**PIPE SIZING FOR INSTRUMENT AIR DELIVERY
TO THE CC AND EC CRYOSTATS**

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D-ZERO ENGINEERING NOTE 3740.000-EN-124

APPROVED:

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INTRODUCTION: This engineering note calculates the minimum required line size for the manifold and the associated piping that deliver instrument air to the three cryostats at the D-Zero project.

SETUP: The piping setup is approximated by figures 1 and 2, attached.

PROBLEM: The air delivery system is driven by a 100 psi, 100 cfm air compressor. There are two questions to be answered:

- 1) For a given 30 ft. manifold the diameter is to be calculated. Air will be tapped at 5 ft., 15 ft. and 25 ft. along the pipe. The requirement is that there be a pressure drop of no more than 1 psi. total along the length of that pipe. The taps go respectively off to the South End Calorimeter Cryostat (SEC), Central Calorimeter Cryostat (CC), and the North End Calorimeter Cryostat (NEC). Each tap leads to 5 separate linear actuators with electropneumatic positioners (Valtek). The flow through each actuator in the steady state is 0.26 Scfm-air. (see ref 1). Actuator transient flow requirements will be addressed by providing a factor of two to steady state flow.
- 2) The size of the pipe from the platform up to the manifold is to be calculated. Again the requirement is that there be a pressure drop of no more than 1 psi. total along the length of that pipe. (see fig 2). A factor of 4 will be introduced into the mass flow to accomodate all other possible users who may tap the line. Capped off tees will be placed at convenient locations along the run in accord with the assumption that there may be future instrument air needs.

CALCULATIONS:

$$\text{USE: } \Delta P / \Delta L = [(5 * 10^9) * \mu^{0.2} * \dot{M}^{1.8}] / [\text{RHO} * R^{4.8}]$$

where: ΔP = The pressure drop in the pipe. (atm.)

ΔL = The length of the pipe where the above ΔP occurs. (cm)

μ = The viscosity of the fluid flowing in the pipe (air) at 300K (room temp), and compressor pressure of (100psi, 7 atm.). (g/[cm-s])

RHO = The density of the fluid (air) at 300K, and 7 atm. (g/cm³)

R = Required radius of the pipe (inside radius). (cm)

$\dot{M}$ = The mass flow of fluid (air) through the pipe. (g/s)

PROBLEM #1**Solve for R:****MDOT:**

The flow through each tap is therefore:

$$5 \text{ actuators} * (@ 0.26 \text{ SCFM}) * (2, \text{ safety factor}) = 2.6 \text{ SCFM}$$

Then the total flow in the 30 ft. section is:

$$3 \text{ taps} * (@ 2.6 \text{ SCFM}) = 7.8 \text{ SCFM-AIR} = \text{MDOT} = 4.20 \text{ g/s}$$

$$\text{From 0-5 ft.,} \quad \text{Mdot} = 4.20 \text{ g/s}$$

$$\text{From 5-15 ft.,} \quad \text{Mdot} = 2.80 \text{ g/s}$$

$$\text{From 15-25 ft.,} \quad \text{Mdot} = 1.40 \text{ g/s}$$

RHO:

From Reference 2, at 300K and 7.00 atm.,

$$\text{RHO} = .00797 \text{ g/cm}^3$$

 μ :

From Reference 2, at 300K and 7.00 atm.,

$$\mu = 180.51 * 10^{-6} \text{ g/[cm-s]}$$

 ΔP :

Assume that the pressure drop is evenly distributed over the three sections (0-5 ft., 5-15 ft., 15-25 ft.) and is therefore equal to .33 psi in each section.

$$\Delta P = .33 \text{ psi} = .023 \text{ atm.}$$

 ΔL :

For section 1, the length is 5 ft.

$$\Delta L = 5 \text{ ft.} = 152.4 \text{ cm.}$$

For sections 2 and 3, the length is 10 ft.

$$\Delta L = 10 \text{ ft.} = 304.8 \text{ cm.}$$

RESULTS:

The results of this calculation show that:

Section 1 (0-5 ft.) requires a inside diameter of .30 inches.

Section 2 (5-15 ft.) requires a inside diameter of .30 inches.

Section 3 (15-25 ft.) requires a inside diameter of .23 inches.

CONCLUSION:

The calculations show that the maximum calculated pipe size has an inside diameter of .300 inches. The 30 foot length of pipe must be at least .300 inches in inside diameter

Note that individual actuator feed lines that meet the same ΔP criteria (and are approximately as long) require a tributary pipe radius of:

$$R_2 = (\dot{M}_2 / \dot{M}_1)^{(1.8/4.8)} * R_1$$

Where: $R_1 = 0.115$ inches (CHECK MINIMUM)

$$\dot{M}_2 / \dot{M}_1 = (1/5) = 0.2$$

Thus $R_2 = 0.063$ inches

This requirement suggests **at least** 1/4" O.D. Tube x 0.035" wall should be used for these tributaries.

The recommended manifold size is thus 1/2 inch schedule 40S pipe which has an inside diameter of 0.622 inches. The actual pipe size may be larger due to other reasoning. This report calculates the minimum size only.

PROBLEM #2
SOLVE FOR R:

$$\Delta P = 1 \text{ psi} = 0.068 \text{ Atm.}$$

$$\Delta L = 981.75' = 2493.64 \text{ cm (includes equivalent length of 3-1" - 90° elbows)} \\ \text{(see Ref. 3)}$$

$$\dot{M} = 7.8 * 4 = 31.2 \text{ SCFM-air} = 16.8 \text{ g/s}$$

ALL OTHER VALUES REMAIN THE SAME AS IN PROBLEM #1

RESULTS:

The results of this calculation show that:

An inside diameter of at least .52" is required for the piping from the platform to the manifold.

CONCLUSION:

The recommended pipe size is 1" schd 40s.

REFERENCES

1. Valtek Linear Actuators, Valtek Inc., Springville, Utah., Rev. 1/82/5M, page 12.
2. Thermodynamic Properties of Nitrogen, (NBS-TN-1025).
3. McAdams, "Heat Transmission", McGraw-Hill, New York, 1954.
(attached)

Calculation of Arline size

⑦

① Sec. 1 0-5'

$$\Delta L = 5' = 152.4 \text{ cm.}$$

$$P_{300K, 7atm, 100psi} = .00797 \text{ g/cm}^3$$

$$\mu_{300K, 7atm, 100psi} = 180.51 \times 10^{-6} \text{ g/cm-s}$$

$$\Delta P = \frac{1 \text{ psi}}{3} = \frac{.068 \text{ atm}}{3} = .023 \text{ atm.}$$

$$\dot{M}_{0-5'} = 7.8 \text{ SCFM} = 4.20 \text{ g/s}$$

$$\frac{\Delta P}{\Delta L} = \frac{.023}{152.4} = \frac{(5 \times 10^{-9}) (180.51 \times 10^{-6})^2 (4.20)^{1.8}}{(.00797) (R^{4.8})}$$

$$R^{4.8} = .0098$$

$$\therefore R = .382 \text{ cm} = .15 \text{ inches}$$

$$\therefore \boxed{\text{I.D. Diameter} = .30''}$$

② Sec. 2 5'-15'

$$\dot{M}_{5'-15'} = \frac{2(7.8 \text{ SCFM})}{3} = 5.2 \text{ SCFM} = 2.80 \text{ g/s}$$

$$\Delta L = 10 \text{ ft} = 304.8 \text{ cm.}$$

$$\frac{\Delta P}{\Delta L} = \frac{.023}{304.8} = \frac{(5 \times 10^{-9}) (180.51 \times 10^{-6})^2 (2.80)^{1.8}}{(.00797) (R^{4.8})}$$

$$R^{4.8} = .0095$$

$$\therefore R = .379 \text{ cm} = .149 \text{ inches}$$

$$\therefore \boxed{\text{I.D. Diameter} \approx .30''}$$

③ Sec. 3 15'-25'

$$\dot{M}_{15-25} = \frac{7.8}{3} = 2.6 \text{ SCFM} = 1.40 \text{ g/s}, \Delta L = 10 \text{ ft} = 304.8 \text{ cm.}$$

$$R^{4.8} = .0027$$

$$\therefore R = .292 \text{ cm} = .115 \text{ inches} \therefore \text{ID.} = \boxed{.23''}$$

Problem: Calculate minimum required pipe size to maintain the following given conditions:

Given:

$$\Delta P = 1 \text{ psi} = .068 \text{ atm}$$

Assumes
3-90° elbows - 1"
See Ref 3.

$$\Delta L = 450'' + 235'' + 104.75'' + 3(32 \times 1) \\ = 991.75'' = 2493.64 \text{ cm.}$$

$$\rho_{300K, 7 \text{ atm}} = .00797 \text{ g/cm}^3$$

$$\mu_{300K, 7 \text{ atm}} = 180.51 \times 10^{-6} \text{ g/cm-s}$$

$$\dot{M} = 7.8 \times 4 = 31.2 \text{ SCFM-air} = 16.8 \text{ g/s}$$

$$\frac{\Delta P}{\Delta L} = \frac{(.068)}{(2493.64)} = \frac{(5 \times 10^{-9})(180.51 \times 10^{-6})^{0.2}(16.8)^{1.8}}{(.00797)(R)^{4.8}}$$

$$\therefore R = \sqrt[4.8]{\frac{(5 \times 10^{-9})(180.51 \times 10^{-6})^{0.2}(16.8)^{1.8}(2493.64)}{(.00797)(.068)}}$$

$$R = .659 \text{ cm} = .26''$$

$$\underline{\underline{\text{SO I.D. DIA} = .52''}}$$

D-ZERO INSTRUMENT AIR DELIVERY SYSTEM

FIGURE 1

FIGURE 2

INSTRUMENT AIR DELIVERY SYSTEM

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Ref 1

(11)

FLOW OF FLUIDS

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(total angle of divergence may be calculated by inte- (6-2c), and (6-8a). Where no simple treatment will ation of Eqs. (6-9b), (6-10),

te inside the straight horizontal of cross section). The air enters and leaves at 180°F. The tubes Calculate (a) the pressure drop ie over-all pressure drop between cross sections twice those of the

f air, expressed as lb/(ft)(sec), is G is (2₁)(2), the values of DG/μ responding values of f are 0.0077

0075. The hydraulic radius r_h = air is 29.0, that is, 29 lb of air occu- sure.

.1 cu ft/lb

ntially normal barometric pressure.

1 cu ft. lb
0.1 cu ft. lb

By Eq. (6-9b)

$$\frac{0.0075(19)(2)^2(20.1)}{(64.4)(1.24)}$$

3 pounds force sq ft

$$\left(\frac{1}{1.2 \text{ ft}^2 \text{ sec}^2}\right) \left(\frac{1}{62.3 \text{ lb ft}^3}\right) \left(\frac{12 \text{ in.}}{1 \text{ ft}}\right) = 0.630 \text{ in. water}$$

ent of the net heat input (Eqs. (6-4a)

$$Q = (0.24)(500 - 180) - \frac{(32.2)^2 - (16.1)^2}{(778)(64.4)} = 76.8 - 0.0257 \text{ Btu/lb}$$

b. From Fig. 6-13, $K_e = 0.3$, whence by Eq. (6-10)

$$p_0 - p_1 = \frac{V_1^2 - V_2^2}{2g_p \rho_{avg}} + \frac{K_e V_1^2}{2g_p \rho_{avg}} = \frac{(32.2)^2 - (16.1)^2}{(64.4)(24.1)} + \frac{(0.3)(32.2)^2}{(64.4)(24.1)} = 1.12 + 0.45 = 1.57 \text{ pounds force/sq ft}$$

By Eq. 6-11)

$$p_2 - p_3 = \frac{V_2^2 - V_3^2}{2g_p \rho_{avg}} + \frac{(V_2 - V_3)^2}{2g_p \rho_{avg}} = \frac{(16.1)^2 - (32.2)^2}{(64.4)(16.1)} + \frac{(32.2 - 16.1)^2}{(64.4)(16.1)} = -0.75 + 0.25 = -0.5 \text{ pound force/sq ft}$$

SUMMARY

Differences	Pounds force Square foot	Inches of water
$p_0 - p_1 = 1.12 + 0.45$	+1.57	+0.301
$p_1 - p_2 = -0.99 + 1.27$	+3.28	+0.630
$p_2 - p_3 = -0.75 + 0.25$	-0.50	-0.096
$p_0 - p_3$	+4.35	0.835

Since 1 atm is equivalent to a pressure of (14.69)(144) = 2115 pounds force/sq ft, little error was made in neglecting the change in p in calculating ρ . Assuming 500 air tubes, the volumetric rate of flow at the exit would be (500)(3.14)(1)/(144)(32.2) = 351 cu ft/sec at normal pressure. With the fan at the exit, the power theoretically required would be (351)(4.35/550) = 2.77 hp.

Fittings. These are allowed for by assigning a fictitious or equivalent length L_e of straight pipe to the existing straight pipe and using the sum $L_e + L$, in Eq. (6-2d) for turbulent flow. For DG/μ above 2100 to 3000,

TABLE 6-1. L_e/D RATIOS FOR SCREWED FITTINGS, VALVES, ETC., TURBULENT FLOW ONLY*

Fitting	L_e/D	Fitting	L_e/D
45-deg elbows	15	Tee (used as elbow entering branch)	90
90-deg elbows, standard radius	32	Couplings, unions	Negligible
90-deg elbows, medium radius	26	Gate valves, open	7*
90-deg elbows, long sweep	20	Gate valves, one-fourth closed	40*
90-deg square elbows	60	Gate valves, one-half closed	200*
180-deg close return bends	75	Gate valves, three-fourths closed	800*
180-deg medium-radius return bends	50	Globe valves, open	300*
Tee (used as elbow, entering run)	60	Angle valves, open	170*

* Perry, 12 p. 390.

* Rough estimate; values depend on construction of valve.