CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY – MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

STCW 95 CHIEF ENGINEER REG. III/2 (UNLIMITED)

041-32 – APPLIED HEAT

MONDAY, 15 JULY 2013

1315 - 1615 hrs

Examination paper inserts:

Notes for the guidance of candidates:

1. Non-programmable calculators may be used.

2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Materials to be supplied by examination centres:

Candidates examination workbook
Graph paper
'Thermodynamic and Transport Properties of Fluids' by Mayhew & Rogers (5^{th} edition)

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. A mass of 0.1 kg of helium is compressed reversibly in a cylinder, according to the law pV^n = constant, from a pressure of 0.98 bar and a temperature of 12°C to a pressure of 8.2 bar. The final temperature is 551.4°C.

   (a) Calculate EACH of the following:

   (i) the index of compression; (3)

   (ii) the magnitude and direction of the work transfer; (2)

   (iii) the magnitude and direction of the heat transfer; (4)

   (iv) the change in entropy. (3)

   (b) Sketch the process on p-V and T-s diagrams. (4)

   Note: For helium, γ = 1.667 and R = 2.077 kJ/kg K.

2. An air standard dual combustion cycle operates with a minimum temperature and pressure of 30°C and 0.98 bar respectively. The volume compression ratio is 23/1. The maximum pressure is 90 bar and the maximum temperature is 1430°C.

   (a) Sketch the cycle on p-V and T-s diagrams. (6)

   (b) Calculate the thermal efficiency of the cycle. (10)

   Note: For air, γ = 1.4 and R = 0.287 kJ/kg K.

3. A fuel has mass analysis 80% carbon, 16% hydrogen, 2% moisture, 0.5% sulphur, remainder ash.

   (a) Calculate the theoretical air/fuel ratio by mass. (8)

   (b) Calculate the volumetric analysis of the dry combustion products (ie excluding H_2O and soluble SO_2) when the fuel is completely burned in 15% excess air. (8)

   Note: relative atomic masses: H = 1; C = 12; N = 14; O = 16; S = 32
   Air contains 21% oxygen by volume.

4. In a regenerative steam power plant, the steam enters the turbine at a pressure of 50 bar and a temperature of 400°C, and leaves at a pressure of 0.08 bar with a dryness fraction of 0.9. Dry saturated steam is bled from the turbine at a pressure of 2 bar, and supplied to a direct mixing feed heater. The feed water leaves the heater at the saturation temperature of the bled steam. The mass of bled steam is 14.7% of the boiler supply.

(a) Sketch the T-s diagram for the cycle. (4)

(b) Determine EACH of the following:

(i) the isentropic efficiency of the turbine; (4)

(ii) the enthalpy of the condensate leaving the condenser; (4)

(iii) the thermal efficiency of the cycle. (4)

Note: Work input to feed pumps may be disregarded.

5. The specific enthalpy drop in the nozzles of a simple impulse turbine is 495 kJ/kg. The moving blades are symmetrical, and the blade velocity coefficient is 0.9. Steam leaves the blades in an axial direction. The diagram efficiency is 0.82.

(a) Sketch the combined velocity diagram, clearly labelling velocities and angles. (5)

(b) Determine EACH of the following:

(i) the blade velocity; (5)

(ii) the change in whirl velocity; (2)

(iii) the nozzle angle; (2)

(iv) the blade angle. (2)

6. In a vapour compression refrigeration cycle the evaporating temperature is -10°C and the condensing temperature is 40°C. The refrigerant enters the compressor as dry saturated vapour, and leaves the condenser as saturated liquid. Compression is isentropic.

(a) Sketch the cycle on p-h and T-s diagrams. (5)

(b) Given that the refrigerant is Tetrafluoroethane (R 134a), determine EACH of the following:

(i) the maximum cycle pressure; (1)

(ii) the maximum cycle temperature; (3)

(iii) the coefficient of performance of the cycle. (3)

(c) The refrigerant is replaced with Ammonia (R 717). Determine EACH of the following:

(i) the maximum cycle pressure; (1)

(ii) the maximum cycle temperature. (3)

7. An aluminium hot air duct has outer diameter 0.9 m and negligible wall thickness. The air in the duct is at a temperature of 50°C and the surrounding air temperature is 22°C. The inner surface heat transfer coefficient is 20 W/m^2K and the outer surface heat transfer coefficient is 15 W/m^2K.

It is proposed to lag the duct with rock wool to a thickness of 200 mm. The rock wool is provided in flat sheets 100 mm thick, each square metre having a quoted thermal resistance of 2.25 K/W. When the lagging is applied to the duct, the outer surface heat transfer coefficient may be assumed to be unchanged.

Calculate EACH of the following:

(a) the rate of heat loss per metre run without lagging; (6)

(b) the rate of heat loss per metre run after the lagging is applied. (10)

8. At the beginning of compression in a single stage, single acting reciprocating air compressor, the air is at a pressure of 1.02 bar and a temperature of 30°C. When the delivery valve opens, the pressure is 6.5 bar. The index of compression and expansion is 1.27. The bore diameter and stroke length are respectively 0.30 m and 0.35 m. The clearance volume is 6% of the swept volume and the compressor runs at 560 rev/min.

(a) Sketch the p-V diagram. (2)

(b) Calculate EACH of the following:

(i) the volumetric efficiency; (3)

(ii) the indicated power; (8)

(iii) the free air capacity in m^3/min, given that the free air conditions are 1.00 bar and 26°C. (3)

Note: For air, R = 0.287 kJ/kg K.

9. (a) Explain the term "choked flow" in a nozzle. (4)

(b) Steam expands isentropically in a convergent-divergent nozzle. The pressure of the steam at nozzle inlet is 10 bar and its temperature is 400°C. The outlet pressure is 2 bar. The expansion follows the law $pv^{1.3}$ = constant. The mass flow rate of steam is 5 kg/s. The overall enthalpy drop is calculated as 410 kJ/kg.

Calculate EACH of the following:

(i) the throat area; (7)

(ii) the exit area. (5)

Note: $p_C = p_O \times \left(\frac{2}{n+1}\right)^{\left(\frac{n}{n-1}\right)}$; $a = \sqrt{npv}$.