# Homework #5

Do problems 8.2 & 8.4 on page 183.

# 8.2

Assume that the gas in the line in Exercise 8.1 condenses 0.01 GPM (1.41 m³/106 m³) over the 8 mile (12.9 km) distance and the line is pigged once a day. How many gallons (m³) of condensate would the pig remove from the line?

Note: the 8.1 problem statement is:
A 6 in. pipe (internal area = 0.2006 ft² [0.01864 m²] gas line transmits 20 MMscfd (0.536 × 10⁶ Nm³/d). An 8 mile (12.9 km) segment of the line is pigged. Assuming that the average pipeline temperature is 80°F (27°C) and average operating pressure is 250 psig (17.2 barg), what would be the average pig speed (mph, km/h) in the line and the minimum time it would take to traverse the pigged segment? Assume that there is minimal gas slippage around the pig & ideal gas behavior.

**Modified #8.4**

Compute the concentration of inhibitor needed (in wt%) to provide 25°F of subcooling into the hydrate region using the Hammerschmidt and Nielsen & Bucklin equations. Do calculations for both ethylene glycol & methanol (assume specific gravity of methanol is 0.79).
**Solutions**

*Problem #8.2 (5 points)*

Assume that the gas in the line in Exercise 8.1 condenses 0.01 GPM (1.41 m³/10⁶ m³) over the 8 mile (12.9 km) distance and the line is pigged once a day. How many gallons (m³) of condensate would the pig remove from the line?

*Solution*

The value for the liquid content takes into account the pipeline length so it does not have to be further used in any calculation. The total liquids that drop out are:

\[
\dot{V}_{\text{liq}} = \left(0.01 \frac{\text{gal}}{10^6 \text{ ft}^3}\right) \left(20 \times 10^6 \frac{\text{ft}^3}{\text{day}}\right) = 200 \frac{\text{gal}}{\text{day}}.
\]

So, in a day's time 200 gal will accumulate.
Modified Problem #8.4 (10 points)
Compute the concentration of inhibitor needed (in wt%) to provide 25°F of subcooling into the hydrate region using the Hammerschmidt and Nielsen & Bucklin equations. Do calculations for both ethylene glycol & methanol (assume specific gravity of methanol is 0.79).

Solution
The following are the Hammerschmidt equations to estimate the mass fraction inhibitor required to provide a specified hydrate subcooling:

$$X_i = \frac{(\Delta T)_p \cdot M}{(\Delta T)_p \cdot M + 2335} \quad \text{for US customary units.}$$

Since methanol has a molecular weight of 32.042 then:

$$X_{\text{MeOH}} = \frac{(25)(32.042)}{(18)(32.042) + 2335} = 0.255$$

The following are the Nielsen and Bucklin equations to estimate the water’s mole fraction required to have a specified hydrate subcooling:

$$(\Delta T)_p = -129.6 \ln (x_w) \quad \text{for US customary units.}$$

So:

$$x_w = \exp \left( \frac{(\Delta T)_p}{-129.6} \right) = \exp \left( \frac{25}{-129.6} \right) = 0.8246$$

Now converting to mass fraction methanol:

$$X_{\text{MeOH}} = \frac{x_{\text{MeOH}} M_{\text{MeOH}}}{x_w M_w + x_{\text{MeOH}} M_{\text{MeOH}}} = \frac{(1-0.8246)(32.042)}{(0.8246)(18.015) + (1-0.8246)(32.042)} = 0.275.$$ 

Note that these values are fairly close together.

For ethylene glycol, with a molecular weight of 62.07, then:

$$X_{\text{EG}} = \frac{(25)(62.07)}{(18)(62.07) + 2335} = 0.399$$

The Nielsen and Bucklin equation will give the same water mole fraction. Converting to a mass fraction of ethylene glycol:
\[ X_{EG} = \frac{x_{EG}M_{EG}}{x_{w}M_{w} + x_{EG}M_{EG}} = \frac{(1-0.8246)(62.07)}{(0.8246)(18.015)+(1-0.8246)(62.07)} = 0.423. \]

Note that these values are quite different. Even though the Hammerschmidt equation can be used for both inhibitors the Nielsen & Bucklin equation should only be used for methanol.