E706 CRYOSYSTEM DESIGN NOTE

E706EN012

TITLE: E706 LAC Dewar Venting

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DATE: August 25, 1986

OBJECTIVE OF NOTE:

This note determines the venting capacity of the existing relief devices on the LAC and also the required capacity per CGA S1.3.5.3.

The calculations assume that the manufacturer's formulas are correct and applicable. Pressure drops assume incompressible flow through inlet piping with the use of the Fanning equation. Saturated argon gas properties were assumed for the inlet condition.

The LAC venting capacity is 20,200 scfm assuming an exit pressure drop no greater than 1 psi. The required capacity is found to be 19,800 scfm.

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RELIEF SIZING

P_o = 1.21 MAWP = 1.21 (16 psig) = 19.4 psig
= 34.1 psia To = 96.1K = 173^oR

$$\left.\frac{P_e}{P_o}\right|_{crit} = \left[\frac{2}{k+1}\right]^{\frac{k}{k-1}} = 0.487$$

$$\left.\frac{P_e}{P_o}\right|_{design} = \frac{14.7}{34.1} = 0.432$$

Since 0.432 < 0.487, Sonic flow

Required Flow Rate per CGA S1.3.5.3

$\dot{V}$ required $Q_a = G_u A^{0.82}$

A = surf area for fire condition
= surf area of insulation *
= $\pi\, d_{cyl}\, L + 2\pi\, r_{head}\, d_{head}$
= (205)(225) + 2π (205)(41.5)
= 198,000 in^2 = 1380ft^2

$$G_u = \frac{6.33 \times 10^5}{LC}\left(\frac{ZT}{M}\right)^{1/2}$$

L = h_{fg} = 154 j/g = 66.2 BTU/hr

* This area actually larger than wetted area

$$G_u = \frac{6.33\times10^5}{66.2 \times 377}\left(\frac{173}{40}\right)^{1/2} = 52.7$$

$\dot{V}_{required}$ = 19,800 SCFM air required flow

Actual flow w/o Δp included due to piping

$$\dot{V}_{rv} = \frac{6.32 \ ACK \ P_1}{\sqrt{MTZ}}$$ Anderson-Greenwood Catalogue

$$= \frac{6.32\ (19.56)(356)(9,845)(34.1)}{\sqrt{29(520)(1)}}$$

= 10300 SCFM

$$\dot{V}_{rd} = \frac{260\ AP_1}{\sqrt{Sp.Gr.\ (T)}}$$ BS&B Catalogue

$$= \frac{260\ \frac{\pi}{4}\ (6)^2\ (34.1)}{\sqrt{520}}$$

= 11000 SCFM

$\dot{V}_{tot}$ w/o Δp_L = 21300 SCFM air

Check Δp in pipe:

worst case is relief piping which is

126" lg sch 40, 6" pipe $\dot{m}$ = 25.5 lbm/s

d_i = 6.065 in = 0.505 ft

L_p = 10.5 ft

K_{inlet} = 0.5 if pipe is cut flush

$$V = \frac{\dot{m}}{\rho A} \quad \frac{25.5 \text{ lbm/s}}{0.781\text{lbm/ft}^3 \; (\; /4)(.505\text{ft})2} = 152 \text{ ft/s}$$

$$K = \sqrt{\lambda RT}$$

$$\approx 577 \text{ ft/s}$$

M = 0.281 assume incomp. flow

$$\Delta p = \left[f \frac{L}{D} + k \right] \left[\frac{m^2}{A^2 \; 2 \; \rho g_c} \right]$$

$$R_D = \frac{\rho VD}{\mu} = \frac{(0.780 \text{ lbm/ft}^3)(182 \text{ ft/s})(0.505 \text{ ft})}{0.538 \times 10^{-5} \text{ lb/ft.s}}$$

$R_D = 9.3 \times 10^6$ F = .015 From Crane <u>Flow of Fluids</u>

$$\Delta p = 0.812 \left[\frac{(25.5 \text{ lb}_m/\text{s})^2}{2(0.2\text{ft}^2)^2(.780\text{lb}_m/\text{ft}^3)(32.2 \frac{\text{ft}}{\text{s2}} \frac{\text{lb}_m}{\text{lb}_f}} \right]$$

$$\approx 263 \text{ psf}$$

$$\boxed{\approx 1.8 \text{ psi drop}}$$

ALLOWABLE PRESSURE DROP THROUGH EXIT PIPING

- let flow through relief at std conditions with air =

  $\dot{V}_{rv}$ = 9800 SCFM

- let flow through rupture disk at std conditions with air =

  $\dot{V}_{rd}$ = 10400 SCFM

- let Δp through both inlets to rd angle rv =

  Δp_{inlet} = 1.8 psi

$$\dot{m}^{argon}_{rv} = \dot{V}_{rv} \left(\frac{M_{argon}}{M_{air}}\right)^{1/2} \left(\frac{C_{argon}}{C_{air}}\right) \left(\frac{P_2}{P_2 - \Delta p_{inlet}}\right) \left(\frac{T_{inlet}}{T_2}\right)$$

$$\times \frac{\rho^{sat}_{inlet}\ (lb_m/ft^3)}{60\ (s/min)}$$

$$= 9800 \left(\frac{40}{29}\right)^{1/2} \left(\frac{377}{356}\right)\left(\frac{14.7}{323}\right)\left(\frac{173}{520}\right)\left(\frac{0.78}{60}\right)$$

= 24.0 lbm/s Sat argon

$$\dot{m}^{argon}_{rd} = \frac{10400}{9800} (24.0)$$

= 25.4 lbm/s sat argon

$$\Delta p = \left(\frac{fL_e}{D} + k\right)\left(\frac{m^2}{2A^2 \rho g_c}\right)$$

$$\Delta p_{rv} = \frac{(0.31 + 0.5)\ (284)}{144}$$

= 1.60 psi

$$\Delta p_{rd} = \frac{(0.28 + 0.5)\ (321)}{144}$$

= 1.74 psi

Now check $\dot{V}$ for both reliefs:

$$\dot{V}_{rv} = \frac{6.32\ ACK\ P_1}{\sqrt{MTZ}}$$ Anderson-Greenwood Catalogue

$$= \frac{6.32\ (19.56)(356)(0.845)(32.3)}{\sqrt{(29)(620)(1)}}$$

$$= 9780 \text{ SCFM}$$

$$\dot{V}_{rd} = \frac{260\ AP_1}{\sqrt{SG(T)}}$$ BS & B Catalogue

$$= \frac{260(\frac{\pi}{4})(6)^2(32.3)}{\sqrt{520}}$$

$$= 10410 \text{ SCFM}$$

$$\dot{V}total = 9780 + 10410$$

$$\boxed{\dot{V}total = 20200 \text{ SCFM}}$$

$$\left.\frac{P_e}{P_o}\right|_{design} = \frac{14.7 + \varepsilon}{34.1 - 1.8}$$

$$\left.\frac{P_e}{P_o}\right|_{design} \leq \left.\frac{Pe}{Po}\right|_{crit}$$

for sonic flow to exist, $\dot{V} \neq f(P_e)$

$$\frac{14.7 + \varepsilon}{34.1 - 1.7} \leq \left[\frac{2}{k + 1}\right]^{\left(\frac{k}{k-1}\right)} = 0.487$$

$$14.7 + \varepsilon \leq 0.487\,(34.1 - 1.8)$$

$$\varepsilon \leq 0.487\,(34.1 - 1.8) - 14.7$$

$$\varepsilon \leq 1.03 \text{ psi}$$

$\therefore$ Pressure drop through exit piping should be no greater than 1 psi at full flow conditions.