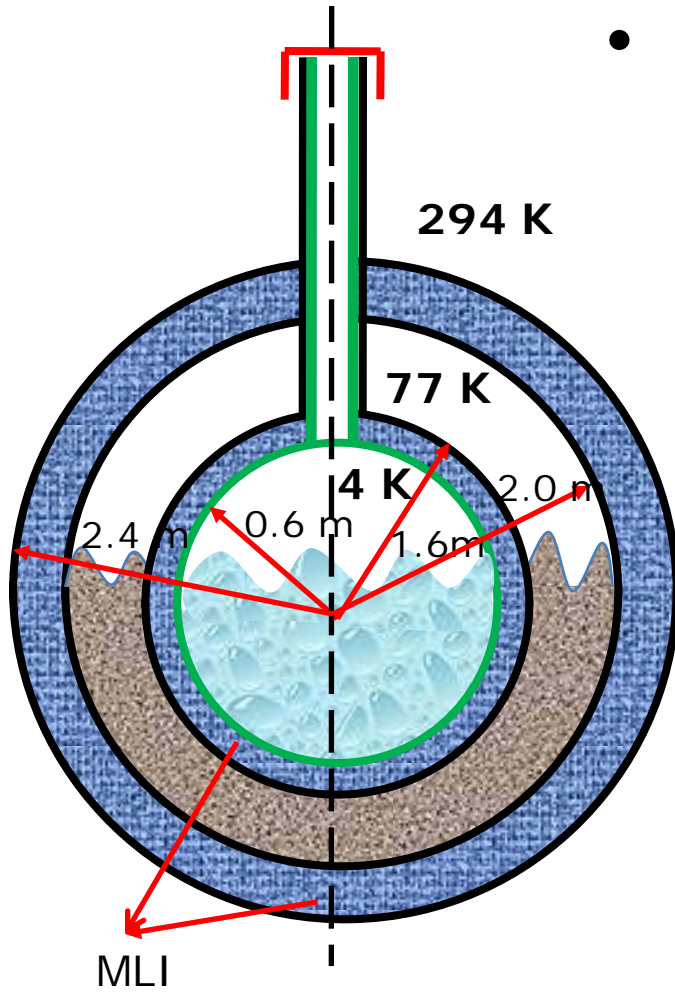


Tutorial



- Consider a spherical **LHe** vessel shielded with **LN2** bath. The radii of the spherical shells are as shown in the figure. MLI (24 layers/cm) is applied at each stage. Calculate the boil off/day of LN2 and LHe.

Given that emissivity of shield is 0.05. Solid conductance of spacer is $0.0851 \text{ W/m}^2\text{K}$ (assumed constant). Also, neglect neck conduction.

Tutorial

Given

Multi Layer Insulation

Operating LN2 boil off : 294 K to 77 K

Temperature LHe boil off : 77 K to 4 K

Emissivity of Shield : 0.05

Number of layers : 24/cm

Solid conductance : 0.0851 W/m²K

Calculate

Boil off of LN2 and LHe on per day basis.

Tutorial

Calculation of k_A for LN2 (294 K to 77 K)

- $\Delta x/N=(1/2400)$, $h_c=0.0851$, $e=0.05$, T_h , T_c .

$$k_A = \left(\frac{\Delta x}{N} \right) \left(h_c + \sigma e (T_h^2 + T_c^2) \left(\frac{T_h + T_c}{2 - e} \right) \right)$$

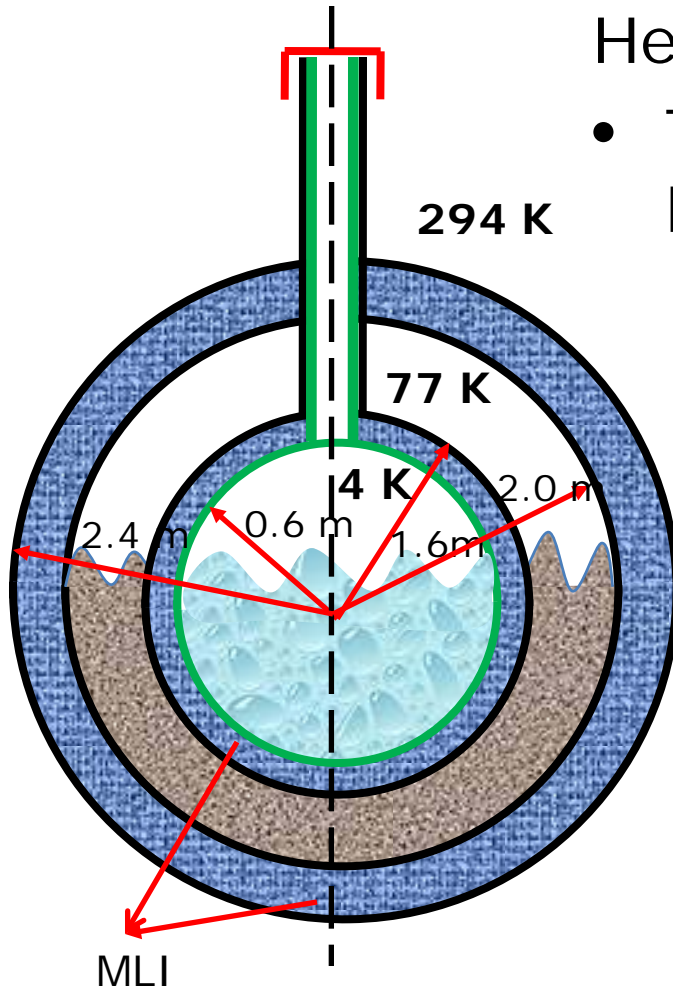
$$k_A = \left(\frac{1}{2400} \right) \left(0.0851 + \frac{(5.669)(10^{-8})(0.05)(92365)(371)}{(2 - 0.05)} \right)$$

$$k_A = 56.2 \mu W / mK$$

Tutorial

Heat in leak for LN2 (294 K to 77 K)

- $T_h, T_c, k_A = 56.2 \mu\text{W/mK}, R_1 = 2.4\text{m}, R_2 = 2.0\text{m}, \Delta T = (294 - 77) = 217.$



$$Q = \frac{4\pi k_A R_1 R_2 \Delta T}{(R_2 - R_1)}$$

$$Q = \frac{4\pi (56.2)(10^{-6})(2.4)(2.0)(217)}{(2.4 - 2.0)}$$

$$Q = 1.84\text{W}$$

Tutorial

Boil off of LN2 (294 K to 77 K)

- Latent heat of LN2 = 200 kJ/Kg, Density of LN2 = 807 kg/m³.
- 1 Lit/hr of LN2 is equivalent to 44.83 W.
- Hence, 1.84 W of heat vaporizes 0.041 Lit/hr.
- Therefore, the total boil off of LN2 in 1 day is 0.985 Lit.

Tutorial

Calculation of k_A for LHe (77 K to 4 K)

- $\Delta x/N=(1/2400)$, $h_c=0.0851$, $e=0.05$, T_h , T_c .

$$k_A = \left(\frac{\Delta x}{N} \right) \left(h_c + \sigma e (T_h^2 + T_c^2) \left(\frac{T_h + T_c}{2 - e} \right) \right)$$

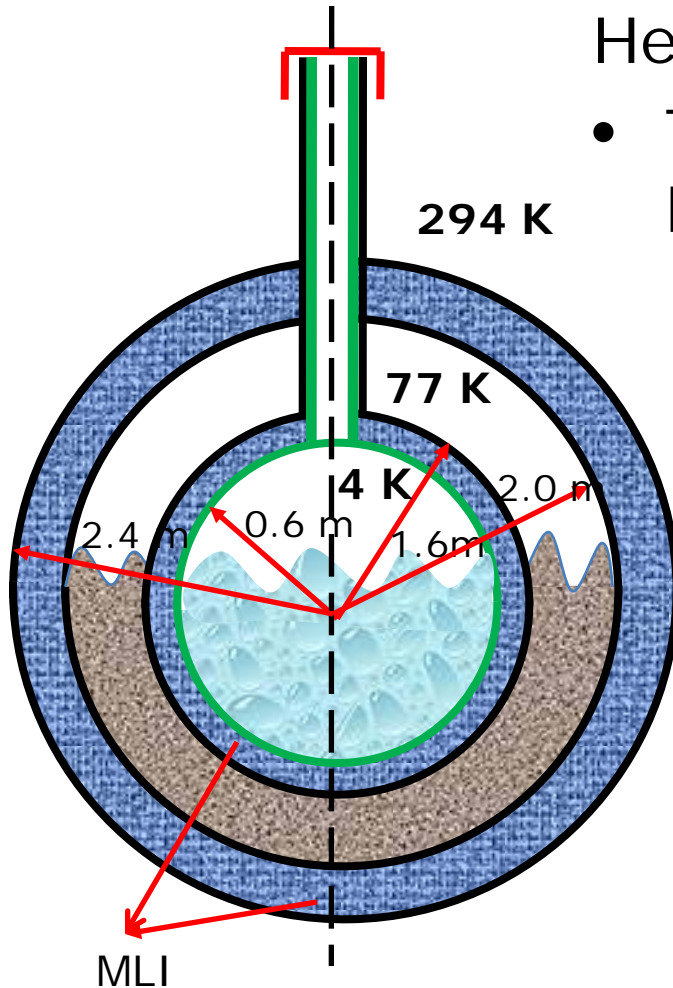
$$k_A = \left(\frac{1}{2400} \right) \left(0.0851 + \frac{(5.669)(10^{-8})(0.05)(5945)(81)}{(2 - 0.05)} \right)$$

$$k_A = 35.7 \mu W / mK$$

Tutorial

Heat in leak for LHe (77 K to 4 K)

- $T_h, T_c, k_A = 35.7 \mu\text{W/mK}, R_1 = 1.6\text{m}, R_2 = 0.6\text{m}, \Delta T = (77 - 4) = 73.$



$$Q = \frac{4\pi k_A R_1 R_2 \Delta T}{(R_2 - R_1)}$$

$$Q = \frac{4\pi (35.7)(10^{-6})(1.6)(0.6)(73)}{(1.6 - 0.6)}$$

$$Q = 0.031\text{W}$$

Tutorial

Boil off for LHe (77 K to 4 K)

- Latent heat of LHe = 20.2 kJ/Kg, Density of LHe = 124.8 kg/m³.
- 1 Lit/hr of LHe is equivalent to 0.7W.
- Hence, 0.031 W of heat vaporizes 0.044 Lit/hr.
- Therefore, the total boil off of LHe in 1 day is 1.062 Lit.

Tutorial

Results

LN2 boil off	LHe boil off
Working Fluid: LN2 between 294 K to 77 K	Working Fluid : LHe between 77 K to 4 K
$k_A = 56.2\mu\text{W/mk}$	$k_A = 35.7\mu\text{W/mk}$
$Q = 1.84 \text{ W}$	$Q = 0.03 \text{ W}$
Boil off : 0.985 Lit/day	Boil off : 1.062 Lit/day