Homework – Cryogenic Systems

Due: Tuesday, 30-Nov-2021, 4:00 PM EST

Unless otherwise specified by the problem, work problems on a mass basis (i.e., not a mole, volume or particle basis). Use an appropriate number of significant digits (usually, 3 to 5 should be sufficient); intermediate results may carry an additional significant digit. Where real fluid properties are needed, use CoolProp. Unless otherwise given in the problem, assume the ambient environment is, $(p_0, T_0) = (1\ \text{bar}, 300\ \text{K})$. Remember, do not use CoolProp to calculate a two-phase mixture state property, or the vapor (or liquid) fraction given the saturated liquid; e.g., for, $y = (1-x)y_f + x\, y_g$, where the variable 'y' is any state property, use this relation to determine the unknown if the others are known, or can be found.

1. It is proposed to use a liquid neon detector deep underground for neutrino research. Determine the following:
   (a) Reversible mass specific input power {i.e., W/(g/s)} required to re-condense saturated vapor at 1 bar, 300 K
   (b) Inverse coefficient of performance {i.e., W/W} for the reversible refrigeration in (a)
   (c) Reversible mass specific input power {i.e., W/(g/s)} required to liquefy the gas from 300 K to the saturated liquid condition at 1 bar
   (d) Reversible mass specific input power {i.e., W/(g/s)} required by a Carnot liquefier to isothermally compress the gas, assuming it behaves as an ideal gas
   (e) Discharge pressure from the reversible-isothermal compressor (using a Carnot liquefier), assuming it behaves as an ideal gas
   (f) Reversible mass specific input power {i.e., W/(g/s)} required by a Carnot liquefier to isothermally compress the gas, assuming it behaves as a real gas
   (g) Reversible mass specific output power {i.e., W/(g/s)} from the adiabatic-isentropic expander (using a Carnot liquefier), assuming it behaves as a real gas

2. Determine on an equal exergy (in Watts) basis how many Watts of isothermal refrigeration is equal to 1 g/s of liquefaction for Hydrogen at 1 bar (saturation conditions); i.e., what is the equivalent refrigeration load to 1 g/s of liquefaction; with the 'equivalence' meaning both require the same amount of reversible input power. Assume normal hydrogen at 1 bar 300 K as the feed gas. Then consider two cases for the liquefied gas: (a) normal hydrogen, (b) para-hydrogen.

3. For the previous problem (#2), determine (1) the ratio of the latent portion of the cooling to the total cooling (latent and sensible), and (2) the ratio of the reversible input power required for the latent cooling to the total reversible input power. As in the previous problem, consider two cases for the saturation condition: (a) normal hydrogen, (b) para-hydrogen.