Flow Rate Calculations

- using orifice plates -

Liquid Flow Rate

The basic formula for liquid flow rate in gph is:

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

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 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:

gpm = $(9075.9) * (1.078) * \sqrt{(dP)} / 60$.
gpm = $163.1 \sqrt{(dP)}$.

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

Flow Rate Calculations

- using orifice plates -

Gas Flow Rate

The basic formula for gas flow rate in scfh is:

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

where:

- $\mathbf{h_w}$ = differential pressure across the orifice plate (in inches of water)
- $\mathbf{P_f}$ = static pressure, psia
- $\mathbf{F_b}$ = basic orifice factor
- $\mathbf{F_{pb}}$ = pressure base factor
- $\mathbf{F_{tf}}$ = flowing temperature factor
- $\mathbf{F_{pv}}$ = supercompressibility factor
- $\mathbf{F_g}$ = specific gravity factor
- $\mathbf{F_r}$ = Reynolds number
- **Y** = expansion factor
- $\mathbf{F_{th}}$ = temperature base factor
- $\mathbf{F_a}$ = orifice thermal expansion factor

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

<u>Amine Tail Gas Loop:</u>

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.

$\mathbf{h_w}$ = measured from the dP transmitter.
$\mathbf{P_f}$ = measured from the pressure transmitter, psig + 14.7 to convert to psia.
$\mathbf{F_b}$ = 1666.7 (interpolated from fig 3-16 in the GPSA Engineering Data Book).
$\mathbf{F_{pb}}$ = 1 (we are at sea level, so no correction is required).
$\mathbf{F_{tf}}$ = $\sqrt{[520/(460+T_f)]}$ where T_f is the flowing temp, = 0.9750. This equation converts to an absolute temperature scale.
$\mathbf{F_{pv}}$ = Unknown. Assume = 1.
$\mathbf{F_a}$ = $\sqrt{[1/G]}$, where G is the specific gravity, = 0.8145.
mcfd = scfh * 24 hrs/day * 1 mcf/1000 scf = 0.024 scfh.

mcfd = $\sqrt{hw} * \sqrt{P_f} * 1666.7 * 1 * 0.9750 * 1 * 0.8145 * 0.024$
mcfd = $31.77 * \sqrt{hw} * \sqrt{P_f}$

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