CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY MARINE ENGINEER OFFICER

STCW 78 as amended MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-32 - APPLIED HEAT

MONDAY, 15 JULY 2024

1315 - 1615 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper Thermodynamic and Transport Properties of Fluids (5th Edition) Arranged by Y.R. Mayhew and C.F.C. Rogers

Examination Paper Inserts

Notes for the guidance of candidates:

1. Examinations administered by the SQA on behalf of the Maritime & Coastguard Agency.
2. Candidates should note that 96 marks are allocated to this paper. To pass, candidates must achieve 48 marks.
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and all intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. A mass of 0.8 kg of argon at a pressure and temperature of 20 bar and 127°C, expands in an isothermally process to a pressure of 2 bar.

   It is then compressed to the original pressure according to the law PV^n = constant with a final temperature of 668 K.

   Calculate EACH of the following:

   (a) the specific gas constant; (3)

   (b) the polytropic index of compression; (4)

   (c) the network transfer; (5)

   (d) the net heat transfer. (4)

   Note: for Argon y = 1.67, C_p = 520.3 J/kgK.

2. For a dual air standard cycle the initial pressure and temperature is 1.02 bar and 274 K, after the initial compression the pressure is 6.27 bar.

   The maximum temperature and pressure are 1480 K and 14 bar, respectively.

   (a) Sketch the processes on P-V and T-s diagrams. (2)

   (b) Calculate EACH of the following:

   (i) the temperature at all points; (10)

   (ii) the thermal efficiency. (4)

   Note: For air y= 1.4 and C_p= 1.005 kJ/kgK C_v= 0.718 kJ/kgK.

3. A single acting THREE stage reciprocating compressor is designed for minimum work with perfect intercooling. It delivers 0.2 kg/s of air from initial conditions of 1.0135 bar and 5°C and has a volume compression ratio of 3.58 for each stage according to the law $PV^{1.25}=C$.

(a) Draw graph PV diagram showing intercooling. (3)

(b) Calculate EACH of the following:

(i) EACH stage delivery pressure; (5)

(ii) the total indicated power; (5)

(iii) the total rate of heat removed in the intercoolers. (3)

Note: For air $\gamma = 1.4$ and $C_p = 1.005$ kJ/kgK $C_v = 0.718$ kJ/kgK.

4. In a steam plant, using reheat, the turbine receives the steam at a pressure and temperature of 70 bar and 300°C respectively. The steam isentropically expands in the first stage until it is just dry saturated.

The steam then enters the reheater and leaves with an enthalpy of 2907 kJ/kg and an entropy of 6.3935 kJ/kgK and is isentropically expanded in the second stage turbine to a condenser pressure of 1 bar.

The feed pump work can be neglected, there is no undercooling in the condenser.

(a) Sketch the T-s diagram for the cycle. (3)

(b) Calculate the thermal efficiency. (13)

5. A vapour compression refrigeration system operates between the pressures of 1.826 bar and 6.516 bar.

R12 refrigerant enters the compressor dry saturated and is isentropically compressed. Upon leaving the condenser it is undercooled by 5 K. The mass flow rate is 690 kg/hour.

(a) Sketch the cycle on pressure-specific enthalpy and Temperature-specific entropy diagrams. (2)

(b) Calculate EACH of the following:

(i) the dryness fraction of the refrigerant entering the evaporator; (3)

(ii) the temperature leaving the compressor; (5)

(iii) the compressor power; (4)

(iv) the coefficient of performance. (2)

6. An LNG carrier has 3 spherical tanks each of diameter 50 m. They contain liquefied gas at a temperature of -163°C. The tanks are insulated with 60 mm thickness of material of fibreglass with a thermal conductivity of 0.02 W/mK.

The outside surface heat transfer coefficient is 4 W/m^2K and the outside air temperature is 18°C.

Each tank contains a liquid volume of 60000 m^3.

(a) Calculate the total rate of heat lost. (7)

(b) Find the external surface temperature. (4)

(c) Calculate the total percentage mass evaporated each day. (5)

Note: $\rho = 1000\ kg/m^3$ *Latent heat of evaporation is 515 kJ/kg.*

7. Butene (C_4H_8) is burned with 11% excess air.

(a) Analyse by volume the percentage dry products. (14)

(b) State what is meant by the HCV. (2)

Note: Air contains 21% O_2 and 79% N_2 by volume.

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8. An impulse turbine has a nozzle at the entrance.

(a) Calculate the nozzle exit velocity if the change in enthalpy across the nozzle is 987 kJ/kg. (2)

(b) Sketch a blade velocity diagram labelling all significant angles and velocities. (3)

(c) The nozzle entrance angle is 20°, the blade velocity is 350 m/s, and the blades are symmetrical and have an angle of 30°. If the blade velocity coefficient is 0.76 and the mass flowrate of the steam is 1.8 kg/s, determine the diagram power. (11)

9. A horizontal pipe carrying fresh water tapers from 50 mm diameter at point 1 to 20 mm diameter at point 2 before increasing again to a diameter of 33 mm at point 3. There is a difference in height of 7 m between point 2 and 3.

The volumetric flowrate is 0.01 m^3/s.

Calculate EACH of the following:

(a) the velocities at all points; (6)

(b) the pressure difference between point 1 and 2 and between point 2 and 3. (10)