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SUSTAINABLE ENERGY MODULES

Geothermal Module Problem Set

Due March 22, 2007 by 5 pm

SP 8.1 A basic binary plant uses isopentane (i-C_5H_{12}) as the cycle working fluid (See Figs. 8.1 and 8.2 in GPP). The brine inlet temperature is 440 K; the pinch-point temperature difference in the preheater-evaporator is 5 K. The i-C_5H_{12} pressure in the preheater-evaporator is 2.0 MPa; the condenser runs at 320 K. The isentropic efficiency for the turbine is 85% and 75% for the feedpump. The geothermal brine heat capacity is 4.19 kJ/kg·K (constant) and density is 897 kg/m^3. The dead-state temperature is 25^{o}C. The cycle is designed to produce 1200 kW net power.

Calculate the following specific terms for the cycle, i.e., in kJ/kg of i-C_5H_{12}:

(A) Turbine work
(B) Heat rejected
(C) Feedpump work
(D) Heat added.

Calculate:

(E) Cycle thermal efficiency
(F) Mass flow rate of i-C_5H_{12}
(G) Mass flow rate of brine
(H) Brine outlet temperature
(I) Utilization efficiency (assuming pure water properties for the brine)
(J) Number of wells needed if a typical well produces 850 gallons/minute (GPM).

SP 8.4 A dual-pressure binary plant depicted in the figure below uses isobutane (i-C_4H_{10}) as the cycle working fluid. Saturated liquid i-C_4H_{10} is pumped from the condenser C through a heater H1 from which it emerges as a saturated liquid. A proportioning valve PV allows 30% of the working fluid to flow to the evaporator E1 and 70% to flow to a feedpump FP. From there this stream is heated (H2), evaporated (E2) and superheated (SH) before entering the turbine T1. The exhaust from T1 is mixed isobarically with the saturated vapor (state 3) coming from evaporator E1 before passing into the second turbine T2. The geothermal brine passes through five heat exchangers in series before being reinjected (state b).

Data: $P_1 = P_9 = P_{10} = P_{11} = 3362$ kPa; $T_1 = 180^o$C; $T_6 = 30^o$C; $T_0 = 25^o$C;
$\eta_{T1} = \eta_{T2} = 85\%$; $\eta_{CP} = \eta_{FP} = 100\%$; $T_a = 200^o$C; $T_b = 100^o$C.
Also, the temperature in E1 is chosen as the average of the condenser temperature and the temperature in E2.

(A) Construct the pressure-enthalpy process flow diagram (schematically, not to scale).
(B) Determine the specific enthalpy of the i-C_4H_{10} at each state point in the cycle.
(C) Calculate the specific work output of the turbines in units of kJ/kg of i-C_4H_{10} flowing at state 6.
(D) Calculate the thermal efficiency of the cycle.
(E) Calculate the required mass flow rate of brine (assumed pure water) per unit flow rate of i-C_4H_{10}.
(F) Calculate the utilization efficiency of the plant based on the exergy of the incoming brine.
(G) If a typical well can produce 90,000 kg/h, how many wells will be needed to generate a net power output of 10 MW?
(H) Is it safe to assume that the plant as described in this problem (i.e. for the given temperatures, pressures, etc.) is actually feasible thermodynamically? To be sure of its feasibility, what should be checked?

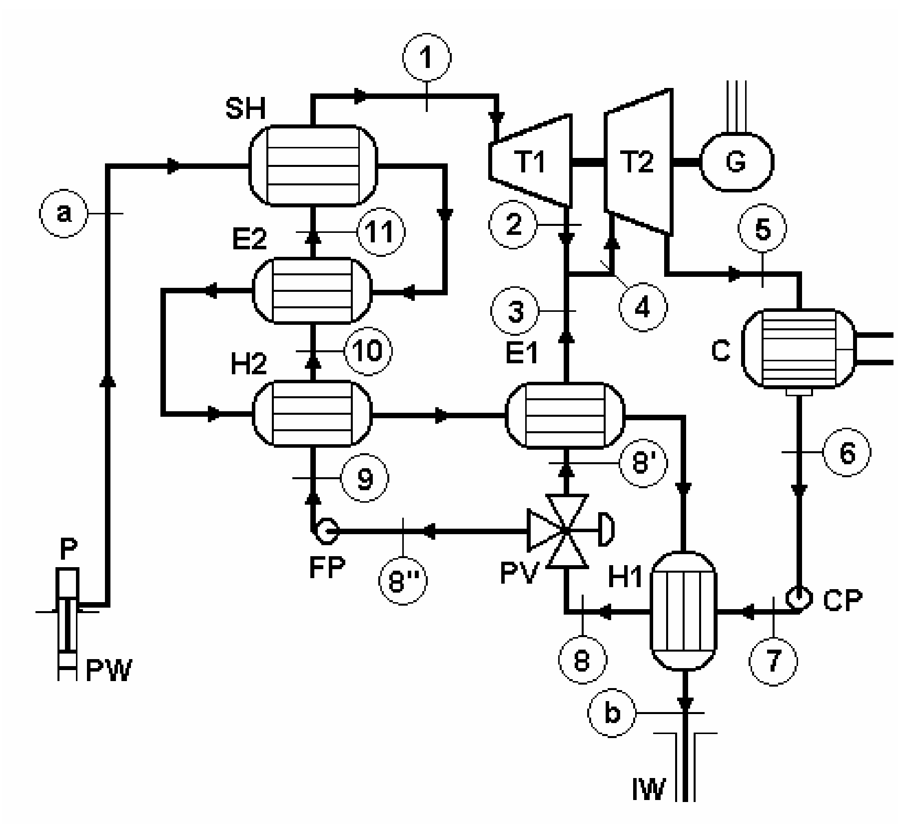

Figure for SP 8.4. Dual-Pressure Binary Power Plant

Office Hours for Gregg:
Monday March 19th, 7-9 pm in 66-156
Wednesday March 21th, 7-9 pm in 66-156
Any additional office hours will be announced in class and over email

Thermodynamic Properties of Isopentane

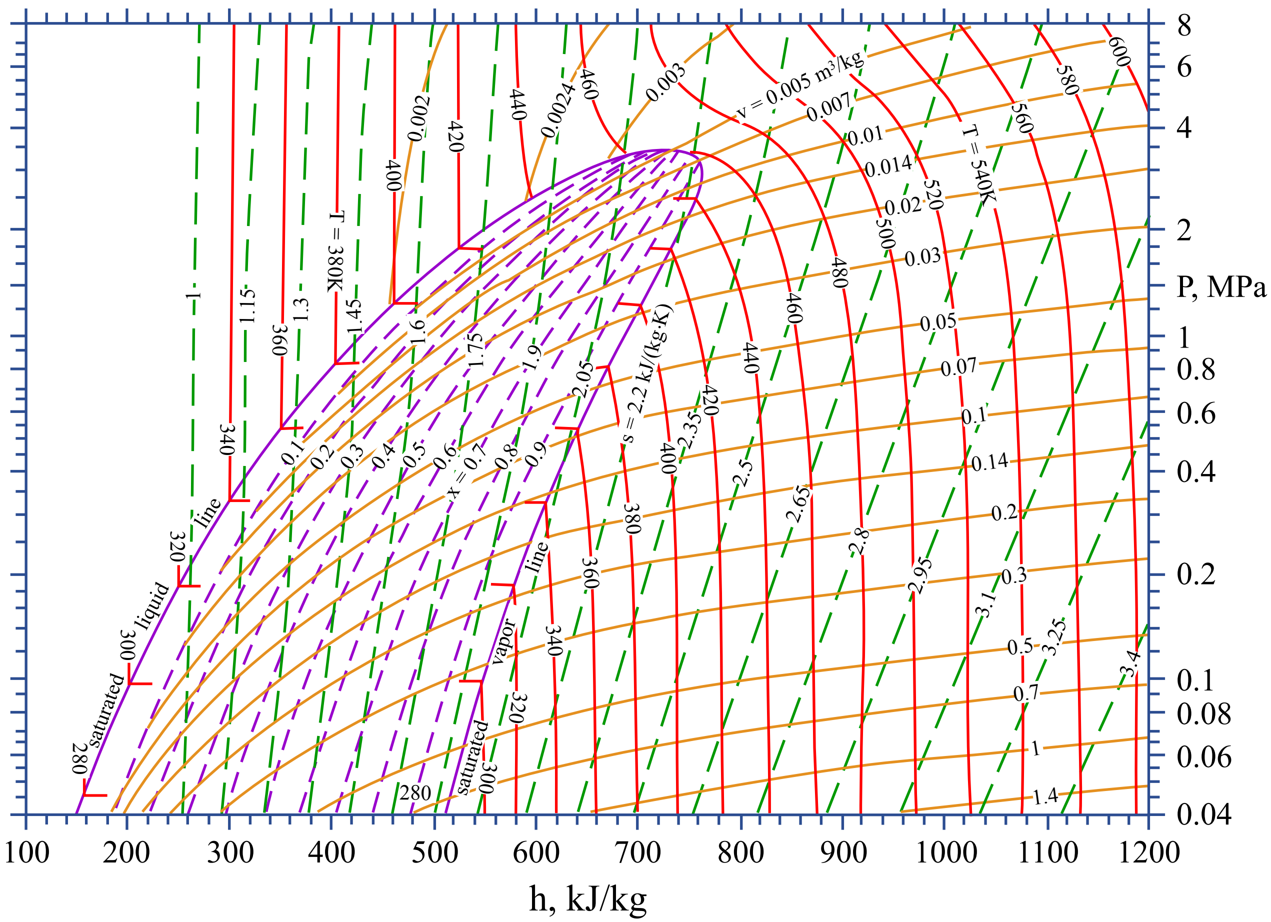

Figure by MIT OCW. (The values in this chart are approximate and are for educational purposes only. This chart should not be used for real design calculations.)