ME 354 THERMODYNAMICS - 2

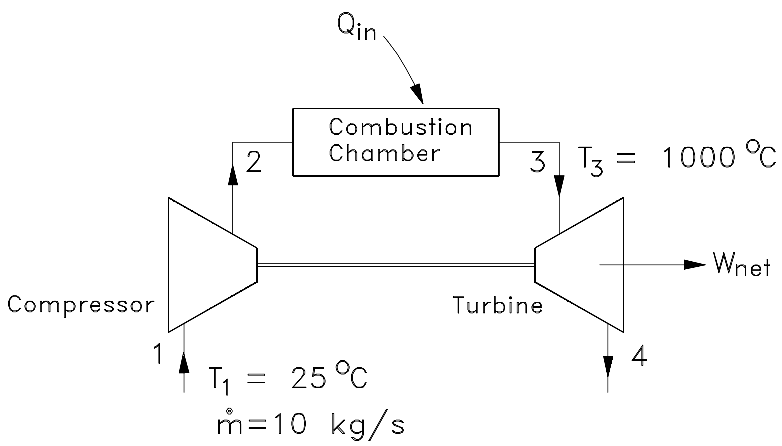
17 April 1998 | Final Examination | R. Culham

- This is a three-hour, closed-book examination.
- You are permitted to use one 8.5 in.× 11 in. crib sheet. (one side only)
- There are 4 questions to be answered. Read the questions very carefully.
- Clearly state all assumptions.
- It is your responsibility to write clearly and legibly.
- Good luck.

Question 1 (25 marks)

A gas turbine engine, as shown below, uses air as the working fluid with a constant specific heat of $c_p = 1.004\ kJ/(kg \cdot K)$ and $k = 1.4$. The compressor has an isentropic efficiency of 100% and a pressure ratio of 18:1, while the turbine has an isentropic efficiency of 85% and a pressure ratio of 18:1. Find the following:

a) the net power output (kW)
b) the overall thermal efficiency of the engine
c) the thermal efficiency of an equivalent ideal cycle
d) the percentage increase in power if pressure ratio was optimized for maximum work output
e) why is it difficult for a gaseous cycle to have Carnot efficiency?



Question 2 (25 marks)

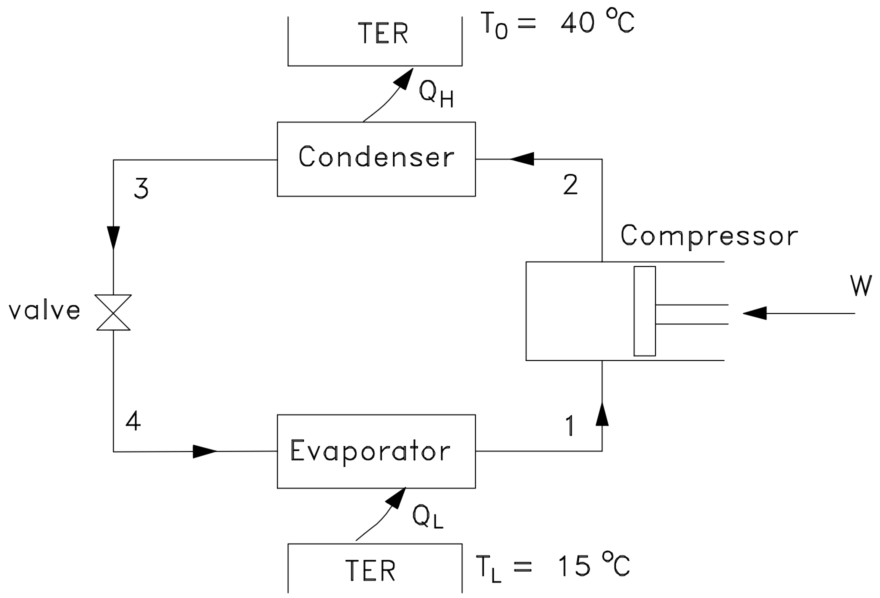
A small gas turbine uses $C_8H_{18}(\ell)$ for fuel and 400% theoretical air. The air and fuel enter at 25 $^\circ C$ and 1 atm, and the products of combustion leave at 900 K. The output of the engine and the fuel consumption are measured and it is found that the specific fuel consumption is 0.25 kg/s of fuel per megawatt of output. Assume a steady-state, steady flow process, all gases are ideal and the combustion is complete.

a) determine the heat transfer from the engine per kmole of fuel
b) if we assume the turbine is adiabatic and the work output is negligible show that the maximum temperature of the products is approximately 960 K. Why is this temperature so low?

Question 3 (25 marks)

A computer facility in the Sahara Desert [$T_0 = 40°C$] is to be maintained at $15°C$ by a vapour-compression refrigeration system that uses water as the refrigerant. The water leaves the evaporator as a saturated vapour at $10°C$. The compressor is reversible and adiabatic. The pressure in the condenser is 0.01 MPa and the water is saturated liquid as it leaves the condenser.

a) determine the coefficient of performance for the cycle
b) determine the second law efficiency of the system, defined as the availability per unit work input
c) if we assume that the valve is heavily insulated, determine the total availability destruction per unit mass of water for the system
d) what caused the exergy destruction in this particular process?



Question 4 (25 marks)

Air enters a tumble dryer at 20 $°C$ and a relative humidity of 65%. If the air leaves the dryer in a saturated condition at 45 $°C$, calculate the mass flow rate of dry air through the dryer in order to evaporate 1 kg of water in 40 minutes. Assume the process to take place at a constant atmospheric pressure of 100 kPa.