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, 28 MARCH 2011

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 (5th edition)

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. Ideal gas in a cylinder is heated at constant volume from a temperature of 600°C to a temperature of 1000°C, and then further heated at constant pressure from 1000°C to 1300°C. The change in specific entropy in the first process is 0.283 kJ/kg K. After being heated, the gas expands isentropically to fifteen times its *initial* volume and a temperature of 306°C.

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

   (b) Determine EACH of the following:

      (i) the values of c_V, c_P and γ for the gas; (6)

      (ii) the change in specific entropy during the constant pressure process; (2)

      (iii) the work transfer per kg of gas during isentropic expansion. (2)

2. In an air standard dual combustion cycle, the volume compression ratio is 20/1. The maximum and minimum temperatures are 2000 K and 300 K respectively. The maximum and minimum pressures are 80 bar and 1 bar respectively.

   (a) Sketch the cycle on p-V and T-S diagrams. (5)

   (b) Determine EACH of the following:

      (i) the thermal efficiency; (7)

      (ii) the mean effective pressure. (4)

   Note: For air, $\gamma = 1.4$ *and* $c_P = 1.005$ *kJ/kg K.*

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3. A gaseous fuel consists of a mixture of equal volumes of methane (CH_4) and ethane (C_2H_6). It is completely burned in 60% excess air. The combustion gases leave at a pressure of 0.991 bar and a temperature of 250°C. The temperature of the surroundings is 27°C.

(a) Formulate the full combustion equation per kmol of fuel. (5)

(b) Determine the mean value of c_P for the dry combustion products. (3)

(c) Estimate (per kmol of fuel) the total quantity of heat which could be recovered by cooling the exhaust gases at constant total pressure to a temperature of 27°C. (8)

Note: *atomic mass relationships: H = 1; C = 12; O = 16; N = 14*
Air contains 21% oxygen by volume.
values of c_P in kJ/kg K: CO_2: 0.945; O_2: 0.944; N_2: 1.047

4. A regenerative steam power cycle operates between pressures of 50 bar and 0.08 bar. The maximum temperature is 450°C. The optimum mass of steam is bled for feed heating at a pressure of 5 bar. A direct mixing feed heater is used.

(a) Sketch the T-s diagram for the cycle. (5)

(b) Determine for the cycle EACH of the following:

(i) the specific work output (taking account of feed pump work); (9)

(ii) the thermal efficiency. (2)

Note: *Expansion in the turbine and compression in the feed pumps are isentropic.*

5. The drop in specific enthalpy as steam passes through the nozzles of a two-row velocity compounded impulse turbine stage is 460 kJ/kg. The nozzle angle is 20° and the blade velocity is 225 m/s. All the blades are symmetrical, and blade friction is negligible. The axial velocity component remains constant throughout the stage.

(a) Sketch the combined velocity diagrams for each moving row, labelling velocities and angles. (6)

(b) Determine EACH of the following:

(i) all the blade angles; (7)

(ii) the blade work per kg. (3)

6. It is proposed that H_2O might be used as the refrigerant in a simple vapour compression cycle to maintain the contents of a container at a temperature of 10°C. The temperature of the surroundings is 35.8°C. To achieve the required heat transfer, the temperature difference between the cold space and the evaporating refrigerant should be 6 K and the minimum temperature difference between the condensing refrigerant and the surroundings should be 10 K. The refrigerant enters the compressor dry and saturated, and there is no undercooling in the condenser. The isentropic efficiency of the compressor is 0.8.

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

(b) Determine EACH of the following:

(i) the evaporating and condensing pressures; (2)

(ii) the temperature at compressor outlet; (6)

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

(c) State ONE major practical drawback of this proposal. (2)

7. Sea water is to be used to cool engine cooling water in a single pass shell and tube heat exchanger. The cooling water is to enter the tubes at a temperature of 80°C and to be cooled to 30°C. The flow rate of cooling water will be 2 kg/s. The sea water will enter at a temperature of 12°C and its flow rate will be 12.5 kg/s. The specific heat capacities of both cooling water and sea water may be taken as 4.2 kJ/kg K. The overall heat transfer coefficient is expected to be 3000 W/m^2 K, based on the outside surface area of the tubes. The tube outside diameter is to be 50 mm.

Determine EACH of the following:

(a) the outlet temperature of the sea water; (3)

(b) the logarithmic mean temperature difference for EACH of the following cases:

(i) counter flow; (3)

(ii) parallel flow; (3)

(c) the total length of tubing required for EACH of the following cases:

(i) counter flow; (4)

(ii) parallel flow. (3)

8. At the beginning of compression in a single stage, single acting reciprocating air compressor, the air is at a pressure of 1.01 bar and a temperature of 28°C. The delivery valve opens at a pressure of 6.2 bar. The delivery temperature is 175°C. The bore diameter and stroke length are 0.25 m and 0.32 m respectively. The clearance volume is 4% of the swept volume and the compressor runs at 500 rev/min.

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

(b) Determine EACH of the following:

(i) the index of compression; (4)

(ii) the volumetric efficiency; (3)

(iii) the indicated work per kg of air; (3)

(iv) the free air capacity in m^3/min, given that free air conditions are 1.03 bar and 25°C. (4)

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

9. (a) Explain why impulse turbine nozzles have convergent-divergent form. (4)

(b) Air expands isentropically in a convergent-divergent nozzle. The pressure at nozzle inlet is 12 bar and the inlet temperature is 400 K. The outlet pressure is 5 bar. The mass flow rate is 5.2 kg/s.

Determine EACH of the following:

(i) the throat area; (6)

(ii) the exit area. (6)

Note: $p_c = p_0 \times \left(\frac{2}{\gamma+1}\right)^{\gamma/(\gamma-1)}$; $T_c = T_0 \times \left(\frac{2}{\gamma+1}\right)$; $a = \sqrt{\gamma R T}$

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