

Flow Rate Calculations

- using orifice plates -

Liquid Flow Rate

The basic formula for liquid flow rate in gph is:

$$\text{gph} = \sqrt{(h_w)} * F_b * F_{gt} * F_r * F_a$$

where:

h_w = differential pressure across the orifice plate (in inches of water)

F_b = basic orifice factor

F_{gt} = gravity temperature factor

F_r = Reynolds number

F_a = orifice thermal expansion factor

If the calculation is not being used for custody transfer or accounting, the last two terms can be eliminated without much error.

Hot Oil Loop Setup:

The following assumptions have been made for the hot oil loop at the Thermal Oxidizer:

Line size: 8" schedule 80, which translates to 7.625" ID.

Orifice plate bore: 5.9996" diameter.

Hot oil line dP transmitter is scaled: 0-200" wc.

Specific gravity: 0.87.

Flowing temperature: 350°F.

Pressure: 70-85 psig.

h_w = measured from the dP transmitter.

F_b = 9075.9 (this number is **estimated** from fig 3-16 in the GPSA Engineering Data Book. According to this table, the existing orifice plate is too large to yield accurate measurement. The largest plate that should be used is 5.5".)

F_{gt} = $1.0057/\sqrt{(0.87)} = 1.078$ Some error will be introduced because we do not know the **specific gravity at the flowing temperature.**

gpm = gph/60.

So the formula which is used in the PLC is:

$$\text{gpm} = (9075.9) * (1.078) * \sqrt{(dP)} / 60.$$

$$\text{gpm} = 163.1 \sqrt{(dP)}.$$

This is calculated on rung 60:98 in the thermal oxidizer Process PLC.

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Gas Flow Rate

The basic formula for gas flow rate in scfh is:

$$\text{scfh} = \sqrt{h_w} * \sqrt{P_f} * F_b * F_{pb} * F_{tf} * F_{pv} * F_g * F_r * Y * F_{th} * F_a$$

where:

h_w = differential pressure across the orifice plate (in inches of water)

P_f = static pressure, psia

F_b = basic orifice factor

F_{pb} = pressure base factor

F_{tf} = flowing temperature factor

F_{pv} = supercompressibility factor

F_g = specific gravity factor

F_r = Reynolds number

Y = expansion factor

F_{th} = temperature base factor

F_a = orifice thermal expansion factor

If the calculation is not being used for custody transfer or accounting, the last four terms can be eliminated without much error.

Amine Tail Gas Loop:

The following assumptions have been made:

Line size: 6" schedule 80, which translates to 5.761" ID.

Orifice plate bore: 2.817" diameter.

Tail gas dP transmitter is scaled: 0-75" wc.

Tail gas pressure transmitter is scaled: 0-50 psig.

Specific gravity: 1.5075.

Flowing temperature: 87°F.

h_w = measured from the dP transmitter.

P_f = measured from the pressure transmitter, psig + 14.7 to convert to psia.

F_b = 1666.7 (interpolated from fig 3-16 in the GPSA Engineering Data Book).

F_{pb} = 1 (we are at sea level, so no correction is required).

F_{tf} = $\sqrt{[520/(460+T_f)]}$ where T_f is the flowing temp, = 0.9750. This equation converts to an absolute temperature scale.

F_{pv} = Unknown. Assume = 1.

F_a = $\sqrt{[1/G]}$, where G is the specific gravity, = 0.8145.

mcf/d = scfh * 24 hrs/day * 1 mcf/1000 scf = 0.024 scfh.

mcf/d = $\sqrt{h_w} * \sqrt{P_f} * 1666.7 * 1 * 0.9750 * 1 * 0.8145 * 0.024$

mcf/d = 31.77 * $\sqrt{h_w} * \sqrt{P_f}$

This is calculated in file 24 of the Thermal Oxidizer Process PLC.