DØ SOLENOID UPGRADE PROJECT

Control Dewar

Liquid Helium Reservoir Sizing

D-ZERO ENGINEERING NOTE # 3823.111 EN-352

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SUBJECT

CONTROL DEWAR LHE VOLUME

NAME

RUSS RUCINSKI

DATE

3-8-93

REVISION DATE

ESTIMATE REQ'D LHE RESERVOIR VOLUME:

• NEED TO MAINTAIN LIQUID FOR;

A) 45 MINUTES (CDF SLOW DUMP TIME)

B) $t = \frac{5000A}{400A/\text{MIN.}} = 12.5 \text{ MIN.}$
(WITH NO LHE SUPPLY)

→ USE 45 MINUTES

{ NOTE:
SDC ~ 90-100L
CDF ~ 50L }

• ESTIMATE HEAT LOAD & CONSUMPTION

1) LEAD FLOW: PER RLS E-MAIL INFORMATION;

a) CDF USES 28.8 LIQUID L/HR

d) SDC LEAD FLOW = 30 L/HR

b) CVM USES 23.6 LIQUID L/HR

c) AMI CATALOG $\dot{m} = 2.8 \times 10^{-3} \text{ L/M} \cdot A \times 6000A = 16.8 \text{ L/HR.}$

2) ASSUME "OPEN NECK" DESIGN

a) CONDUCTION DOWN WALL

$$Q = \frac{A}{L} \int K dT$$

$$A = \pi D t = \pi (6.5 \text{ in}) (0.0625 \text{ in}) \left(\frac{.0254 \text{ m}}{1 \text{ in}} \right)^2 = 8.23 \times 10^{-4} \text{ m}^2$$

$$L = 10" = .254 \text{ m}$$

$$\int_{T=4K}^{T=80K} K dT = 349 \text{ W/m} \quad \left\{ \text{REF. BARRON, TABLE 7.9} \right\}$$

$$Q = \frac{8.23 \times 10^{-4} \text{ m}^2}{.254 \text{ m}} (349 \text{ W/m}) = 1.13 \text{ W}$$

b) CONDUCTION DOWN GHE

$$A = \frac{\pi D^2}{4} = \frac{\pi (6.5 \text{ in})^2}{4} \left(\frac{.0254 \text{ m}}{1 \text{ in}} \right)^2 = 2.14 \times 10^{-2} \text{ m}^2$$

$$L = 15 \text{ in.} = .381 \text{ m}$$

$$\int_{T=4K}^{T=300K} K dT = 23 \text{ W/m} \quad \left\{ \text{FROM 5/12/92 RAR VLPC QUICK CALCS. PG. 2} \right\}$$

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b) (cont.)

$$Q = \frac{A}{L} \int k dT = \frac{2.14 \times 10^{-2} \text{ m}^2}{.381 \text{ m}} (23 \text{ W/m}) = 1.29 \text{ W}$$

c) OTHER ADD $Q = 1 \text{ WATT}$ FOR LHC PROBES, PIPING, ETC, ETC.

$$\text{CONSUMPTION} = \frac{Q_{\text{TOTAL}}}{h_{fz}} + \text{LEAD FLOW}$$

$$= \frac{1.13 + 1.29 + 1 \text{ W}}{29.72 \frac{\text{J}}{\text{g}} - 13.38 \frac{\text{J}}{\text{g}}} + 28.8 \frac{\text{L}}{\text{hr.}}$$

$$= 0.209 \frac{\text{g}}{\text{s}} + 28.8 \frac{\text{L}}{\text{hr.}}$$

$$= .209 \frac{\text{g}}{\text{s}} \times \frac{1 \text{ L}}{124.9 \text{ g}} \times \frac{3600 \text{ s}}{1 \text{ hr.}} + 28.8 \frac{\text{L}}{\text{hr.}} = 6.03 \frac{\text{L}}{\text{hr.}} + 28.8 \frac{\text{L}}{\text{hr.}}$$

$$= \underline{34.8 \frac{\text{L}}{\text{hr.}}}$$

NOTE: CONSUMPTION WILL GO DOWN AS LIQUID LEVEL DROPS DUE TO INCREASED "L" IN CONDUCTION EQUATIONS.

THIS IS A ROUGH ESTIMATE.

$$V|_{45 \text{ MIN.}} = 34.8 \frac{\text{L}}{\text{hr.}} \times .75 \text{ hr} = \underline{26 \text{ L}}$$

→ MINIMUM LIQUID VOLUME REQ'D = 26L

← FOR OPEN
NECK
TYPE
DEWAR

• RE CALCULATE ASSUMING SLEEVED DESIGN

1) LEAD FLOW SAME

2) USE 2 TUBES, MOST HEAT GETS PICKED UP BY LEAD FLOW.

3) ADD 1 WATT EXTRA

$$\text{CONSUMPTION} \approx \frac{1}{3} (6.03 \frac{\text{L}}{\text{hr.}}) + 28.8 \frac{\text{L}}{\text{hr.}} = 30.8 \frac{\text{L}}{\text{hr.}}$$

$$V_{\text{REQ'D}} = \underline{23 \text{ L}} \quad \text{NOT A BIG SAVINGS.}$$

CONCLUSION: BETTER MAKE LHC RESERVOIR $\geq 26 \text{ L}$

PER BRUCE SQUIRES, 45 MIN. WOULD BE ADEQUATE FOR SLOW DUMP.

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• SIZE VOLUME.

PER 2/23/93 SKETCH, MINIMUM SIZE WAS;

8 1/2" O.D. x ≈ 16" LONG LIQUID VOLUME

$$V = \frac{\pi D^2}{4} \cdot L = 908 \text{ in}^3 \times \left(\frac{2.54 \text{ cm}}{1 \text{ in.}} \right)^3 \times \left(\frac{1 \text{ L}}{1000 \text{ cm}^3} \right) = 14.9 \text{ L}$$

TRY 12" IPS (REASONABLY COMMON SIZE) & V = 30L

$$L = \frac{4V}{\pi D^2} = \frac{4(30 \text{ L})}{\pi (12.39 \text{ in})^2} \times \frac{1000 \text{ cm}^3}{1 \text{ L}} \times \left(\frac{1 \text{ in.}}{2.54 \text{ cm}} \right)^3 = 15.18 \text{ in.}$$

I THINK A "SLEEVED" TUBE PENETRATION IS THE PROPER WAY TO GO FOR THE AMI LEADS. THERE WILL BE LESS STEADY STATE HEAT LOAD THAN A NECK TYPE DESIGN.

WHAT INTERNAL PRESSURE RATING IS 12" SCH 10S GOOD FOR?
(REF. UG-27)

$$P = \frac{SEt}{R + 0.6t}$$

$$SE = (18.8 \text{ ksi})(0.8)(.65) \quad \text{FERMI FACTOR}$$

$$= 9.776 \text{ ksi}$$

$$t = 0.180 \text{ in.}$$

$$R = 6.195 \text{ in.}$$

$$P = \frac{(9776 \text{ psi})(.180 \text{ in.})}{(6.195 + 0.6(.180))} = 279 \text{ psi}$$

✓ OK.

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EXTERNAL PRESSURE: DESIGN CHART, $t_{MIN}|_{12" \phi} = .095 \text{ IN.}$

12" SCH. 10S IS ADEQUATE FOR EXTERNAL PRESSURE. ✓ O.K.

• SIZE ULLAGE SPACE

'STD' IS 10%.

ASSUME 30L OF LIQUID.

INLET & OUTLET VALVES CLOSE, LEAD FLOW STOPPED

LIMIT PRESSURE RISE TO SAY; $\frac{145 \text{ PSI}}{30 \text{ MIN.}} = 4.83 \text{ PSI/MINUTE}$

$$\text{HEAT INLEAK} = 16.8 \frac{\text{W}}{\text{m}^2} \times \frac{10 \text{ W}}{144 \text{ m}^2} + 3.29 \text{ W} = 12 \text{ W} + 3.29 = 15.3 \text{ W}$$

$$P_c = 227,460 \text{ Pa} = 2.2449 \text{ ATM} = 33.0 \text{ psia} = 18.3 \text{ psig}$$

{REFERENCE TECHNOLOGY OF LIQUID HELIUM SEC. 5.4.1 PRESSURE RISE }

$$Q = \Delta U = \Delta H - U \Delta P$$

U - SPECIFIC VOLUME - CONSTANT
 Q - HEAT INPUT

→ TRY 2L ULLAGE SPACE

$$m_{\text{TOTAL}} = m_{\text{GAS}} + m_{\text{LIQ.}} = V_{\text{GAS}} \rho_{\text{GAS}}|_{.14 \text{ MPa}} + V_{\text{LIQ.}} \rho_{\text{LIQ.}}|_{.14 \text{ MPa}}$$

$$= \left[(2 \text{ L}) \left(24.09 \frac{\text{kg}}{\text{m}^3} \right) + (30 \text{ L}) \left(116.8 \frac{\text{kg}}{\text{m}^3} \right) \right] \frac{1 \text{ m}^3}{1000 \text{ L}} = 3.55 \text{ kg}$$

$$U = \frac{V}{m} = \frac{32 \text{ L}}{3.55 \text{ kg}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{1000 \text{ cm}^3}{1 \text{ L}} = 9.0 \frac{\text{cm}^3}{\text{g}}$$

CONSTANT THRU OUT PRESSURE RISE

FOR THE INITIAL STATE $t=0$; $P=.14 \text{ MPa}$

$$x = \frac{m_g}{m_{\text{TOTAL}}} = \frac{.04818 \text{ kg}}{3.55 \text{ kg}} = .0136$$

$$U_i = x U_g + (1-x) U_F = (.0136) \left(24.5 \frac{\text{J}}{\text{g}} \right) + (1-.0136) \left(10.9 \frac{\text{J}}{\text{g}} \right)$$

$$= 11.08 \frac{\text{J}}{\text{g}} \quad U_i = m \cdot U_i = 3.55 \text{ kg} \left(11.08 \frac{\text{J}}{\text{g}} \right) = 39,352 \text{ Joules}$$

FOR TIME = 30 MIN.,

$$Q = \Delta U = 15.3 \frac{\text{J}}{\text{s}} \times 30 \text{ MIN.} \times \frac{60 \text{ s}}{1 \text{ MIN.}} = 27,540 \text{ Joules}$$

$$U_{t=30 \text{ min.}} = U_i + \Delta U = 11.08 \frac{\text{J}}{\text{g}} + \frac{27,540 \text{ J}}{3550 \text{ g}} = 18.84 \frac{\text{J}}{\text{g}}$$

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FROM FIG. 2.7 P. 15. U, AND FOLLOWING $\tau = 9 \text{ cm}^3/g$

$$P_{t=30 \text{ min.}} = 9.6 \text{ ATM.} \times \frac{14.7 \text{ psia}}{1 \text{ ATM}} = 141.1 \text{ psia} = 126 \text{ psig.}$$

THIS IS ACCEPTABLE. DESIGN PRESSURE IS 150 psig OR SO.

CONCLUSION:LIQUID VOLUME $\approx 30 \text{ L}$ GAS VOLUME $\approx 2 \text{ L}$

VOLUME OF DISHED HEAD:

$$V = \frac{2}{3} \pi K R^3$$

$$R = \frac{12.39''}{2(12)} = .5163 \text{ Ft.}$$

$$K = M - \sqrt{(M-1)(M+1-2m)}$$

$$M = \frac{MR}{R}$$

$$m = \frac{mR}{R}$$

REFERENCE: CBI BULLETIN #594
"TABLES - FORMULAS"

$$MR \approx 1 \text{ Ft.} \Rightarrow M \approx 2$$

$$mR \approx .8'' = .067 \text{ Ft.} \Rightarrow m \approx .129$$

$$K = 2 - \sqrt{1(3 - .26)} = 0.344$$

$$V = \frac{2}{3} \pi (.344)(.5163 \text{ Ft.})^3 = .099 \text{ Ft.}^3$$

$$= .099 \text{ Ft.}^3 \times \frac{28.3 \text{ L}}{\text{Ft.}^3} = 2.8 \text{ L} \quad \checkmark \left\{ \begin{array}{l} \text{EQUIV. TO } 12'' \phi \times 1.5' \text{ DEEP} \\ \text{CYLINDER - QUICK CHECK} \end{array} \right.$$

WE WILL WANT REFRIGERATOR RETURN TO COME INTO SHELL.

 $\therefore$ ULLAGE WILL BE $> 2.8 \text{ L}$

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FROM TECHNOLOGY OF LIQUID HELIUM

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PROPERTIES OF HELIUM

FIGURE 2.7. Pressure-internal energy diagram.