Estimate Storage Tank Emissions

JIMMY PERESS,
TRITECH CONSULTING
ENGINEERS

Use this shortcut to quickly determine emissions from fixed-roof storage tanks.

Fixed-roof storage tanks containing organic liquids are widely used in all industries that produce or consume organic liquids. Emissions from fixed-roof storage tanks consist of working losses and breathing losses (often referred to as standing losses).

Engineers often need to estimate emissions from the storage tanks to prepare air permits or develop emission estimates. The EPA has published a detailed method for calculating losses from storage tanks *(1)*. However, it is quite tedious and time-consuming to the occasional user.

To assist industry, the EPA has developed a software program to calculate storage tank losses. The software program, entitled TANKS 4.09, is available for downloading from the EPA Web site *(2)*. Other commercial software is also available (see the *CEP* Software Directory at www.aiche.org/software).

This article presents an adaptation of the conventional EPA method tgo provide a quick estimate of the emissions from fixed-roof storage tanks.

Simplified procedure — working losses

Working losses occur when the vapor in the vapor space over the liquid is displaced from the tank by the addition of organic liquid during tank filling. Working losses depend on the annual amount of material pumped, the vapor pressure of the material stored, and the ambient temperature.

The working losses can be estimated by:

$$L_w = Q_w\,(1/359)(273.15/T)(VP/760)(MW)(K_N)(K_p) \qquad (1)$$

K_N, the turnover factor, is based on the number of turnovers per year, N, which is defined as $N = Q_w/V_T$. $K_N = (180 + N)/6N$ for $N > 36$ and $K_N = 1$ for $N < 36$. K_p, the working loss product factor, is defined as $K_p = 0.75$ for crude oils and $K_p = 1.0$ for organic liquids.

Simplified procedure — breathing losses

Breathing losses occur because differences in temperature (such as changes between day and night temperatures) affect the vapor space pressure inside storage tanks. Vapors expand with an increase in temperature and contract with a decrease in temperature. In addition, the saturated vapor concentration of a substance in air increases with increasing temperature and decreases with decreasing temperature. As the outside temperature rises during the day, the pressure inside a tank increases and air will be expelled from the tank. As the temperature falls during the night, pressure in the tank decreases and fresh air flows into the tank.

The simplified method for calculating the breathing losses is an adaptation of an EPA method published in Ref. 1.

Consider a tank with a volume of V_T and a liquid level L_T. The vapor space of the tank is:

$$V_v = V_T(100 - L_T)/100 \qquad (2)$$

The vapor expansion factor due to day-night temperature fluctuation is defined as:

$$K_E = T_R/T \qquad (3)$$

where the average ambient temperature is T and the day-night temperature fluctuation is T_R,.

The total air displaced per day is calculated by:

$$M_{air} = (V_v)(1/359)(K_E)(273.15/T) \qquad (4)$$

The breathing losses can now be estimated from:

$$L_b = 365M_{air}(VP/760)(MW) \qquad (5)$$

Conventional EPA methodology

The EPA procedure for estimating working losses assumes a constant temperature of 15°C (59°F), but it is otherwise identical to the shortcut method described above.

The method adopted by the EPA to estimate breathing losses is described in full in Ref. 1. The basic equation is:

$$L_s = 365(V_v)(W_v)(K_E)(K_s) \qquad (6)$$

In general terms, the vapor space expansion factor (K_E) represents the combined effect of the day-night temperature fluctuation on the volume of the vapors and on the vapor pressure of the liquid in the tank.

The vented vapor saturation factor (K_s) can be viewed as the approach to saturation of the liquid in the vapor space. It is governed by the vapor pressure of the liquid and the tank outage (height of the vapor space in the tank). The saturation factor approaches 1.0 when the vapor pressure is low or the tank outage is small.

Ref. 1 provides detailed guidelines for evaluating each of

Table. Comparison of shortcut procedure and EPA method.

Organic Liquid	EPA Method			Simplified Method			Discrepancy		
	Working Losses, lb/yr	Breathing Losses, lb/yr	Total Losses, lb/yr	Working Losses, lb/yr	Breathing Losses, lb/yr	Total Losses, lb/yr	Working Losses	Breathing Losses	Total Losses
Toluene	603.9	319.7	923.6	584.3	317.2	901.6	–3.2%	–0.8%	–2.4%
o-Xylene	147.1	85.1	232.2	141.2	76.7	217.9	–4.0%	–9.9%	–6.2%
Methanol	915.9	413.8	1,329.7	885.4	481.0	1,366.4	–3.3%	+16.2%	+2.8%
Cumene	111.9	65.5	177.4	107.1	58.2	165.3	–4.3%	–11.1%	–6.8%
Acetone	3,443.7	1,338.3	4,782.0	3,360.4	1,825.7	5,186.1	–2.4%	+36.4%	+8.5%
o-Dichlorobenzene	42.3	25.1	67.4	40.4	22.0	62.4	–4.5%	–12.4%	–7.4%

Notes:
1. Storage tank is 40 ft high x 20 ft dia., and on average is half full.
2. Total annual throughput is 939,967 gal/yr (125,664 ft^3/yr).
3. Daily average temperature is 54.55˚F (12.53˚F).
4. Daily average temperature range is 15.3˚F (8.5˚F).

the above terms. The EPA method recognizes that the temperature of the liquid and the temperature of the vapor space may be different from the ambient temperature. Empirical formulas are provided to determine the temperatures of the liquid and the vapors if the ambient temperature and the daily range are given.

Example

A fixed-roof vertical tank contains toluene (MW = 92.14). The tank has a volume of 93,997 gal (40 ft dia. by 20 ft high) and is half full. The total annual throughput is 939,967 gal/yr (125,664 ft^3/yr). From meteorological data, the daily average ambient temperature is 54.55°F (12.53°C) and the daily average temperature range is 15.3°F (8.5°C). The toluene vapor pressure at the daily average temperature is 14.40 mmHg. From Eq. 1, working losses are determined to be L_w = 584.3 lb/yr. From Eqs. 2–5, breathing losses are calculated to be L_b = 317.3 lb/yr. The total losses are the sum of L_w and L_b, or 901.6 lb/yr.

Comparing the methods

The table summarizes the results of emissions calculations for the example and for the same storage tank containing other organic liquids. In most cases, the simplified procedure presented here yields results that are in reasonable agreement with the results obtained using the conventional EPA methodology. Depending on the assumed ambient temperature, the discrepancy for working losses between the two methods is in the order of 2–3 %.

The shortcut technique for breathing losses incorporates some simplifications that may lead to a somewhat larger discrepancy. As illustrated in the table, the difference is within 10% for liquids such as toluene, *o*-xylene, cumene, or *o*-dichlorobenzene, where the vapor pressure is up to about 30 mm Hg. For more volatile liquids, such as acetone or methanol, the shortcut method may lead to overly conservative values for breathing losses.

Program available

A template to estimate emissions via the simplified procedure and the EPA method is available on an Excel spreadsheet. Readers interested in obtaining a copy of the template free of charge may contact the author at peressj@nyc.rr.com. CEP

Nomenclature

K_E = vapor space expansion factor, dimensionless
K_N = annual turnover factor, dimensionless
K_p = working loss product factor, dimensionless
K_s = vented vapor saturation factor, dimensionless
L_b = breathing losses, lb/yr
L_s = standing storage loss, lb/yr
L_T = liquid level in tank, % of total height
L_w = working losses, lb/yr
M_{air} = air displaced from tank due to expansion, lbmole/d
MW = molecular weight of the liquid stored
N = number of turnovers per year
Q_w = annual throughput of organic liquid pumped to the tank, ft^3/yr
T = ambient temperature, K
T_R = day-night temperature fluctuation, K
VP = vapor pressure of the organic liquid at the ambient temperature, mmHg
V_T = tank capacity, ft^3
V_v = vapor space in tank, ft^3
W_v = vapor density, lb/ft^3

Literature Cited

1. **U.S. Environmental Protection Agency,** "Supplement E to AP-42, Compilation of Air Pollutant Emission Factors, Volume 1," U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC (Oct. 1992).
2. **U.S. Environmental Protection Agency,** "TANKS 4.09 Software zProgram," U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC, available at www.epa.gov/ttn/chief/software/tanks.

J. PERESS, P.E., is director of Tritech Consulting Engineers, Jamaica, NY (Phone: (718) 454-3920; Fax: (718) 454-6330; E-mail: peressj@nyc.rr.com). He has over 30 years of professional experience in process engineering, process troubleshooting, software development, and regulatory compliance (emission inventories and air permitting). Prior to starting his consulting practice in 1983, he was a process development manager and a senior consultant for Chem Systems, Inc. He earned a BSChE from the Israel Institute of Technology and an MSChE from the City University of New York. He is a Professional Engineer registered in New York, New Jersey, and Delaware, and he holds seven U.S. patents. He is a member of AIChE and the American Chemical Society.