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Design Curve for Liquid Helium Storage Vessels

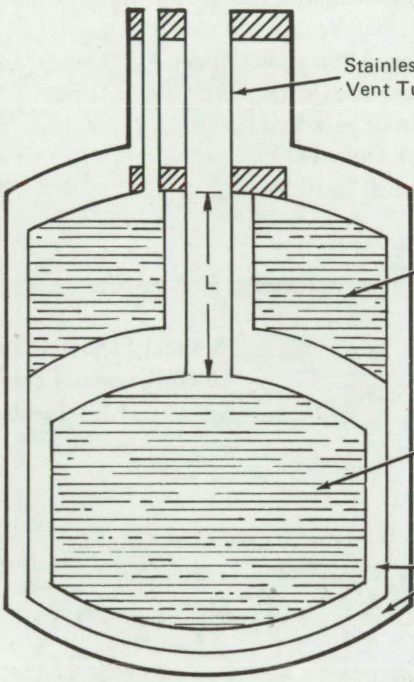

Figure 1.

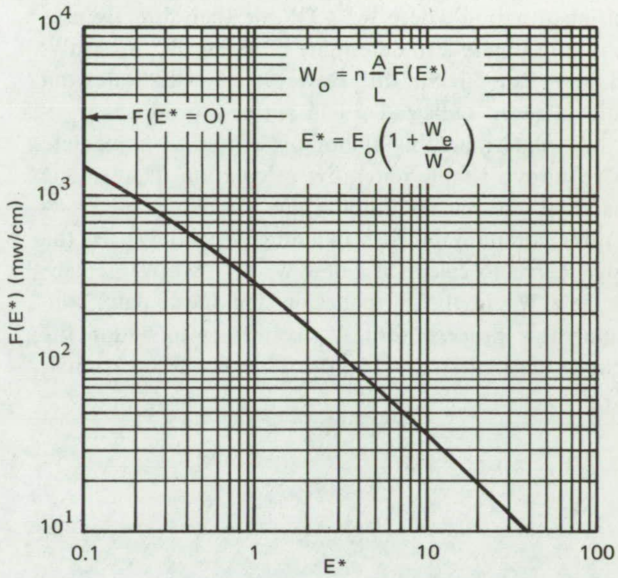

Figure 2.

The problem:

A major problem in the design of an efficient liquid helium storage vessel is the reduction of heat conduction along the stainless steel tubes which support the helium reservoir. A schematic of such a helium storage vessel is shown in Figure 1. This is usually solved by allowing the boil-off helium vapor to escape through the tubes so that a substantial portion of the conduction heat will be absorbed into the vapor and thereby prevented from reaching the liquid helium. Based on the assumption that maximum absorption can be achieved with baffles or other inserts, design curves have been computed for predicting that portion of the conduction heat which still reaches the liquid helium. However, there are frequent applications in which the interior of the support tubes cannot be obstructed by baffles or similar devices. In these cases, finite tube lengths and vapor flows preclude the attainment of maximum or perfect heat transfer. Therefore, use of such curves for the determination of liquid helium hold-times becomes unwarranted.

The solution:

The single design curve shown in Figure 2 and its working equations have been derived for estimating the effects of either perfect or imperfect heat transfer in the tubes. The W_o (mW), is the conduction heat reaching a helium reservoir supported by n vapor-cooled stainless-steel vent tubes each with cross sectional area $A(cm^2)$, length $L(cm)$, and constant end-point temperatures of 4 and 77 K. The W_e (mW) includes all helium reservoir heat inputs other than W_o. For perfect transfer, the parameter E_o=1; for imperfect transfer, $E_o < 1$.

It can be estimated from:

$$E_o \approx L/(L + 2\dot{m})$$

(continued overleaf)

where $\dot{m}$ = 1.4 (W_o + W_e)/n is the helium vapor flow (liquid cm^3/hr) passing through each tube. In most imperfect transfer problems, E_o has a value between 0.1 and 0.7.

How it's done:

Given any three of the four design parameters A, L, W_o, W_e, the fourth can be easily determined by using the data in Figure 2 and its working equations. For instance, consider the design problem to determine the total boil-off rate $\dot{M}$ (=n$\dot{m}$) for a helium reservoir supported by two (n=2) unobstructed stainless tubes each with A = 0.4 cm^2 and L = 20 cm. Because $\dot{m}$ is not known, an intermediate value of E_o = 0.4 should be assumed. In the limiting situation where W_e = O, one then directly uses the data in Figure 2 to determine E* = 0.4, W_o = 24 mW, and $\dot{M}$ = 2$\dot{m}$=34 cm^3/hr. However, if radiation from liquid nitrogen radiation shield surfaces produces W_e = 10 mW, determination of boil-off is not as immediate but requires a simple reiterative calculation. That is, one must first assume an initial value for W_o (e.g., W_o = 24 mW), compute the corresponding E* (≈0.57), use the design curve to calculate a new W_o (= 18 mW), replace this new W_o in the E* equation and recalculate, continuing this process until W_o converges to within the accuracy desired: W_o = 16 mW. Thus for W_e = 10 mW, $\dot{M}$ = 36 cm^3/hr. This result in turn yields E_o = 0.36, a value consistent with the initial E_o assumption. If perfect transfer (E_o = 1) had been assumed, one would have obtained $\dot{M}$=17 cm^3/hr for W_e = 0 and $\dot{M}$ = 20 cm^3/hr for W_e = 10 mW, or an error in the liquid helium hold-time of approximately 100%.

Notes:

1. The following reference contains background information on the technique described: Design Curve for Liquid Helium Cryostats with Vapor-Cooled Vent Tubes, J. A. DiCarlo, The Review of Scientific Instruments, Vol. 42, No. 2, pp. 262-264, February 1971.
2. No further documentation is available. Specific questions, however, may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
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   Reference: B72-10286

Patent status:

No patent action is contemplated by NASA.

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