Power systems

First semester 2019-2020 **Name (Print):** _____
Topic 2
13/01/20
Time Limit: 90 Minutes Total: 100 points

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1. Consider the hybrid CSP-Gas power plant with a combined cycle shown in Figure 1. This power plant burns natural gas to heat air and generate electricity with a gas turbine. The exhaust air is utilized to generate further electricity with a Rankine cycle that also utilizes heat from the parabolic solar field. The fluid in the Rankine cycle is R113 (a kind of freon) and the fluid in the solar field is Hitec oil.

   The following are some additional parameters of the plant:

   - Efficiency of the heat exchangers (HE-1 to HE-4): $\eta_H E = 90\%$
   - Electrical generators efficiency: $\eta_g = 98\%$ and Turbines mechanical efficiency: $\eta_m = 97\%$
   - Rankine cycle efficiency: $\eta_S = 13\%$
   - Hitec oil heat capacity: $1.56 kJ/kgK$
   - Fuel LHV: $4.83 \cdot 10^4 kJ/kg$
   - Compression ratio in the Bryton cycle: 10

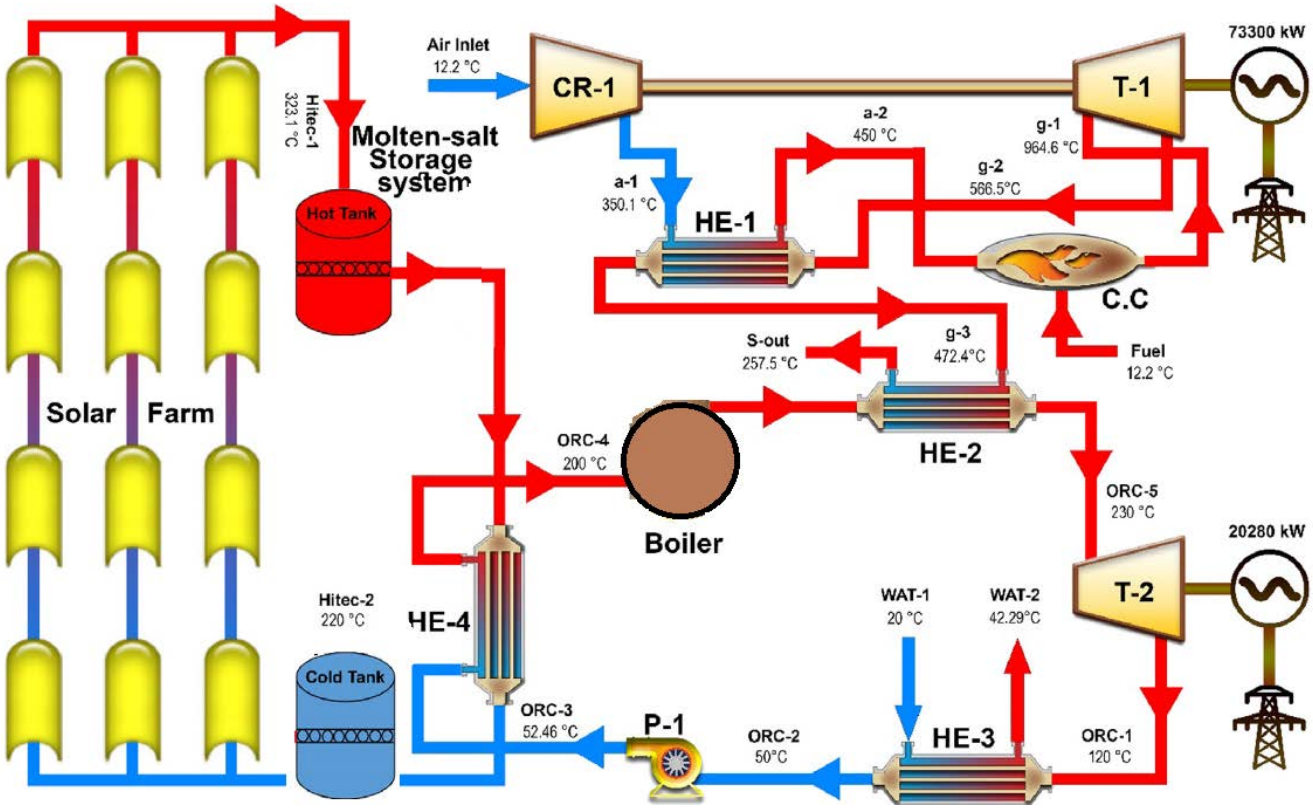

Figure 1: Scheme of the CSP-CCPP power plant.

(a) (20 points) Draw approximately the T-S diagram for both the Bryton and the Rankine cycles.

(b) (10 points) Calculate the efficiency of the gas cycle (Bryton) for electricity production.

(c) (10 points) What is the internal efficiency of the compressor (use the Rivkin method)?

(d) (10 points) What is the mass flow through the gas turbine T-1?

(e) (15 points) The Rankine cycle of this power plant uses an organic fluid (we don't know Cp and other properties so we CANNOT use the temperature data). What is the power delivered to the Rankine cycle at the HE-4 heat exchanger?

(f) (10 points) What is the mass variation in the cold tank during one hour at night?

2. (15 points) Consider a Pressurized water reactor working at 100% power conditions with the control rods slightly inserted in the reactor (40 out of 270 steps). There is a malfunction in the Boron control system that reduces the boron concentration by 21 ppm. Considering that the boron worth is 5.5pcm/ppm, what will be approximately the new power? (Use the values in Table 1)

2. _____

Power (%)	Reactivity (pcm)	Coolant temperature (C)
90	1280	304
95	1350	305
100	1420	306
105	1550	307

Coolant temperature (C)	Reactivity (pcm)
304	250
305	210
306	170
307	130

Table 1: Left: Reactivity and mean coolant temperature as a function of the nuclear power. Right: Reactivity as a function of the coolant temperature

3. (5 points) What is the difference between thermal and fast neutrons? Answer below!

4. (5 points) A nuclear reactor has rated power of 1266 MW. Assuming that the overall effiency is 33 % and that the total mass of fuel is 79 tonnes, calculate the average burnup of the fuel during 1 cicle of 18 months at full power? Answer below!

4. _____