaporization of the product stored in the fixed cover tanks without an internal floating roof.

References

1. Liviu Toader, - *Research Studies Concerning the Diminishing of Petroleum Products Losses from Storage Tanks* - Doctorate Thesis, Ploieşti, 2007.
2. *** API-650, *Welded Steel Tanks for Oil Storage*. This document governs the construction of tanks storing products with internal pressures up to 2.5 psig.
3. *** API-2000, *Venting Atmospheric and Low-Pressure Storage Tanks*.
4. *** *Evaporation Loss from Internal Floatig-Roof Tanks*, API Publication 2519, Third Edition, March 1990.
5. *** Manual of Petroleum. Measurement Standards, *Evaporation Loss from Internal Floating-Roof Tanks* , API Publication 2519, June 1993.

Diminuarea pierderilor de produse petroliere la depozitarea în rezervoare cu capac fix

Rezumat

Lucrarea este elaborată ca un studiu privind diminuarea pierderilor de produse petroliere la depozitarea în rezervoarele de depozitare atmosferică şi vizează exploatarea raţională, respectiv procesarea conformă a produselor petroliere stocate, ceea ce conduce la minimizarea emisiilor poluante în atmosferă şi reducerea riscurilor de poluare, din punct de vedere al securităţii tehnice/tehnologice.