University of Nottingham

Department of Mechanical, Materials and Manufacturing Engineering

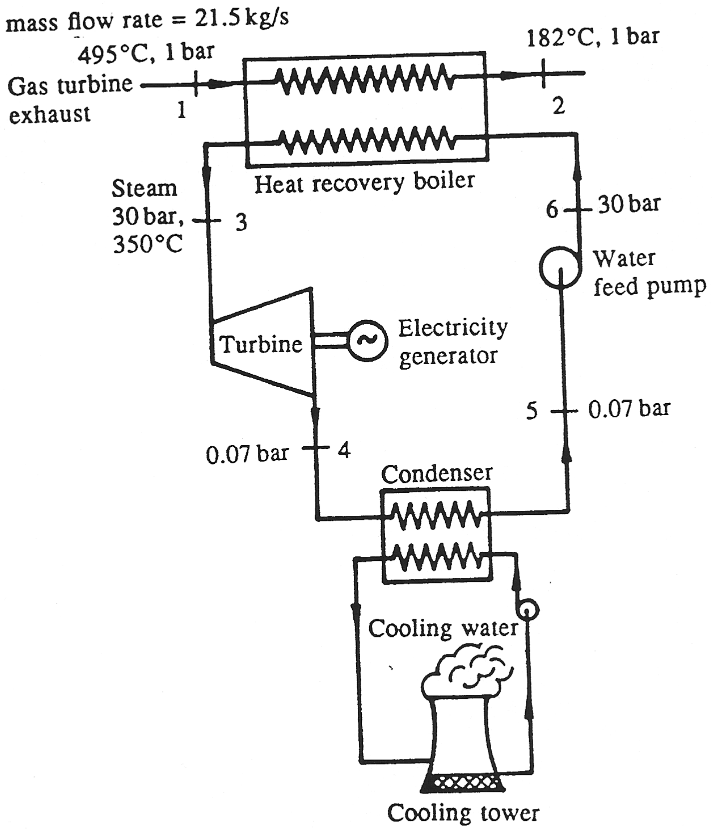
Thermofluids 3

Self Assessment Exercise Sheet - Exergy Analysis 2

1. Fig. 1 shows a steam cycle in which heat is recovered from the exhaust of a gas turbine to generate electricity. The figure shows the main steam and gas conditions. The isentropic efficiency of the turbine is 85% and the mechanical to electrical generation efficiency of the generator is 95%. The mean specific heat capacity of the exhaust gas is 1.09 kJ/kgK. The temperature of the environment is 27°C. Assume that water is liquid at the environmental state. Neglect any changes in entropy and enthalpy in the water feed pump.

   Calculate:
   - a) the electricity output from the generator;
   - b) the irreversibility rate in the boiler, steam turbine generator and condenser;
   - c) the rational efficiencies of the boiler and steam turbine generator;
   - d) the overall efficiency of conversion of the exergy in the input to the steam to electricity;
   - e) the overall efficiency of conversion of the energy input in the steam to electricity.

   [a) 2050 kW, b) 928 kW, 473 kW, 204 kW, c) 74.6%, 81.2%, d) 75%, e) 27.9%]



This question will increase your understanding of exergy in compressed air systems, but you won't be asked an examination question on this topic.

2. A single-stage electrically driven rotary air compressor is used to compress dry air from 1 bar to 3 bar. The air flow rate is 2 kg/s. The compressor has an isentropic efficiency of 80% and the electric motor an efficiency of 95%. After the compressor the air is passed through a cooler and cooled to 45°C. Water passes through the cooler to cool the air and is raised in temperature from 35°C to 65°C. Calculate:

   a) The electric power input to the compressor
   b) The exergy flow rate in the compressed air before and after the cooler.
   c) The enthalpy flow rate in the compressed air before and after the cooler
   d) The rate of heat transfer in the cooler
   e) The irreversibility rate and the rational efficiency of the cooler.

   Assume c_p for the air of 1.01 kJ/kgK.
   Assume the environmental temperature is 20°C and that air has zero enthalpy at 20°C.

   Compare the exergy in the compressed air after the cooler with the enthalpy and explain the significance of the difference.

   [a) 287 kW, b) 233.2 kW, 186.9 kW, c) 272.7 kW, 50.5 kW, d) 222.2 kW, 25.8 kW, 44.3%]

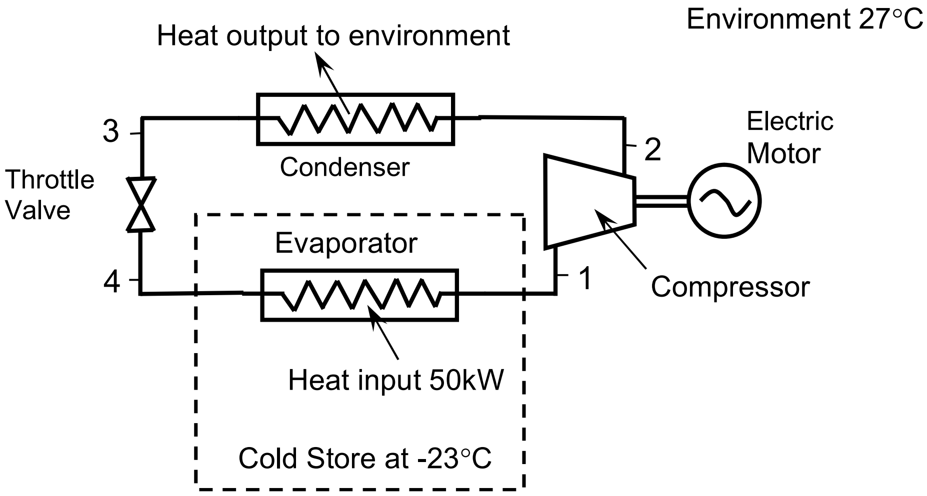
   For air compressor calculations see Appendix 2 in Exergy Lecture notes

3. The working fluid in a refrigeration system condenses in the condenser at a temperature of 45°C. Due to fouling (dirt) in the heat exchanger, the condensation temperature rises to 48°C. In each case the heat dissipation is 10kW.

   Calculate the increase in irreversibility as a result of this increase in condenser temperature. The environmental temperature is 15°C.

   What effect will this increase in temperature have upon the operation of the compressor?
   [84.6 W]

4. A vapour-compression refrigeration system is used to provide cooling for a frozen food storage facility, as shown in the diagram.



The temperature, pressure, enthalpy and entropy of the refrigerant (R134a) at each point in the system are given in the table below. (You may like to look the values up yourself from your Tables!)

Point	Temp (°C)	Pressure (bar)	Enthalpy (kJ/kg)	Entropy (kJ/kgK)
1	-28	0.8435	381.9	1.758
2	62.3	10.163	443.7	1.786
3	+30	10.163	241.7	1.143
4	-30	0.8435	241.7	1.181
Environment	+27	1.0	426.3	1.907

The electrical and mechanical efficiency of the electric motor is 89%

Calculate:

a) The exergy flow rate from the evaporator into the Cold Store
b) The electricity input to the motor
c) The total irreversibility and rational efficiency of the refrigeration system
d) The irreversibility in the motor, the compressor, the condenser, the throttle and the evaporator as a percentage of the input exergy.

[a) 10 kW, b) 24.76 kW, c) 14.76 kW, 40.4%, d) 2.72 kW, 3.0 kW, 3.24 kW, 4.07 kW, 1.733 kW]