Estimating LEL and Flash

The lower explosive limit (LEL) is the minimum concentration of a vapor in air that will support a flame when ignited. The flash point is the lowest temperature of a liquid that produces sufficient vapor for an open flame to ignite in air.

Gooding provides ways to estimate these two important safety-related properties. The methods make use of the following observed rules:

1. The LEL occurs at about 50% of the stoichiometric oxidation concentration at ambient temperature and pressure.
2. The flash point occurs at about the temperature at which the liquid has a vapor pressure equal to the LEL partial pressure.
3. It follows then, that knowing the stoichiometry and having a vapor pressure chart, one can determine the LEL and flash point. Also if either the LEL or flash point is known, a vapor pressure chart can be used to estimate the other.

Example:
Estimate the LEL and flash point for ethanol.

The oxidation (combustion) equation is:

$$C_2H_5OH + 3O_2 = 2CO_2 + 3H_2O$$

For 1 mol of ethanol we need:
3 mols of O_2
or 3/0.21 = 14.28 mols of air

The stoichiometric concentration of ethanol in air is thus 1/15.28 = 0.0654 mol fraction. The LEL is 50% of this or 0.0327 mol fraction. This matches the reported value of 3.3% by volume.

The partial pressure of LEL ethanol is 0.0327 atm. The temperature that produces a vapor pressure of 0.0327 atm is 11°C, which is our predicted flash point. This is close to the reported 13°C.

The Gooding article presents graphs that show high accuracy for these methods.

Source

Gooding, Charles H., "Estimating Flash Point and Lower Explosive Limit," Chemical Engineering, December 12, 1983.

Tank Blanketing

Inert gas is used to blanket certain fixed-roof tanks for safety. Here is how to determine the inert gas requirements. Inert gas is lost in two ways: breathing losses from day/night temperature differential, and working losses to displace changes in active level.

Breathing Losses

1. Determine the vapor volume, V_0

$$V_0 = \pi D^2/4(\text{avg. outage})$$

where

D = Tank diameter, ft
avg. outage = Average vapor space, ft
V_0 = Vapor volume, scf

2. Calculate daily breathing loss (DBL)

$$DBL = V_0\{[(460 + T_s + T_{dc}/2)/(460 + T_s + \Delta - T_{dc}/2)] - 1.0\}$$

where

T_s = Storage temperature, °F
T_{dc} = Daily temperature change, °F
DBL = Daily breathing loss, scf
Δ = Adjustment for the differential between blanketing and pressure-relief settings (normally 2–4°F)

3. See Figures 1 and 2 for T_s and T_{dc}

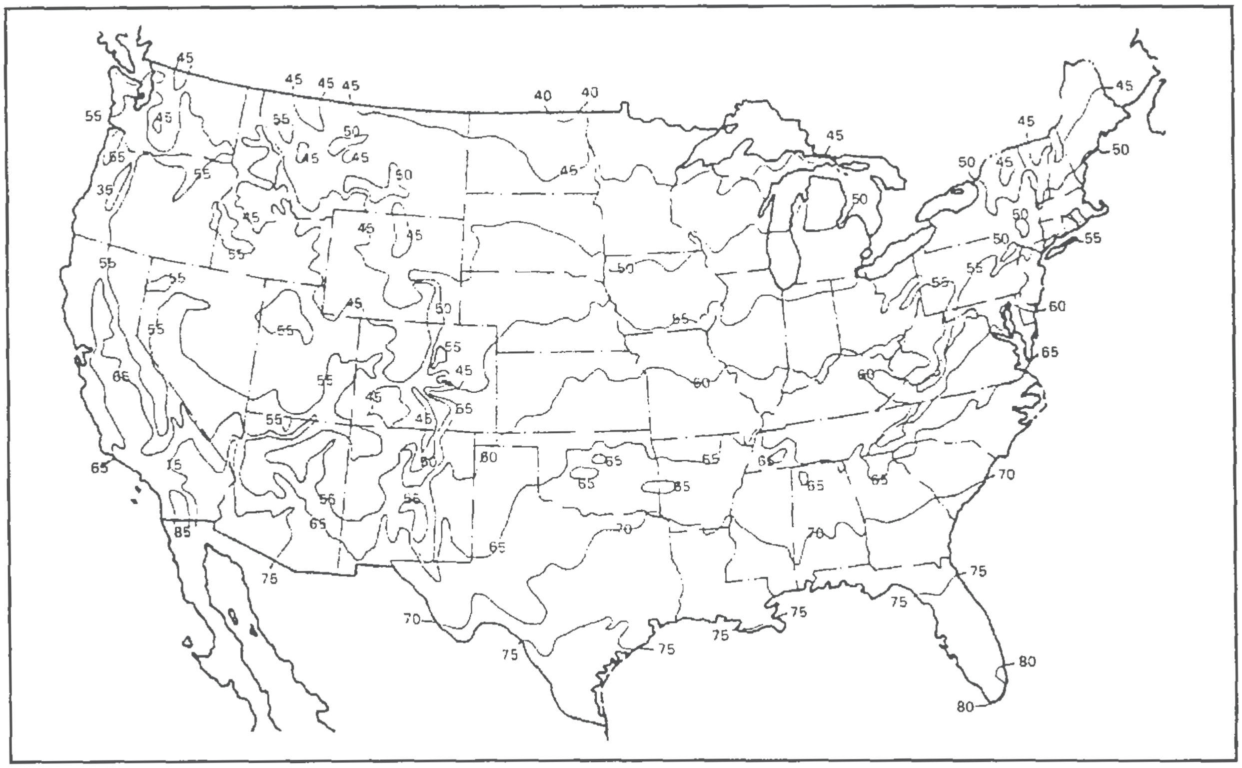

Figure 1. Average storage temperatures for the U.S. used to estimate breathing losses.

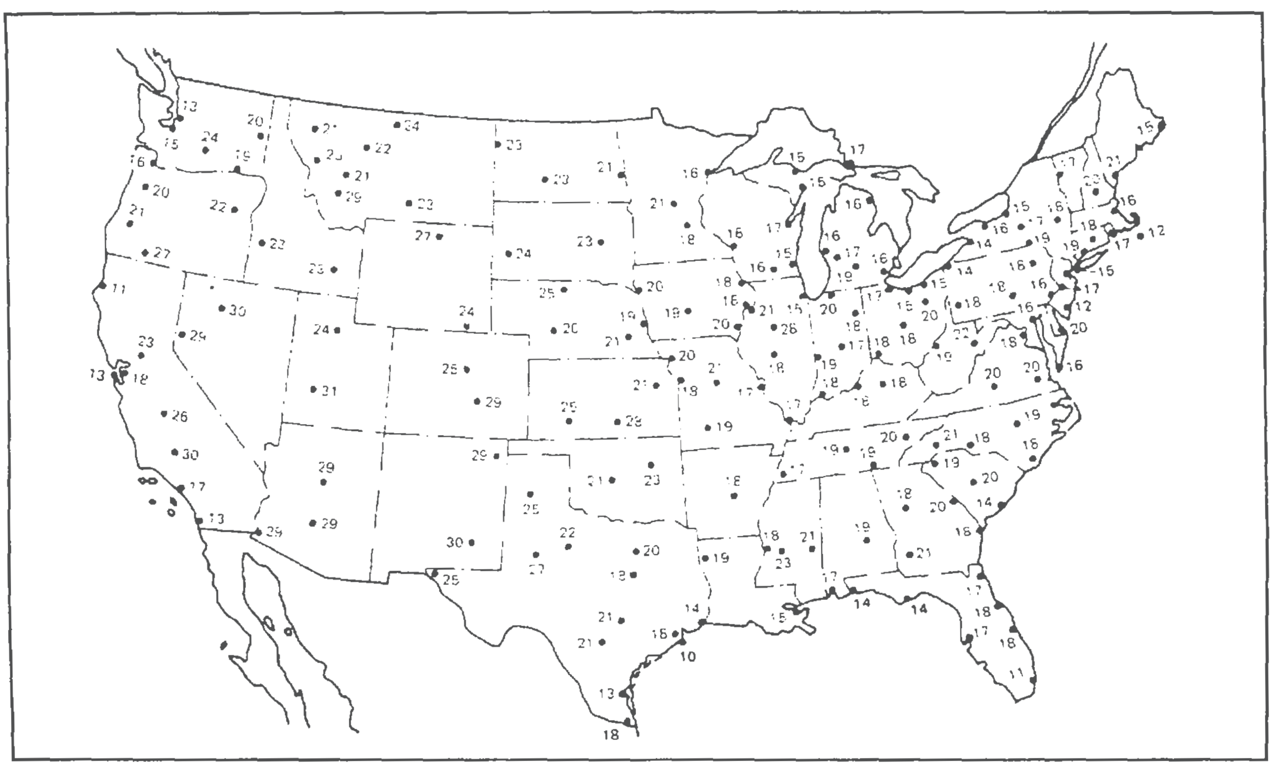

Figure 2. Average daily temperature changes for the U.S. used to estimate breathing losses.

Working Losses

Use the following displacement equivalents of inert gas to tank liquid:

1 gal × 0.1337 = 1 scf inert gas
1 bbl × 5.615 = 1 scf inert gas

Example: A fixed-roof tank
D = 128 ft
Height = 36 ft
Avg. outage = 12 ft
Annual throughput = 300,000 bbl
Location = New Orleans
Determine monthly inert gas usage
Solution:

$T_s = 75°F$ (Figure 1)
$T_{dc} = 15°F$ (Figure 2)
$\Delta = 2°F$ (Assumed)

Vapor volume $= \pi(128)^2/4(12) = 155{,}000\,ft^3$

$$DBL = 155{,}000\{[(460 + 75 + 15/2)/(460 + 75 + 2 - 15/2)] - 1.0\}\ scf/d$$

$$= 3{,}805\ scf/d \text{ or } 3{,}805(30)$$
$$= 114{,}000\ scf/mo$$

Monthly working loss = 300,000/12(5.615) = 140,000 scf/mo
Total inert gas usage 254,000 scf/mo

Source

Blakey, P. and Orlando, G., "Using Inert Gases For Purging, Blanketing and Transfer," *Chemical Engineering*, May 28, 1984.

Equipment Purging

Blakey and Orlando give useful methods for determining inert gas purging requirements.

Dilution Purging

- The inert gas simply flows through the vessel and reduces the concentration of unwanted component.
- It is used for tanks, reactors, and other vessels.
- Use Figure 1 to determine the quantity of inert purge gas required.

Example: A tank full of air (21% O_2) needs to be purged to 1% O_2. From Figure 1, 3.1 vessel volumes of inert gas are required.

Pressure-Cycle Purging

- The vessel at 1 atm is alternately pressured with inert gas and vented.
- It is used for vessels that can withstand 30 psig or more, vessels with only one port, or vessels with coils or baffles inside. It is useful when pressurization is needed anyway, such as for testing.
- The dilution ratio is $(1/P)^n$
  where
  P = pressure, atm
  n = number of cycles

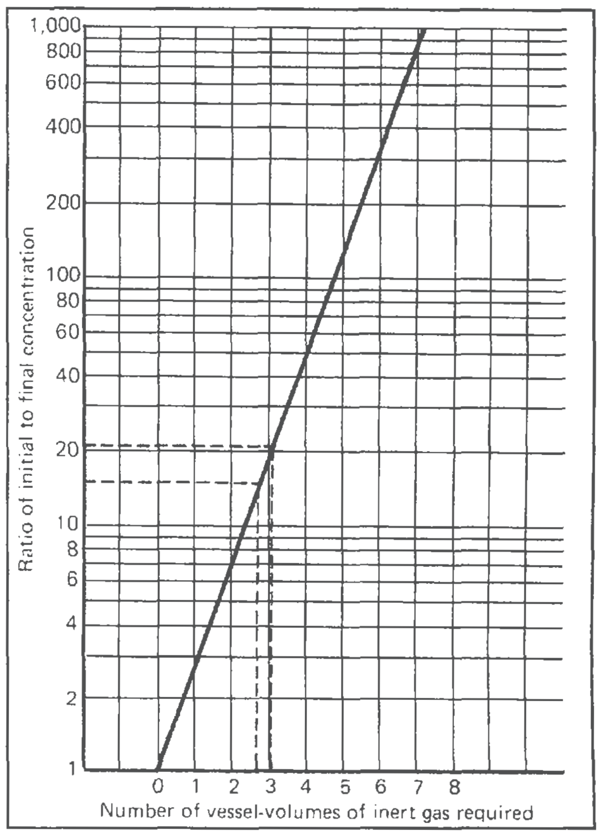

Figure 1. Vessel-volume of inert gas is determined by ratio of final to initial gas.