ENERGY CONVERSION A
2016-17

Name/Lastname:____ Code n.___________

Exam 03/02/2017

Exercise 1 (10 points)

A thermal power source of constant heat capacity equal to 200 kW/°C at a temperature of 600°C can be cooled down as much as possible to ambient. Such a source is exploited by an open-loop air cycle employing a two-time intercooled compression. The two intercoolers use cooling water available at 15°C. Ambient air is instead at 20°C.

Neglecting all pressure drops, but the pressure drop on the air side of the heat exchanger for the heat input to the cycle equal to 5%, and considering non-ideal machines (i.e. assume efficiencies), please:

i. highlight clearly throughout the text all assumed parameters and their values (1 point);
ii. sketch a plant layout (1 point);
iii. calculate the expansion ratio such that the expander outlet temperature is 250°C (1 point);
iv. draw the T-s diagram of the cycle and the T-Q diagram of the heat input (hot source-air) exchanger (2 points);
v. compute the second-law efficiency of the air plant (3 point);
vi. estimate the number of stages required to assure a high-efficiency expander and estimate the rotational speed such that the specific rotation speed (Ns) is close to 0.1 (2 points).

Exercise 2 (12 points)

Consider a biomass-fired steam Rankine cycle in cogenerative architecture. The plant heats up a flow of diathermic oil exploiting the condensation of steam in two diverse heat exchangers, HX1 and HX2. The oil enters the plant at 15°C, and flows first in HX1 and then in HX2 (V_{oil}=2700 m^3/h, ρ_{oil}=800 kg/m^3, cp_{oil}=2100 J/kgK).

The high pressure steam produced in the boiler (T=450°C, p=30 bar, T_{sat}(30 bar)=230°C) is expanded in a high-pressure turbine, operating with a pressure expansion ratio of 5, and then split into two flows as here described.

- The first stream (A) returns to the boiler for resuperheating at 450°C and then is expanded in a low-pressure turbine to the minimum pressure, at which the steam is condensed in HX1 at 60°C, while heating the oil (condensation enthalpy at 60°C is about 2350 kJ/kg).
- The second stream (B) is condensed and subcooled in HX2, while heating further the oil. The subcooled water is sent then to the outlet of the condensate extraction pump of HX1.

Both HX1 and HX2 are designed with the same pinch-point temperature difference. Please:

i. highlight clearly throughout the text all assumed parameters and their values (1 point);
ii. sketch the plant layout, without detailing the biomass-fired boiler (2 points);
iii. draw a single TQ diagram for both HX1 and HX2 (2 points);
iv. compute the mass flow rate of steam at the inlet of the low-pressure turbine and at the inlet of the high-pressure turbine, considering HX1 and HX2 as countercurrent heat exchangers (4 points);
v. determine the wasted power due to the heat transfer irreversibility in only HX2 (3 points);

Questions (2.5 points each)

1. Explain why carbon dioxide emissions from a natural gas-fired combined cycle power plant and a coal-fired steam cycle power plant are different.

2. Why the steam drum have typically high wall thicknesses? How does it affect the flexibility of the plant?

3. On the specific volume-temperature diagram of water, sketch three isobars (10, 200 and 300 bar) from super-heated steam to subcooled liquid.

4. Reasoning at same velocity triangles, how does the efficiency of a single-shaft multi-stage expander vary as a function of the overall volume ratio? why?