Self Evaluation

MODULE B.4.1

TURBINE WITH REHEAT

1. Both the moisture separation and reheat processes occur at constant pressure. On a Mollier diagram the moisture separation is shown as a line running from the intersection of the constant pressure line at 1.5 MPa and the 12% moisture line, up to the saturation line. The reheat process is shown as a continuation along the constant pressure line into the superheat region.

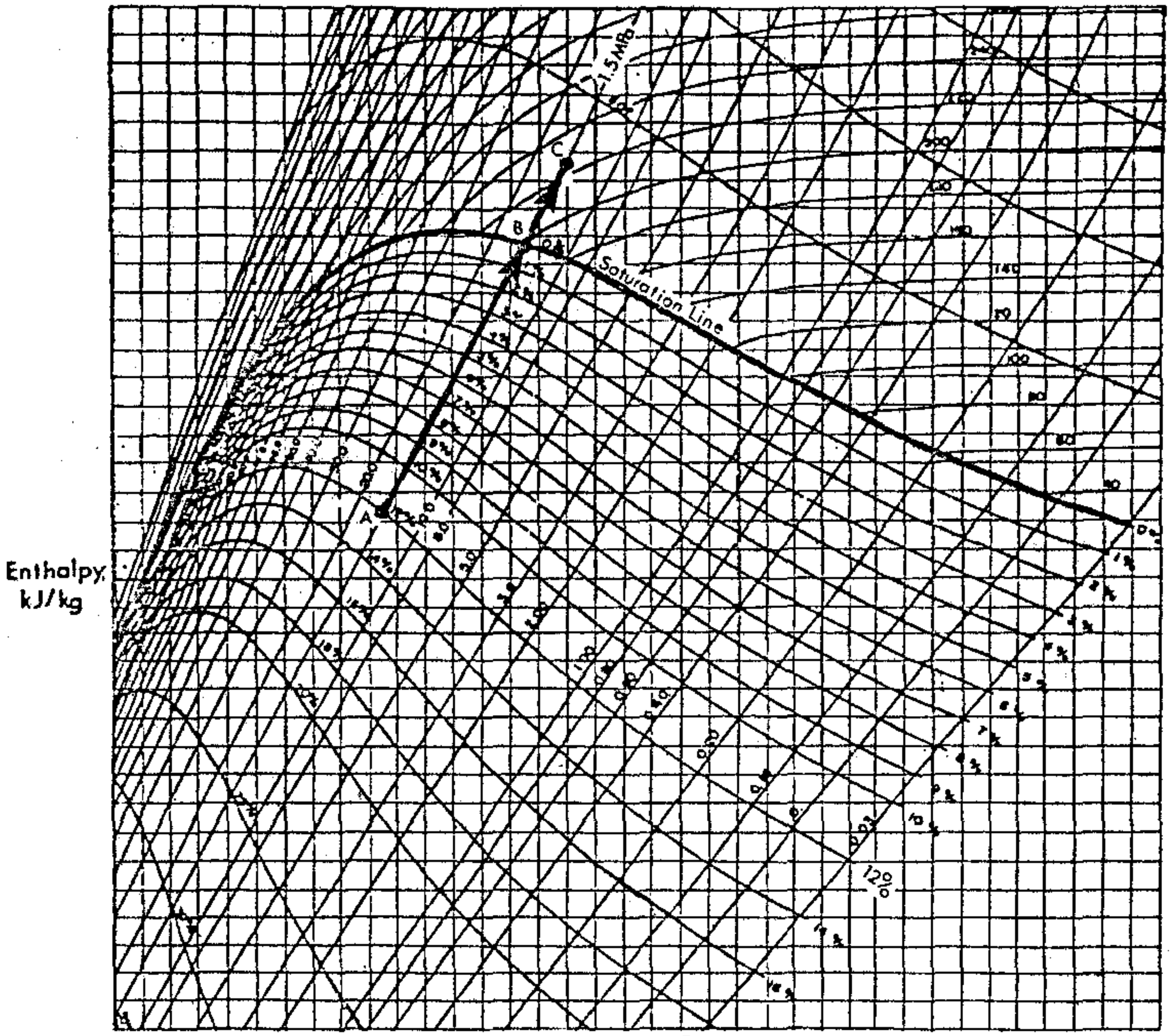

Fig.4.1.13

Step AB represents the moisture separation.
Step BC represents the reheat process.

Point	Flowrate	Pressure	Moisture Content
A	1100 kg/s	1.5 MPa	12%
B	968 kg/s	1.5 MPa	0%
C	968 kg/s	1.5 MPa	0%

Flowrate

This is reduced as the moisture is removed in the separator. Reduced flowrate out of the separator is 1100 x 0.88 = 968 kg/s.

Pressure

Ignoring the pressure drops through the system, there is no change in pressure.

Moisture Content

Reduced to zero in the moisture separator as saturated steam is produced and remains zero as the saturated steam is superheated in the reheater.

The next step to determine the temperature of the process steam leaving the reheater is based upon equating the heat lost by the heating steam in the reheater to the heat gained by the process steam in the reheater.

Heat Lost by the Heating Steam

The steam to the reheater is saturated at a pressure of 3.8 MPa. There is no subcooling of the condensate. This means that the heat removed from the heating steam is the latent heat h_{fg}. From tables h_{fg} = 1728.4 kJ/kg.

Total heat lost by the heating steam is the product of the mass flowrate, 36 kg/s and the enthalpy change, 1728.4 kJ/kg.

Heat lost per second = 39 x 1728.4 kJ

= 67408 kJ.

The heat lost by the heating steam is gained by the process steam. The heat gained per kg of process steam will be $\frac{1}{968}$ of 67408 kJ = $\frac{67408}{968}$ = 69.6 kJ/kg.

The enthalpy of the superheated process steam at 1.5 MPa is the sum of the enthalpy at saturation plus 69.6 kJ/kg.

From tables h_g at 1.5 MPa = 2790 kJ/kg.

Enthalpy of steam leaving the reheater,
2790 + 69.6 = 2859.6 kJ/kg.

Using superheated steam tables, we can find the temperature of the steam.

At 1.5 MPa and 200°C h = 2795 kJ/kg.
At 1.5 MPa and 250°C h = 2924 kJ/kg.

For a change of 50°C the difference in enthalpy is 129 kJ/kg. The enthalpy of the process steam is 2859.6 kJ/kg which is 2859.6 - 2795 = 64.6 kJ/kg due to superheating.

This is exactly half the difference between the enthalpy value at 200°C and that at 250°C, so the final temperature corresponding to the enthalpy will be 225°C.

2. In this question the solution is found by using the entropy of the initial condition and equating it to the final condition to determine the moisture content.

From superheated steam tables at 1.5 MPa, the entropy of steam at 225°C is the mean value of the entropy of 200°C, 6.451 kJ/kg°C and the value of entropy at 250°C, 6.710 kJ/kg°C.

Entropy at 225 = (6.710 + 6.451) 0.5

= 6.5805 kJ/kg°C.

Entropy remains constant throughout the turbine expansion because it is isentropic. We can equate the value of entropy of the superheated steam to the expression for the entropy of the wet steam at the turbine exhaust at a pressure of 15 kPa(a).

At 15 kPa(a) s_f = 0.7549 kJ/kg°C
s_{fg} = 7.2544 kJ/kg°C.

Equating the entropies:

$6.5805 = 0.7549 + q\ (7.2544)$

$5.8256 = q\ (7.2544)$

$q = \underline{80.3\%}.$

The moisture content is therefore 19.7%.

3. The steam entering the hp turbine is saturated, which means that the temperature and pressure are dependent on each other. If the pressure falls, then the temperature falls and vice versa.

At how loads and low steam flows significant throttling occurs past the GSV's which results in low pressure and temperature of steam entering the high pressure turbine. As the load increases the GSV's open further and reduce the throttling causing pressures and temperatures to increase throughout the turbine unit.

It is interesting to note that the temperature of the steam leaving the reheater actually decreases with increasing steam flow due to primarily to the shorter time available for heat transfer to the process steam in the reheater.

* * * * *

Discuss your test with the Course/Shift Manager and have your progress summary sheet signed off when you are both satisfied with the results.

When you are ready to progress, move to Module B.3.2 or B.2.