INDIAN MARITIME UNIVERSITY

(A Central University, Government of India)

M. Tech. (Marine Engineering & Management)

May-June 2018 End Semester Examinations

SEMESTER-II

Cryogenic and LNG Vessels (PG13E1201)

Date:04-06-2018 Maximum Marks:100

Time: 3 Hrs Pass Marks: 50

Note: Answer any five questions. Assume any missing data.
All questions carry equal marks. (5×20=100 Marks)

1. Explain the operation of Simple Linde-Hampson Process with a schematic diagram and T-S diagram for liquefaction process.

2. Find the fraction of liquefaction (y), the work of liquefaction (W_l) and the Figure of Merit (FOM) for 200 atm pressure delivered by the compressor in a Pre-cooled Linde-Hampson cycle operating with nitrogen. The inlet stream is at 1 atm and 300 K. Liquid nitrogen is removed at 1 atm. Freon-12 is used as the refrigerant for pre cooling. The ratio of mass of refrigerant used to the total mass of gas compressed, r = 0.1. Assume a 5 K temperature difference at approach for the heat exchanger. Enthalpy data for the refrigerant: h_a = 207.94 J/g, h_b = 250.2 J/g, h_c = 61.23 J/g.

   Required entropy and enthalpy data (from T-s diagram for nitrogen) are as follows:

Stream	Pressure (atm)	Temperature (K)	Enthalpy (J/g)	Entropy (J/g-K)
1	1	300	462	4.42
2	200	300	430	2.75
6	1	77	35	0.5
9	1	295	457	

3. What is the advantage of NTU-effectiveness approach over LMTD method in case of design of heat exchanger. Derive the expression of NTU-effectiveness relationship for counterflow heat exchanger.

4. In the counterflow heat exchanger in a nitrogen liquefaction system, warm nitrogen gas (c_h = 1.600 kJ/kg-K= 0.382 Btu/lbm-^{0}R) enters at [illegible]
   kJ/kg-K = 0.251 Btu/lbm-^{o}R) enters at 78 K (140 ^{o}R) and 1 atm

(101.3 kPa or 14.7 psia) at a mass flow rate of 0.80 kg/s (6349 lbm/hr). The overall heat transfer coefficient for the heat exchanger is 150 W/m^2-K (26.4 Btu/hr-ft^2-°F), and the heat transfer surface area is 50 m^2 (538 ft^2). Determine the heat transfer rate for the exchanger and the exit temperature of both streams. The ineffectiveness for the counterflow heat exchanger may be determined from following equation:

$$(1 - \varepsilon) = \frac{(1-C_R)\exp[-N_{tu}(1-C_R)]}{1-C_R\exp[-N_{tu}(1-C_R)]}$$

The terms have their usual meaning.

5. Describe the various modes of two-phase flow in pipe. Explain the application of the Baker diagram in predicting two-phase flow regimes in cryogenic systems.

6. Two-phase nitrogen flows in a horizontal 8-in nominal SCH 5 pipe (inside diameter, 8.407 in or 213.5 mm) at a total mass flow rate of 4.50 kg/s (35,700 lbm/hr). The fluid temperature is 85 K (153°R), and the corresponding saturation pressure is 228 kPa (33.1 psia). The quality of the two-phase mixture is 0.150, and the length of the pipe is 800 m (2645 ft). Determine the two-phase frictional pressure drop, assuming that the fluid quality is relatively constant.

The properties of liquid and vapor nitrogen at 85 K and saturation conditions are as follows:

liquid density, ρ_L = 771.0 kg/m^3=48.13 lbm/ft^3
vapour density, ρ_G = 9.789 kg/m^3= 0.611 lbm/ft^3
liquid viscosity, μ_L = 0.119 mPa-s = 0.119 cP
surface tension, σ_L = 7.18 mN/m = 0.00049 lbf/ft

The viscosity of the vapour phase,

μ_G = 6.21 μPa-s

Lockhart-Martinelli parameter,

$$(X_{tt})^2 = \left(\frac{1-x}{x}\right)^{1.8}\left(\frac{\mu_L}{\mu_G}\right)^{0.2}\left(\frac{\rho_G}{\rho_L}\right)$$

Lockhart –Martinelli Correlation

$\varnothing_L = [1+ (C/X) + (1/ x^2)]^{1/2}$, C = 20

Single-phase pressure drop per unit length

$$\left(\frac{\Delta p}{\Delta L}\right)_L = \frac{f_L (G_L)^2}{2 g_c D \rho_L}$$

Two -phase pressure drop per unit length

$\left(\frac{\Delta p}{\Delta L}\right) = (\O L)^2 \left(\frac{\Delta p}{\Delta L}\right)_L$

The terms have their usual meaning.

7. A regenerator consists of 1.6 mm (0.063 in) diameter lead shot (density, 11,350 kg/m^3 = 708.6 lbm/ft^3; specific heat, 0.1208 kJ/kg-K = 0.0289 Btu/lbm-°F). The porosity or void volume of the matrix is 0.38. The lead shot is contained inside a pipe having an ID of 154 mm (6.065 in) and a length of 915 mm (36.0 in). Nitrogen gas at an average pressure of 2 atm (202.6 kPa or 29.4 psia) and an average temperature of 200 K (360 °R) flows through the regenerator at a mass flow rate 0.080 kg/s (635 lbm/hr). Determine the convective heat transfer coefficient and the friction factor for the regenerator.

At 200K and 202.6 kPa, the following properties for nitrogen gas are found:

Viscosity, μ= 12.95 μPa-s= 0.0313 lbm/ft-hr
Specific heat, c_p = 1.043 kJ/kg-K = 0.2491 Btu/lbm- °F
Prandtl number, Pr = 0.750
Density, ρ = (1.711)(2) = 3.422 kg/m^3 = 0.214 lbm/ft^3

The following equations may be used for calculations:-
The mass flow rate per unit free flow area,

$$G = \frac{m}{e_v A_f r}$$

The equivalent diameter for the flow passage:

$$D_e = \frac{2 e_v D_s}{3(1 - e_v)}$$

The Colburn J-factor for packed spheres
$J_H = 0.23\ Re^{-0.3} = h_c P_r^{2/3} / C_p G$
For $R_e < 1000$,
$f = (172.6/Re)\ (1 + 0.0288\ Re^{0.86})$

The pressure drop through the regenerator matrix

The terms have their usual meaning.

8. Write short notes on any **four** of the following:
   a) Joule-Thomson expansion
   b) Gifford-McMohan Refrigerator
   c) Plate-fin Heat Exchanger
   d) Unique properties of Helium-4
   e) The Kapitza Process

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