5.6 Deviation of Actual Cycle from Ideal Cycle:

The actual cycle deviates from the ideal cycle for the following reasons.

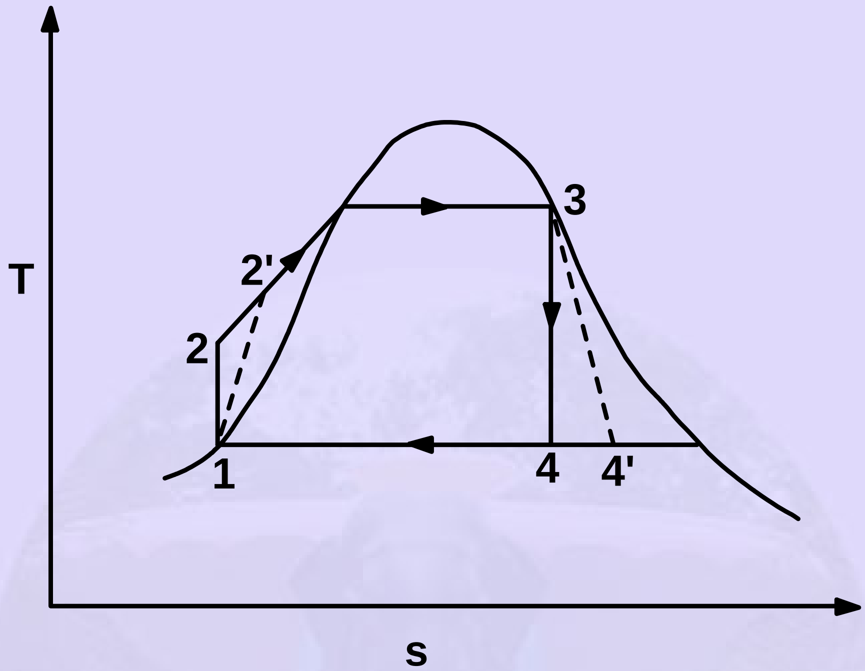


Fig.5.6. T-s diagram of actual and ideal cycle

1) Turbine Losses:

During the expansion of steam in the turbine there will be heat transfer to the surroundings and the expansion instead of being isentropic will be polytropic as shown in the figure.

$$3-4 \rightarrow \text{Isentropic expansion}$$

$$3-4' \rightarrow \text{Acutal expansion}$$

$$\text{Turbine efficiency} = \eta_t = \frac{h_3 - h_4'}{h_3 - h_4}$$

2) Pump Losses:

There are losses in the pump due to irreversibility and the process of compression is polytropic instead of isentropic as shown above.

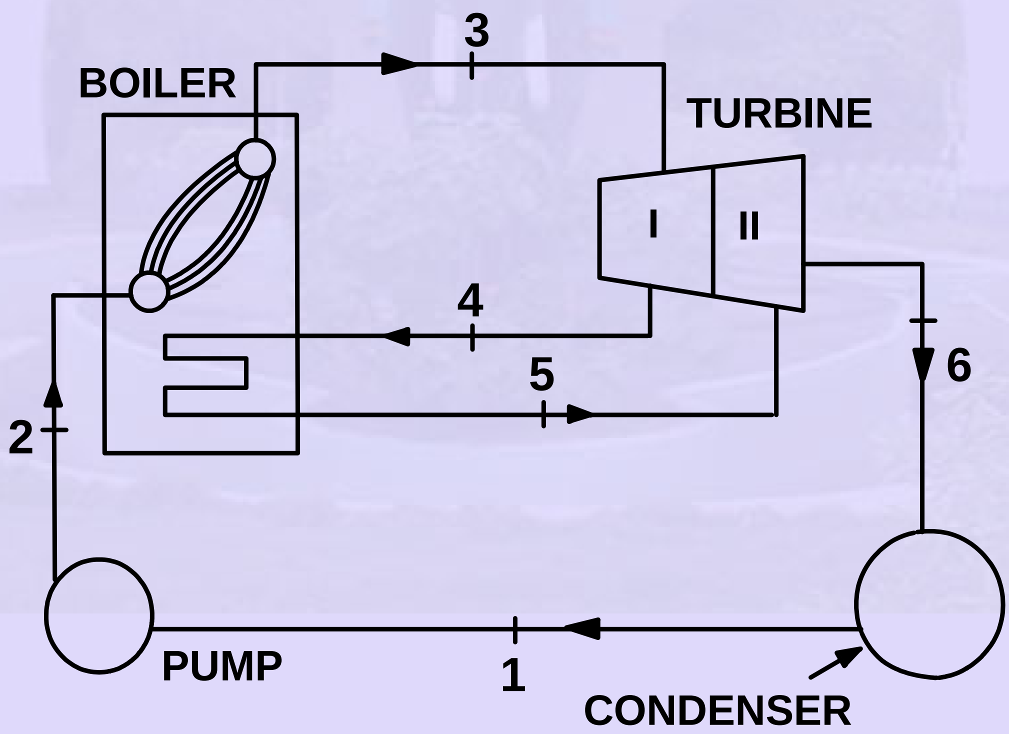
$$\text{Pump efficiency} = \eta_p = \frac{h_2 - h_1}{h_2' - h_1}$$

3) Condenser Losses:

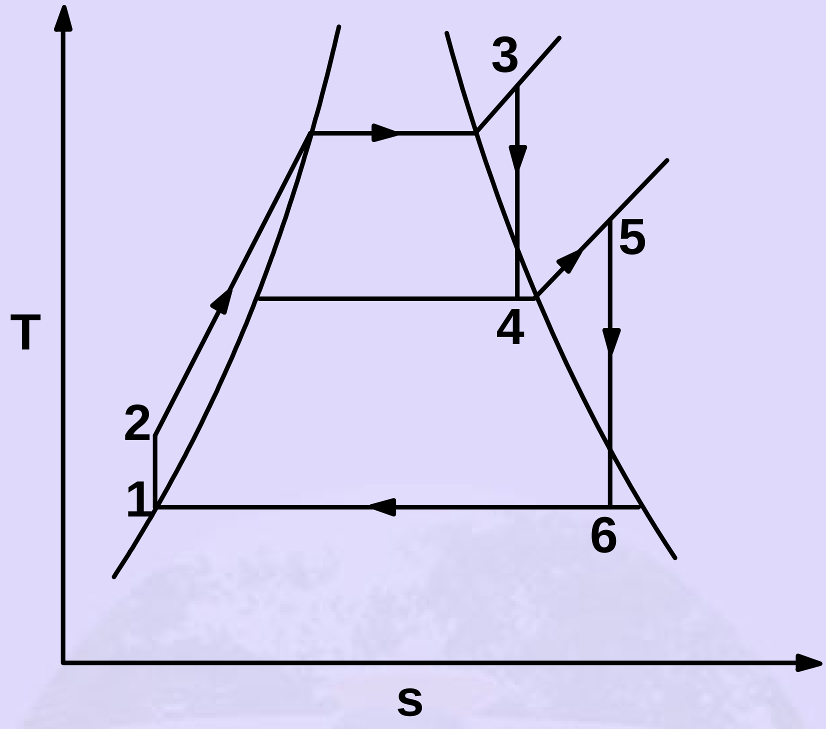
Due to pressure loss in the condenser, fluid cools below the saturation temperature, which requires additional heat energy to bring the liquid to the saturation temperature.

Methods of Increasing the Efficiency of Simple Rankine Cycle:

1) Rankine Cycle With Reheat:



(a)



(b)

Fig.5.6.1(a & b). Rankine cycle with reheat

In reheat Rankine cycle, the expansion of steam is carried out in several stages and the steam is reheated by addition of heat between the stages of turbine. Thus excessive moisture in the low-pressure stages of the turbine is avoided.

Above figure shows schematic and corresponding T-s, p-v diagrams of a reheat Rankine cycle with two turbine stages. Steam is expanded from the boiler pressure P_3 to some intermediate pressure P_4 in the first stage of the turbine. It is then reheated in the boiler from state 4 to state 5 and finally expanded from $P_4 = P_5$ to the exhaust pressure $P_1 = P_6$, in the second stage of the turbine. Note that we can employ any number of turbine stages.

Reheating does not result in any appreciable gain in thermal efficiency, because the average temperature of heat addition is not changed. The main advantage is that the moisture content of steam is reduced to a safe value.

Thermal efficiency of Reheat cycle:

$$\eta_{reheat} = \frac{\text{Net workdone}}{\text{Heat supplied}}$$

$$= \frac{\left(h_3 - h_4\right) + \left(h_5 - h_6\right) - \left(h_2 - h_1\right)}{\left(h_3 - h_2\right) + \left(h_5 - h_4\right)}$$

Neglecting pump work,

$$\eta_{reheat} = \frac{(h_3 - h_4) + (h_5 - h_6)}{(h_3 - h_1) + (h_5 - h_4)}$$

Optimum Intermediate Pressure and Temperature for Reheat Cycle:

The reheat Rankine cycle will perform efficiently when intermediate pressure for reheating is optimized. First, the intermediate temperature is determined as follows:

$$T_4 = \frac{h_3 - h_2}{s_3 - s_2}$$

And then, the intermediate pressure will be equal to saturation pressure corresponding to the above temperature.

2) Regenerative Feed Heating Cycles:

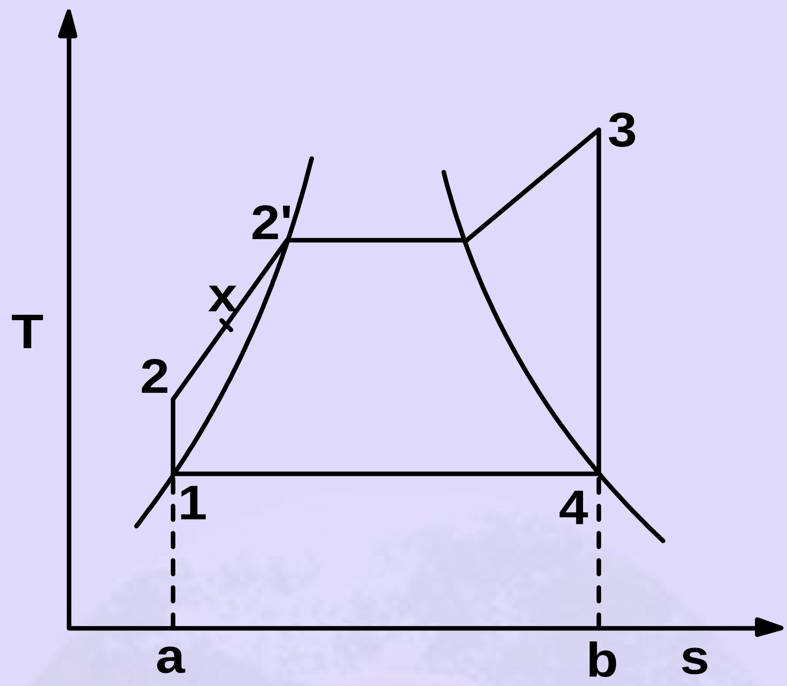


Fig.5.6.1(c). T-s diagram

The object of regenerative feed heating cycle is to supply the working fluid to the boiler at some state between 2 and 2', thereby increasing the average temperature of heat addition to the cycle.

(a) Single stage regenerative cycle

(i) Open feed water heater

(ii) Closed feed water heater

(b) Multiple stage regenerative cycle.