Tutorial – 1

(First three problems solved/discussed during the Tutorial 1)

1. A textile factory requires 10 t/h of steam for process heating at 3 bar saturated and 1000 kW of power, for which a back pressure turbine of 70% internal efficiency is to be used. Find the steam condition required at inlet of the turbine. [37.3 bar, 344°C]
2. In a thermal power plant operating on a reheat cycle steam at 50 bar and 500°C enters a high pressure turbine and leaves at 10 bar. Then this steam is reheated to 500°C before it is fed to a low pressure turbine. The condenser is maintained at 0.05 bar. Calculate the thermal efficiency of the power plant, the mass flow rate of steam for a net power output of 20 MW and the quality of steam at the exit of the low pressure turbine. [41.22%, 12.79 kg/s, 0.92]
3. Rework Example 8.21, if the isentropic efficiency of each turbine is 0.8 and the isentropic efficiency of the pump is 0.7. Estimate the thermal efficiency and the steam flow rate. [33.73%, 16.03 kg/s]

Problems solved during class (25 Oct 2017)

4. Find the number and length of superheater coils of 60 mm id and 5 mm thickness to be provided if steam at exit is at 80 bar, 500°C and flows with a velocity of 10 m/s. The mass flow rate of steam is 80 kg/s. Due to restriction by materials, the heat flux in the superheater coils needs to be limited to 150 kW/m^2.
   [118, 13.13 m]
5. A boiler plant has an economiser, an air preheater, and generates steam at 100 bar and 500°C. The coal feeding rate is 520 kg/hr and it has a calorific value of 25 MJ/kg. The temperature of the feedwater at the inlet of the economiser is 40°C. The flue gases are cooled at the economiser from 395°C to 225°C. The flue gases then enter the air preheater in which the temperature of combustion air is raised by 75°C. A forced draught fan delivers the air to the air preheater at a pressure of 1.02 bar and a temperature of 15°C with a pressure rise across the fan of 20 cm of water. The power input to the fan is 6 kW and it has a mechanical efficiency of 75%. The boiler has an efficiency of 84%. Neglecting the heat losses and taking the specific heat as 1.01 kJ/kg.K for flue gases, calculate (a) the mass flow rate of air, (b) the temperatire of flue gases leaving the plant, (c) the flow rate of steam, and (d) the temperature of the feedwater after the economiser. Specific heats of water may be taken as 4.182 kJ/kg-K.
   [2.83 kg/s, 154°C , 3406 kg/s, 169.1°C]

Some more practice problems (to be solved by you or in another tutorial)

6. A forced draught fan supplies air at 10m/s against a draught of 20 mm of water across the fuel bed. Estimate the power required to run the fan if 2500 kg/h of coal is consumed and 16 kg of air is supplied per kg of coal burned. The temperature of the flue gas and the ambient air may be taken as 600 K and 300 K respectively. If the forced draught fan is replaced by an induced draught fan, what will be the power required to drive the fan? [2.41 kW, 4.29 kW]
7. A furnace wall riser, 20 m long, 80 mm OD and 8 mm thick receives saturated water at 100 bar and 1.6 m/s velocity. Assuming a circulation ratio of 12.5 and a slip ratio of 1.2, determine (a) the pressure head developed, (b) the void fraction at riser exit, and (c) the heat transfer rate per unit projected area of the riser tube. [64.46 kPa, 0.4736, 0.284 kg/s, 233.83 kW/m^2]
8. A power plant producing 100 MW of electricity has steam condition at boiler outlet as 100 bar, 500°C and the condenser pressure is 0.1 bar. The boiler efficiency is 90%. The boiler consumes coal of calorific value 25.0 MJ/kg. The feedwater temperature at boiler inlet is 180°C. The steam generator has risers in the furnace wall 40m high and unheated downcomers. The quality at the top of the riser is 8% and a minimum exit velocity of mixture leaving the riser and entering the drum is required to be m/s. The risers have 80mm o.d. and 6 mm wall thickness. Neglecting any pressure drop and heat loss, as well as the pump work, estimate (a) the steam generation rate, (b) the fuel burning rate, (c) the evaporation factor, (d) the pressure head available for natural circulation, (e) the circulation ratio, (f) the number of risers required, and (g) the heat absorption rate per unit projected area of the riser.
   [77.82 kg/s, 8.13 kg/s, 9.573, 67.68 kPa, 12.5, 414, 73.92 kW/m^2]

Some useful definitions:

$$\text{Evaporation factor} = \frac{\text{Mass flow rate of steam}}{\text{Mass flow rate of coal}}$$

$$\text{Circulation ratio} = \frac{1}{x_{\text{top}}}, \quad x_{\text{top}} = \text{top dryness fraction (dryness fraction at the top of the riser)}$$

$$\text{Slip ratio}, S = \frac{\mathrm{V_g}}{\mathrm{V_f}} = \frac{\text{Velocity of vapor in a two} - \text{phase mixture}}{\text{Velocity of liquid in a two} - \text{phase miture}}$$

Voidage of void fraction α may be defined as

$$\alpha = \frac{v_g}{v_f + v_g}.$$

Here, v_g is the specific volume of vapour and v_f is the specific volume of liquid, and total volume of the mixture is

$$v = (1 - x)v_f + xv_g = v_f + xv_{fg}.$$

It can be shown that $\alpha = \left[1 + \frac{1-x}{x}\psi\right]^{-1}$, where $\psi = \frac{v_f}{v_g}S$ and x is the dryness fraction.