

1. Figure 1 shows a schematic of a solar thermal power plant of CSP with a thermal energy storage (TES) system. The fluid circulating through the solar field is a synthetic oil whereas the TES fluid is molten salt. The thermal energy is then transferred to a Rankine cycle to produce electricity. The power plant is also equipped with a gas heater that may be used to directly heat the oil. The following are some additional parameters of the plant:

- Nominal electric output power: 11MW
- LHV of the Gas:  $33000\text{kJ}/\text{m}^3$
- Electrical generator efficiency:  $\eta_g = 0.97\%$
- Turbine mechanical efficiency:  $\eta_m = 0.95\%$
- Suppose that heat exchangers are ideal
- synthetic oil heat capacity:  $2.05\text{kJ}/\text{kgK}$
- synthetic oil hot temperature:  $381^\circ\text{C}$
- synthetic oil cold temperature:  $293^\circ\text{C}$
- Effective area of sun collection in the solar field  $250000\text{m}^2$

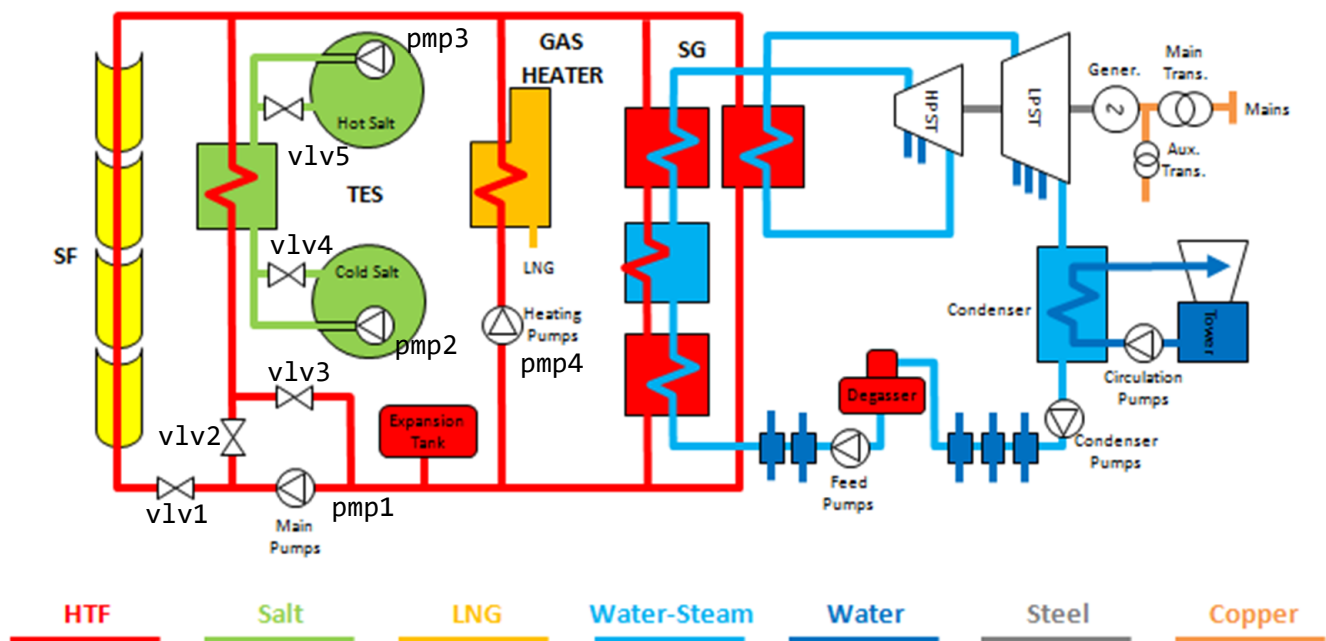


Figure 1: Scheme of the CSP-gas power plant.

- (15 points) Draw approximately the T-S diagram of the water-steam circuit (Table 1 displays the points in the Rankine cycle).
- (10 points) What is the efficiency of the Rankine cycle?
- (15 points) The synthetic oil circuit is connected with the water-steam circuit with two parallel lines (the synthetic oil flow is distributed in these two lines). What is the flow ratio between the two lines (percentage of flow to each line)?
- (10 points) During the night, the power plant is working thanks to the TES stored energy only. Indicate the position of valves v1v1 to v1v5 (open or closed) and the actuation of pumps pmp1 to pmp4 (active or not).

Table 1: Pressure and enthalpy of different points of the Rankine cycle

Point	Pressure (bar)	Enthalpy (kJ/kg)
1	0.05	138
2	46	142
3	46	3132
4	10	2777
5	10	3202
6	0.05	2197

- (e) (15 points) In a sunny day with a solar radiation of  $850W/m^2$ , the thermal and optical losses in the solar field amount to 55%. What is the mass flow of synthetic oil through the solar field?
- (f) (15 points) During the last 4 weeks, the plant has been able to operate at nominal power with a capacity factor of 77 %. The total sun irradiation at the site has been  $22.05GWh$  and the amount of gas burned at the furnace has been  $504m^3$  . What is the average efficiency of the plant?
2. Consider a PWR reactor with a power of 1270 MWe and a thermal efficiency of 34%
- (a) (10 points) If the initial mass of the fuel was 76 tones, calculate the average fuel burn up for one full year of operation non-stop.
- (b) (10 points) If the average energy of one fission reaction is 200Mev. How many fission reactions have occurred in the last year?