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, 9 DECEMBER 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 (5th 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 0.2 kg of methane is compressed reversibly in a cylinder, according to the law pV^n = constant, from a pressure of 1 bar and a temperature of 300 K to a pressure of 2 bar. The final temperature is 378 K.

(a) Calculate EACH of the following:

(i) the index of compression; (3)

(ii) the work transfer; (2)

(iii) the heat transfer; (4)

(iv) the change in entropy. (3)

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

Note: For Methane, R = 0.520 kJ/kg K and c_P = 2.33 kJ/kg K.

2. A gas turbine plant operates on the ideal air standard Joule cycle. The minimum pressure and temperature are respectively 0.98 bar and 288 K. The maximum pressure and temperature are respectively 10 bar and 1400 K.

(a) Calculate EACH of the following:

(i) the thermal efficiency; (2)

(ii) the heat supplied per kg; (3)

(iii) the net work output per kg. (2)

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

(c) While the maximum and minimum temperatures remain unchanged, the pressure ratio is increased so that the compressor delivery temperature rises to 1300 K. With the help of a T-s diagram, explain the effect of this change on:

(i) thermal efficiency; (3)

(ii) specific work output. (3)

Note: For air, γ = 1.4 and c_P = 1.005 kJ/kg K.

3. A fuel has the following mass analysis: carbon 87.10%; hydrogen 12.43%; remainder ash. The calorific value is 40.0 MJ/kg. It is completely burned in 30% excess air.

Determine EACH of the following:

(a) the mass analysis of the total flue gas; (13)

(b) the "carbon content" of the fuel expressed in kg of carbon per GJ of heat produced. (3)

Note: atomic mass relationships: H = 1; C = 12; O = 16; N = 14; S = 32

Air contains 21% oxygen by volume.

4. (a) A Carnot cycle uses saturated water and steam as the working fluid, and operates between pressures of 0.07375 bar and 44 bar. At the beginning of heat supply, the state of the fluid is saturated liquid, and at the end of heat supply it is dry saturated vapour.

(i) Sketch the cycle on p-V and T-s diagrams. (4)

(ii) Determine the thermal efficiency of the cycle. (2)

(iii) Determine the specific work output of the cycle. (2)

(b) An ideal Rankine cycle using steam operates between the same pressures as the Carnot cycle in Q4(a). The steam is dry saturated at the beginning of expansion, and saturated liquid leaves the condenser.

(i) Sketch the cycle on the T-s diagram. (2)

(ii) Determine the specific work output of the cycle, allowing for feed pump work. (4)

(iii) Determine the thermal efficiency of the cycle. (2)

5. In a 50% reaction turbine stage, steam leaves the fixed blades with a velocity of 250 m/s, the blade/steam speed ratio is 0.80 and the fixed blade outlet angle is 35°. The mean blade ring diameter is 0.70 m.

(a) Sketch the combined velocity diagram, labelling all velocities and angles. (4)

(b) Determine EACH of the following:

(i) the speed of rotation of the turbine rotor; (2)

(ii) the blade inlet angle; (3)

(iii) the diagram efficiency. (7)

6. A vapour compression cycle uses R134a and operates between pressures of 1.3272 bar and 10.163 bar. The refrigerant enters the compressor as dry saturated vapour and leaves at a temperature of 55°C. The temperature at outlet from the condenser is 35°C. The cooling load is 30 kW and the volumetric efficiency of the compressor is 0.80.

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

(b) Determine EACH of the following:

(i) the coefficient of performance of the cycle; (4)

(ii) the isentropic efficiency of the compressor; (4)

(iii) the compressor swept volume per second. (2)

7. A two pass shell and tube condenser has 11000 tubes of outside diameter 16 mm and wall thickness 1.2 mm. The tubes are each 3.7 m long. Cooling water flows in the tubes and steam condenses in the shell. The steam enters at a pressure of 0.07 bar with dryness fraction 0.94, and is fully condensed without undercooling. The cooling water enters at a temperature of 15°C and leaves at a temperature of 28.1°C. The mass flow rate of the steam is 30 kg/s.

Determine EACH of the following:

(a) the rate of heat transfer; (3)

(b) the logarithmic mean temperature difference; (4)

(c) the overall heat transfer coefficient (based on tube outside surface area); (3)

(d) the mean flow velocity of the cooling water in the tubes. (6)

Note: For the cooling water, $c_P = 4.2$ *kJ/kg K and* $\rho = 1000$ *kg/m*^{3}.

8. (a) Sketch the p-V diagram for a two-stage reciprocating air compressor, indicating the area(s) which represent the work saved by intercooling. (4)

(b) In a two-stage reciprocating air compressor, the LP suction pressure is 0.95 bar and the HP delivery pressure is 11 bar. The interstage pressure is 3.5 bar. The LP suction temperature is 303 K and the HP suction is temperature 310 K. The index of compression and expansion is 1.3.

Calculate EACH of the following:

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

(ii) the heat removed in the intercooler per kg of air; (2)

(iii) the heat removed in each cylinder per kg of air; (4)

(iv) the isothermal efficiency. (3)

Note: For air, R = 0.287 kJ/kg K and c_P *= 1.005 kJ/kg K.*

9. (a) State Dalton's Law of Partial Pressures. (4)

(b) A vessel of volume 10.58 m^3 contains a mixture of nitrogen and superheated steam. The temperature is 50°C. When the contents cool to a temperature of 44°C, 0.0515 kg of steam condenses, and the total pressure drops to 1.20 bar.

Determine EACH of the following:

(i) the total mass of water and steam present; (3)

(ii) the mass of nitrogen present; (4)

(iii) the initial total pressure. (5)

Note: For nitrogen, R = 0.297 kJ/kg K