Self Evaluation

MODULE B.3.1

CONDENSER PERFORMANCE

1. Avoid using the cycle efficiency first because the whole aspect of efficiency depends upon being able to reject steam at a saturation temperature below that of 100°C which can only be done AFTER we have decided to use a condenser.

There are four basic points to cover:

a) If steam was not recovered from the system, the costs would be enormous. The water treatment plant would have to be capable of treating water at a rate exceeding the combined station unit full load mass flowrate, ie, in excess of 4000 kg/s. That would be some water treatment plant! The reserve feedwater capacity would have to be significantly increased.

   This point concerns the practicality of size of water treatment and storage plus costs.

b) If all the steam was rejected to atmosphere, there would be no recovered heat in the system from the condensate. Low pressure feedheating using steam at sub-atmospheric pressures would not be possible.

c) If we agree that it is to the systems advantage to return the working fluid to the system, we have to ask how it may be done. If we have to pump the vapour, we need an axial compressor at least as large as the turbine and would be unlikely to produce any net power.

   By reducing the volume of steam by a factor of around 30000/1, we can pump the liquid with a relatively small pump.

d) Having decided to use a condenser, we can ask about the operating conditions that will increase the unit thermal efficiency. In principle, the lower we make the condenser temperature, the more efficient the unit cycle will become. In practice, this minimum temperature is governed by the cooling water supply and results in designed condenser temperature around 36°C.

The lower temperature means higher cycle efficiency, greater turbine efficiency because of more work extracted per kilogram of steam, extraction steam available at sub-atmospheric pressures for feedheating.

In summary, your responses should follow:

- What are the problems of not returning the working fluid?
- What are the problems of returning the working fluid without condensation?
- Having decided on condensation, what other benefits arise?

2. Assume that we have steady state conditions in the condenser, ie, the heat lost by the steam is equal to the heat gained by the cooling water.

   If the CCW inlet temperature falls the average CCW temperature will fall which will increase the temperature difference between the steam space and the CCW. As a result, more heat will be transferred from the steam space which will lower the temperature in the condenser.

   The pressure will decrease with the condenser temperature which will result in an increased steam flow through the turbine to the condenser.

	Steam	CCW
Flowrate	Increase	Same
Inlet Temp	X	Decrease
Outlet Temp	X	Decrease
Ave Temp	Decrease	Decrease
Pressure	Decrease	X

3. The best plan to adopt is to examine the possibilities in the most likely sequence. We should look at all the possible causes because there may well be more than one reason for the increase in condenser pressure.

   a) Check the CCW inlet temperature. If this has increased, the average CCW temperature will have increased and caused a corresponding increase in the steam space. If the inlet temperature is the same, then this option is out.

b) Has the steam flow to the condenser changed because of changes in power or extraction steam flow?

If the steam flow to the condenser has increased for whatever reason, this will cause a rise in temperature in the steam space so that the extra heat may be transferred to the CCW. If there is no obvious change, then this is an unlikely option.

c) Has the CCW flowrate decreased due to tube blockage or CCW pump trip? This condition would be indicated if all temperatures had increased with the exception of the CCW inlet temperature. Make sure that the condensate temperature has also increased.

The reduced CCW flowrate would result in a higher CCW outlet temperature which would raise the CCW average temperature and result in an increase in the steam temperature to transfer the same amount of heat.

d) If air is getting into the condenser, this will act as an insulator around the heat transfer surfaces and this could result in a reduced heat transfer with a lower CCW outlet temperature. The condensate temperature would be below the condenser exhaust temperature and the whole situation would be confirmed by a significant rise in dissolved oxygen in the feedwater.

e) If the heat transfer surfaces had become flooded, the condensate would show a marked degree of subcooling. The temperature would rise in the condenser because the CCW is not only trying to remove the latent heat but is removing some of the sensible heat as well in subcooling the condensate.

f) Tube fouling, as opposed to tube blockage which restricts CCW flow, reduces the efficiency of heat transfer. This situation does not usually occur rapidly and is more associated with scale or oxide formation but could result from oil contamination on either of the two heat transfer surfaces of the condenser tube.

This condition would result in no significant change on the CCW circuit but a higher temperature in the steam space to overcome the increased resistance to heat transfer.

By analyzing the conditions of the steam system and the CCW, it is reasonably easy to decide which system caused the change.

4. Operation above design pressure

a) The first option is fairly obvious and is basically an economic consideration. If the condenser is operating above design pressure, the steam flow will be reduced and if the GSVs are in the 100% power position, turbine power will be reduced and the output and efficiency of the unit will suffer.

b) If the low pressure blades, which travel around 800 mph at the tips, are allowed to heat up in the higher density steam, permanent elongation may occur and close the radial clearances. This problem is overcome by the use of a vacuum unloader which reduces the turbine load as the pressure rises. A vacuum trip shuts the turbine down in the event that the vacuum unloader cannot control condenser pressure.

Operation below design pressure

Both problems are blade related problems. As the condenser pressure is lower, more work may be extracted from the steam. The extra work results in an increased moisture level which results in accelerated erosion of the turbine blades.

As the condenser pressure is reduced, the steam flow through the turbine increases and this also results in a higher turbine power level.

The overpowering of the turbine results in higher blade stresses which result in a reduced blade lifetime and an increased possibility of blade failure due to fatigue.

5. Using heat by the steam is equal to heat gained by the CCW, we can determine the unknown quantity - CCW flowrate.

Heat lost by steam

A temperature enthalpy sketch may help.

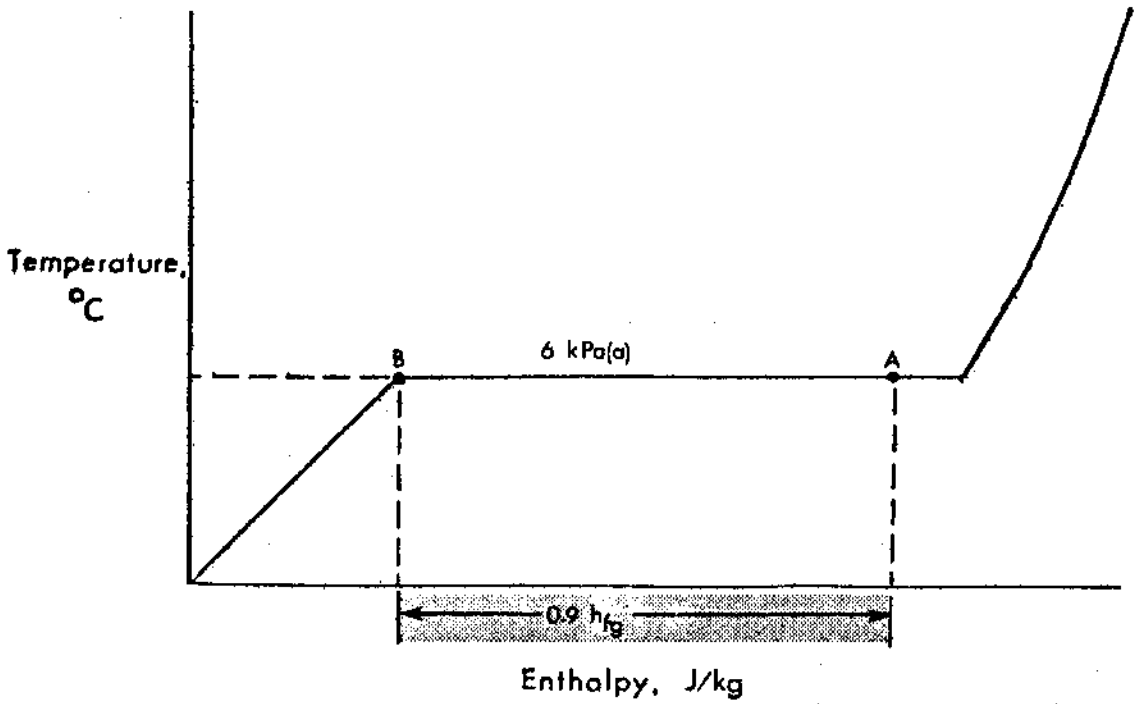

Fig. 3.1.8

The steam enters the condenser at point A where it has already lost 10% of its latent heat. The condensate leaves the condenser at point B where it is saturated liquid. The change in enthalpy is the remaining latent heat, ie, 0.9 h_{fg} at 6 kPa(a).

$$h_{fg} \text{ at } 6 \text{ kPa(a)} = \underline{2416} \text{ kJ/kg}$$

$$0.9 \times 2416 = \underline{2174.4} \text{ kJ/kg.}$$

Total heat lost by the steam per second is the enthalpy difference (2174.4 kJ/kg) multiplied by the mass flowrate (700 kg/s).

$$\text{Total heat lost by the steam} = 2174.4 \times 700$$

$$= \underline{1522 \times 10^3} \text{ kJ/s.}$$

This heat is gained by the CCW system every second.

Heat gained by CCW

Inlet temperature 5°C.

Outlet temperature 14°C.

Heat gained per kilogram of CCW

$= h_{f_{14}} - h_{f_5}$

$= 58.75 - 21.01$

$= \underline{37.74}$ kJ/kg.

The CCW removes 37.74 kJ for every kilogram of cooling water until 1522×10^3 kJ are removed every second.

Thus, the CCW flowrate is

$1522 \times 10^3/37.74$

$= \underline{40330}$ kg/s.