

Because there is no simple equation relating n and dn/dR , it is not possible to obtain an expression for R_{opt} although a method of solution is given in the Example 11.18 which is based on the work of HARKER⁽³²⁾.

In practice, values of 110–150 per cent of the minimum reflux ratio are used although higher values are sometimes employed particularly in vacuum distillation. Where a high purity product is required, only limited improvements can be obtained by increasing the reflux ratio and since there is a very large increase in the number of trays required, an arrangement by which the minimum acceptable purity is achieved in the product is usually adopted.

11.4.4. Location of feed point in a continuous still

From Figure 11.20 it may be seen that, when stepping off plates down the top operating line AB, the bottom operating line CE cannot be used until the value of x_n on any plate is less than x_e . Again it is essential to pass to the lower line CE by the time $x_n = x_b$. The best conditions are those where the minimum number of plates is used. From the geometry of the figure, the largest steps in the enriching section occur down to the point of intersection of the operating lines at $x = x_q$. Below this value of x , the steps are larger on the lower operating line. Thus, although the column will operate for a feed composition between x_e and x_b , the minimum number of plates will be required if $x_f = x_q$. For a binary mixture at its boiling point, this is equivalent to making x_f equal to the composition of the liquid on the feed plate.

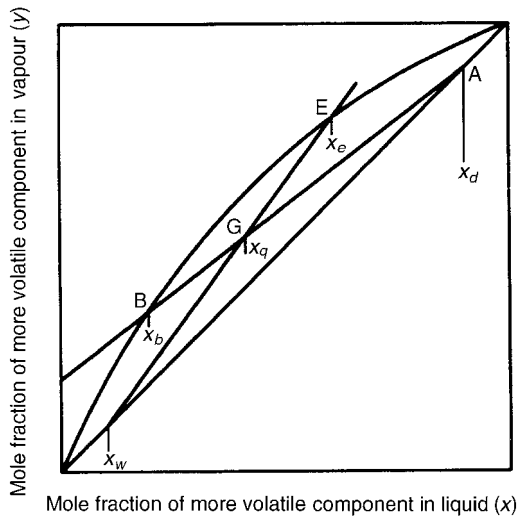


Figure 11.20. Location of feed point

11.4.5. Multiple feeds and sidestreams

In general, a sidestream is defined as any product stream other than the overhead product and the residue such as the streams S' , S'' , and S''' in Figure 11.21. In a similar way,

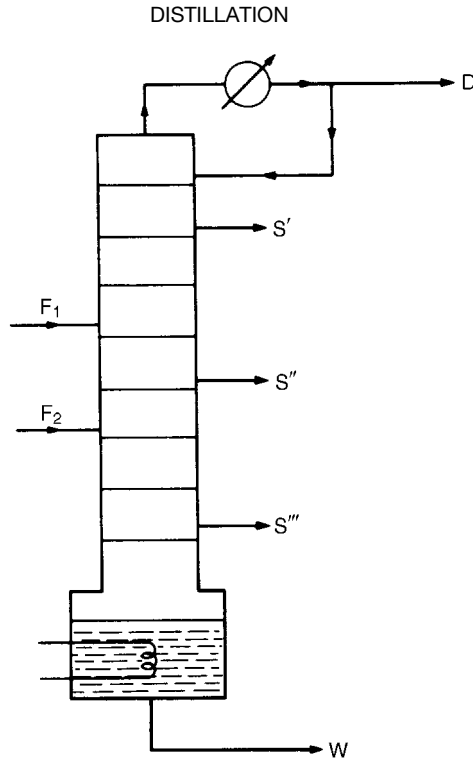


Figure 11.21. Column with multiple feeds and sidestreams

F_1 and F_2 are separate feed streams to the column. Sidestreams are most often removed with multicomponent systems, although they may be used with binary mixtures. A binary system is now considered, with one sidestream, as shown in Figure 11.22. S' represents the rate of removal of the sidestream and $x_{s'}$ its composition.

Assuming constant molar overflow, then for the part of the column above the sidestream the operating line is given by:

$$y_n = \frac{L_n}{V_n}x_{n+1} + \frac{Dx_d}{V_n} \tag{equation 11.35}$$

as before. Balances for the part of the tower above a plate between the feed plate and the sidestream give:

$$V_s = L_s + S' + D \tag{11.69}$$

and:
$$V_s y_n = L_s x_{n+1} + S' x_{s'} + D x_d \tag{11.70}$$

Thus:
$$y_n = \frac{L_s}{V_s} x_{n+1} + \frac{S' x_{s'} + D x_d}{V_s} \tag{11.71}$$

Since the sidestream is normally removed as a liquid, $L_s = (L_n - S')$ and $V_s = V_n$.

The line represented by equation 11.35 has a slope L_n/V_n and passes through the point (x_d, x_d) . Equation 11.71 represents a line of slope L_s/V_s , which passes through the point

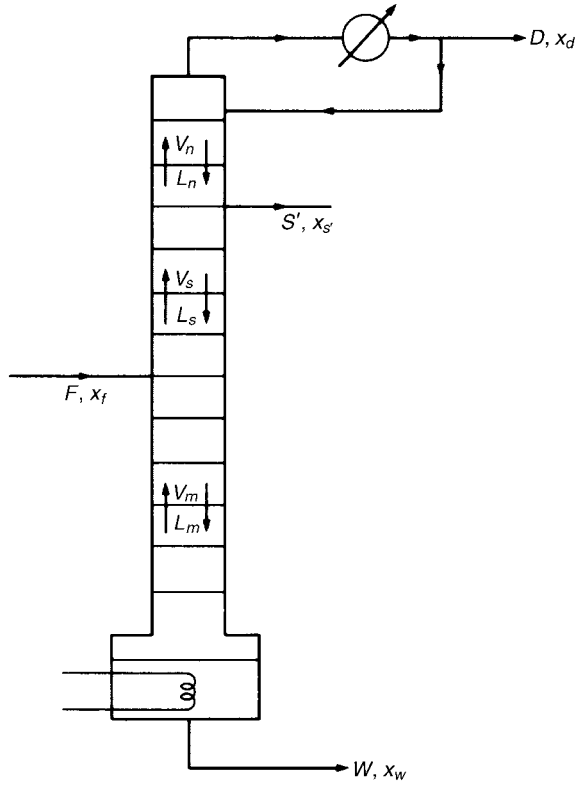


Figure 11.22. Column with a sidestream

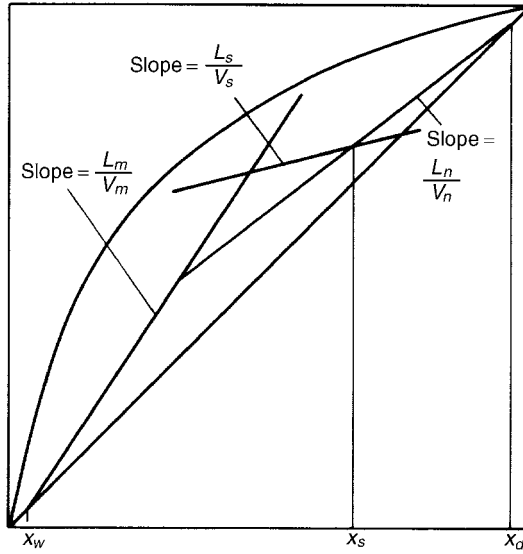


Figure 11.23. Effect of a sidestream

$y = x = (S'x_{s'} + Dx_d)/(S' + D)$, which is the mean molar composition of the overhead product and sidestream. Since $x_{s'} < x_d$, and $L_s < L_n$, this additional operating line cuts the $y = x$ line at a lower value than the upper operating line though it has a smaller slope, as shown in Figure 11.23. The two lines intersect at $x = x_{s'}$. Plates are stepped off as before between the appropriate operating line and the equilibrium curve. It may be seen that the removal of a sidestream increases the number of plates required, due to the decrease in liquid rate below the sidestream.

The effect of any additional sidestream or feed is to introduce an additional operating line for each stream. In all other respects the method of calculation is identical with that used for the straight separation of a binary mixture.

The Ponchon–Savarit method, using an enthalpy–composition diagram, may also be used to handle sidestreams and multiple feeds, though only for binary systems. This is dealt with in Section 11.5.

11.5. CONDITIONS FOR VARYING OVERFLOW IN NON-IDEAL BINARY SYSTEMS

11.5.1. The heat balance

In previous sections, the case of constant molar latent heat has been considered with no heat of mixing, and hence a constant molar rate of reflux in the column. These simplifying assumptions are extremely useful in that they enable a simple geometrical method to be used for finding the change in concentration on the plates and, whilst they are rarely entirely true in industrial conditions, they often provide a convenient start for design purposes. For a non-ideal system, where the molar latent heat is no longer constant and where there is a substantial heat of mixing, the calculations become much more tedious. For binary mixtures of this kind a graphical model has been developed by RUHEMANN⁽³³⁾, PONCHON⁽³⁴⁾, and SAVARIT⁽³⁵⁾, based on the use of an enthalpy–composition chart. A typical enthalpy–composition or $H - x$ chart is shown in Figure 11.24, where the upper curve V is the dew-point curve, and the lower curve L the boiling-point curve. The use of this diagram is based on the geometrical properties, as illustrated in Figure 11.25. A quantity of mixture in any physical state is known as a “phase” and is denoted by mass, composition and enthalpy. The phase is shown upon the diagram by a point which shows enthalpy and composition, though it does not show the mass. If m is the mass, x the composition and H the enthalpy per unit mass, then the addition of two phases A and B to give phase C is governed by:

$$m_A + m_B = m_C \quad (11.72)$$

$$m_A x_A + m_B x_B = m_C x_C \quad (11.73)$$

and:
$$m_A H_A + m_B H_B = m_C H_C \quad (11.74)$$

Similarly, if an amount Q of heat is added to a mass m_A of a phase, the increase in enthalpy from H_A to H_C will be given by:

$$H_A + \frac{Q}{m_A} = H_C \quad (11.75)$$