The number of plates to be provided = (5/0.6) = 8.33, say 9.
The feed is introduced just below the third ideal plate from the top, or just below the fifth actual plate.
The heat input at the boiler per unit mass of bottom product is:

$$\frac{Q_B}{W} = 582 - (-209) = 791$$

$$\text{Heat input to boiler} = (791 \times 0.78) = \underline{\underline{617 \text{ kW}}}$$

$$\text{Condenser duty} = \text{length NL} \times D$$

$$= (1984 - 296) \times 0.22$$

$$= \underline{\underline{372 \text{ kW}}}$$

11.5.4. Multiple feeds and sidestreams

The enthalpy–composition approach may also be used for multiple feeds and sidestreams for binary systems. For the condition of constant molar overflow, each additional sidestream or feed adds a further operating line and pole point to the system.

Taking the same system as used in Figure 11.22, with one sidestream only, the procedure is as shown in Figure 11.30.

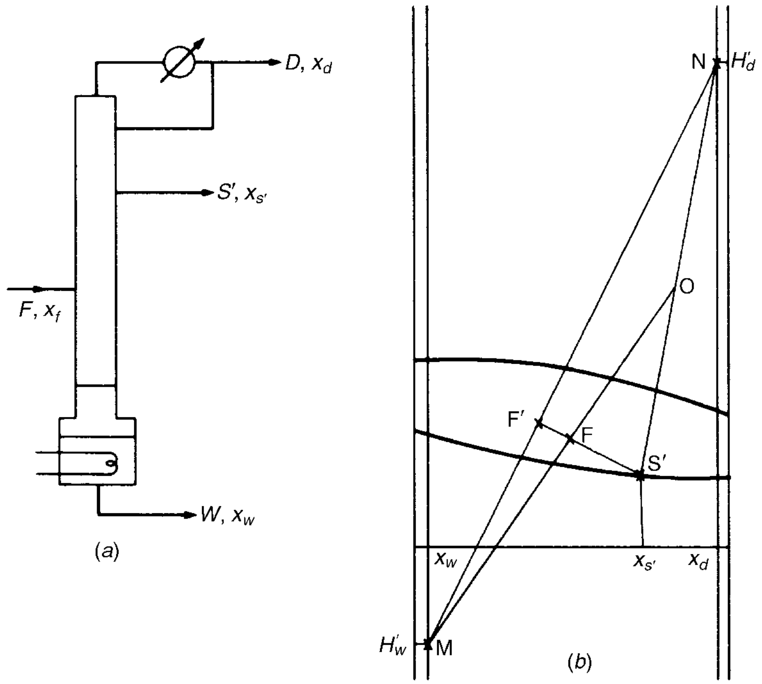

Figure 11.30. Enthalpy–composition diagram for a system with one sidestream

The upper pole point N is located as before. The effect of removing a sidestream S' from the system is to produce an effective feed F', where $F' = F - S'$ and where $F'S'/F'F = F/S'$. Thus, once S' and F have been located in the diagram, the position of F' may also be determined. The position of the lower pole point M, which must lie on the intersection of $x = x_w$ and the straight line drawn through NF′, may then be found. N relates to the section of the column above the sidestream and M to that part below the feed plate. A third pole point must be defined to handle that part of the column between the feed and the sidestream.

The pole point for the intermediate section must be on the limiting operating line for the upper part of the column, that is NS′. This must also lie on the limiting operating line for the lower part of the column, that is MF or its extension. Thus the intersection of NS′ and MF extended gives the position of the intermediate pole point O.

The number of stages required is determined in the same manner as before, using the upper pole point N for that part of the column between the sidestream and the top, the intermediate pole point O between the feed and the sidestream, and the lower pole point M between the feed and the bottom.

For the case of multiple feeds, the procedure is similar and may be followed by reference to Figure 11.31.

Example 11.11

A mixture containing equal parts by mass of carbon tetrachloride and toluene is to be fractionated to give an overhead product containing 95 mass per cent carbon tetrachloride, a bottom product of 5 mass per cent carbon tetrachloride, and a sidestream containing 80 mass per cent carbon tetrachloride. Both the feed and sidestream may be regarded as liquids at their boiling points.

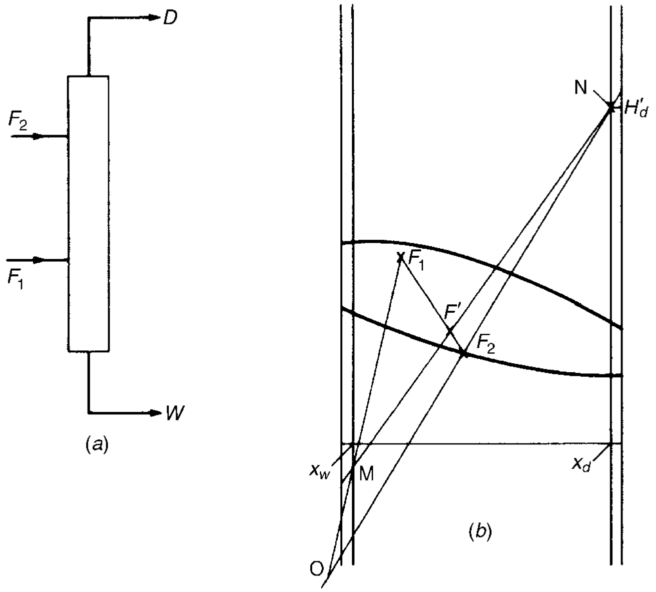

Figure 11.31. Enthalpy–composition diagram for a system with two feeds

The rate of withdrawal of the sidestream is 10 per cent of the column feed rate and the external reflux ratio is 2.5. Using the enthalpy composition method, determine the number of theoretical stages required, and the amounts of bottom product and distillate as percentages of the feed rate.

It may be assumed that the enthalpies of liquid and vapour are linear functions of composition. Enthalpy and equilibrium data are provided.

Solution

Basis: 100 kg feed.

An overall material balance gives:

$$F = D + W + S'$$

or:

$$100 = D + W + 10$$

$$Fx_f = Dx_d + Wx_w + S'x_{s'}$$

and:

$$50 = 0.95D + 0.05W + 8$$

Thus:

$$\underline{\underline{D = 41.7 \text{ per cent;} \quad W = 48.3 \text{ per cent}}}$$

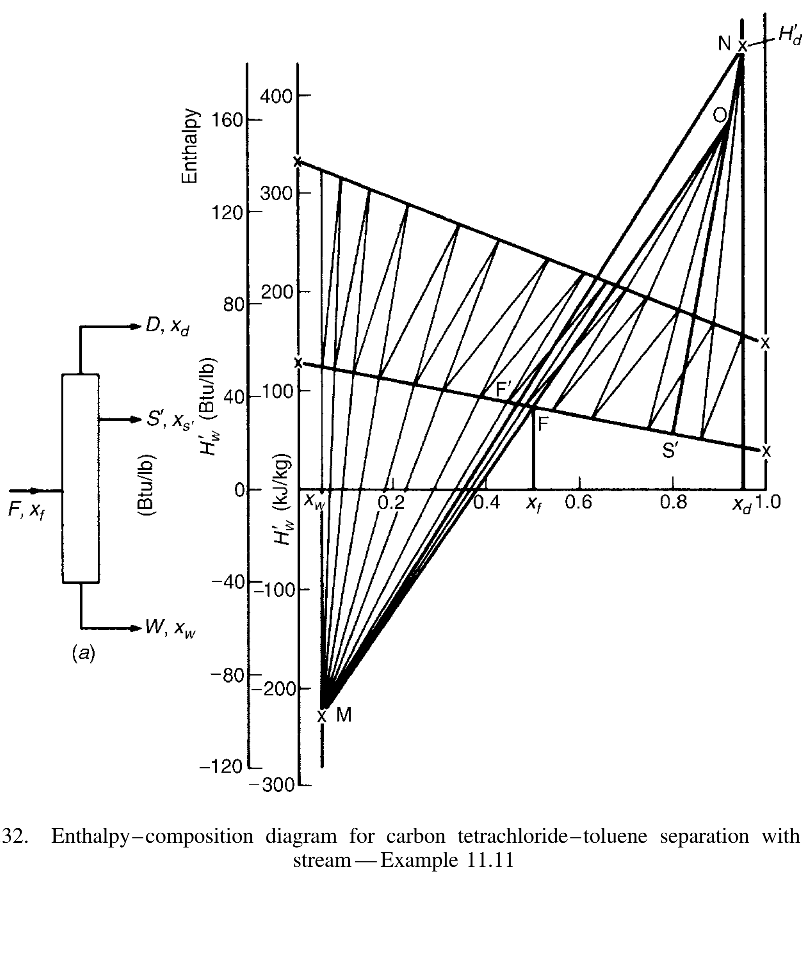

Figure 11.32. Enthalpy–composition diagram for carbon tetrachloride–toluene separation with one sidestream — Example 11.11

From the enthalpy data and the reflux ratio, the upper pole point M may be located as shown in Figure 11.32. Points F and S′ are located on the liquid line, and the position of the effective feed, such that F′S′/F′F = 10. NF′ is joined and extended to cut $x = x_w$ at M, the lower pole point.

MF is Joined and extended to cut NS′ at O, the immediate pole point. The number of stages required is then obtained from the figure and

13 theoretical stages are required.

11.6. BATCH DISTILLATION

11.6.1. The process

In the previous sections conditions have been considered in which there has been a continuous feed to the still and a continuous withdrawal of products from the top and bottom. In many instances processes are carried out in batches, and it is more convenient to distil each batch separately. In these cases the whole of a batch is run into the boiler of the still and, on heating, the vapour is passed into a fractionation column, as shown in Figure 11.33. As with continuous distillation, the composition of the top product depends on the still composition, the number of plates in the column and on the reflux ratio used. When the still is operating, since the top product will be relatively rich in the more volatile component, the liquid remaining in the still will become steadily weaker in this component. As a result, the purity of the top product will steadily fall. Thus, the still may be charged with S_1 mols of a mixture containing a mole fraction x_{s1} of the more volatile component. Initially, with a reflux ratio R_1, the top product has a composition

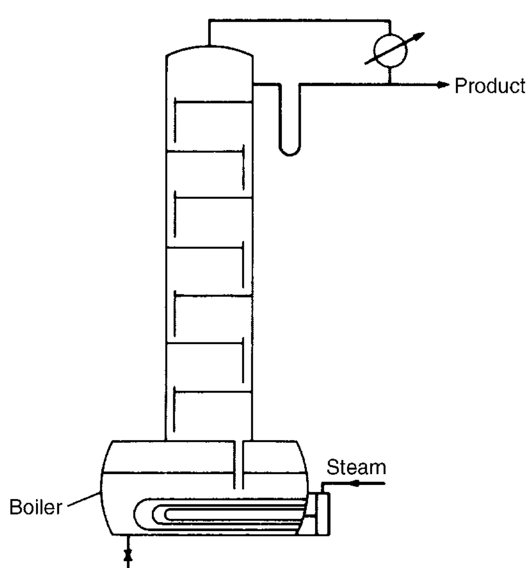

Figure 11.33. Column for batch distillation