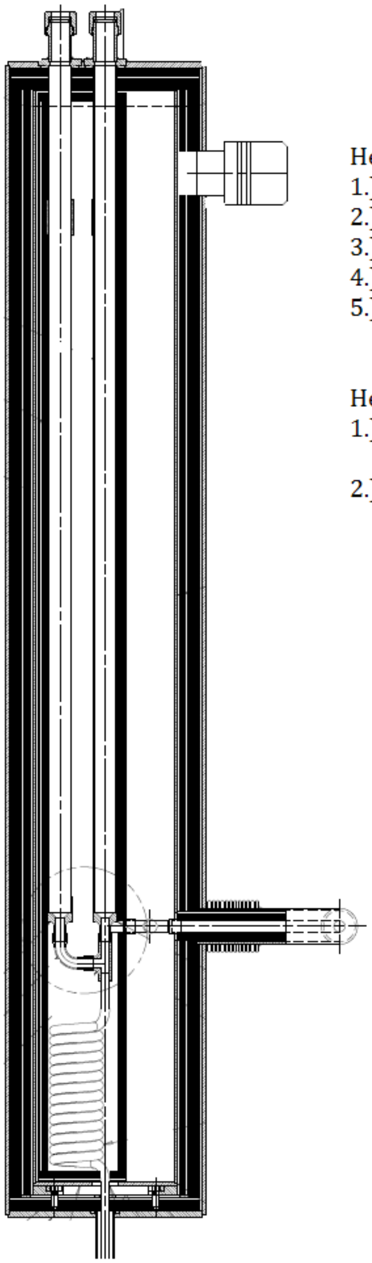
Heat Loss To SCDMS Helium System

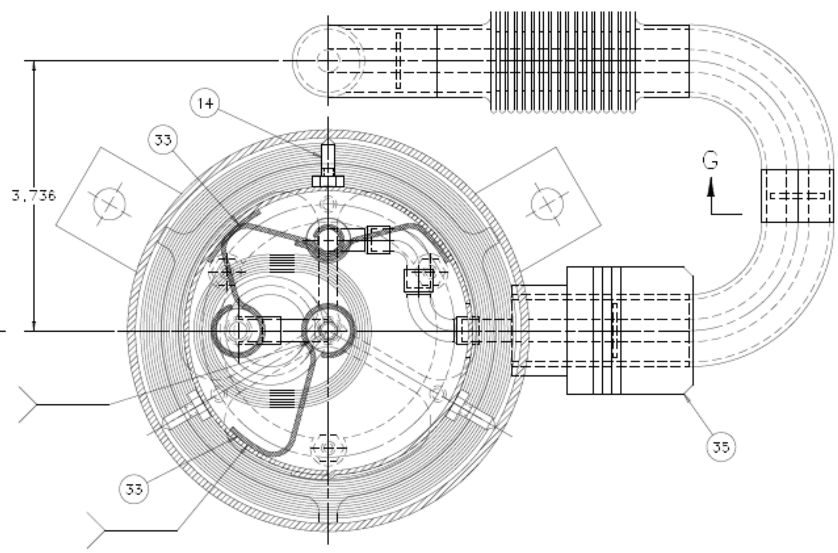


Heat Leak Contributors Calculated:

1.) Conduction of 2 stainless steel stinger inserts in Y
2.) Conduction of helium gas in voids between stinger inserts and stingers
3.) Radiation to 2 stainless steel stinger inserts in Y
4.) Radiation to Coil
5.) Conduction through the centering ring at the bottom of the Y just above the bottom stinger

Heat Leak Contributors Ignored:

1.) Heat leak of top 2 stingers
(should already be included in capacity of re-liquefiers)
2.) Bottom stinger
(current design already uses a stinger in this port and it is assumed this stinger will have a comparable heat load)



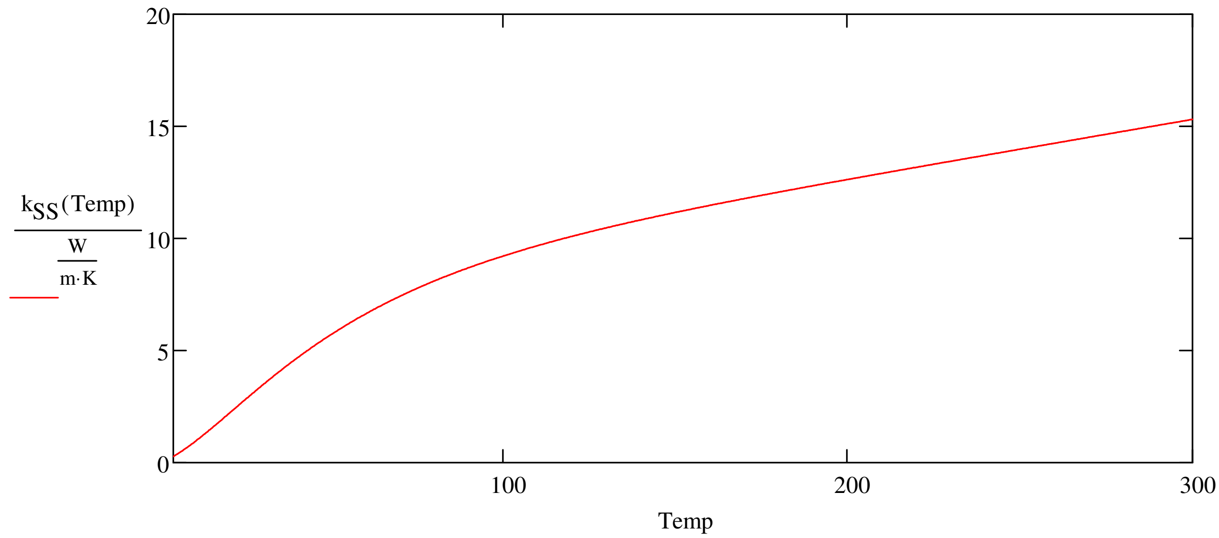
Material Properties for Stainless Steel, G10, and Helium

$T_{amb} := 293K$ $\quad T_{He} := 4K$ $\quad T_{N2} := 77K$

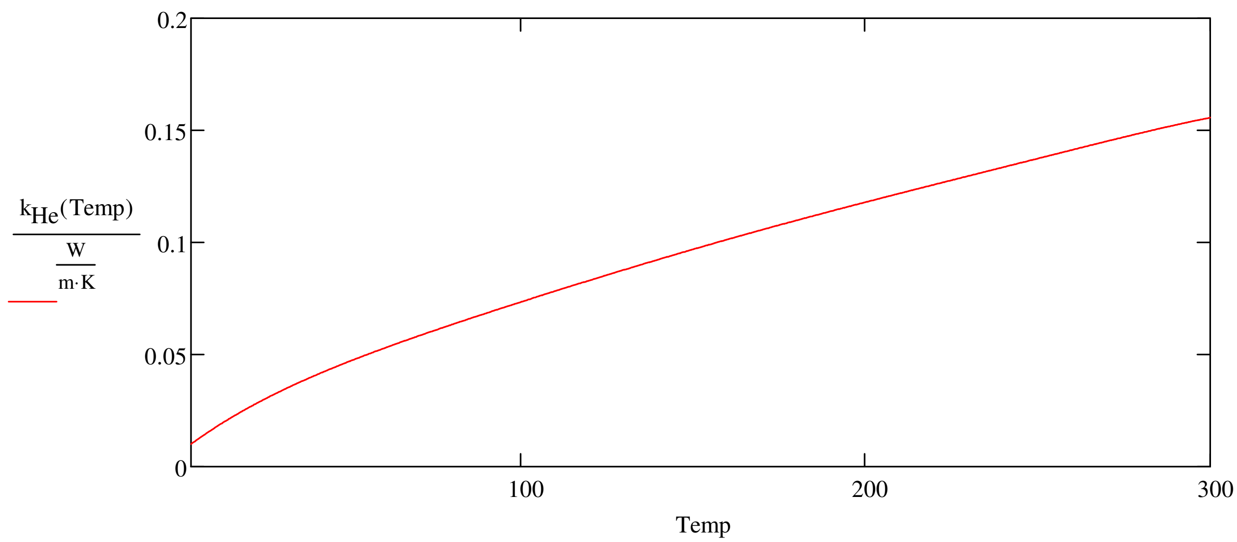
$$\begin{pmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \\ i \end{pmatrix} := \begin{pmatrix} -1.4087 \\ 1.3982 \\ .2543 \\ -.6260 \\ .2334 \\ .4256 \\ -.4658 \\ .1650 \\ -0.0199 \end{pmatrix}$$

http://cryogenics.nist.gov/MPropsMAY/304Stainless/304Stainless_rev.htm

$$k_{SS}(Tp) := 10^{a+b\cdot\log(Tp)+c\cdot\log(Tp)^2+d\cdot\log(Tp)^3+e\cdot\log(Tp)^4+f\cdot\log(Tp)^5+g\cdot\log(Tp)^6+h\cdot\log(Tp)^7+i\cdot\log(Tp)^8}\cdot\frac{W}{m\cdot K}$$

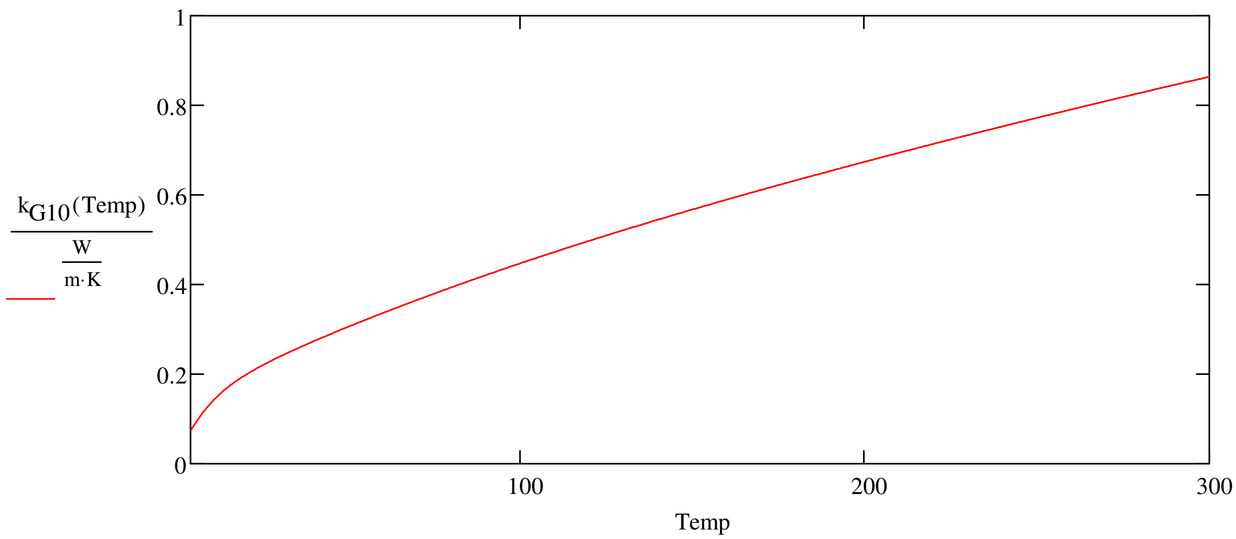


$$k_{He}(Temp) := \text{interp}(\text{regress}(MTemp, vk, 6), MTemp, vk, Temp)\cdot\frac{mW}{m\cdot K}$$



$$\begin{pmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \\ i \end{pmatrix} := \begin{pmatrix} -2.64827 \\ 8.80228 \\ -24.8998 \\ 41.1625 \\ -39.8754 \\ 23.1778 \\ -7.95635 \\ 1.48806 \\ -0.11701 \end{pmatrix}$$

$$k_{G10}(Tp) := 10^{a+b\cdot\log(Tp)+c\cdot\log(Tp)^2+d\cdot\log(Tp)^3+e\cdot\log(Tp)^4+f\cdot\log(Tp)^5+g\cdot\log(Tp)^6+h\cdot\log(Tp)^7+i\cdot\log(Tp)^8}\cdot\frac{W}{m\cdot K}$$



Heat Loss Calculations

<u>1.) Conduction of two stainless steel stinger inserts</u>

Length of the stinger *Distance from braid attachment and top of tube*

$L_{stinger} := 24in - 1in$ $braidDistance := 4in$

Dimensions for tube around and supporting the stinger

$OD_{tube} := \frac{5}{8}in$ $t_{tube} := 0.02in$ $ID_{tube} := OD_{tube} - 2\cdot t_{tube}$ $Area_{tube} := \frac{\pi}{4}\cdot\left(OD_{tube}^2 - ID_{tube}^2\right)$

Heat loss due to tube conduction for each tube would be:

$$Q_{SSCond} := \int_{\frac{T_{He}}{K}}^{\frac{T_{amb}}{K}} \frac{k_{SS}(Temp)\cdot Area_{tube}\cdot K}{L_{stinger} - braidDistance}\, dTemp = 148.608\cdot mW$$

<u>We must use active shielding</u>

Actively Cooled with LN2 would yield:

$$Q_{SSCond\_N2cooled} := \int_{\frac{T_{He}}{K}}^{\frac{T_{N2}}{K}} \frac{k_{SS}(Temp) \cdot Area_{tube} \cdot K}{L_{stinger} - braidDistance} \, dTemp = 16.573 \cdot mW$$

2.) Heat loss due to helium conduction for each tube would be:

Dimensions for the void of Helium between the stinger and the tube:

$ID_{void} := 0.5in$ $OD_{void} := ID_{tube}$ $Area_{Void} := \frac{\pi}{4} \cdot \left(OD_{void}^{2} - ID_{void}^{2}\right)$

$$Q_{HeCond} := \int_{\frac{T_{He}}{K}}^{\frac{T_{N2}}{K}} \frac{k_{He}(Temp) \cdot Area_{Void} \cdot K}{L_{stinger} - braidDistance} \, dTemp = 0.278 \cdot mW$$

3.) Heat loss due to radiation to the stinger inserts (MLI):

$AveCircumferenceMLI := \left(\frac{5}{8}in + 1.25in\right) \cdot 2$ $Length_{MLI} := 28in$

$Flux_{MLI\_77to4} := 0.05 \frac{W}{m^{2}}$ *Figure 3 of "Thermal performance of MLI down to 4.2K" 30 Layers*

$$Q_{RadTubes} := Flux_{MLI\_77to4} \cdot AveCircumferenceMLI \cdot Length_{MLI} = 3.387 \cdot mW$$

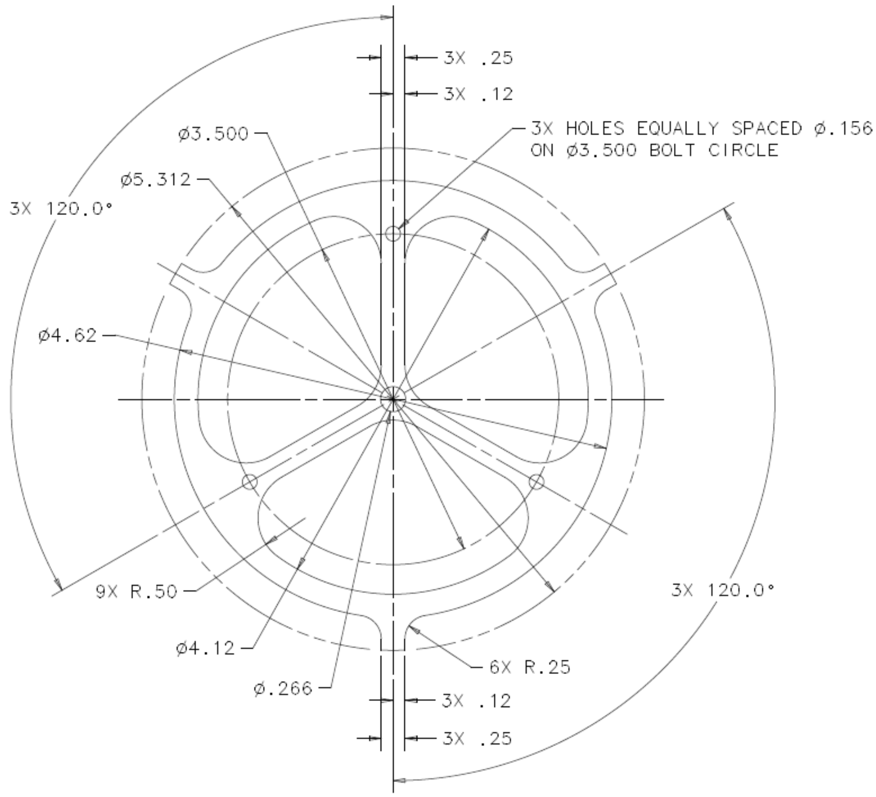
4.) Heat loss due to radiation for the coil (MLI):

$OC_{coil} := \pi \cdot 1.5in$ $Length_{Coil} := 3.5in$

$Flux_{MLI\_77to4} := 0.05 \frac{W}{m^{2}}$

$$Q_{RadCoil} := Flux_{MLI\_77to4} \cdot OC_{coil} \cdot Length_{Coil} = 0.532 \cdot mW$$

5.) Heat loss due to conduction through the G10 centering Ring:



$$Path_{Thickness} := 0.25in$$

$$Path_{width} := 0.0625in$$

$$num_{Path} := 3$$

$$Path_{Length} := \frac{3.25in}{2}$$

$$Path_{Size} := Path_{width} \cdot Path_{Thickness}$$

$$Q_{RingCond\_80to4} := num_{Path} \cdot \frac{Path_{Size}}{Path_{Length}} \cdot \int_{\frac{T_{He}}{K}}^{\frac{T_{N2}}{K}} k_{G10}(Temp)\, dTemp \cdot K = 14.192 \cdot mW$$

Summary of all heat loads

$$Heat_{LeakWye} := \begin{pmatrix} 2 \cdot Q_{SSCond\_N2cooled} \\ 2 \cdot Q_{HeCond} \\ Q_{RadTubes} \\ Q_{RadCoil} \\ Q_{RingCond\_80to4} \end{pmatrix} = \begin{pmatrix} 33.146 \\ 0.557 \\ 3.387 \\ 0.532 \\ 14.192 \end{pmatrix} mW$$

$$\sum_{n=0}^{4} Heat_{LeakWye_n} = 51.814\, mW$$

Absolute minimum ideal case

Largest heatload is in the actual stingers themselves