E706 CRYOSYSTEM DESIGN NOTE

E706EN010

TITLE: **ARGON FLOW RATES**

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This note determines the maximum flow rates possible through the argon liquid and gas lines running from the storage dewar to the LAC. This information will be useful concerning operations and relief valve sizing.

Assume:

Fanning equation applies, equivalent lengths are similar to "book" values, transition to 1" diameter flex hose on gas line has a negligible effect, gas flow is at 100K, LAC pressure is a minimum and storage pressure a maximum (50 psig).

Maximum flow through gas line is 20 acfm at 100K and 71 gpm through liquid line with the storage dewar at 50 psig.

K. Dixon

Fermilab

July 22nd, 1986
KD/ad

To : E706 Cryogenic Safety Panel
From : K. Dixon
Re : Argon Flow Rates

Attached are calculations of the maximum flow rates possible to the LAC vessel from the liquid and gas spaces of the storage dewar. Both sets of calculations assume that the storage vessel is at its maximum primary relief pressure, 50 psig and that the LAC pressure is at 0 psig. The relations used to derive flow rates are variations of the standard Fanning equation using equivalent lengths available in most fluid mechanics texts.

Assuming the LAC vessel to be empty, the maximum flow rate is 71 gpm. This will be hardly attainable given the fact that during the initial fill the storage dewar pressure will be around 2 psig. The filling operations will be monitored by experienced Cryogenic Dept. operating personel (operating procedures forthcoming).

Through the 3/4 in, Sch 40 gas line, maximum flow will be around 20 cfm. This assumes the gas to be 100K throughout its journey and does not take into account that the pipe enlarges to a 1 in flex-hose and pipe at the LAC. This omission has a negligible affect on relief value sizing for the LAC.

Any questions concerning the physical dimensions of the piping systems should be referred to John Urbin, X3355.

XC : R.P. Smith
F. Lobkowicz MS 221
W. Baker

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Max Flow into LAC from 1A Dewar

Δp_{max} = dewar relief press - LAC min press

= 50 - 0 = 50 psig = 7200 psf

d = 0.069 ft length = 80 ft

est no. valves = 3 , le/d = 340 , lv = 70 ft

est no. 90^0els = 4 , le/d = 30 , lel = 8 ft

est no. tees = 8 , le/d = 20 , lt = 11 ft

* le_{tot} = 80 + 70 + 8 + 11 + 169 ft

$$\Delta p\ tot = \frac{8f\rho v^2 le}{g_c \pi^2 d^5} \qquad \rho\Big|_{3atm}^{100k} = 0.98\ {}^{lbm}/_{ft^3}$$

$$E/_d = .002 \qquad f = .025$$

$$\dot{V} = \left(\frac{\pi^2 g_c \Delta p d^5}{8f\rho le}\right)^{1/2}$$

$$\dot{V}_{max} = \left(\frac{\pi^2 (32.2)(7200)(.069)^5}{8(.025)(0.98)(169)}\right)^{1/2}$$

$\dot{V}_{max}$ = 0.33 $ft^3/_s$		argon gas at 100k (est.)
$\dot{V}_{max}$ = 19.7 cfm		
$\dot{m}$ = 0.32 $lbm/_s$		

Fill / Dump Line Flowrates

est. no tees = 7 , le/d = 20

est. no 90^Oels = 15, le/d = 30

$d = \frac{1.682}{12}$ ft = 0.14 ft   l = 90 ft

let flow = 40 gpm = 0.089 $ft^3/_s$

* Doesn't take into account the ~50 ft 1" Ø pipe and long flexhose.

Δp filter = 1 psi estimate

Δp venturie = 0.4 psi

Δp valves = no. valves $(\frac{\text{flow rt.}}{Cv})^2$ Sp.Gr.

$= 6 \left(\frac{40}{34}\right)^2 1.4$

$= 11.6$ psi

$le_{/d} = \frac{K}{f}$ K = 1.5 for entrance and exit losses

$le_{/d} = 71.4$ let f = .021

$le_{/d}\Big|_{tot} = 71.4 + 7(20) + 15(30) = 661$

le = 93ft $l_{tot} = 183$ ft

$\mu\Big|_{1atm}^{95k} = 0.2075 \times 10^{-3} \frac{Ns}{m^2} = 1.39 \times 10^{-4} \frac{lbm}{ft.s}$

$\rho\Big|_{atm}^{sat} = 33.8 \frac{mol}{lit} = 84.2\ lbm_{/ft^3}$

$Rd = \frac{4(.089)(84.2)}{\pi(1.39\times10^{-4})(0.14)} = 4.9 \times 10^5$

f = .021 from Moody Chart

$\Delta_{p1} = \frac{8(.021)(84.2)(.089)^2(183)}{(32.2)\ \pi^2\ (0.14)^5}$

$= 1200\ lbf_{/ft^2}$

$= 8.3$ psi

$\Delta_{ptot} = 8.3 + 11.6 + 0.4 + 1.0$

$\Delta_{ptot} = 21.3$ psi for 40 gpm flow

maximum flow :

$\Delta p\Big|_{available}^{max}$ = p dewar +p head

= 60 psi

$\dot{V}_{max} = \left(\frac{60}{21.3}\right)^{0.556} 40$ gpm

$\dot{V}_{max} = 71.1$ gpm

atm liq flashing :

$$p_{bottom}^{dewar} = 16.7 + 21.3 - 9.6 \text{ psia}$$

$$= 28.4 \text{ psia}$$

$$hf\Big|_{sat}^{28.4} = 35.3 \text{ BTu}/\text{lbm} \qquad hf_{sat}^{16.7} \text{ psia} = 32.4 \text{ BTu}/\text{lbm}$$

$$hg\Big|_{sat}^{16.7} = 101.6 \text{ BTu}/\text{lbm}$$

$$X = \frac{hi - h_f{}_{sat}^{16.7}}{hg_{sat}^{16.7} - hf_{sat}^{16.7}} = \frac{2.9}{69.2} = .042$$

$\therefore$ ~ 4% liq mass will flash