Self Evaluation

MODULE B.4.2

ENTROPY, THROTTLING & MOLLIER DIAGRAM

1. Using Table 1, S_g at 186°C = 6.5346 kJ/kg°C.

   At 42°C S_f = 0.5987 kJ/kg°C

   and S_{fg} = 7.6222 kJ/kg°C.

   The entropy before the expansion is equal to the entropy after the expansion.

   $$S_{g186} = S_{f42} + qS_{fg42}$$

   $$6.5346 = 0.5987 + q \times 7.6222$$

   $$5.9359 = q \times 7.6222$$

   $$q = \frac{5.9359}{7.6222}$$

   $$= \underline{77.9\%}.$$

2. a) Let's make two assumptions to help clarify the answer:

   i) the steam has moisture content 10%
   ii) the steam temperature is 150°C.

   From Table 1 h_f at 150°C is 632.1 kJ/kg; h_g at 150°C is 2745.4 kJ/kg.

   1 kg of the wet steam is composed of a mixture of 0.9 kg of saturated steam and 0.1 kg of saturated liquid. The enthalpy of the wet steam is:

   0.9 x (2745.4) + 0.1 x (632.1) = 2534.1 kJ/kg.

   After moisture separation, the steam is saturated at 150°C. Its enthalpy is 2745.4 kJ/kg.

   The enthalpy (which is per kg of fluid) has increased from 2534.1 kJ/kg to 2745.4 kJ/kg. However, for every kg of wet steam entering the moisture separator, 0.9 kg of saturated steam exits, ie, even though each kg of steam contains more heat after the moisture separator, there is 10% less steam flowing.

b) In the reheater, main steam from the balance header is used to heat the process steam. The temperature and enthalpy of the process steam is increased by this addition of heat. Temperature of process steam typically increases from around 175°C to 235°C.

3. Remember this is a constant enthalpy process. We can determine the enthalpy of the superheated steam. Using Table 3, at 1.5 bar and 150°C, the enthalpy is 2773 kJ/kg.

Before throttling, the steam is at 194°C. Using Table 1 h_f at 194°C = 825.4 kJ/kg

and h_{fg} = 1961.7 kJ/kg.

Using $h = h_f + qh_{fg}$

$$2773 = 825.4 + q \times 1961.7 \text{ kJ/kg}$$

$$1947.6 = q \times 1961.7$$

$$q = \frac{1947.6}{1961.7}$$

$$= 99.3\%.$$

4.

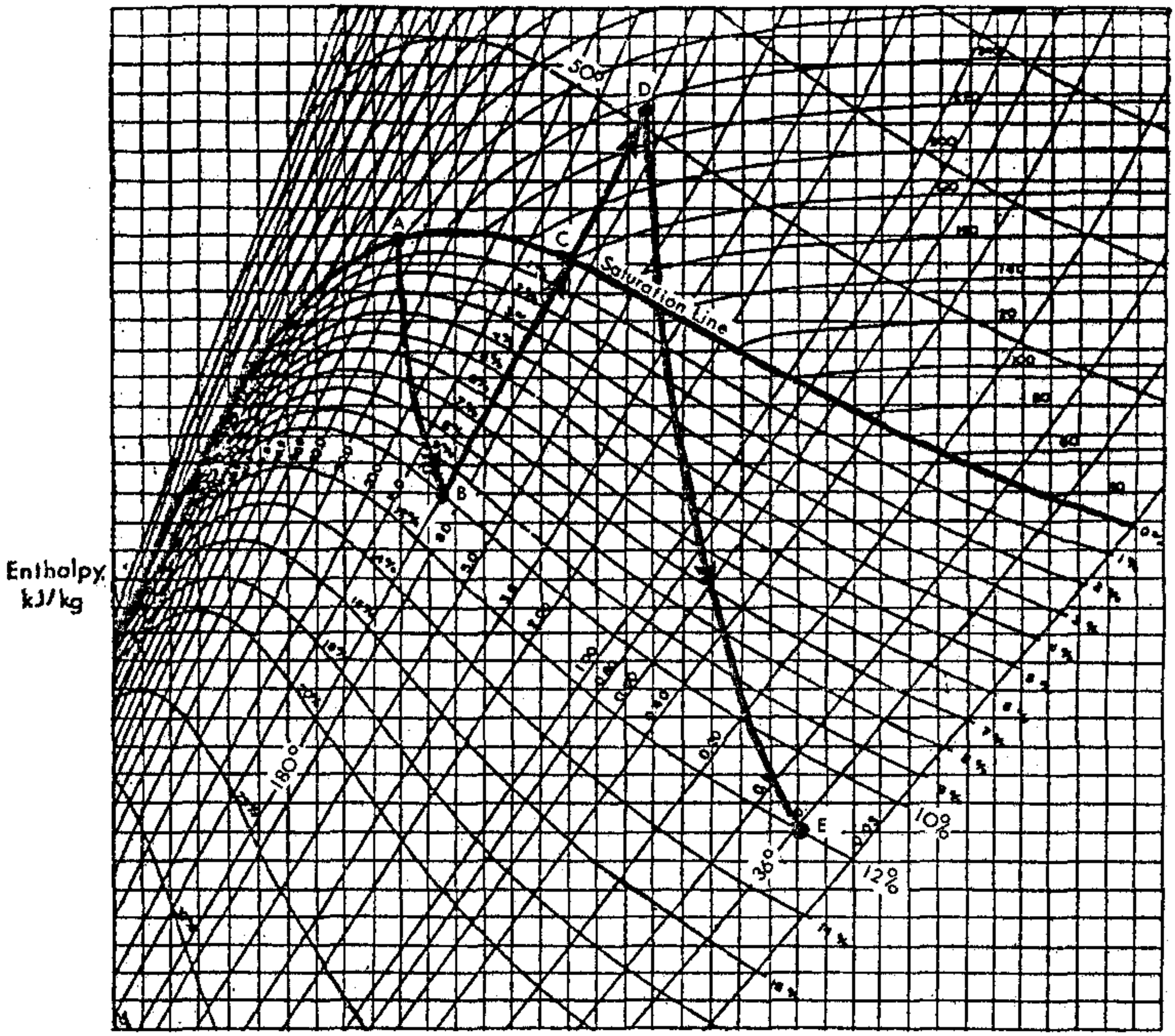

Fig. 4.2.20

A - B   hp turbine
B - C   moisture separator
C - D   reheater
D - E   lp turbine

5.

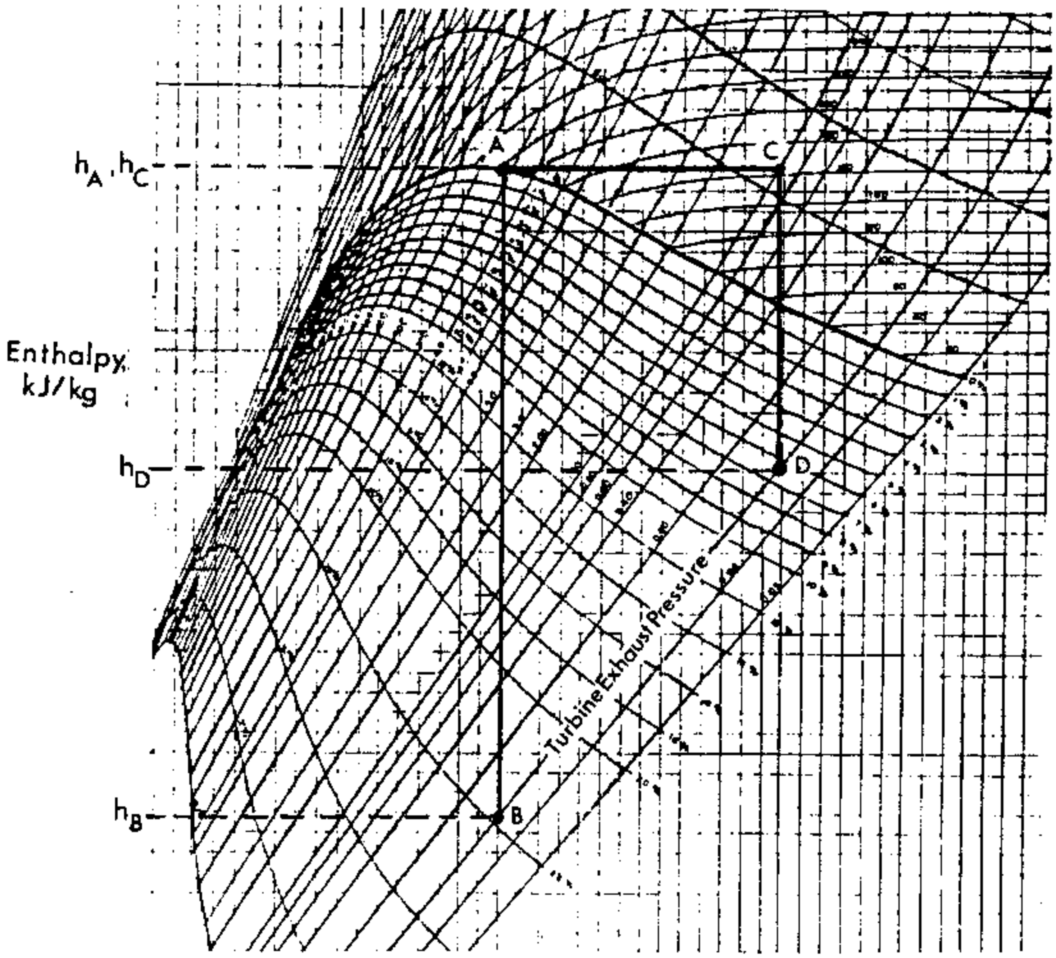

Fig. 4.2.22

Peak loading turbines operate at varying power levels, while base loading turbines generally operate at 100% power for long periods of time.

Let's assume that we have a peak loading turbine that will be operating at 50% power and that the unit has four governor steam valves. If the unit is nozzle governed, in principle, two governor valves will be wide open and two will be fully closed. No throttling will occur and the enthalpy drop available at the turbine is $h_A - h_B$. If the unit is throttle governed, all four governor valves will be partly open. Each valve will be throttling steam; the unit process is shown from A to C (throttling) then from C to D (turbine expansion). The enthalpy drop available at the turbine is $h_C - h_D$.

The enthalpy that is available in the nozzle governing system is greater than that available in the throttle governing system. This is true for all power levels up to 100%, so a peak loading turbine capable of operating at varying power levels will be nozzle governed.

In base load turbines that operate 100% power for the majority of operation, all the governor steam valves in both nozzle and throttle governing systems will be wide open and no throttling will occur. The enthalpy used by the turbine will be the same in either system, ie, $(h_A - h_B)$. The choice between systems is one of economics. Since throttle governing is less costly, due to simple turbine casing, governor valve sequencing and less complicated hydraulics, it is used for base load turbines.

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When you and the Course/Shift Manager are satisfied with your performance, have the progress summary sheet signed and proceed to Module B.4.1.