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, 16 JULY 2012

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 0.08 kg of helium expands reversibly in a cylinder, according to the law pV^n = constant, from a pressure of 8.20 bar and a temperature of 900°C to a pressure of 1.3 bar. The final temperature is 362°C.

   (a) Determine EACH of the following:

   (i) the index of expansion; (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 Helium, R = 2.077 kJ/kg K and c_P = 5.193 kJ/kg K.

2. The thermal efficiency of an air standard Otto cycle is 62% and the indicated mean effective pressure is 850 kN/m^2. The minimum cycle temperature is 300 K and the minimum cycle pressure is 98 kN/m^2.

   (a) Sketch the cycle on p-V and T-S diagrams. (3)

   (b) Determine EACH of the following:

   (i) the volume compression ratio; (3)

   (ii) the temperature after compression; (2)

   (iii) the specific work output; (5)

   (iv) the maximum cycle temperature. (3)

   Note: For air, c_V = 0.718 kJ/kg K and R = 0.287 kJ/kg K.

3. The shaft output of a marine engine at economical cruising speed is 50 MW and the brake thermal efficiency is 48%.

Calculate the CO_2 emission in tonne/day for EACH of the following cases:

(a) the fuel is natural gas; (8)

(b) the fuel is residual oil. (8)

Notes: *atomic mass relationships: H = 1; C = 12; O = 16*
The properties of natural gas may be estimated by assuming that it consists of 92% CH_4 by mass, remainder non-combustibles.
The properties of residual oil may be estimated by assuming that it consists of 96% $C_{30}H_{62}$ by mass, remainder non-combustibles.
The CV of carbon may be taken as 32.8 MJ/kg.
The LCV of hydrogen may be taken as 120.9 MJ/kg.

4. A regenerative steam power cycle operates between pressures of 40 bar and 0.05 bar. The maximum temperature is 425°C. The optimum mass of steam is bled for feed heating at a pressure of 5 bar. A surface feed heater is used, and the drain from this is throttled and returned to the main condenser.

(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 pump are isentropic.*

5. In a 50% reaction turbine stage, steam leaves the fixed blades with a velocity of 220 m/s, the blade/steam speed ratio is 0.70 and the fixed blade outlet angle is 28°. The mean blade ring diameter is 0.81 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 refrigerator uses R134a and operates between pressures of 1.3272 bar and 10.163 bar. The refrigerant enters the compressor at a temperature of -15°C with specific volume 0.15097 m^3/kg and the isentropic efficiency of the compressor is 88%. The temperature at outlet from the condenser is 35°C. The cooling load is 50 kW and the volumetric efficiency of the compressor is 0.86.

(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; (7)

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

7. A counter flow shell and tube oil cooler has 100 tubes of inside diameter 25 mm and wall thickness 2.5 mm. The tubes are each 2.8 m long. Oil flows in the tubes and water in the shell. The surface heat transfer coefficient on the oil side is 950 $W/m^2 K$. The oil enters at a temperature of 82°C and leaves at 45°C and the water enters at 18°C. The mass flow rate of the oil is 8 kg/s and that of the water is 25 kg/s. The specific heat capacities are 2.0 kJ/kg K and 4.2 kJ/kg K for oil and water respectively.

Determine EACH of the following:

(a) the rate of heat transfer; (2)

(b) the logarithmic mean temperature difference; (6)

(c) the surface heat transfer coefficient on the water side. (8)

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

(b) In a two stage reciprocating air compressor, the LP suction pressure is 1.02 bar and the HP delivery pressure is 10.5 bar. The LP suction temperature is 303 K. The index of compression and expansion is 1.3. The HP suction temperature is 310 K, and the HP suction pressure is 3.5 bar.

Determine EACH of the following:

(i) the indicated work per kg of air; (7)

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

(iii) 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 0.8 m^3 contains a mixture of 494.2 g of air together with a certain mass of wet steam. The temperature is 30°C. When the contents have been heated to a temperature of 150°C, all the liquid has evaporated and the total pressure is 2.25 bar.

Determine EACH of the following:

(i) the total mass of steam present; (4)

(ii) the initial total pressure; (4)

(iii) the mass of liquid present at the initial condition. (4)

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