Fermilab

SSC DETECTOR SOLENOID DESIGN NOTE #125

TITLE: Heat Leak Estimate for a Pump Dewar located at the Detector

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ABSTRACT: This design note contains a preliminary heat leak calculation for a pump dewar located at the detector.

SUMMARY: The helium heat leak was calculated to be 8 watts. A value of 15 watts will be used in other calculations until the pump dewar design is known.

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SUBJECT: HEAT LEAK ESTIMATE FOR A PUMP DEWAR LOCATED AT THE DETECTOR

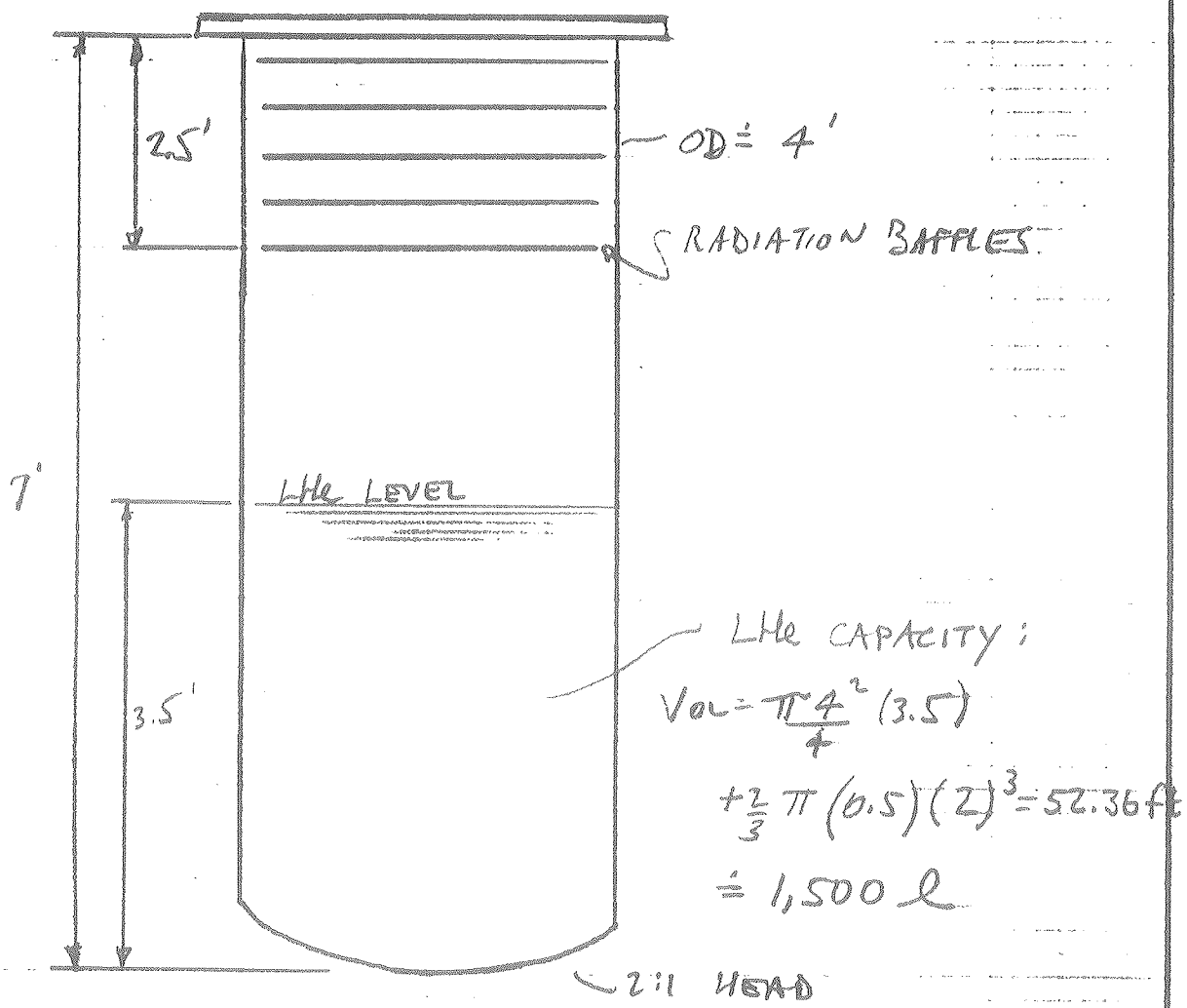
NAME: AMS

DATE: 9/6/90

REVISION DATE:

REFER TO CVM AS A GUIDE.

ASSUME 4 PUMPS ARE INSTALLED IN THE DEWAR (1 ACTIVE AND 3 STANDBY.)



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NAME: AMS

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CONNECTIONS	HEAT SINK
PUMP CONNECTION TUBES (3/pump)	LHe
PUMP PISTON RODS (3/pump)	LHe
VALVE ACTUATOR RODS (6)	LHe
LHe DISCHARGE LINE (1)	LHe
LHe FILL LINE (1)	LHe
LI HIGH PRESSURE LEG (1)	LHe
MISC LINE (HV 060) (2)	LHe
GHe RETURN LINE (1)	GHe (CONDUCTION) LHe (RADIATION)
GHe POWER LEAD SUPPLY (1)	GHe (CONDUCTION) LHe (RADIATION)

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1.0 HEAT LOADS

1.1 VESSEL ONLY (WITHOUT NECK RADIATION HEAT LEAK - COVERED IN 1.10)

A WELL CONSTRUCTED VESSEL OF THIS CAPACITY WOULD HAVE A HEAT LEAK OF 0.5 TO 0.75 % /DAY BOILOFF. THESE BOILOFF VALUES ARE FOR MLI INSULATED VESSELS WITH A GHe OR LN2 SHIELD. WITHOUT A SHIELD, BOILOFF CAN BE ~ 4%/DA

$\therefore 1{,}500\ \ell \times 0.05 \frac{\text{day}}{\text{day}} \times \frac{\text{day}}{24\ \text{hr}} = 3.125\ \ell/\text{hr}$ USE 5%/DAY.

$Q = 3.125\ \ell/\text{hr} \times \frac{\text{hr}}{3600\ \text{s}} \times 1000 \frac{\text{cc}}{\ell} \times 0.12517 \frac{\text{g}}{\text{cc}} \times 20.94 \frac{\text{J}}{\text{g}} = 2.3\ \text{W}$

1.2 PUMP CONNECTION TUBES (SS) (ASSUME NO LN2 INTERCEPT)

DIMENSIONS: 0.67" OD × 0.63" ID × 3.5' TO LHe LEVEL

$A = \frac{\pi}{4}(0.67^2 - 0.63^2) = 0.041\ \text{in}^2$

$$Q = \frac{A}{\ell}\int_4^{300} k\,dT$$

$$Q\Big|_{\text{ONE TUBE}} = \frac{0.041\ \text{in}^2}{3.5(12)\ \text{in}}\left(77.724 \frac{\text{W}}{\text{in}}\right) = 0.076\ \text{W}$$

NO OF TUBES $= \frac{3}{\text{pump}} \times 4\ \text{pumps} = 12$

$Q = 12(0.076\ \text{W}) = 0.912\ \text{W}$

1.3 PUMP PISTON RODS (SS) THERE ARE 12 RODS TOTAL.

DIMENSIONS: 0.55" × 0.47" × 3.5' TO LHe LEVEL

$A = \frac{\pi}{4}(0.55^2 - 0.47^2) = 0.064\ \text{in}^2$

$$Q\Big|_{\text{ONE ROD}} = \frac{0.064}{3.5(12)}(77.724) = 0.118\ \text{W}$$

$Q = 12(0.118\ \text{W}) = 1.42\ \text{W}$

1.4 VALVE ACTUATOR RODS

ASSUME SAME DIMENSIONS AS PUMP PISTON RODS.

$Q = 6\,(0.118\ W) = \underline{0.71\,W}$

1.5 LHe DISCHARGE LINE

DIMENSIONS 1" ϕ SCH 5S (SS)

$A_c = 0.2553\ in^2$

3.5' TO LHe LEVEL

$$Q = \frac{0.2553\ in^2}{3.5\,(12)\ in} \times \left(77.724\ \frac{W}{in}\right) = \underline{0.473\,W}$$

1.6 LHe FILL LINE

SAME AS DISCHARGE LINE (1.5)

$Q = \underline{0.473\,W}$

1.7 LI HIGH PRESSURE LEG (SS) 3.5' TO LHe LEVEL

DIMENSIONS: 1/4" OD X 0.035" WALL

ID = 0.25" 2(0.035") = 0.18"

$$A = \frac{\pi}{4}\left(0.25^2 - 0.18^2\right) = 0.024\ in^2$$

$$Q = \frac{0.024\ in^2}{3.5\,(12)\ in}\left(77.724\ \frac{W}{in}\right) = \underline{0.05\,W}$$

1.8 MISC LINES

SAME AS DISCHARGE LINE (1.5)

$Q = 2\,(0.473\ W) \doteq \underline{1\ W}$

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1.9 GHe RETURN LINE & GHe POWER LEAD SUPPLY

DIMENSIONS : 2"φ SCH 5S (SS)

FLOW AREA = 3.958 in²

CONDUCTION HEAT LOAD DOWN PIPE WALL IS INTERCEPTED BY FLOWING GHe.

RADIATION : ASSUME THERE ARE NO RADIATION BAFFLES FOR THESE TWO LINES.

$$Q = \mathcal{F}\sigma A\left(T_H^4 - T_C^4\right)$$

$\epsilon_{ENDS} = 1$ $\quad D/L = \frac{2.245\ in}{2.5(12)\ in} = 0.075 \Rightarrow \mathcal{F} = 0.1$

$$Q\Big|_{\substack{ONE\\PIPE}} = 0.1\left(0.1714\times10^{-8}\ \frac{Btu}{hr\text{-}ft^2\text{-}°R^4}\right)\left(\frac{3.958\ in^2}{144\ in^2}\ ft^2\right)\left(540^4 - 7.56^4\right)°R^4$$

$= 0.4$ Btu/hr $= 0.12$ W

$Q = 2(0.12) = \underline{0.24\ W}$

1.10 NECK RADIATION HEAT LEAK.

ASSUME INNERMOST SHIELD IS AT 90 K (162 °R)

$\epsilon_1 \doteq 0.03$ FOR ALUMINUM SHIELD

$\epsilon_2 = 1$ FOR LHe SURFACE

$$\therefore\ Q = A\epsilon\sigma\left(T_H^4 - T_C^4\right) = \left(\frac{\pi}{4}4^2\ ft^2\right)0.03\left(0.1714\times10^{-8}\ \frac{Btu}{hr\text{-}ft^2\text{-}°R^4}\right)\left(162^4 - 7.56^4\right)°R^4$$

$= 0.445$ Btu/hr $= \underline{0.13\ W}$

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1.11 SUM THE HEAT LOADS

$$2.3 + 0.912 + 1.42 + 0.71 + 0.473 + 0.473 + 0.05 + 1 + 0.24 + 0.13 = 7.708\ W$$

USE 15 W. (DOUBLE THE CALCULATED LOAD)

1.12 LHe BOILOFF RATE

$$15\ \frac{J}{s} * 20.94\ \frac{g}{J} * 0.12517\ \frac{cc}{g} * 1000\ \frac{l}{cc} * 3600\ \frac{s}{hr}$$

$$= 20.6\ l/hr$$

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