Self Evaluation

MODULE B.3.2

FEEDHEATER OPERATION

1. Perhaps the least confusing way to present this information is to use some form of a table and fill in the "Givens" and then work through the rest.

	Feedwater	Steam
Flowrate	Increase(G)	Increase
Inlet Temp 1	Constant(G)	Reduce
Outlet Temp 2	Reduce	N/A
Feedwater ΔT(2-1)	Reduce	N/A
Pressure	N/A	Reduce

(G) Information Given

As the feedwater flowrate increases, heat is being removed from the heater at a greater rate than is being supplied and the temperature in the heater starts to fall. As the temperature starts to fall, the pressure in the shell side of the heater also falls. The falling heater pressure increases the pressure difference which exists between the turbine and the feedheater and more extraction steam flows to the heater.

Although more heat is being transferred to the feedwater, the outlet temperature will have dropped because of the lower temperature existing in the heater shell and so the feedwater temperature rise across the heater will also fall.

2. The approach to this problem is to equate the heat gained by the feedwater to the heat lost by the extraction steam. The enthalpy rise of the feedwater is

$$h_{f_{162}} - h_{f_{134}} = 684.2 - 563.4 \text{ kJ/kg}$$

$$= \underline{120.8} \text{ kJ/kg.}$$

The total heat gained by the feedwater in one second is the product of the mass flow (740 kg/s) and the enthalpy change (120.8 kJ/kg).

Total heat gained = 740 x 120.8 kJ/s

= 89392 kJ/s.

Using the temperature/enthalpy diagram, we can see how much heat is lost by the extraction steam.

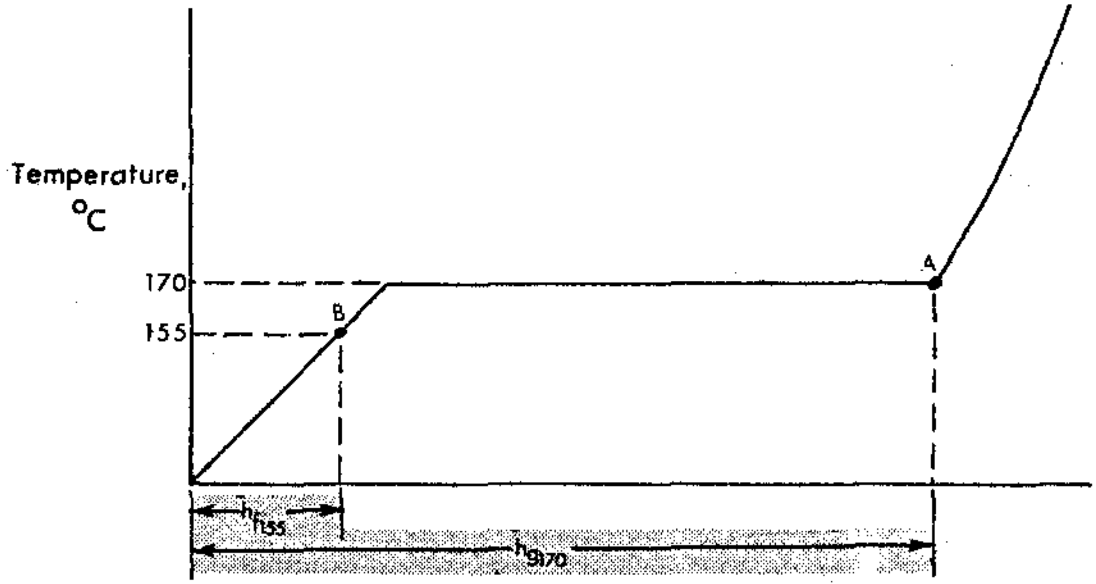

Fig. 3.2.9

The change in enthalpy is found by subtracting the enthalpy of the liquid at 155°C ($h_{f_{155}}$) from the enthalpy of the saturated steam at 170°C ($h_{g_{170}}$)

$h_{f_{155}}$ = 653.8 kJ/kg

$h_{g_{170}}$ = 2767.1 kJ/kg.

enthalpy change = 2767.1 - 653.8

= <u>2113.3</u> kJ/kg.

If $\overset{o}{m}$ is the mass of steam flowing per second, then $\overset{o}{m}$ x 2113.3 is the heat lost per second by the steam and gained by the feedwater.

Thus, 89392 = $\overset{o}{m}$ x 2113.3 kJ

and $\overset{o}{m}$ = 89392/2113.3 kg/s

= <u>42.3</u> kg/s.

3. In practice, the steam leaves the turbine with around 80% of its thermal energy unused. The majority of this energy will be rejected to the CCW system whilst the remainder will return to the feedwater system.

   There are two reasons for feedheating. The first is to use heat which would otherwise be rejected out of the system. The second is to increase the cycle efficiency by raising the feedwater temperature as close as possible to the saturation temperature in the steam generator.

   In the first case, low temperature steam shows high benefits for heating as the value for doing work in the turbine is small. As the steam temperature rises, the penalty of lost work in the turbine becomes greater if the steam is used for feedheating and there is an economic limit which on the Candu cycle leaves the feedwater inlet temperature to the preheater at around 175°C.

   Even if the first conditions were not applicable, there is a thermodynamic limit based on time and temperature difference, as to how close you can heat the feedwater to 250°C with steam at the same temperature.

4. In this exercise, we must consider the two cases of a turbine with and without feedheating. Before we go any further, some thought should be given to the conditions that we are going to use in the problem and make some statements as to the assumptions we have made.

   Assumptions

   a) You cannot compare the potential value of the steam in the turbine if the exhaust pressure/temperature is unknown.

   Assumption A Exhaust temperature is 35°C

   b) The exhaust steam is going to be wet and you could assume an ideal expansion, ie, isentropic expansion but this is academic and for the purposes of illustration, we should choose a practical value of moisture.

   Assumption B Exhaust moisture is 10%

   c) The heat recovered from the condensate will be affected by any subcooling which occurs in the condenser although this is an undesirable condition.

Assumption C Condensate in the hotwell is not subcooled.

d) We have to take a proportion of the turbine steam flow and use it for heating steam. In reality, the overall percentage is around 25% turbine steam flow extracted for feedheating. This figure is academic and if you average this percentage across five heaters, each heater would use roughly 5% of the total extraction steam flow. Use an easy figure for the purpose of demonstration.

Assumption D Extraction steamflow is 10%.

Now we are ready to consider the case of the turbine without feedheating.

A sketch of the temperature/enthalpy diagram is useful to identify the recoverable heat.

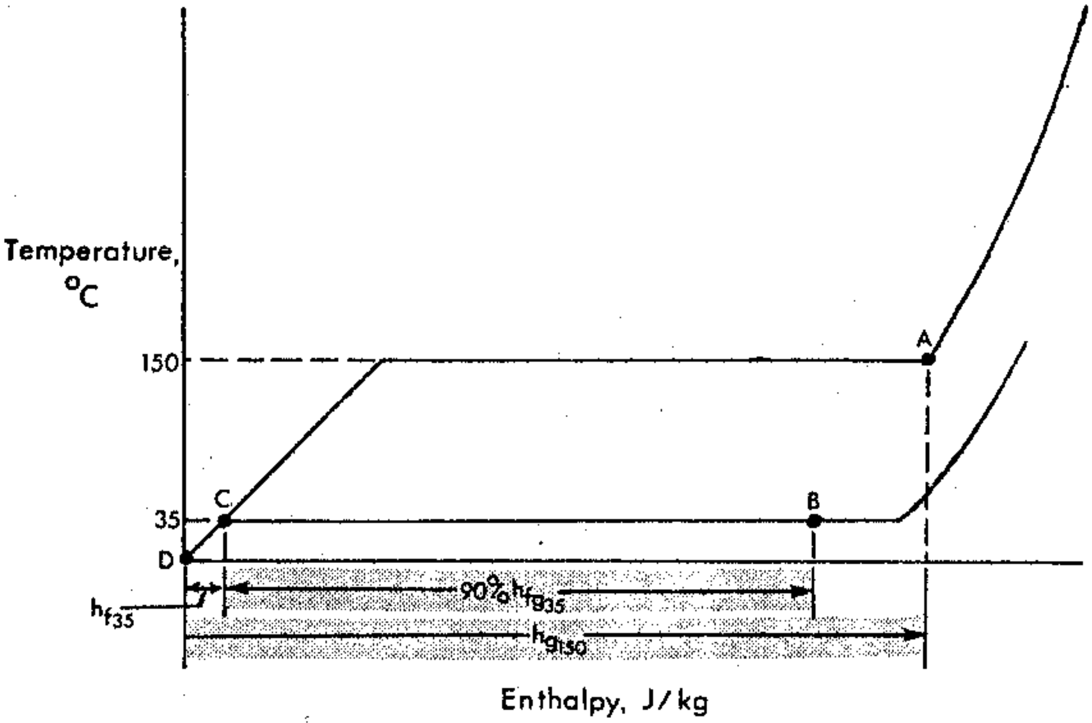

Fig. 3.2.10

A-B This represents the change in enthalpy from saturated steam at 150°C to steam having 10% moisture at a temperature of 35°C. This change in enthalpy represents the work done in the steam turbine.

B-C This is the heat rejected to the CCW in the condenser and is energy lost from the system.

C-D Represents the heat left in the condensate in the hotwell which is recovered when the condensate is returned to the feedheating system.

We can see that the only heat lost is the remaining latent heat. Thus, the recoverable heat per kilogram of steam entering the steam turbine is $h_{g_{150}} - h_{fg_{35}}$

$$h_{g_{150}} = 2745.4 \text{ kJ/kg}$$

$$h_{fg_{35}} = 2418.8 \text{ kJ/kg.}$$

The recoverable heat = 2745.4 - 0.9 (2418.8). (Remember the steam has already lost 10% of the latent heat because it is 10% wet.)

= 2745.4 - 2176.9

= <u>568.5</u> kJ/kg of steam at 150°C.

Turbine with Feedheating

If 10% of the steam is to be extracted for feedheating, then less work will be available and less condensate - in fact 10% less recoverable heat from the turbine.

Recoverable heat from the turbine with 10% steam extracted for feedheating is 90% of the recoverable heat from the turbine without feedheating = 0.9 x 568.5

= 511.7 kJ/kg of steam at 150°C.

Now we must consider the extraction steam and again a temperature/enthalpy diagram is useful.

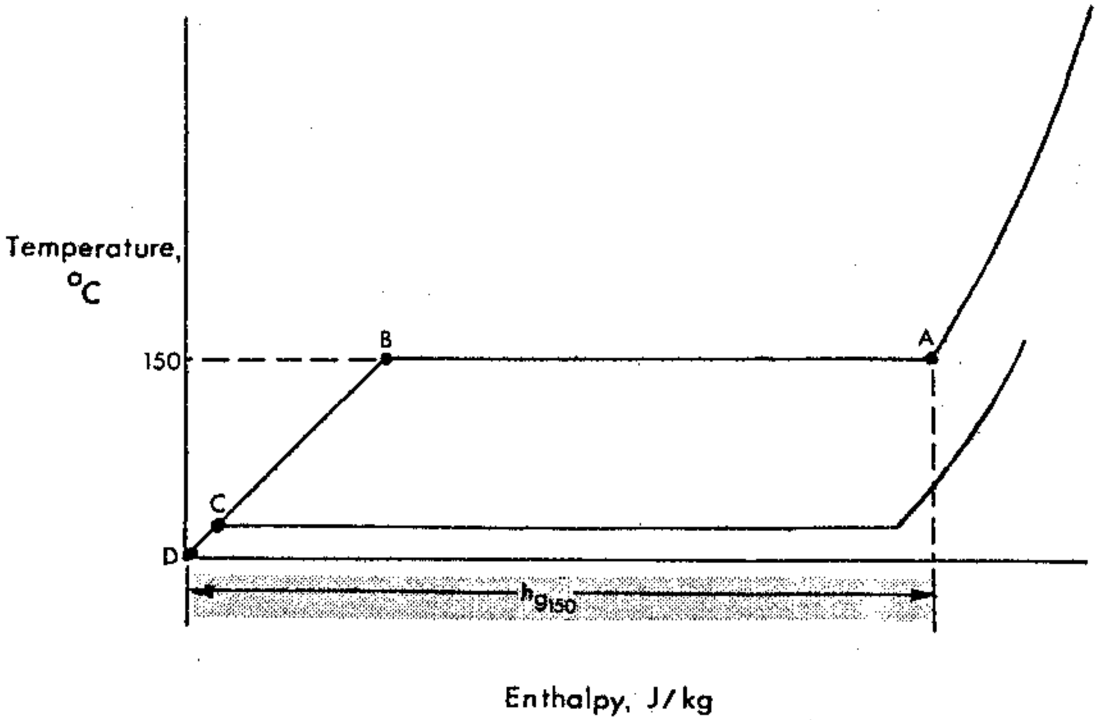

Fig. 3.2.11

A-B is the latent heat which is removed by the feedwater and causes condensation in the feedheater.

B-C This is the heating lost as the feedwater subcools the drains.

C-D is the heat left in the heater drains which remain in the system.

Consequently, no heat is lost from the system. All the heat from the extraction steam is recovered.

Recovered heat per kg = h_{g150}

$$h_{g150} = 2745.4 \text{ kJ/kg}$$

thus 0.1 kg has 274.5 kJ of heat.

Total recoverable heat using feedheating is 511.7 kJ from the turbine plus 274.5 kJ from the feedheater making a total of 786.2 kJ per kg of 150°C steam compared with 568.5 kJ/kg of 150°C steam in the turbine without feedheating.

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When you have compared your test with the self evaluation sheet, take both the test and self evaluation sheet to the Course/Shift Manager and let him discuss your test. If you are both satisfied with the results, ask the Manager to sign the personal progress summary sheet and proceed to Module B.3.1 "Condenser Performance".

If further reinforcement is necessary in some areas, work on these and take the test again when you are confident.