



**Time: Three Hours**

**Only Steam tables and Chart are allowable**

**Q1 (30 points)**

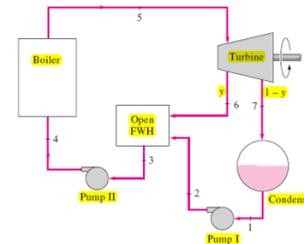
**1.1) Explain with drawing a regenerator (FWH) the theory, types and comparison?**

A feedwater heater is basically a heat exchanger where heat is transferred from the steam to the feedwater either by mixing the two fluid streams (open feedwater heaters) or without mixing them (closed feedwater heaters). Regeneration with both types of feedwater heaters is discussed below.

**Open Feedwater Heaters**

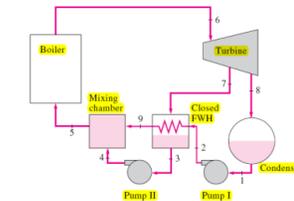
An open (or direct-contact) feedwater heater is basically a mixing chamber, where the steam extracted from the turbine mixes with the feedwater exiting the pump. Ideally, the mixture leaves the heater as a saturated liquid at the heater pressure. The schematic of a steam power plant with one open feedwater heater (also called single-stage regenerative cycle) and the T-s diagram of the cycle are shown in Fig. 10–15.

In an ideal regenerative Rankine cycle, steam enters the turbine at the boiler pressure (state 5) and expands isentropically to an intermediate pres-



**Closed Feedwater Heaters**

Another type of feedwater heater frequently used in steam power plants is the closed feedwater heater, in which heat is transferred from the extracted steam to the feedwater without any mixing taking place. The two streams now can be at different pressures, since they do not mix. The schematic of a



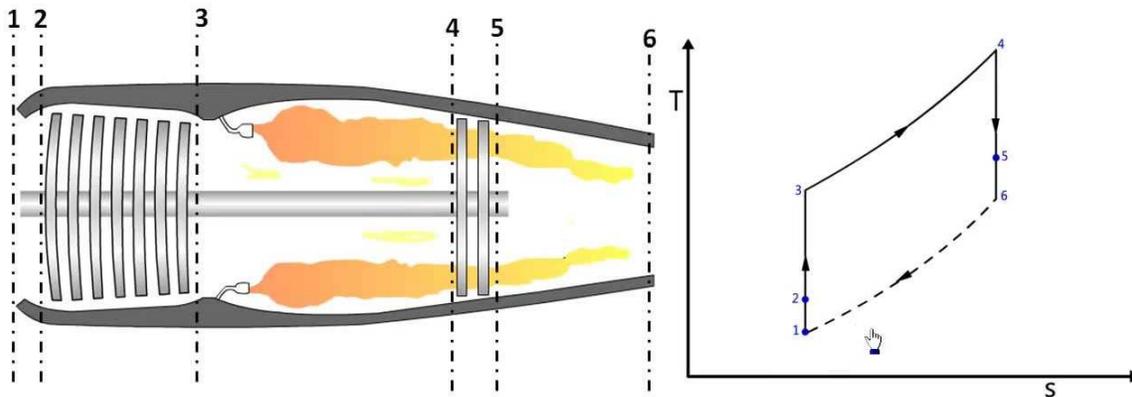
The open and closed feedwater heaters can be compared as follows. Open feedwater heaters are simple and inexpensive and have good heat transfer characteristics. They also bring the feedwater to the saturation state. For each heater, however, a pump is required to handle the feedwater. The closed feedwater heaters are more complex because of the internal tubing network, and thus they are more expensive. Heat transfer in closed feedwater heaters is also less effective since the two streams are not allowed to be in direct contact. However, closed feedwater heaters do not require a separate pump for each heater since the extracted steam and the feedwater can be at different pressures. Most steam power plants use a combination of open and closed feedwater heaters, as shown in Fig. 10–17.

**1.2) What are the different applications of a gas turbine engine and explain with details one of them? And explain briefly for different application how to start a gas turbine engine?**

Gas turbines are used mainly for two purposes.

- First, for power production.
- Second, for generating thrust force in an aircraft.

## BRAYTON CYCLE



Variation of state of fluid from inlet to exit of gas turbine engine is shown in Fig.5 in a T-s diagram. Point 1 is the inlet condition of a gas turbine engine, which is same as state of surrounding air. Due to diffuser effect pressure and temperature of the fluid increases slightly, entropy remains same assuming this is an adiabatic reversible process (1-2). Next in compressor stage also same process continues, temperature and pressure rise to a level where combustion process is sustainable (2-3). Now fuel injection and heat addition to the fluid, this process happens almost at constant pressure, here pressure raises to very high level (3-4). Right after that, turbine will absorb some amount of energy which is required by the compressor. So here temperature and pressure of the fluid come down (4-5). Now the last section, which produces high velocity jet. This is again a constant entropy process, where internal energy of the fluid gets converted into kinetic energy. Here pressure expands to the surrounding pressure (5-6).

### - How to Start gas turbine engine

- by small air turbine starter connected with the gear box

Need outer small engine-compressor system to compress air to the air turbine and give motion to the gear box that is connected to the main shaft until the rotating speed of the shaft reaches 200-500 rpm then the injected fuel is working and ignition system is work on to fire the fuel inside the combustion chamber until the speed of the main shaft reaches to 3000 rpm. Hence, the outer engine-compressor system is disconnected.

- by injected of air inside the manifold to rotate the turbine.

Force of air jet rotated the turbine. This system of starting jet engine takes much more air at higher pressure than the first one (air turbine starter).

- The air turbine starter is more efficient than the injected air

**1.3)** The gas-turbine portion of a combined gas–steam power plant has a pressure ratio of 16. Air enters the compressor at 300 K at a rate of 14 kg/s and is heated to 1500 K in the combustion chamber. The isentropic efficiency of the compressor and that of the gas turbine is 80 percent. The combustion gases leaving the gas turbine are used to heat the steam to 400°C at 10 MPa in a heat exchanger for a high pressure turbine. A reheat is used to heat steam to 350°C and optimum pressure. The combustion gases leave the heat exchanger at 420 K. The steam leaving the low pressure turbine is condensed at 15 kPa. Draw the schematic and T-S diagram of

this system and determine (a) the mass flow rate of the steam, (b) the net power output and the thermal efficiency of the steam, gas, combined cycles and comment. For air, assume constant specific heats at room temperature.

**Q2 (25 points)**

**2-1) Define and limitation of each statement?**

1) Load Factor (LF)

*It is defined as the ratio of the average load to the peak load during a certain prescribed period of time. Always less than unity.*

$$LF = [\text{Average load (Max. demand)}] / [\text{Peak Load (Max. Load)}]$$

2) Utility Factor (UF)

*It is the ratio of the units of electricity generated per year to the capacity of the plant installed in the station. It is always less than unity.*

$$UF = [\text{Average load (max. demand)}] / [\text{Capacity of the plant (Rated capacity of a plant)}]$$

3) Demand Factor (DF)

*This ratio of the maximum demand of a system to its connected load is termed as demand factor. It is always less than unity.*

$$DF = \text{Max. demand} / \text{Total connected load}$$

**2.2) 2. A generating station has a maximum demand of 80MW, a load factor of 65%, a plant capacity factor of 40% and a plant use factor of 85%. Find:**

a. Daily energy produced.

b. Reserve capacity of plant.

c. The maximum energy that could be produced daily if the plant was running all the time.

d. The maximum energy that could be produced daily if the plant was running as per operating schedule.

a. Average demand = Load factor \* Maximum demand = 0.65 \* 80MW  
= 52MW

Daily energy produced = 52 \* 24 = 1248MWh

b. Installed capacity = Average demand/ Plant capacity factor  
= 52MW/ 0.4 = 130MW

Reserve capacity = Installed capacity – Maximum demand  
= 130MW – 80MW = 50MW

c. Maximum energy that could be produced daily if it was running all the time = Installed capacity \* 24 = 130 \* 24 = 3120MWh

d. Maximum energy that could be produced daily if the plant was running as per operating schedule = Daily energy produced/ plant use factor  
= 1248/ 0.85 = 1468.23MWh

**2-3)** Determine the thermal efficiency of a steam power plant and its coal bill per annum (the station work 24h/day and 365day/annum) using the following data.

Maximum demand = 24000 kW

Load factor = 40%

Boiler efficiency = 90%

Turbine efficiency = 92%

Coal consumption = 0.87 kg/kWh

Price of coal = 280 LE per tone

**Solution.**

$$\begin{aligned}\eta &= \text{Thermal efficiency} \\ &= \text{Boiler efficiency} \times \text{Turbing efficiency} \\ &= 0.9 \times 0.92 = 0.83\end{aligned}$$

Load factor = Average Load/Maximum Demand

Average Load =  $0.4 \times 24000 = 9600$  kW

E = Energy generated in a year =  $9600 \times 8760 = 841 \times 10^5$  kWh

$$\begin{aligned}\text{Cost of coal per year} &= (E \times 0.87 \times 280)/1000 \\ &= (841 \times 10^5 \times 0.87 \times 280)/1000 \\ &= \text{Rs. } 205 \times 10^5. \quad \text{Ans.}\end{aligned}$$

### **Q3 (25 points)**

**3-1)** How the loads can be regulated in:

Pelton, Francis, Kaplan and Propeller turbines.

- ✓ For pelton turbine (by needle and reflectors)
- ✓ For Francis turbine (by wicket gate)
- ✓ For Kaplan turbine (by wicket gate)
- ✓ For Propeller turbine (by wicket gate and runner blade)

**3-2)** In which of the above turbines do we use draft tubes? Why?

- ✓ For pelton turbine (not use draft tubes, because the water exit at atmosphere pressure)
- ✓ For Francis, Kaplan and Propeller turbine (use draft tubes, because the water exit from these turbine with K.E, the draft tubes convert K.E to pressure energy and reduces the sacrifice in the river)

**3-3)** What is the function of the spiral casing, guide vanes, guide blade (wicket gate) and draft tube for a hydraulic turbine?

- ✓ spiral casing, distributes the flow and convert some of the flow potential and pressure energies into K.E

- ✓ guide vanes, guidance or directing the flow and convert some of the flow potential and pressure energies into K.E
- ✓ wicket gate, control of flow rate discharge according to load and convert some of the flow potential and pressure energies into K.E
- ✓ draft tube, convert residual K.E to pressure energy and reduces the sacrifice in the river

**Q4 (10 points)**

**4-1) Where the Diesel engine power plants are installed?**

1. Supply of coal and water is not available in desired quantity.
2. Where power is to be generated in small quantity for emergency services.
3. Standby sets are required for continuity of supply such as in hospital, telephone exchange.

**4-2) What are the disadvantages of diesel power plant?**

The disadvantages of diesel power plants are listed below.

1. High Maintenance and operating cost.
2. Fuel cost is more, since in India diesel is costly.
3. The plant cost per kW is comparatively more.
4. The life of diesel power plant is small due to high maintenance.
5. Noise is a serious problem in diesel power plant.
6. Diesel power plant cannot be constructed for large scale.

*With best wishes  
Dr. Mohamed Ramadan*