10-162 A 6-m-diameter spherical tank filled with liquefied natural gas (LNG) at -160°C is exposed to ambient air. The time for the LNG temperature to rise to -150°C is to be determined.

Assumptions **1** Heat transfer can be considered to be steady since the specified thermal conditions at the boundaries do not change with time significantly. **2** Heat transfer is one-dimensional since there is thermal symmetry about the midpoint. **3** Radiation is accounted for in the combined heat transfer coefficient. **3** The combined heat transfer coefficient is constant and uniform over the entire surface. **4** The temperature of the thin-shelled spherical tank is said to be nearly equal to the temperature of the LNG inside, and thus thermal resistance of the tank and the internal convection resistance are negligible.

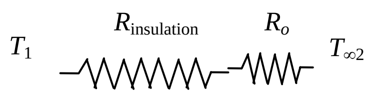
Properties The density and specific heat of LNG are given to be 425 kg/m^3 and 3.475 kJ/kg·°C, respectively. The thermal conductivity of super insulation is given to be k = 0.00008 W/m·°C.

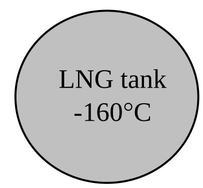
Analysis The inner and outer surface areas of the insulated tank and the volume of the LNG are

$$A_1 = \pi D_1^{\,2} = \pi(4\text{ m})^2 = 50.27\text{ m}^2$$

$$A_2 = \pi D_2^{\,2} = \pi(4.10\text{ m})^2 = 52.81\text{ m}^2$$

$$V_1 = \pi D_1^{\,3}/6 = \pi(4\text{ m})^3/6 = 33.51\text{ m}^3$$





The rate of heat transfer to the LNG is

$$R_{\text{insulation}} = \frac{r_2 - r_1}{4\pi k r_1 r_2} = \frac{(2.05 - 2.0)\text{ m}}{4\pi(0.00008\text{ W/m.°C})(2.0\text{ m})(2.05\text{ m})} = 12.13071\text{ °C/W}$$

$$R_o = \frac{1}{h_o A} = \frac{1}{(22\text{ W/m}^2\text{.°C})(52.81\text{ m}^2)} = 0.00086\text{ °C/W}$$

$$R_{total} = R_o + R_{insulation} = 0.00086 + 12.13071 = 12.13157\text{ °C/W}$$

$$\dot{Q} = \frac{T_{\infty 2} - T_{\text{LNG}}}{R_{\text{total}}} = \frac{[24 - (-155)]\text{°C}}{12.13157\text{ °C/W}} = 14.75\text{ W}$$

We used average LNG temperature in heat transfer rate calculation. The amount of heat transfer to increase the LNG temperature from -160°C to -150°C is

$$m = \rho V_1 = (425\text{ kg/m}^3)(33.51\text{ m}^3) = 14{,}242\text{ kg}$$

$$Q = mc_p\Delta T = (14{,}242\text{ kg})(3.475\text{ kJ/kg.°C})\left[(-150) - (-160)\text{°C}\right] = 4.95\times 10^5\text{ kJ}$$

Assuming that heat will be lost from the LNG at an average rate of 15.17 W, the time period for the LNG temperature to rise to -150°C becomes

$$\Delta t = \frac{Q}{\dot{Q}} = \frac{4.95\times 10^5\text{ kJ}}{0.01475\text{ kW}} = 3.355\times 10^7\text{ s} = 9320\text{ h} = \mathbf{388\text{ days}}$$