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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, 17 JULY 2023

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 gas with molar mass 44 kg/kmol and mass 0.0 11 kg is cooled at constant pressure of 0.115 bar from 281 K to half of its original volume.

   It is then isentropically compressed according to $PV^{1.4}=C$ to half of its secondary volume.

   (a) Sketch PV and Ts diagrams. (2)

   (b) Calculate the specific gas constant. (2)

   (c) Calculate the work done during the initial cooling. (3)

   (d) Calculate the heat of the initial cooling. (3)

   (e) Calculate EACH of the following:

   (i) the final temperature; (3)

   (ii) the isentropic work done. (3)

   Note: Ru= 8.314kJ/kmolK and Cv=751J/kgK

2. In an air standard dual combustion cycle, the initial volume compression ratio is 7/1.

   The maximum and minimum temperatures are 1500 K and 300 K, respectively.

   The maximum and minimum pressures are 42 bar and 1.42 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; (2)

   (iii) the mean effective pressure. (2)

   Note: For air y= 1.4 Cp= 1.005 kJ/kgK Cv=0.718 kJ/kgK

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3. A single cylinder, single acting air compressor has a swept volume of 0.055 m^3 and a clearance volume of 0.0030 m^3 and runs at 500 rpm. The air is compressed from 1 bar and 27°C to 6.0 bar. The index of compression and expansion is 1.29.

(a) Sketch the cycle on a pressure - volume diagram. (2)

(b) Calculate EACH of the following:

(i) the volumetric efficiency; (5)

(ii) the mass of air delivered per second; (5)

(iii) the indicated power. (4)

Note: For air Cp= 1.005 kJ/kgK Cv=0.718 kJ/kgK

4. A boiler generates 5500 kg of steam per hour at 60 bar. The steam temperature is 314°C and the feedwater temperature is 4°C. The fuel supplied has a calorific value of 45.5 MJ/kg and is supplied at a rate of 0.13 kg/s. On exiting the boiler, the steam is further heated to 450°C before being throttled to 10 bar.

(a) Calculate the boiler efficiency. (10)

(b) Calculate the specific heat required in the superheater. (3)

(c) Draw the process on a pressure enthalpy diagram. (3)

5. A vapour compression refrigeration system using Ammonia (R717) operates between the pressures of 5.346 bar and 13.89 bar.

It enters the compressor dry saturated and compressed thru a compressor with an isentropic efficiency of 82%.

6 K undercooling takes place in the condenser.

(a) Draw the cycle on pressure-specific enthalpy and temperature-specific entropy diagrams. (2)

(b) Calculate EACH of the following:

(i) the temperature leaving the compressor; (11)

(ii) the coefficient of performance. (3)

6. Hot oil of 0.564 kg/s at 91°C enters a pipe heat exchanger and is cooled to 37°C. The water enters at 10°C and is warmed to 33°C.

(a) Sketch the exchanger showing counter flow. (2)

(b) Calculate the log mean temperature difference for the counter flow arrangement. (3)

(c) Calculate the rate of heat transfer. (2)

(d) Calculate the mass flow rate of water. (2)

(e) If the overall heat transfer coefficient is 2500 W/m^2K and the diameter is 50 mm, calculate the length of the tubes. (4)

(f) Explain the difference for each of the calculated values above if a parallel flow arrangement was used. (3)

Note: Cp of hot oil= 2.2 kJ/kgK Cp of water= 4.18 kJ/kgK

7. Heptane (C_7H_{16}) is burned with 15% excess air.

(a) Analyse the volumetric percentage dry products. (14)

(b) Explain the LCV. (2)

Note: 21% of Air is oxygen by volume.

8. (a) Explain the difference between impulse and reaction turbines. (2)

(b) An impulse turbine has a nozzle at the entrance.

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

(c) The steam enters the blades at a velocity of 750 m/s and nozzle angle of 20°, the blade velocity is 250 m/s, and the blades are symmetrical and have an angle of 30°.

The blade velocity coefficient is 0.95 and the mass flowrate of the steam is 2 kg/s.

Calculate the diagram power. (11)

9. A centrifugal bilge pump impeller is 250 mm outside diameter and 200 mm inside diameter and runs at 430 rpm.

The radial velocity at the inlet and the outlet is 8.2 m/s.

The tangential component is 2.1 m/s, and the volumetric flow rate throughout is 400 m^3/hr

Calculate EACH of the following:

(a) the blade outlet angle; (4)

(b) the blade inlet angle; (4)

(c) the width of the impeller at the inlet and outlet; (4)

(d) the power. (4)

Note: The density of dirty water is 1015kg/m^3.