



MEMO

July 20, 1998

TO: Mr. Curt D. Johnson, Chairperson, National Work Group on Leak Detection  
Evaluations

FROM: Sam Gordji<sup>1</sup>

SUBJECT: The Analysis of the Unaccounted or Lost Gasoline Vapor in the UST

Several years ago, a SIR company wanted to adjust for the vapor gas that is transferred from the UST to the transport during a delivery. The following is a part of the analysis that I performed for them and is needed to obtain the amount of vapor gas that is moved from the UST to the transport. The amount of the vapor gas transferred to the transport is considerable and is a function of the temperature and the volume. This amount should be accounted for especially for the high throughput USTs. The following two equations ( equations 1 & 2) should be solved for a given temperature and tank size to obtain the correct amount of liquid gas transferred to the transport. Not compensating for this amount of vapor may cause errors that will show as loss especially for the large throughput USTs. A small computer program may be executed to calculate the amount of the liquid gas lost when the delivery occurs.

The following parameters are needed to solve equations 1, and 2.

T = temperature in degrees kelvin:  $T(K) = 273.15 + T(C)$

R = gas constant = 0.083145 bar liter/(K mole) = 8.3145 J/(K mole)

dl = mole density of liquid (moles/liter)

w = molar mass of gasoline (kg/mole)

p = vapor pressure of the gas (bar)

Vl = volume occupied by the liquid (liters)

Vg = volume occupied by the gas (liters)

V = total volume of the tank (liters)

ml = mass of liquid (kg)

m = total mass of gasoline (kg)

nl = moles of liquid = dl \* Vl

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$n_g$  = moles of gas

$n$  = total moles of gasoline =  $m/w$

The volume of the tank is fixed, so  $V_l + V_g = V$ , which is a constant.

Mass is conserved, so  $n_l + n_g = n$ , which is also a constant.

According to the ideal gas law,

$$\begin{aligned} V_g &= (n_g \cdot R \cdot T) / P = [(n - n_l) \cdot R \cdot T] / P = \{ [n - (d_l \cdot V_l)] \cdot R \cdot T \} / P \\ &= \{ [n - d_l \cdot (V - V_g)] \cdot R \cdot T \} / P \\ &= [(n - d_l \cdot V) \cdot R \cdot T / P] + (V_g \cdot d_l \cdot R \cdot T / P) \end{aligned}$$

Solving for  $V_g$ :

$$\begin{aligned} V_g - [(V_g \cdot d_l \cdot R \cdot T) / P] &= [(n - d_l \cdot V) \cdot R \cdot T] / P \\ V_g &= [ \{ (n - d_l \cdot V) \cdot R \cdot T \} / P ] / [ 1 - (d_l \cdot R \cdot T) / P ] \end{aligned} \quad (1)$$

The pressure in this equation is the vapor pressure of the gasoline, which depends on the temperature according to this equation:  $dP = (\Delta H / R) \cdot (dT / T)$ , after integrating this equation and substitution of the proper constants we arrive at the following equation:

$$P(\text{bar}) = \exp \{ (\Delta H / R) \cdot [(1/T_b) - (1/T)] \} \quad (2)$$

Where  $\Delta H$  is the heat of vaporization,  $R$  is the gas constant, and  $T_b$  is the normal boiling point.

To solve for the fraction of the total mass which is in the form of the liquid, we can plug the equation for  $V_g$  into:

$$\begin{aligned} m_l / m &= (n_l \cdot w) / m = (d_l \cdot V_l \cdot w) / m \\ &= \{ d_l \cdot (V - V_g) \cdot w \} / m \end{aligned}$$

The following constants are for pure octane but may be used for gasoline:

$w = 0.11423$  kg/mole

$d_l = 6.116$  mole/liter

$\Delta H = 34410$  J/mole

$T_b = 398.82$  K

To obtain a volume that is occupied by vapor gas, equation 2 is solved for a given temperature and the result is substituted into equation 1. Solving equation 1 will give the volume occupied by vapor gasoline. **Going through the above calculations is the only way to obtain the amount of vapor gas transferred from the UST to the delivery truck.**

Cc: National Work Group on Leak Detection Evaluations

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