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 DECEMBER 2014

1315 - 1615 hrs

Examination paper inserts:

Worksheet Q4 - Specific Enthalpy-Specific Entropy Chart for Steam

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:

Candidate's 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. Air at a pressure and temperature of 1 bar and 32°C respectively is compressed in an isentropic process from BDC to TDC in an engine. Heat is then added reversibly at constant volume until the pressure reaches 35.5 bar.

   The clearance volume is 1.82 litres and the bore and stroke are 250 mm and 350 mm respectively.

   (a) Sketch the p-V and T-s diagrams. (3)

   (b) Calculate EACH of the following:

   (i) the compression ratio; (3)

   (ii) the work transfer; (4)

   (iii) the total change in entropy. (6)

   Note: For air $c_v = 0.718$ *kJ/kgK and* $R = 0.287$ *kJ/kgK*

2. Air enters the compressor of a simple gas turbine plant at a pressure and temperature of 1.03 bar and 305 K respectively. It is compressed to 6.18 bar with an isentropic efficiency of 83%.

   The hot gases leave the combustion chamber and enter the turbine at a pressure of 6.18 bar and a temperature of 1210 K.

   The turbine exhausts at a pressure of 1.03 bar and a temperature of 805 K.
   The fuel air ratio is 0.0125.

   (a) Sketch the cycle on a Temperature-specific entropy diagram. (3)

   (b) Calculate EACH of the following:

   (i) the isentropic efficiency of the turbine; (3)

   (ii) the net work output per kg of exhaust gas; (6)

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

   Note: For air: $\gamma = 1.4$ *and* $c_p = 1.005$ *kJ/kgK*
   For the hot gas: $\gamma = 1.33$ *and* $c_p = 1.15$ *kJ/kgK*

3. Octane (C_8H_{18}) is burned in 15% excess air.

The dry flue gas analysis shows they contain 2.5% carbon monoxide by volume.

Calculate, using molar volumes for 1 kmol of fuel, EACH of the following:

(a) the actual amount of oxygen supplied; (3)

(b) the full combustion equation; (10)

(c) the volumetric analysis of the total flue gas. (3)

Note: Air contains 21% oxygen by volume.

4. In a regenerative steam power plant, steam enters the turbine at a pressure and temperature of 80 bar and 500°C respectively.

It then expands to 0.1 bar with an isentropic efficiency of 85%.

Steam is bled from the turbine at 4.5 bar and is fed to a direct contact feed heater.
The feed water leaves the heater at the saturation temperature of the bled steam.
There is no under cooling in the condenser and the feed pump work may be ignored.

(a) Sketch the cycle on a temperature-specific entropy diagram. (4)

(b) Plot the straight line expansion process on Worksheet Q4. (2)

(c) Determine EACH of the following:

(i) the mass flow rate of bled steam per kg of steam flowing; (4)

(ii) the thermal efficiency of the cycle. (6)

5. In a two row velocity compounded impulse turbine stage, steam leaves the nozzles with a velocity of 950 m/s at an angle of 20º to the plane of rotation. The mean blade velocity is 190 m/s.

The fixed and moving blade rows are symmetrical each with a velocity coefficient of 0.92.

(a) Draw to scale a velocity diagram for each row. (4)

(b) Determine EACH of the following:

(i) the magnitude of the steam velocity entering and leaving EACH blade; (2)

(ii) the fixed and moving blade angles; (2)

(iii) the total blade work per kg of steam flowing; (4)

(iv) the diagram efficiency. (4)

6. A vapour compression refrigeration cycle operating between pressures of 2.006 bar and 10.163 bar is to be used as a heat pump supplying a heating load of 10 kW.

The working fluid is R134a which enters the compressor as a dry saturated vapour and leaves at a temperature of 50ºC.

The liquid enters the expansion valve with 5 K of sub-cooling.

(a) Sketch the cycle on P-h and T-s diagrams. (4)

(b) Determine EACH of the following:

(i) the mass flow of refrigerant required; (3)

(ii) the cooling load based on the mass flow obtained Q6b(i); (2)

(iii) the heat pump co-efficient of performance; (3)

(iv) the isentropic efficiency of the compressor. (4)

7. A wire of 1.8 mm diameter carries an electric current which generates 2.1 watts of heat per metre length.

It is covered with insulation 1.22 mm thick and thermal conductivity 0.11 W/mK.

If the surrounding air temperature and surface heat transfer coefficient remain unchanged at 27°C and 12 W/m^{2}K respectively.

(a) Calculate EACH of the following:

(i) the temperature of the wire without insulation; (3)

(ii) the temperature of the wire with insulation; (5)

(iii) the surface temperature of the insulated cable. (3)

(b) Comment on the values obtained in Q7(a)(i) (ii) and (iii). (5)

8. The free air capacity of a two stage reciprocating air compressor is 18 m^3/min. The free air suction pressure and temperature are 1.05 bar and 25°C respectively. The delivery pressure is 9.45 bar.

The stage pressure ratios are equal, inter-cooling is perfect and the polytropic index for EACH expansion and compression is 1.26.

(a) Sketch the cycle on a p-V diagram. (4)

(b) Calculate EACH of the following:

(i) the total indicated power; (5)

(ii) the rate of inter-cooling; (3)

(iii) the power saved by inter-cooling. (4)

Note: For air R = 0.287 kJ/kgK c_p*= 1.005 kJ/kgK*

9. Air leaks from a pressure vessel to the surroundings which are at a pressure of 1.02 bar.

The passage through which the air leaks may be considered as a convergent nozzle with an exit area of 0.6 mm^2. The flow within the passage is assumed to be isentropic and the temperature of the vessel remains constant at 28°C.

(a) With reference to nozzles, explain the term choked flow. (4)

(b) Calculate the critical pressure ratio. (2)

(c) Calculate the mass flow when the pressure in the vessel is:

(i) 2.5 bar; (6)

(ii) 1.4 bar. (4)

Note: For air: c_v *= 0.718 kJ/kgK and* c_p *= 1.005 kJ/kgK*

$$\frac{P_c}{P_i} = \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}}$$