## DEPARTMENT OF AEROSPACE ENGINEERING

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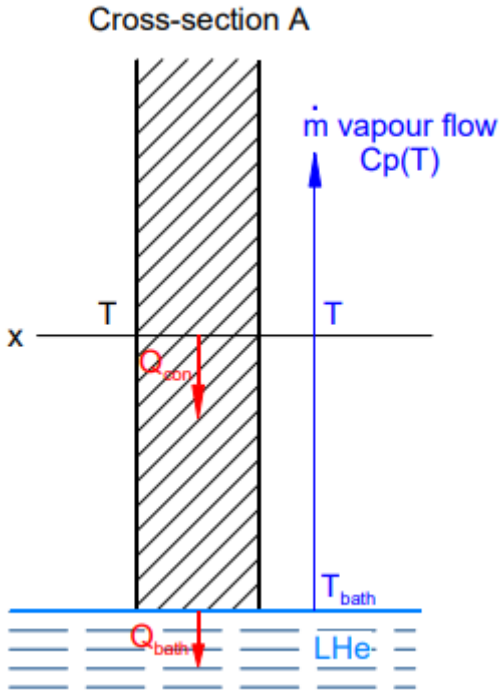
| Year & Branch | : | **III AEROSPACE** | Semester | : | **V** |
| Course | : | **19AST301 - Space Propulsion** | | | |

## UNIT III - CRYOGENIC ENGINEERING

The enthalpy of cryogen vapor escaping from a liquid bath can be used to continuously intercept conduction heat along solid supports and necks connecting the cryogenic bath with the room temperature environment




Vapour cooling of necks and supports with perfect heat exchange

Assuming steady state and perfect heat exchange between the escaping vapor and the solid, the energy balance equation reads

$$k(T)\,A\frac{\mathrm{d}T}{\mathrm{d}x} = Q_v + \dot{m}\,C\left(T - T_v\right)$$

where $Q_v$ is the heat reaching the liquid bath and m& is the vapor mass flow-rate. In the particular case of self-sustained vapor cooling, i.e. when the vapor mass flow-rate m & precisely equals the boil-off from the liquid bath,

$$Q_V = L_V \dot{m}$$

Combining above equations integrating yields the value of Qv

$$Q_v = \frac{A}{L}\int_{T_v}^{T_0} \frac{k(T)}{1 + (T - T_v)\dfrac{C}{L_v}}\,\mathrm{d}T$$

The denominator of the integrand clearly acts as an attenuation term for the conduction integral. Numerical results for helium and a few materials of technical interest appear in Table. If properly used, the cooling power of the vapor brings an attenuation of one to two orders of magnitude in the conductive heat in-leak.

| Material | Purely conductive regime | Self-sustained vapor cooling |
|---|---|---|
| ETP copper | 1620 | 128 |
| OFHC copper | 1520 | 110 |
| Aluminum 1100 | 728 | 39.9 |
| Nickel 99% pure | 213 | 8.65 |
| Constantan | 51.6 | 1.94 |
| AISI 300 stainless steel | 30.6 | 0.92 |

Vapor cooling can also be used for continuous interception of other heat loads than solid conduction. In cryogenic storage and transport vessels with vapor-cooled shields, it lowers shield temperature and thus reduces radiative heat in-leak to the liquid bath. In vapor-cooled current leads, a large fraction of the resistive power dissipation by Joule heating is taken by the vapor flow, in order to minimize the residual heat reaching the liquid bath. A worked-out example of how these diverse thermal insulation techniques are implemented in a real design is given in reference.