D∅ SOLENOID UPGRADE PROJECT

Solenoid insulating vacuum vessel; Relief path capacity calculation

D-ZERO ENGINEERING NOTE # 3823.111- EN-345

May 26, 1993
Rev. August 2, 1993

Russ Rucinski & David Bell

This engineering note documents the calculations done to determine the relief capacity of the solenoid vacuum pumping line. The calculations were done by David Bell, a co-op student from the University of Wisconsin. The calculations are attached. The conclusion is that the vacuum pumping line has a venting capacity of 129 g/s warm helium or 298 g/s warm nitrogen. Both of these capacities are much larger than the expected operating mass flow rates of the liquid helium (5 to 15 g/s) or liquid nitrogen (2 or 3 g/s) circuits. The calculations assume the solenoid vacuum vessel is at 3 psig and the relief plate is set at 1.5 psig.

Additional calculations were done to prove that the venting capacity of the vacuum pumping line exceeded flowrates due to a failure mode. These calculations are attached. Since the system is not finalized, (pipe sizes not determined, components sized...) the calculations were done by first picking reasonable line sizes based on known allowed pressure drops in the system and then doing a maximum delivery rate calculation if a line was completely severed in the vacuum space of the solenoid/control dewar. The numbers from these calculations say that failure mode flow rates are 80 g/s liquid helium or 80 g/s liquid nitrogen. Both these values are less than the capacity of the relief line.

In the five months since the (12/92 Dave Bell) calculations were done, some changes occured to the relief path. The most notable is that the radiation shield is now considered to be 6.625" O.D. instead of 6.00" used in the venting calculation. This change would tend to lower the capacity numbers. Another change was that for about half the venting path the chimney vacuum shell size was increased to 10" pipe. This change tends to increase the capacity numbers which were done assuming 8" pipe. These changes taken together probably offset each other or make the capacity numbers better. In either case, since the margin of safety is large, the calculations have not been redone.

Russ Rucinski
RD/DØ Mech. 8/2/93

IT IS DESIRED TO DETERMINE THE RELIEF CAPACITY OF THE VACUUM PUMPING LINE.

REQUIREMENTS - RELIEF OPENS AT 1.5 PSIG. THE SOLENOID SHOULD BE RUN AT NO HIGHER THAN 3 PSIG → PRESSURE DROP IN PIPE SHOULD BE NO MORE THAN 1.5 PSIG -

THE PROBLEM - DETERMINE MAX FLOW RATE THROUGH VACUUM JACKET

ASSUME: ① T = 300 K

② 5" BULKHEAD CONVERGES TO 3"x7" OBROUND

③ OBROUND 3" x 7" SECTION FROM A to B

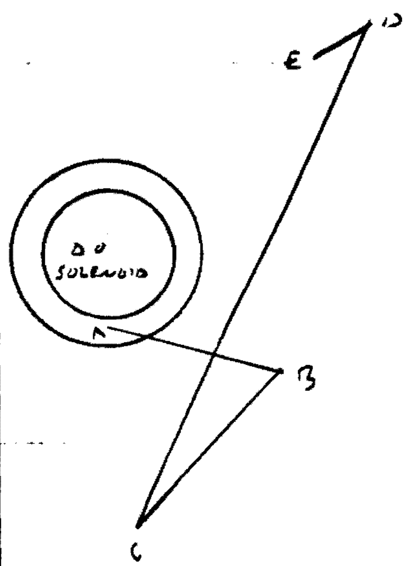
④ CIRCULAR SECTION B to C & C to D BETWEEN 6" & 8.5" pipes

⑤ B IS ASSUMED TO BE A REGULAR ELBOW & C

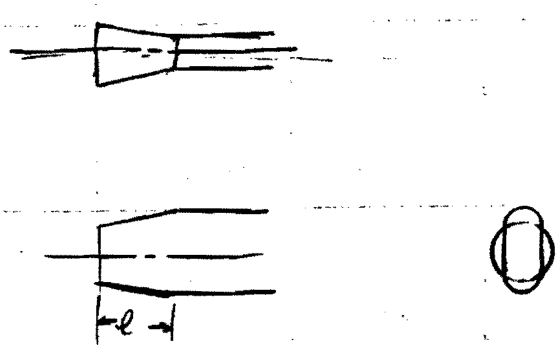
⑥ VENT IS AT OR NEAR D

⑥ Pipe ε = 0.00015 ft

⑦ ASSUME LAMINAR FLOW



AB = 105 in
BC = 109 in
CD = 264 in



THE length of the 5" BULKHEAD TO 3"x7" OBROUND ADAPTER IS NOT YET KNOWN. ASSUME IT TO BE AN INLET CONDITION TO THE PIPE WITH K=1

PROPERTIES

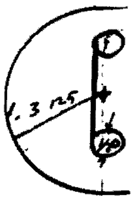
17.646 psia = 122.010 kPa
16.646 psia = 114.66 kPa

He ~ .120 MPa
300K $\rho = 0.1925\ kg/m^3$, $V_{sound} = 1020\ m/s$ visc = 19.92 μPa·s

He ~ .11 MPa (MIDWAY BETWEEN .10 & .12
$\rho = .1775\ kg/m^3$ visc = 19.92 μPa·s

N_2 ~ 1.2 atm
300K $v = 731.995\ cc/g$ V_{sound} 353.2 M/s PRANDTL NUMBER = .725
$v_{isc} = 179.57$ M.·G
$\rho = 0.001366\ \frac{g}{cc}$ ... g/CM·S
~ 1.1 atm $v = 798.5\ cc/g$

OBROUND SECTION, IF CONSIDERED TO BE 2 PARALLEL PIPES



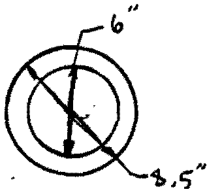
AREA $\approx \frac{1}{2}\pi r^2 = 2.70594\ in^2$

$P = \frac{1}{2}(2\pi r) + \frac{1}{2}(\pi\ \frac{1}{2}) + 1\frac{3}{8} = 6.2837$

$D_h\ \frac{4(2.70594)}{6.2837} \approx 1.72\ in$ $D_h = 4[\pi](3^2) +$

$\frac{\epsilon}{D} = \frac{0.00015}{(1.72/12)} = 0.00105$

CIRCULAR SECTION



$D_{h\ annulus} = 2(a-b) = 2(4.25 - 3) = 2.5\ in$

$\epsilon/d = \frac{0.00015}{(2.5/12)} = 0.00072$

$A = \frac{\pi}{4}(8.5^2 - 6^2) = 28.47\ in^2$

VENT CAP LOCATED AT OR NEAR SECTION D

ASSUME THAT INLET TO OBROUND AND ADAPTER BETWEEN OBROUND AND ANNULUS ARE EQUIVALENT TO ENTRANCE CONDITIONS WITH MAX RESISTANCE COEFFICIENT OF 1

USE CRANE FLOW EQNS 2-1 to 2-4, OR WHITE, FLUID MECHANICS 1986
combine into form McGraw-Hill 2nd ed 6-111

$$\Delta h_{total} = \frac{V_{AB}^2}{2g}\left(f\frac{L_{AB}}{D_B}\right) + \frac{V_{BC}^2}{2g}\left(f\frac{L_{BC}}{D_{BC}}\right) + \frac{V_{CD}^2}{2g}\left(f\frac{L_{CD}}{D_{CD}}\right) + \frac{V_{BC}^2}{2g}(K_B) + \frac{V_{CD}^2}{2g}K_C$$

$$+ \frac{V_{CD}^2}{2g}k_D + \frac{V_{AB}^2}{2g}K_A + \frac{V_{CD}^2}{2g}(k_{out})$$

I wrote the equation in this form to distinguish each term (the first 3 are head loss through segments AB, BC, & CD, respectively.)

K_B is for the adapter between the 3"×7" obround and the annulus. Assume it is A constant value restriction = 1 with negligible length

K_C is ASSUMED TO BE A REGULAR ELBOW 5AF 90° R≈29"
$r/D = \frac{29"}{2.5"} = 11.6$ from crane (TOTAL Resistance in bend is taken as an additional length of pipe from the chart on P A-27 in CRANE FLUID FLOW

$k_C = f\frac{L_{equiv.}}{D}$ and $L_{equiv.}$ @ $r/d = 11.6$: 320

k_D is a mitre bend of about 33° $L/D \approx 9.5$ from CRANE FLUID FLOW P A-27

K_A is the inlet condition to the OBROUND MAX VALUE = 1

K_{out} is OUTLET AT D, MAX Value = 0.5

THE ACCEPTABLE ΔP = 1.5 psig = 216 lbf/ft²

$$\Delta P = \rho g h \Rightarrow h = \frac{216\ lbf/ft^2}{(.1925\ \frac{kg}{m^3})(1.9403\times10^{-3}\ \frac{lbf\,s^2/ft^4}{kg/m^3})\ 32.174\ \frac{ft}{s^2}} = 17993\ ft$$
for He

$$\frac{lbf/ft^2}{\frac{lbf}{ft^3}}\quad \left(\frac{lbf}{ft^2} \Big/ \frac{lbm\ ft}{lbf\ s^2}\right)$$

for N_2
$$h = \frac{216\ lbf/ft^2}{(1.366\ \frac{kg}{m^3})\left(1.9403\times10^{-3}\ \frac{lbf\,s^2/ft^4}{kg/m^3}\right) 32.174\ \frac{ft}{s^2}} = 2532.96\ ft$$

If we take a value of 16 g/s flow rate into $= 16\times10^{-3}\ \frac{kg}{s}$

$$= \frac{(16\times10^{-3}\ \frac{kg}{s})(6.85224\times10^{-2}\ \frac{lbf\,s^2}{ft\ s})}{\frac{kg}{s}} = 1.096\times10^{-3}\ \frac{lbf\ s}{ft}$$

$\dot{m} = \rho V A$ where A is approximate area

Helium

$$V_{ave}\ \text{OBROUND} = \frac{\dot{m}}{\rho A} = \frac{1.096\times10^{-3}\ \frac{lb}{ft}}{(1.1925\ \frac{kg}{m^3})(1.9403\times10^{-3}\ \frac{lb_f\ ft^2}{ft^4} / \frac{kg}{m^3})(2)(2.70594\ in^2)(\frac{1ft}{12in})^2}$$

↑ 1.366 N_2 — 24.47

$$V_{ave\ He} = 78.10\ \frac{ft}{s}$$

$$V_{ave}\ \text{Annulus} = \frac{\dot{m}}{\rho A} = 14.85\ \frac{ft}{s}$$

NITROGEN V_{ave} obround $= 11.01$ ft/s

V_{ave} annulus $= 2.09$ ft/s

$$\nu = \frac{\mu}{\rho}$$

$$\nu\ N_2 @ 1.1\ atm \quad \frac{179.55\ \mu P}{.001252\ \frac{g}{cc}} = 0.14338\ \frac{cm^2}{s}\cdot\left(\frac{1m}{100cm}\right)^2$$

$$1.4338\times10^{-5}\ \frac{m^2}{s} = 1.5433\times10^{-4}\ \frac{ft^2}{s}$$

$$\nu\ He @ 1.2\ atm \quad \frac{19.92\times10^{-6}\ (\frac{kg}{m\,s})}{.1925\ \frac{kg}{m^3}} = 1.0348\times10^{-4} = 1.1139\times10^{-3}$$

$$\frac{\mu}{\rho} = \frac{kg\ m/s}{m^2}$$

$$Re_{He}\ \text{obround} = \frac{(78.10\ ft/s)(\frac{1.72}{12})ft}{1.1139\times10^{-3}\ \frac{ft^2}{s}} = 10050$$

$$\text{annulus}\ \frac{[(14.85\ ft/s)](\frac{2.5}{12}ft)}{1.1139\times10^{-3}\ \frac{ft^2}{s}} = 2776$$

$$Re_{N_2}\ \text{obround}\ \frac{(11.01\ \frac{ft}{s})\cdot(\frac{1.72}{12}\ ft)}{1.5433\times10^{-4}\ \frac{ft^2}{s}} = 10225$$

$$Re_{N_2}\ \text{Annulus}\ \frac{(2.09\ ft/s)(\frac{2.5}{12})ft}{1.5433\times10^{-4}\ \frac{ft^2}{s}} = 2821$$

I will use $f=0.02$ to determine an approximate max acceptable mass flow rate

$$V_{ave} = \frac{\dot{m}}{\rho A}$$

He

$$17993\ ft = \frac{\left[\frac{\dot{m}}{(0.1925)(1.9403\times10^{-3})(2)(2.70594)\frac{1}{12^2}}\right]^2}{2\left(32.174\ \frac{ft}{s^2}\right)}\left(1+.02\frac{(105)}{1.72}\right)$$

$$+\frac{\left[\frac{\dot{m}}{(0.1925)(1.9403\times10^{-3})(28.47)(\frac{1}{12})^2\ \frac{lbf\, s^2}{ft^4}\ ft^2}\right]^2}{2(32.174)}\left(43+.02\frac{(109)}{2.5}+\frac{.02(264)}{2.5}\right)$$

$$(17993\ ft)(2)(32.174\ ft/s^2) = \dot{m}^2(1.27\ 1\times10^{10}) + \dot{m}^2(3.6053\times10^{9})\ \frac{ft^4}{lb^2\, s^4}$$

$$\dot{m}^2 = 7.7824\times10^{-5}\ \frac{lb_f^2\, s^2}{ft^2} \rightarrow \dot{m} = 0.00881\frac{lbf\, s}{ft}\cdot\frac{1\ \frac{kg}{s}}{6.8522\times10^{-2}\ \frac{lbf\, s^2}{ft}}$$

$$= \frac{.1287\ kg}{s}$$

$$= 128.7\frac{g}{s}$$

N_2

$$2532.96\ ft = \frac{\frac{\dot{m}^2}{(1.366)^2(1.9403\times10^{-3})^2(2)^2(2.70594)^2(\frac{1}{12})^2}\left[1+.02\left(\frac{105}{1.72}\right)\right]\frac{ft^4}{lb_f^2 s^4}}{2(32.174)\ \frac{ft}{s^2}}$$

$$+\frac{\frac{\dot{m}^2}{(1.366^2)(1.9403\times10^{-3})^2(28.47)^2(\frac{1}{12})^2}\left[43+0.02\left(\frac{109}{2.5}\right)+.02\left(\frac{264}{2.5}\right)\right]\frac{ft^4}{lb_f^2 s^4}}{2(32.174\ ft/s^2)}$$

$$(2532.96)(2)(32.174)\frac{ft^2}{s^2} = \left(\dot{m}^2(2.23833\times10^{8}) + 1.67442\times10^{8}\ \dot{m}^2\right)\frac{ft^4}{lb_f^2 s^4}$$

$$\dot{m}^2 = 4.165\times10^{-4} \rightarrow \dot{m} = 0.0204\ \frac{lbf\, s}{ft}\left(\frac{1\ \frac{kg}{s}}{6.8522\times10^{-2}\ \frac{lbf\, s^2}{ft\, s}}\right)$$

$$= 0.2978\ \frac{kg}{s} = 297.8\ \frac{g}{s}$$

(7)

THESE VALUES ARE CONSIDERABLY HIGHER THAN THE EXPECTED SOLENOID FLOW RATES OF 16 g/s LH_e - 39/s LN_2

$$\Delta h_{total} = \frac{V_{AB}^2}{2g}\left(f_{AB}\frac{L_{AB}}{D_{AB}}\right) + \frac{V_{BC}^2}{2g}\left(f_{BC}\frac{L_{BC}}{D_{BC}}\right) + \frac{V_{CD}^2}{2g}\left(f_{CD}\frac{L_{CD}}{D_{CD}}\right) + \frac{V_{BC}^2}{2g}(1) + \frac{V_{CD}^2}{2g}\left(f_{CD}\frac{32\,D}{D}\right)$$

$$+ \frac{V_{CD}^2}{2g}\left(f_{CD}(9.5)\right) + \frac{V_{AB}^2}{2g}(1) + \frac{V_{CD}^2}{2g}(0.5)$$

for N_2 $V_{AB} = V_{N_2}$ in Obround $= 11.01$ ft/s
$V_{BC} = V_{CD} = V_{N_2}$ in Annulus $= 2.09$
$f_{ab} = .033$ } MOODY CHART
$f_{bc} = 0.023$ ← $64/Re$

$$\Delta h_{N_2} = \frac{(11.01\ \frac{ft}{s})^2}{2(32.174\frac{ft}{s^2})}\left(.033\ \frac{\frac{105}{12}ft}{\frac{1.22}{12}ft}\right) + \frac{(2.09\ \frac{ft}{s})^2}{2(32.174\frac{ft}{s^2})}\left(.023\cdot\frac{109}{2.5}\right) + \frac{(2.09\ \frac{ft}{s})^2}{2(32.174\frac{ft}{s^2})}\left(0.033\cdot\frac{264}{2.5}\right)$$

$$+ \frac{11.01}{32.174}ft(1.5 + 32 + 9.5) + \frac{11.01^2}{2(32.174)}ft(1) = 5.68 + 3.14 = 8.8\ ft$$

for He $V_{ab} = V_{He}$ in obround $= 78.10$ ft/s
$V_{BC} = V_{CD} = V_{He}$ in annulus $= 14.85$ ft/s
$f_{ab} = .033$ } MOODY
$f_{bc} = .045$ } transition?

$$\Delta h_{He} = \frac{78.1^2}{2(32.174)}ft\left(1 + (.033)\frac{105}{1.22}\right)ft + \left(\frac{14.85^2}{2(32.174)}\right)\left[43 + (.045)\frac{109}{2.4} + (.033)\left(\frac{264}{2.5}\right)\right]$$

$= 285.8 + 170.4 = 456$ ft

THESE ARE WELL BELOW THE P. 3 HEAD VALUES

WHAT ABOUT A 5 FOLD INCREASE IN FLOW (ΔP increases in proportion to V^2)

80 g/s $= 5.48\times10^{-3}$ $\frac{lb_f\,s}{ft}$

He, $V_{obround}$ 390.05 ft/s
$V_{annulus}$ 74.23 ft/s

N_2 $V_{obround}$ 55.03 ft/s
$V_{annulus}$ 10.46 ft/s

He, $h = 5395.3 + 3976.9 = 9371.2$

N_2 $h = 101.65 + 78.44 = 180.1$

He Re_{ob} 50890 → f = 0.021
$Re_{annulus}$ 9552 → f = .023
N_2 Re_{ob} = 74286 → f = .019
$Re_{annulus}$ 14,120 → f = .021

STILL LESS THAN MAX ACCEPTABLE HEAD VALUE.

IT CAN BE SEEN THAT THE FRICTION FACTORS ARE CONVERGING TO AN UPPER BOUND OF ABOUT 0.02.

I WILL USE $f = 0.02$ To determine an approximate max acceptable mass flow rate

$$V_{ave} = \frac{\dot{m}}{\rho A}$$

He

$$17993\ ft = \frac{\left[\frac{\dot{m}}{(0.1925)(1.9403\times10^{-3})(2)(2.70594)\frac{ft^2}{12^2}\ \frac{lbf\, s^2}{ft^4}}\right]^2}{2\left(32.174\ \frac{ft}{s^2}\right)}\left(1 + .02\frac{(105)}{1.72}\right)$$

$$+\frac{\left[\frac{\dot{m}}{(0.1925)(1.9403\times10^{-3})(28.47)\left(\frac{1}{12}\right)^2\ \frac{lbf\, s^2}{ft^4}\ ft^2}\right]^2}{2(32.174)}\left(43 + .02\frac{(109)}{2.5} + \frac{.02(264)}{2.5}\right)$$

$$(17993\ ft)(2)(32.174\ ft/s^2) = \dot{m}^2(1.27\times10^{10}) + \dot{m}^2(3.6053\times10^{9})\frac{ft^4}{lb^2\, s^4}$$

$$\dot{m}^2 = 7.7824\times10^{-5}\ \frac{lb_f^2\, s^2}{ft^2} \rightarrow \dot{m} = 0.00881\ \frac{lbf\, s}{ft}\cdot\frac{1\ \frac{kg}{s}}{6.8522\times10^{-2}\ \frac{lbf\, s^2}{ft\, s}}$$

$$= .1287\ \frac{kg}{s}$$

$$= 128.7\ \frac{g}{s}$$

N_2

$$2532.96\ ft = \frac{\dot{m}^2}{\frac{(1.366)^2(1.9403\times10^{-3})^2(2)^2(2.70594)^2\left(\frac{1}{12}\right)^2}{2(32.174)\ \frac{ft}{s^2}}}\left[1 + .02\left(\frac{105}{1.72}\right)\right]\frac{ft^4}{lb^2 s^4}$$

$$+\frac{\dot{m}^2}{\frac{(1.366^2)(1.940^3\times10^{-3})^2(28.47)^2\left(\frac{1}{12}\right)^2}{2(32.174\ ft/s^2)}}\left[43 + 0.02\left(\frac{109}{2.5}\right) + .02\left(\frac{264}{2.5}\right)\right]\frac{ft^4}{lb^2 s^4}$$

$$(2532.96)(2)(32.174)\frac{ft^2}{s^2} = \left(\dot{m}^2(2.23833\times10^{8}) + 1.674425\times10^{8}\ \dot{m}^2\right)\frac{ft^4}{lb^2 s^4}$$

$$\dot{m}^2 = 4.165\times10^{-4} \rightarrow \dot{m} = 0.0204\ \frac{lbf\, s}{ft}\left(\frac{1\ \frac{kg}{s}}{6.8522\times10^{-2}\ \frac{lbf\, s^2}{ft\, s}}\right)$$

$$= 0.2978\ \frac{kg}{s} = 297.8\ \frac{g}{s}$$

THESE VALUES ARE CONSIDERABLY HIGHER THAN THE EXPECTED SOLENOID FLOW RATES OF 16 g/s LHe - 3 g/s LN_2

FERMILAB ENGINEERING NOTE	SECTION	PROJECT	SERIAL-CATEGORY	PAGE
	RD/DØ	DØ UPGRADE SOLENOID	3823.111	1

SUBJECT: DØ SOLENOID - VACUUM VESSEL RELIEF CAPACITY REQUIREMENT

NAME: RUSS RUCINSKI

DATE: 7/27/93

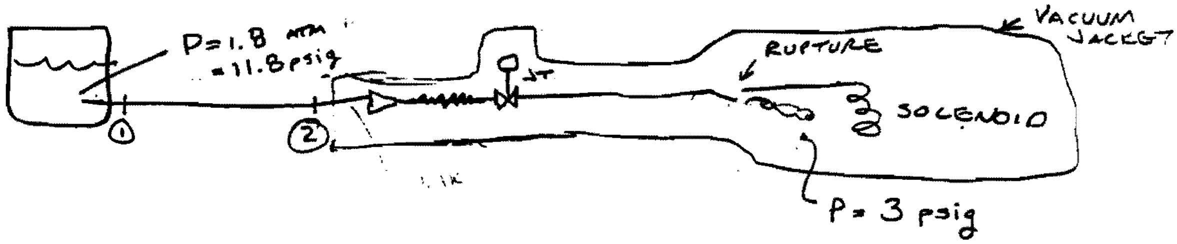
REVISION DATE:

IT HAS BEEN CALCULATED THAT THE CHIMNEY VACUUM JACKET HAS 130 g/s HELIUM OR 300 g/s NITROGEN VENTING CAPACITY FOR 3 PSIG AT THE SOLENOID & 1.5 PSIG LIFT PLATE.

I WILL TRY TO PROVE THAT THIS CAPACITY IS GREATER THAN THAT POSSIBLE BY A "FAILURE" MODE. [NOTE OPERATIONAL FLOW RATES ARE EXPECTED TO BE 15 g/s He MAX. AND 3 g/s N_2.]

– TRY MOST CONSERVATIVE (& EASIEST) ASSUMPTIONS.

LHe MAX. DELIVERY RATE: STORAGE DEWAR AT 1.8 ATM



HARD #'S ARE NOT AVAILABLE SINCE THE LINE FROM THE STORAGE DEWAR TO CONTROL DEWAR IS NOT SIZED YET.

→ ESTIMATE CRITEREA FOR LINE SIZING

1) . P_1 = 1.8 ATM = 11.8 psig
P_2 = 1.7 ATM = 10.3 psig } AT 15 g/s MAX. EXPECTED OPERATIONAL FLOW

LENGTH OF PIPE ≈ 200 ft FOR COLL. HALL DETECTOR POSITION (LONGEST)

$$\Delta P = 3.36 \times 10^{-6} \frac{f L W^2}{\rho d^5}$$

KNOWING W, L, ρ, ΔP FIND d & Re

W = 15 g/s μ_1 = 2.864 μPa-s ρ_1 = 106.7 kg/m³

⑧

$$Re = \frac{d\dot{m}}{A\mu}$$

SUBJECT: DØ SOLENOID – VACUUM VESSEL RELIEF CAPACITY REQUIREMENT

NAME: RUSS RUCINSKI

DATE: 7/28/93

REVISION DATE:

(f: OFF MOODY.)

d	Re	f	ΔP_{100}
.75	350,052	.014	.042 psi
.62"	423,451	.0135	.105 psi
.37"	709,566	.012	1.24 psi
.495	530,382	.013	0.312 psi ←

BASED ON THESE CALCULATIONS I WOULD ESTIMATE THAT WE WILL PROBABLY USE 5/8" O.D. x .065" WALL STAINLESS TUBING FOR THE X-FER LINE FROM THE DEWAR TO CONTROL DEWAR. ΔP TO COLLISION HALL AT MAX. FLOW RATE ≈ 0.62 psi.

FOR ASS'Y HALL $\Delta P \approx 0.312$ psi. SINCE WE ARE IN TURBULENT FLOW REGIME, $\Delta P \propto W^2$

$$\Delta P_1 = 0.312 \text{ psi} \qquad W_1 = 15\ g/s$$

$$\Delta P_2 = 8.8 \text{ psi} \qquad W_2 = ?$$

⇐ $\Delta P = 11.8$ psig − 3 psig LEAK/RUPTURE IN SOLENOID / CONTROL DEWAR

$$\frac{\Delta P_1}{W_1^2} = \frac{\Delta P_2}{W_2^2} \Rightarrow W_2^2 = \frac{\Delta P_2}{\Delta P_1} W_1^2$$

$$W_2 = \sqrt{\frac{\Delta P_2}{\Delta P_1} W_1^2} = \sqrt{\frac{8.8}{.312}(15\ g/s)^2} = \underline{79.7\ g/s}$$

FOR UPSET CONDITIONS, WORST CASE MAXIMUM LHe FLOW ALLOWED THRU SUPPLY LINE TO CONTROL DEWAR OR SOLENOID IS 80 g/s. THIS IS LESS THAN 130 g/s CAPACITY OF RELIEF PATH.

SUBJECT: DØ SOLENOID - VACUUM VESSEL RELIEF CAPACITY REQUIREMENT.

NAME: RUSS RUCINSKI

DATE: 7/28/93

REVISION DATE:

LN_2 MAX. DELIVERY. RATE:

THE LN_2 CIRCUIT WILL RUN IN THE SAME VACUUM JACKET AS THE LHe PIPES FROM THE LHe STORAGE DEWAR TO THE CONTROL DEWAR. THE EXPECTED OPERATIONAL MASS FLOW RATE IS ABOUT 2-3 g/s.

L = 100 ft ASS'Y HALL POSITION
200 ft COLL. HALL POSITION

AT THE INLET TO THE CONTROL DEWAR THE OPERATIONAL PRESSURE OF THE LN_2 CIRCUIT WILL BE ABOUT 10 PSIG.

THE TUBING IN THE TRANSFER LINE WOULD BE NO LARGER THAN 1/2" O.D. × .065" WALL TUBE WHICH WOULD GIVE AN OPERATIONAL PRESSURE DROP OF:

$$d = 0.37\,in, \quad \rho = 771\ kg/m^3, \quad \mu = 120\ \mu Pa\text{-}s \quad \{\text{SAT. } LN_2\ 228\ kPa\}$$

$$Re = 3386 \Rightarrow \text{TRANSITION} \quad \frac{64}{Re} \quad .019 < f < 0.04$$

$$.01 < \Delta P_{100} < .02\,psi \quad \text{WHICH IS NEGLIGIBLE.}$$

{IN REAL CASE SOME 2Ø WOULD BE FLOWING TENDING TO INCREASE ΔP.}

USING SAME REASONING AS WITH LHe

$$W_2 = \sqrt{\frac{\Delta P_2}{\Delta P_1} W_1^2}$$

WHERE: SUBSCRIPT-2 REFERS TO SEVERED LINE CASE

$$W_2 = \sqrt{\frac{(10\,psig - 3\,psig)}{(10.02 - 10\,psig)}(3\,g/s)^2} = \underline{56\ g/s}$$

* TK says 80 g/s

THIS IS LESS THAN 300 g/s CAPACITY OF RELIEF PATH. (10)

SUBJECT: DØ SOLENOID - VACUUM VESSEL RELIEF CAPACITY REQUIREMENT.

NAME: RUSS RUCINSKI

DATE: 7/28/93

REVISION DATE:

NOTE TO CALCULATIONS:

THESE CALCULATIONS ARE ONLY MEANT FOR THE PURPOSE OF BOUNDING THE WORST CASE SCENARIO. ASSUMPTIONS WERE MADE ABOUT THE TRANSFER LINE SIZES. VALUES USED FOR THE OPERATIONAL PRESSURES AND FLOWRATES, ARE PRETTY WELL KNOWN AT THIS TIME. IT IS NOT REALISTIC TO ASSUME THAT A COMPLETE RUPTURE INTO THE SOLENOID VACUUM JACKET WILL OCCUR.

THE REAL VALUE OF THESE CALCULATIONS IS THAT I FEEL IT PROVES THE VALIDITY OF THE STATEMENT,

"THE RELIEF VENTING PATH CAPACITY IS MUCH GREATER THAN POSSIBLE FAILURE MODE FLOWRATES".

THIS IS STATED IN MY CHAPTER 5 OF THE SOLENOID DESIGN REPORT.

St Input	Name	Output	Unit	Comment
				D0 Solenoid LN2 line Russ Rucinski RD/DØ 7/28/93 ** FLUID FLOW IN PIPES ** Pressure drop equation from Crane Technical paper 410
100	L		ft	length of pipe
.37	d		in	pipe inside diameter
.04	f			friction factor of pipe
	Re	3386.996		Reynolds number of pipe flow
795	rho		kg/m^3	fluid mass density
	dP	.02212023	lb/in^2	pressure drop across pipe of length L
	Area	.10752101	in^2	cross-sectional area of pipe
3	mdot		g/s	mass flow rate
.00012	mu		Pa-s	fluid viscosity
	W	23.80968	lb/hr	

St Input	Name	Output	Unit	Comment
				D0 Solenoid LN2, max flow with delta P of 7 psi Russ Rucinski RD/DØ 7/28/93 ** FLUID FLOW IN PIPES ** Pressure drop equation from Crane Technical paper 410
100	L		ft	length of pipe
.37	d		in	pipe inside diameter
.019	f			friction factor of pipe
	Re	90319.894		Reynolds number of pipe flow
795	rho		kg/m^3	fluid mass density
	dP	7.4717217	lb/in^2	pressure drop across pipe of length L
	Area	.10752101	in^2	cross-sectional area of pipe
80	mdot		g/s	mass flow rate
.00012	mu		Pa-s	fluid viscosity
	W	634.9248	lb/hr	

St Input	Name	Output	Unit	Comment
				D0 Solenoid LHe line Russ Rucinski RD/DØ 7/28/93 ** FLUID FLOW IN PIPES ** Pressure drop equation from Crane Technical paper 410
100	L		ft	length of pipe
.495	d		in	pipe inside diameter
.013	f			friction factor of pipe
	Re	530382.82		Reynolds number of pipe flow
106.7	rho		kg/m^3	fluid mass density
	dP	.3124628	lb/in^2	pressure drop across pipe of length L
	Area	.19244218	in^2	cross-sectional area of pipe
15	mdot		g/s	mass flow rate
2.864E-6	mu		Pa-s	fluid viscosity
	W	119.0484	lb/hr	