

Calc of Argon condensed and N2 vaporized for a given heat exchange:

This calculation takes a heat load and determines the Argon vaporization rate from that heat load and the flow of liquid Nitrogen required to condense back this vaporized Argon.

The heat load used is twice the estimated heat absorbed through the tank insulation.

Heat Absorbed by LAPD Tank (result of separate calc)

$$\text{Heat}_{\text{Absorbed}} := 1645 \cdot \text{W}$$

Q for condensing/vaporizing taken as twice the estimated tank heat absorbed

$$Q_{\text{cond}} := 2 \cdot \text{Heat}_{\text{Absorbed}}$$

$$Q_{\text{cond}} = 3290 \cdot \text{W}$$

Argon Data

Argon physical properties from NIST REFPROP

Argon Liquid Density

$$\text{Ldens}_{\text{Ar}} := 1395 \cdot \frac{\text{kg}}{\text{m}^3}$$

Argon Heat of Vaporization

$$\text{Hvap}_{\text{Ar}} := 161 \cdot \frac{\text{kJ}}{\text{kg}}$$

Nitrogen Data

Nitrogen physical properties from NIST REFPROP

Nitrogen Liquid Density

$$\text{Ldens}_{\text{N}_2} := 807 \cdot \frac{\text{kg}}{\text{m}^3}$$

Nitrogen Vapor Density

$$\text{Vdens}_{\text{N}_2} := 4.5 \cdot \frac{\text{kg}}{\text{m}^3}$$

Nitrogen Heat of Vaporization

$$\text{Hvap}_{\text{N}_2} := 199 \cdot \frac{\text{kJ}}{\text{kg}}$$

Calc of Argon vaporized and then condensed

The vaporized Argon becomes the condensed Argon in the condenser. The mass rate of Argon is equal to Q divided by the heat of vaporization of Argon. The Argon liquid flow rate out of the condenser is calculated from the mass rate and Argon liquid density.

$$mflow_{Ar} := \frac{Q_{cond}}{Hvap_{Ar}} \quad mflow_{Ar} = 162.184 \cdot \frac{lb}{hr}$$

$$Lflow_{Ar} := \frac{mflow_{Ar}}{Ldens_{Ar}} \quad Lflow_{Ar} = 1.862 \cdot \frac{ft^3}{hr} \quad Lflow_{Ar} = 0.232 \cdot gpm$$

Calc of Nitrogen flow required

The Argon condenser uses liquid Nitrogen coolant. The mass rate of Nitrogen vaporized is calculated from Q and the heat of vaporization of Nitrogen. The mass rate of Nitrogen entering the condenser is the Nitrogen vaporized divided by an outlet vapor quality. The vapor quality is set to 70% to keep the Nitrogen side wet for better heat transfer. The Nitrogen liquid flow rate into the condenser is calculated from the mass rate of Nitrogen and Nitrogen liquid density.

$$Qual_{vapor} := 70\%$$

$$mflow_{N2} := \frac{Q_{cond}}{Hvap_{N2}} \cdot \frac{1}{Qual_{vapor}} \quad mflow_{N2} = 187.448 \cdot \frac{lb}{hr}$$

$$Lflow_{N2} := \frac{mflow_{N2}}{Ldens_{N2}} \quad Lflow_{N2} = 0.464 \cdot gpm$$

Calc max Cv for N2 solenoid valve (volumetric flow units)

ref: Fischer Control Valve Handbook, 4th ed.

pipng geometry factor

$F_p := 1$ assumed straight in / out piping with no reducer or expander

equation

$N_1 := 1 \cdot \frac{\text{gpm}}{\text{psi}^{\frac{1}{2}}}$ the equation constant makes the Cv unitless

upstream absolute static pressure

$$P_1 := 30 \cdot \text{psi} + 14.69 \cdot \text{psi}$$

$$P_1 = 44.69 \cdot \text{psi}$$

downstream absolute static pressure

$$P_2 := 28 \cdot \text{psi} + 14.69 \cdot \text{psi}$$

$$P_2 = 42.69 \cdot \text{psi}$$

$$G_f := \frac{L_{\text{densN}_2}}{62.37 \cdot \frac{\text{lb}}{\text{ft}^3}} \quad G_f = 0.808$$

liquid specific gravity
(relative to water @ 60F)

$$C_{V_{N_2}} := \frac{L_{\text{flowN}_2}}{N_1 \cdot F_p \cdot \sqrt{\frac{P_1 - P_2}{G_f}}} \quad C_{V_{N_2}} = 0.295$$

$$\text{Tube}_{\text{OD}} := \left(\frac{1}{4}\right) \cdot \text{in}$$

$$\text{Tube}_{\text{wall}} := 0.028 \cdot \text{in}$$

$$\text{Vel}_{\text{tube}} := \frac{L_{\text{flowN}_2}}{\pi \cdot \left(\frac{\text{Tube}_{\text{OD}} - 2 \cdot \text{Tube}_{\text{wall}}}{2}\right)^2} \quad \text{Vel}_{\text{tube}} = 5.035 \cdot \frac{\text{ft}}{\text{s}}$$