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 13 DECEMBER 2010

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 0.15 kg of helium is compressed reversibly in a cylinder, according to the law pV^n = constant, from a pressure of 0.95 bar and a temperature of 15°C to a pressure of 7.6 bar. The final temperature is 550°C.

   (a) Determine 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 He, R = 2.077 kJ/kg K and c_P = 5.193 kJ/kg K.

2. A 6 cylinder 2-stroke diesel engine runs at 200 rev/min. The cylinder bore diameter is 800 mm and the stroke length is 1000 mm. The indicated mean effective pressure is 7.6 bar. The mechanical efficiency is 88%. The fuel consumption is 1.44 tonne/h, the calorific value of the fuel is 42000 kJ/kg and the fuel contains 15% hydrogen by mass. The air/fuel ratio by mass is 25/1. The exhaust gases leave at a temperature of 300°C, and a pressure of 1.05 bar and the dew point temperature of the exhaust is 41.5°C. The temperature of the surroundings is 30°C. The temperature rise of the cooling water is 14 K and the mass flow rate of cooling water is 80 kg/s.

   Determine EACH of the following:

   (a) the brake thermal efficiency; (5)

   (b) the rate of heat loss to the cooling water; (2)

   (c) the rate at which heat could be recovered from the exhaust gases if they were cooled at constant total pressure to a temperature of 30°C, estimating that in this process 50% of the water vapour condenses; (7)

   (d) the rate of stray heat loss (not accounted for above). (2)

   Note: For water, c_P = 4.2 kJ/kg K.
   For dry exhaust gases, c_P = 1.1 kJ/kg K and R = 0.287 kJ/kg K.

3. A pure hydrocarbon fuel has the chemical formula $C_n H_{2n+2}$ (where n is a positive integer). When the fuel is burned in air, the dry products contain 10.78% CO_2, 0.98% CO and 4.21% O_2 by volume.

Determine EACH of the following:

(a) the chemical formula of the fuel; (10)

(b) the percentage excess air supplied. (6)

Note: atomic mass relationships: H = 1; C = 12; O = 16; N = 14
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 0.07 bar and 80 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 200 m/s, the blade/steam speed ratio is 0.75 and the fixed blade outlet angle is 30°. The mean blade ring diameter is 0.78 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 angles; (3)

(iii) the diagram efficiency. (7)

6. A vapour compression cycle uses R134a and operates between pressures of 1.0637 bar and 11.595 bar. The refrigerant enters the compressor as dry saturated vapour and leaves at a temperature of 60°C. The temperature at outlet from the condenser is 35°C. The cooling load is 40 kW and the volumetric efficiency of the compressor is 0.82.

   (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; (3)

      (iii) the compressor swept volume rate. (3)

7. A counter flow shell and tube oil cooler has 150 tubes of inside diameter 20 mm and wall thickness 3 mm. The tubes are each 3.2 m long. Oil flows in the tubes and water in the shell. The surface heat transfer coefficients are 1000 $W/m^2 K$ and 2000 $W/m^2 K$ on the oil and water sides respectively. Oil enters at a temperature of 80°C and water enters at 20°C. The mass flow rate of the oil is 16 kg/s and that of the water is 20 kg/s. The specific heat capacities are 2.0 kJ/kg K and 4.2 kJ/kg K for oil and water respectively.

   (a) Determine the overall U value based on the outside surface area of the tubes. (8)

   (b) Verify that the rate of heat transfer is approximately 880 kW. (8)

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 LP suction temperature is 303 K. The index of compression and expansion is 1.3. Intercooling is perfect, and the stage pressures are in geometric progression.

   Determine EACH of the following:

      (i) the indicated work per kg of air; (4)

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

      (iii) the work saved per kg of air by intercooling; (3)

      (iv) the isothermal efficiencies with and without intercooling. (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 1.71 m^3 contains a mixture of air and superheated steam. The temperature is 100°C. When the contents have cooled to a temperature of 50°C, 0.358 kg of steam condenses, and the total pressure drops to 2.12 bar.

Determine EACH of the following:

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

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

(iii) the initial total pressure. (5)

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