Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project Internal Reference:

Project: MicroBoone

Title: MicroBoone Purge System Sizing

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Reviewer(s):

Key Words: MicroBoone, Purge System

Applicable Codes:

Abstract Summary:

The following note determines the header and drilled nozzle sizes for the MicroBoone purge system based on applicable gage pressures

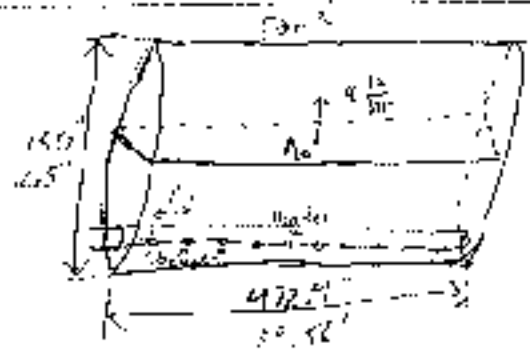
Aerobacon Purge System | [illegible]

Discussion

- Fluid is liquid Argon
  Supply line pressure is 10 psig
- Tank pressure is 3 psig (max)
- Nozzles are holes drilled in the header
- Flow rate at largest cross-section of the tank should be 4 ft/hr
- Piping is schedule 105
- Local P_{atm} = 14.35 psi
- $P_{Abs} = P_{atm} + P_{gage} = 14.35 + 10 = 24.35$ psi
- Equations and coefficients from Crane 410

Microbrine Surge System | M. Zuckerbrod Western

→ Mass Flow



* Area of largest cross-section

→ $A_c = 12.5 \times 39.56 = 492\ ft^2$

→ $\dot{V} = A_c V = 492\ ft^2 \times 4\ ft/hr = 1968\ \frac{ft^3}{hr}$

→ $\rho_w = 12.35\ psia = 0.12735\ \frac{lb}{ft^3}$

→ $\dot{M} = \dot{V}\rho = 1968\ \frac{ft^3}{hr} \times .12735\ \frac{lb}{ft^3} = 241\ \frac{lb}{hr}$

→ $\dot{V} = 1968\ \frac{ft^3}{hr} = 34012.20\ \frac{in^3}{hr} \times \frac{.004329\ gal}{in^3}$

$\dot{V} = 14224\ \frac{gal}{hr} = \frac{1\ hr}{60\ min} = 237\ gpm$

→ Header Length = 39.56'

$39.56'/1' = 39.56$

→ set 38 nozzles +

38 sections of header

→ Mass Flow through each nozzle

$\dot{M}_N = \dot{M}/38 = 6.34\ \frac{lb}{hr}$

Microwave Surge system | M. Gutierrez 2/20/09

→ Nozzle Sizing

- Since the pressure in the header is 10 psig and the maximum pressure for the tank is set at 3 psig; the necessary pressure drop across each nozzle is 7 psig

→ Max Flow through an orifice

$$\dot{M}_v = 1891\, Y d_o^2 C \sqrt{\frac{\Delta P}{\nu}}$$

solving for the orifice diameter:

$$d_o = \left[\frac{\dot{M}_v}{1891\, Y C \sqrt{\frac{\Delta P}{\nu}}}\right]^{\frac{1}{2}}$$

; where:

- d_o = orifice diameter (in)
- $\dot{M}_v$ = mass flow rate through the nozzle ($\frac{lbm}{hr}$)
- Y = Net expansion factor
- C = Flow Coefficient
- ΔP = Pressure change
- ν = specific volume

→ Y (Crane 410, A-21)

$$\frac{\Delta P}{P_1} = \frac{7}{29.35} = .24 \Rightarrow Y = .81$$

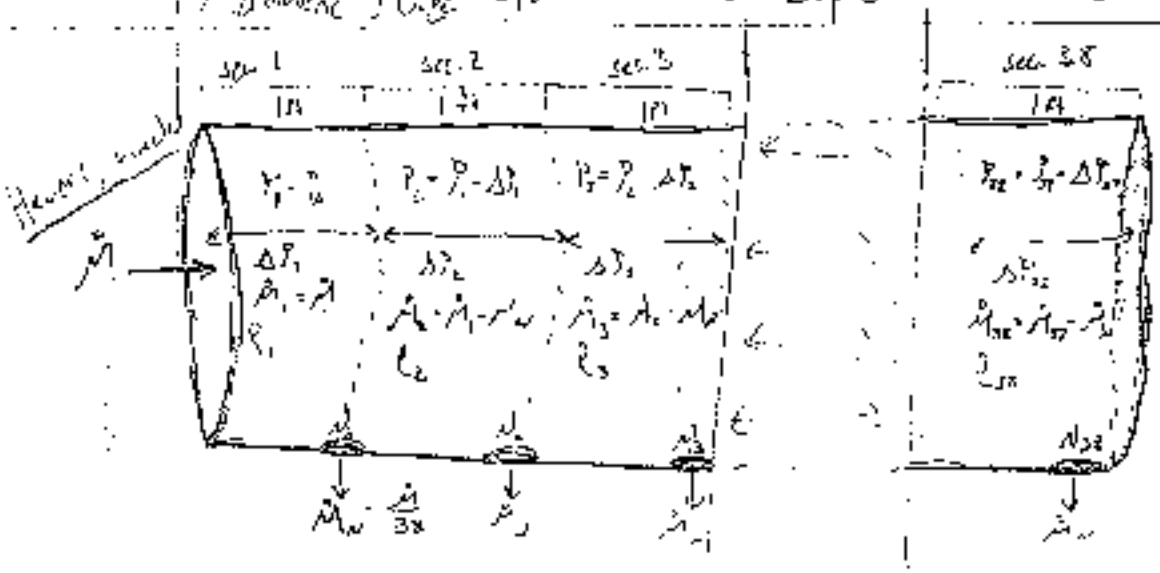
→ C (Crane 410, A-20) → $\frac{d_o}{d_{manifold}}$ will be << .2

$C \approx .97$

$$d_o = \left[\frac{6.34}{1891(.97)(.81)\sqrt{7 \cdot 17 \cdot 35}}\right]^{\frac{1}{2}} = \boxed{0.06245}$$

orifice diameter

Hydrogen Purge System M. Zaidiyar 8/20/04



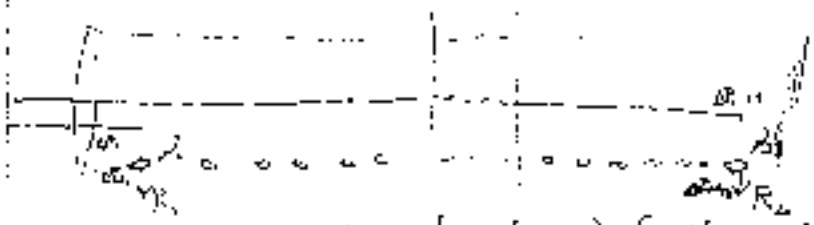
- Pressure loss through straight pipe

$\rightarrow \Delta P = .00021 \frac{f L \rho Q^2}{d^5}$; where

- f = friction factor
- L = length w/o nozzles (ft)
- ρ = density at absolute pressure
- Q = flow rate (gpm)
- d = pipe diameter

- $P_{A,initial} = P_{Atm} + P_0 = 14.35 + 10 = 25.35$ psia

$P_{A,final} = P_{A,initial} - \Delta P_{1-38}$



→ By adjusting the closest and furthest flows to equalize pressure losses, the difference in nozzle flows

Microbrane Fridge System | [illegible] 8/[illegible]/09

- Calculations were done for every section using an excel spreadsheet
- First and last sections will be shown as an example
- Density's at different pressures were determined using the relationship: $-.0007\left[\frac{P_A - 14.6}{-.1}\right] + .1731 = \rho(P_A)$
  → found from graphing ρ as function of P_A

1st section (setting Manifold n.d. at 2")

$$Re = 50.6\frac{Q_{c1}\rho_1}{\mu_1 d} = \frac{2.37(.17135)}{(.0200)(.5045)2.157} = 6.3519960$$

$f = .019$

$$\Delta P_1 = .000216\frac{(.019)(1)(.17135)(2.37)^2}{(2.157)^2} = .000846 \text{ psi}$$

→ Making the absolute pressure in section 2:

$P_A - \Delta P_1 = 14.35 - .000846 = 14.34815$ psia

And the flow $\dot{V}_1 - \dot{V}_A = 237 - 6.237 = 230.76$ gpm
sec. 2 flow

→ Total R_1 $\Delta P = 7$ (at nozzle 1) $+ .000846$ (at 1) psi
$= 7.000846$ psi / vis in shortest route

Membrane Purge System M. Zuckerbrot 8/20/09

Last Section

$$R_{e} = 50.6 \frac{\bar{Q}_{38} \ell_{38}}{\mu_{38} d} = \frac{(6.69)(0.17127)}{(1.0000130.14)(2.157)} = 1655.667$$

→ f = .19 for all sections

$$\Delta P_{38} = \frac{f_{14} \ell_{38} Q_{38}^2}{d^5} = \frac{(6.69)(0.17127)(6.34)^2}{(2.152)^5} = 5.86e^{-7}$$

→ Makes $P_{38} = P_{38} \Delta P_{38}$ ⇒ 24.53886 psia

Total $R_2 \Delta P = \Delta P_{Nozzle\ 38} + \Delta P_{1-38}$

$$\rightarrow \Delta P_{Nozzle\ 38} = \left[\frac{\mu_{38}}{189 \cdot 1.0 \cdot \pi}\right]^2 \frac{1}{\sigma_{38}}$$

$$= \left[\frac{1.34}{189(1.97)(.81)(2.157)^2}\right]^2 \frac{1}{.171177} = 7.003187 \text{ psi}$$

$$R_2 \Delta P = \underbrace{7.003187}_{\text{Mass}} + \underbrace{(.011139)}_{\text{f x found in worksheet}} = 7.014326 \text{ psi}$$

Loss felt in longest route

→ using the excel spreadsheet to adjust the first and last nozzle flow rates to equalize the total pressure losses felt ($R_1 \Delta P$, $R_2 \Delta P$), to within less than 1% of each other;

→ ΔP through nozzle 1 = 7.007007 psi

→ ΔP through nozzle 38 = 6.99685 psi

→ a difference of .0081642 psi; or 0.15%

→ The difference in nozzle flows = $\sqrt{\%\Delta P \text{ diff}}$

$= \sqrt{.15\%} = .39\%$ diff. in flows

Microbrone Purge System Meadbird 8/20/09

→ The following was determined with an excel spread sheet using the same method previously described

Nominal diameter (in)	Inner diameter (in)	% difference flow through first and last nozzles
2	2.157	.15
1½	1.682	.40
1	1.097	2.13
¾	0.889	3.37
½	0.674	5.92
⅜	0.545	7.93
¼	0.41	9.13

→ With the nozzles drilled at 1.0524 s" a header pipe 1¾" or larger is recommended to keep nozzle flow difference at < 5% of each other

→ Note: When the purge substance is a is the pressure in the evacuation pipe will be higher in the same size nozzles, due to its much lower density.

Pump

→ NWF Needle gas does not make a cryptonan pump with a high enough flow rate ...

→ Ingersoll-Rand does: ARD 3" Diaphragm Metallic w/ 257 gpm capacity (8[illegible] gpm)