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Project No.: LAPD
Date: 11/12/09
Revision: A

Argon Pressure Drops to and from Condenser

The Argon vapor line to the condenser and liquid line from the condenser are sized for low pressure drop.

Argon Data

Argon physical properties from NIST REPROP

argon liquid density

$\rho_{Ar_l} := 1396 \cdot \frac{kg}{m^3}$

argon vapor density

$\rho_{Ar_v} := 0.4 \cdot \frac{lb}{ft^3}$

argon liquid visc

$\mu_{Ar_l} := .261 \cdot cP$

argon liquid viscosity

$\mu_{Ar.l} := 0.26 \cdot cpoise$

argon gas viscosity

$\mu_{Ar.v} := 0.00717 \cdot cpoise$

argon heat capacity ratio

$\gamma_{Ar} := 1.72$

argon MW

$MW_{Ar} := 39.948 \cdot \frac{gm}{mole}$

argon mass flowrate

$mflow_{Ar} := 208 \cdot \frac{lb}{hr}$

define parameters for pressure drop calc - Argon vapor to condenser

Tube Outlet Pressure assuming 0 psi in condenser

$P_{out} := 0 \cdot psi + atm$

Outlet Temperature

$T_{out} := 88 \cdot K$

heat capacity ratio

$\gamma := \gamma_{Ar}$

molecular weight

$M_w := MW_{Ar}$

viscosity

$\mu := \mu_{Ar.v}$

mass flow

$mflow := mflow_{Ar}$

Vapor Pipe inside diameter

$D_v := 2.157 \cdot in$

Vapor Pipe Length

$L_v := 75 \cdot ft$

Pipe Roughness:

$\varepsilon := 0.00015 \cdot ft$

define initial guesses for calc

Pressure Drop initial guess

$\Delta P := 0.5 \cdot psi$

Pipe Inlet Pressure

$P_{in} := P_{out} + \Delta P$ $\quad P_{in} - atm = 0.5 \cdot psi$

Temperature Change initial guess

$\Delta T := 0.05 \cdot K$

Inlet Temperature

$T_{in} := T_{out} + \Delta T$

Friction factor initial guess

$f := 0.004$

Calc vapor pipe velocity

$$V_1 := \frac{\frac{mflow}{\rho_{Ar_v}}}{\left(\frac{D_v}{2}\right)^2 \cdot \pi} = 5.692 \cdot \frac{ft}{s}$$

Calc Reynolds number

$$Re_{num} := \frac{V_1 \cdot D_v \cdot \rho_{Ar_v}}{\mu} = 84944$$

Pipe Pressure Drop Equations

Given

Fanning Friction Factor
tradional straight pipe

$$\frac{1}{\sqrt{f}} = -4.0\cdot\log\left(\frac{\varepsilon}{3.7\cdot D_v} + \frac{1.255}{4\cdot\frac{mflow}{D_v\cdot\pi\cdot\mu}\cdot\sqrt{f}}\right)$$

Adiabatic compressible flow equations

$$\frac{mflow}{\left(\frac{D_v}{2}\right)^2\cdot\pi} = \sqrt{2\cdot\frac{M_w}{R_g}\cdot\left(\frac{\gamma}{\gamma-1}\right)\cdot\left[\frac{T_{out}-T_{in}}{\left(\frac{T_{in}}{P_{in}}\right)^2-\left(\frac{T_{out}}{P_{out}}\right)^2}\right]}$$

$$\left[\frac{\gamma+1}{\gamma}\cdot\ln\left(\frac{P_{in}\cdot T_{out}}{P_{out}\cdot T_{in}}\right)-\left(\frac{\gamma-1}{2\cdot\gamma}\right)\cdot\left(\frac{P_{in}^2\cdot T_{out}^2-P_{out}^2\cdot T_{in}^2}{T_{out}-T_{in}}\right)\cdot\left(\frac{1}{P_{in}^2\cdot T_{out}}-\frac{1}{P_{out}^2\cdot T_{in}}\right)\right]+\frac{4\cdot f\cdot L_v}{D_v} = 0$$

ref: Chemical Process Safety: Fundamentals with Applications. 2nd ed.

$$\begin{pmatrix} f \\ T_{in} \\ P_{in} \end{pmatrix} := \mathrm{Find}(f, T_{in}, P_{in})$$

Results

Inlet Pressure

$P_{in} - atm = 0.01\cdot psi$

Inlet Temperature

$T_{in} = 88\cdot K$

Fanning Friction factor

$f = 0.005$

Argon Vapor line to HXPressure Drop

$P_{in} - P_{out} = 0.015\cdot psi$

define parameters for pressure drop calc - Argon liquid from condenser

Tube Inlet Pressure assuming 0 psi in condenser

$P_{out} := 0 \cdot psi + atm$

viscosity

$\mu := \mu_{Ar.l}$

Liquid Pipe inside diameter

$D_l := 0.674 \cdot in$

Liquid Pipe Length

$L_l := 125 \cdot ft$

Pipe Roughness:

$\varepsilon := 0.00015 \cdot ft$

Liquid Pipe velocity

$$V_l := \frac{\frac{mflow_{Ar}}{\rho_{Ar_l}}}{\left(\frac{D_l}{2}\right)^2 \cdot \pi} = 0.268 \frac{ft}{s}$$

Liquid Reynolds number

$$Re_l := \frac{V_l \cdot D_l \cdot \rho_{Ar_l}}{\mu_{Ar.l}} = 7497$$

define initial guesses for calc

Guess f $f := 0.5$

Friction factor calculation

Given $$\frac{1}{\sqrt{f}} = -4.0 \cdot \log\left(\frac{\varepsilon}{3.7 \cdot D_v} + \frac{1.256}{Re_l \cdot \sqrt{f}}\right)$$

Colebrook formula valid for Re>4000

$f := Find(f) \qquad f = 0.0086$

Liquid Pressure drop

$$\Delta P_{liq} := \frac{2 \cdot L_l \cdot \rho_{Ar_l} \cdot \left[\frac{\frac{mflow_{Ar}}{\rho_{Ar_l}}}{\left(\frac{D_l}{2}\right)^2 \cdot \pi}\right]^2 \cdot f}{D_l}$$

$\Delta P_{liq} = 0.052 psi$