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 78 as amended MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-32 - APPLIED HEAT

MONDAY, 11 DECEMBER 2017

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:

Thermodynamic and Transport Properties of Fluids (5th Edition)
Arranged by Y.R. Mayhew and C.F.C. Rogers

APPLIED HEAT

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. A volume of 0.0869 m^3 of air is heated at a constant pressure of 15 bar until the temperature rises from 30°C to 500°C.

   It is then expanded according to the law $pV^{1.33}$ = constant, until the pressure is 1.5 bar.

   (a) Sketch the processes on pressure-Volume and Temperature-specific entropy diagrams. (2)

   (b) Calculate EACH of the following:

   (i) the total change in entropy; (8)

   (ii) the total work transfer; (4)

   (iii) the net change in the internal energy of the air. (2)

   Note: for air R = 287 J/kgK and c_v *= 718 J/kgK*

2. Air enters an open cycle gas turbine plant at a pressure and temperature of 0.95 bar and 15°C respectively. It is then compressed to a pressure of 12 bar in two stages of equal pressure ratio with perfect intercooling.

The combustion products enter the single stage turbine at a pressure of 12 bar and temperature of 980°C and leave at a pressure of 0.95 bar.

The isentropic efficiency of each compressor stage is 0.8.

The isentropic efficiency of the turbine is 0.85.

The air to fuel ratio is 70:1

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

(b) Calculate EACH of the following:

(i) the specific net work output; (7)

(ii) the cycle thermal efficiency. (5)

Note: for air $\gamma = 1.4$ *and* $c_p = 1.005$ *kJ/kgK*
for the combustion products $\gamma = 1.33$ *and* $c_p = 1.15$ *kJ/kgK*

3. Benzene (C_6H_6) is burned in 15% excess air by mass.

Analysis of the exhaust gas shows they contain 0.05 kg of carbon monoxide per kg of fuel burned.

Calculate EACH of the following:

(a) the mass of carbon burned to CO_2 per kg of fuel; (4)

(b) the air to fuel ratio by mass; (4)

(c) the volumetric analysis of the exhaust gas. (8)

Note: atomic mass relationships $H = 1$, $C = 12$, $O = 16$, $N = 14$.
air contains 23.3% oxygen by mass.

4. The plant shown in Fig Q4, produces 9 tonne /hour of dry saturated steam at a pressure of 1 bar from steam at 10 bar and 300°C.

Some of the steam expands through a turbine producing 847 kW with an isentropic efficiency of 0.91.

Excess steam flow is passed through a throttle and then cooled at constant pressure. The amount of cooling is controlled to allow the adiabatic mixing of the two streams to give the required outlet condition.

Pressure losses in the cooler and mixing vessel may be ignored.

(a) Calculate EACH of the following:

(i) the dryness fraction of the steam leaving the turbine; (5)

(ii) the degree of superheat of the steam leaving the throttle; (3)

(iii) the heat removed in the cooler. (5)

(b) Sketch the processes on a specific enthalpy-specific entropy diagram. (3)

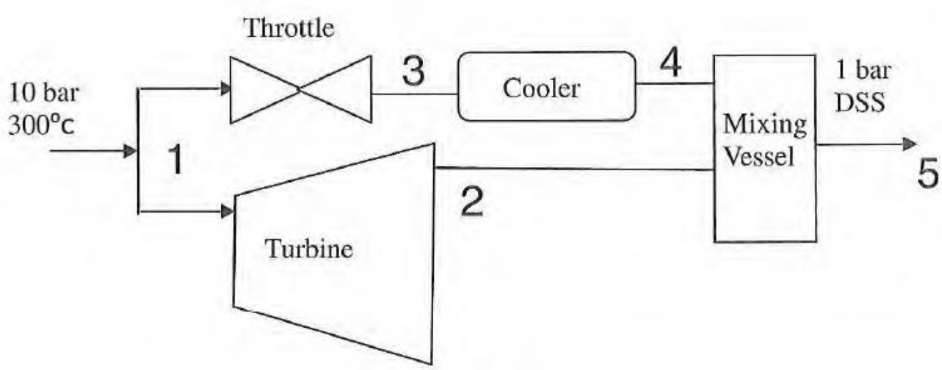

Fig Q4

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5. In a 50% reaction turbine stage, the steam leaves the fixed blades with a velocity of 500 m/s.

The mean diameter of the blade ring is 900 mm and the speed of rotation is 8000 rev/min.

The inlet angle of the blading is 70°.

Calculate EACH of the following:

(a) the blading outlet angle; (4)

(b) the blade work per kg of steam flow; (4)

(c) the enthalpy drop across the moving blade; (4)

(d) the diagram efficiency. (4)

6. In a vapour compression refrigeration plant, the R134a enters the compressor at a pressure and temperature of 1.0637 bar and -20°C respectively. At these conditions the specific volume is 0.1859 m^3/kg.

The refrigerant undergoes isentropic compression to 8.8672 bar and leaves the condenser with 10 K subcooling.

The 6 cylinder single stage compressor runs at a speed of 200 rev/min and has a bore and stroke of 190 mm and 200 mm respectively.

The volumetric efficiency at this speed is 86%.

(a) Sketch the cycle on a pressure-specific enthalpy diagram indicating areas of heat and work transfer. (2)

(b) Sketch the cycle on a Temperature-specific entropy diagram indicating areas of superheat and sub cooling. (2)

(c) Calculate EACH of the following:

(i) the temperature at the end of compression; (5)

(ii) the coefficient of performance; (3)

(iii) the compressor Power. (4)

7. A spherical steel pressure vessel has an internal diameter of 1.5 m and a wall thickness of 20 mm.

It is covered with two layers of insulation, each 25 mm thick.

The inner surface temperature of the steel is 450°C and the surrounding air temperature is 25°C.

Calculate EACH of the following:

(a) the heat loss from the pressure vessel per m^2 of surface area. (8)

(b) the temperature drop across EACH layer. (6)

(c) the outer surface temperature. (2)

Note: the heat transfer coefficient of the inner surface may be ignored.
the thermal conductivity of steel = 52 W/mK
the thermal conductivity of the inner insulation = 0.04 W/mK
the thermal conductivity of the outer insulation = 0.25 W/mK
the heat transfer coefficient of the outer surface = 2 W/m^2K

8. In a single acting, single stage reciprocating air compressor, the conditions at the beginning of compression are 0.95 bar and 12°C. When the delivery valve opens the cylinder conditions are 7.6 bar and 157°C.

The diameter of the cylinder bore is 200 mm and the compressor stroke is 300 mm.

The clearance volume is 5% of the swept volume and the compressor runs at a speed of 360 rev/min.

(a) Sketch the cycle on a pressure-Volume diagram. (2)

(b) Calculate EACH of the following:

(i) the index of compression; (3)

(ii) the volumetric efficiency; (2)

(iii) the compressor indicated power; (5)

(iv) the compressor isothermal efficiency. (4)

9 A tank containing oil of density 850 kg/m^3 has two sharp edged outlet orifices on one side of the tank. The upper orifice is 15 mm diameter and has its centre 1.3 m below the oil surface. The lower orifice is 20 mm diameter and has its centre 2.8 m below the oil surface. Oil is supplied to the tank at 1.8 kg/s to maintain a constant tank level.

Calculate EACH of the following:

(a) the mass flow rate of oil from the 15 mm diameter orifice; (8)

(b) the coefficient of velocity for the 20 mm diameter orifice. (8)

Note: For 15 mm diameter orifice, Coefficient of Velocity = 0.97
Coefficient of Contraction = 0.68
For 20 mm diameter orifice, Coefficient of Contraction = 0.72