DØ SOLENOID UPGRADE PROJECT

Control Dewar
Liquid Helium Reservoir Sizing

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Russ Rucinski
RD/D-Zero Mechanical Group
CONTROL DEWAR LHe VOLUME

ESTIMATE REQ'D LHE RESERVOIR VOLUME:

* NEED TO MAINTAIN LIQUID FOR:
  A) 45 MINUTES (CFD SLOW DUMP TIME)
  B) \( t_1 = \frac{5000}{400 \text{ A/min}} = 12.5 \text{ min.} \)
  (WITH NO LHE SUPPLY)

\[ \text{\textbf{USE} 45 MINUTES} \]

* ESTIMATE HEAT LOAD & CONSUMPTION

1) LEAD FLOW: PER RLS E-MAIL INFORMATION:
   a) CDF USES 28.8 LIQUID \( \text{L/HR} \)
   b) CVM USES 23.6 LIQUID \( \text{L/HR} \)
   c) AME CATALOG \( m = 2.0 \times 10^{-3} \text{ W/K} x 6000 = 12.6 \text{ W} \)

2) ASSUME "OPEN NECK" DESIGN

   \[ 6.5" \text{ O.D.} \]
   \[ t_{\text{min}} = 0.05" \] (FROM DESIGN CHART VACUUM PIPES)
   USE \( t_{\text{WALL}} = 0.0625" \)

\[ \text{\textbf{a) CONDUCTION DOWN WALL}} \]
\[ Q = \frac{A}{L} \sum KdT \]
\[ A = \pi D^2 = \pi (6.5\text{ in.})(0.0625\text{ in.})^2 = 0.23 \times 10^{-4} \text{ m}^2 \]
\[ L = 10" = 0.254\text{ m} \]
\[ \sum_{T_{0}}^{T_{300\text{K}}} KdT = 349 \text{ W/m} \] \{REF. BARRON, TABLE 79\}
\[ Q = \frac{8.23 \times 10^{-4} \text{ m}^2}{0.254\text{ m}} (349 \text{ W/m}) = 1.13 \text{ W} \]

\[ \text{\textbf{b) CONDUCTION DOWN GHE}} \]
\[ A = \frac{\pi D^2}{4} = \frac{\pi (6.5\text{ in.})^2}{4} (0.0254\text{ m})^2 = 2.14 \times 10^{-2} \text{ m}^2 \]
\[ L = 15\text{ in.} = 0.381\text{ m} \]
\[ \sum_{T_{0}}^{T_{300\text{K}}} KdT = 23 \text{ W/m} \] \{FROM 5/12/92 RAR VLPC\}

\[ \text{\textbf{QUICK CALCPS. P6.2}} \]
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 WATT FOR LHE PROBES, PIPING, ETC, ETC.

**Consumption** = \( \frac{Q_{total}}{L} + \text{Lead Flow} \)

\[ = \frac{1.13 + 1.29 + 1 \text{ W}}{29.72 \text{ g} - 13.38 \text{ g}} + 28.8 \text{ L/h} \]

\[ = \frac{0.209 \text{ W}}{124.9 \text{ g}} \times 3600 \text{ s} + 28.8 \text{ L/h} = 6.03 \text{ L/h} + 28.8 \text{ L/h} \]

\[ = 34.8 \text{ L/h} \]

**NOTE:** Consumption will go down as liquid level drops due to increased "L" in conduction equations.

**This is a rough estimate.**

\[ V_{\text{min.}} = 34.8 \text{ L/h} \times 0.75 \text{ hr} = 26 \text{ L} \]

\[ \text{Minimum Liquid Volume Req'd} = 26 \text{ L} \]

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**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

**Consumption** ≈ \( \frac{1}{3} (6.03 \text{ L/h}) + 28.8 \text{ L/h} = 30.8 \text{ L/h} \)

\[ V_{\text{req'd}} = 23 \text{ L} \]

**Conclusion:** Better make LHE Reservoir ≥ 26L

*Per Bruce Squires, 45 min. would be adequate for slow dump.*
CONTROL DEWAR LHE VOLUME

- SIZE VOLUME.

PER 2/23/93 SKETCH, MINIMUM SIZE WAS 33;

8 1/2" O.D. X ~ 16" LONG LIQUID VOLUME

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

TRY 12" IPS (REASONABLY COMMON SIZE) & \[ V = 30 \text{L} \]

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

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

\[ \text{WHAT INTERNAL PRESSURE RATING IS 12" SCH 10S GOOD FOR?} \]

(REF. UG-27) \[ P = \frac{\text{SE} \times t}{R + 0.6t} \]

\[ \text{SE} = (18.8 \text{ksi})(0.8)(.65) \]

\[ \text{FEMI FACTOR} = 9.776 \text{ksi} \]

\[ t = 0.180 \text{in.} \]

\[ R = 6.195 \text{in.} \]

\[ P = \frac{(9.776 \text{ psi})(0.180 \text{ in.})}{(6.195 + 0.6(0.180))} = 279 \text{ psi} \]

\[ \sqrt{\text{OK.}} \]
CONTROL DEWAR LHE VOLUME

EXTERNAL PRESSURE: DESIGN CHART, $t_{min} = 0.095$ in. 

12” SCH. 105 IS ADEQUATE FOR EXTERNAL PRESSURE. ✓ O.K.

0 SIZE ULLAGE SPACE

'STD' IS 10%.

ASSUME 30L OF LIQUID.

INLET & OUTLET VALVES CLOSE, LEAD FLOW STOPPED LIMIT PRESSURE RISE TO SAY: $145 \text{ psi} = 4.83 \text{ psi/minute}$

HEAT INLEAK $= 16.8 \frac{\text{W}}{\text{atm}} \times \frac{10^6}{1\text{H}_{\text{PA}}} + 3.29 N = 12W + 3.29 = 15.3 \text{W}$

$P_c = 227.4 \text{ atm} = 2.2449 \text{ atm} = 33.0 \text{ psia} = 18.3 \text{ psig}$

[REFERENCE TECHNOLOGY OF LIQUID HELIUM, SEC. 5.4.1 PRESSURE RISE]

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

$V = \text{SPECFIC VOLUME} = \text{CONSTANT}$

$\theta = \text{HEAT INPUT}$

⇒ TRY 2L ULLAGE SPACE

$$m_{total} = m_{cryo} + m_{liq} = V_{cryo} \rho_{cryo} \frac{1}{14 \text{MPa}} + V_{liq} \rho_{liq} \frac{1}{14 \text{MPa}}$$

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

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

CONSTANT THRU OUT PRESSURE RISE

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

$$x = \frac{m_0}{m_{total}} = \frac{0.4818 \text{ kg}}{3.55 \text{ kg}} = 0.136$$

$$U_i = x U_g + (1-x) U_f = (0.136)(24.5 \frac{J}{g}) + (1 - 0.136)(10.9 \frac{J}{g})$$

$$= 11.08 \frac{J}{g}$$

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

FOR TIME $= 30 \text{ MIN.}$

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

$$U_{total} = U_i + \Delta U = 11.08 \frac{J}{g} + \frac{27,540 \text{ J}}{3550 \text{ g}} = 18.84 \frac{J}{g}$$
CONTROL DEWAR LHC VOLUME

From Fig. 2.7 P vs. U, and following \( V = \frac{9}{3} \cdot 3^3 \)

\[ P_{\text{at}} = 9.6 \text{ atm.} \times \frac{14.7 \text{ psia}}{1 \text{ atm}} = 141.1 \text{ psia} = 126 \text{ psig}, \]

This is acceptable. Design pressure is 150 psig or so.

**Conclusion:**

LIQUID VOLUME \( \geq 30 \text{ L} \)

GAS VOLUME \( \geq 2 \text{ L} \)

Volume of Dished Head:

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

\[ K = M - \sqrt{(M-1)(M+1-2M)} \]

\[ M = \frac{M_R}{R} \quad M_R = \frac{m_R}{R} \]

\[ M_R = 1 \text{ ft}^2 \implies M = 2 \]

\[ M = 0.067 \text{ ft}^2 \implies M = 0.129 \]

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

\[ V = \frac{2}{3} \pi (0.344)(0.5163 \text{ ft})^3 = 0.099 \text{ ft}^3 \]

\[ = 0.099 \text{ ft}^3 \times \frac{28.3 \text{ L}}{\text{ft}^3} = 2.8 \text{ L} \]

We will want Refrigerator Return to come into shell.

Volume will be \( > 2.8 \text{ L} \)

**Sketch - Dimensional Outline of LHC Volume.**

Details of Internal Contents not shown or figured into Volumes.
From Technology of Liquid Helium

Figure 2.7. Pressure-internal energy diagram.