***Dew point*** The procedure is similar to that for the bubble point. The first estimate is 80°C (176°F), whence $\Sigma y_i/\alpha_{i,C_5} = 1.081$ (column 4 = $m_{C_5}$ [Eq. (9.29)]. The corresponding temperature is 83.7°C (183°F). Repetition leads to $m_{C_5} = 1.103$, corresponding to 84.0°C, which is the dew point. The corresponding dew-point-liquid compositions are listed in column 8 (0.00818/1.103 = 0.0074, etc.).

## SINGLE-STAGE OPERATION—FLASH VAPORIZATION

Flash vaporization, or equilibrium distillation as it is sometimes called, is a single-stage operation wherein a liquid mixture is partially vaporized, the vapor allowed to come to equilibrium with the residual liquid, and the resulting vapor and liquid phases are separated and removed from the apparatus. It may be batchwise or continuous.

A typical flowsheet is shown schematically in Fig. 9.13 for continuous operation. Here the liquid feed is heated in a conventional tubular heat exchanger or by passing it through the heated tubes of a fuel-fired furnace. The pressure is then reduced, vapor forms at the expense of the liquid adiabatically, and the mixture is introduced into a vapor-liquid separating vessel. The separator shown is of the cyclone type, where the feed is introduced tangentially into a covered annular space. The liquid portion of the mixture is thrown by centrifugal force to the outer wall and leaves at the bottom, while the vapor rises through the central chimney and leaves at the top. The vapor may then pass to a condenser, not shown in the figure. Particularly for flash vaporization of a volatile substance from a relatively nonvolatile one, operation in the separator can be carried out under reduced pressure, but not so low that ordinary cooling water will not condense the vapor product.

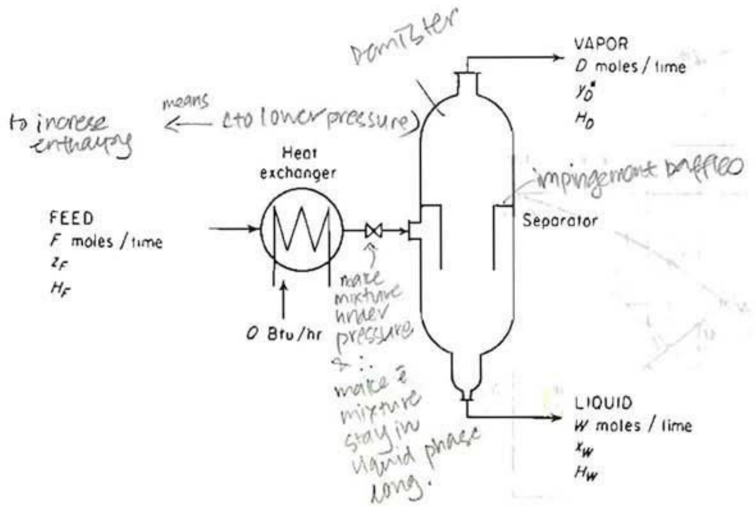


**Figure 9.13** Continuous flash vaporization.

The product, $D$ mol/time, richer in the more volatile substance, is in this case entirely a vapor. The material and enthalpy balances are

$$F = D + W \tag{9.31}$$

$$Fz_F = Dy_D + Wx_W \tag{9.32}$$

$$FH_F + Q = DH_D + WH_W \tag{9.33}$$

Solved simultaneously, these yield

$$-\frac{W}{D} = \frac{y_D - z_F}{x_W - z_F} = \frac{H_D - (H_F + Q/F)}{H_W - (H_F + Q/F)} \tag{9.34}$$

On the $Hxy$ diagram, this represents a straight line through points of coordinates $(H_D, y_D)$ representing $D$, $(H_W, x_W)$ representing $W$, and $(H_F + Q/F, z_F)$ representing the feed mixture after it leaves the heat exchanger of Fig. 9.13. It is shown on the upper part of Fig. 9.14 as the line $DW$. The two left-hand members of Eq. (9.34) represent the usual single-stage operating line on distribution coordinates, of negative slope as for all single-stage (cocurrent) operations (see Chap. 5), passing through compositions representing the influent and effluent streams, points $F$ and $M$ on the lower figure. If the effluent streams were in equilibrium, the device would be an equilibrium stage and the products

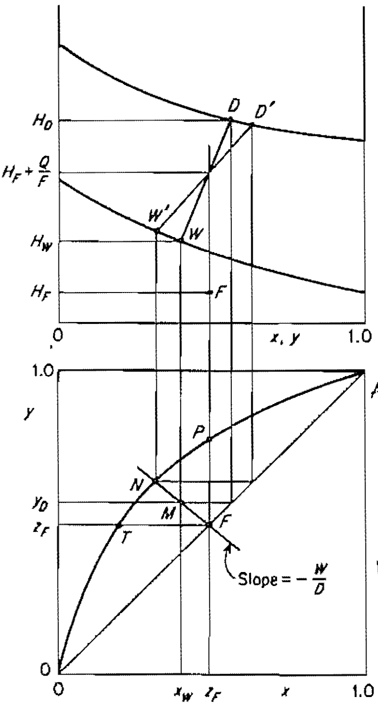


**Figure 9.14** Flash vaporization.

Actual process from F → M

N-M-P represents the flash vaporization process.

$D'$ and $W'$ would be on a tie line in the upper figure and on the equilibrium curve at $N$ on the lower figure. The richest vapor, but infinitesimal in amount, is that corresponding to $P$ at the bubble point of the feed; and the leanest liquid, but also infinitesimal in amount, is that corresponding to $T$ at the dew point of the feed. The compositions of the actual products will be between these limits, depending upon the extent of vaporization of the feed and the stage efficiency.

## Partial Condensation

All the equations apply equally well to the case where the feed is a vapor and $Q$, the heat removed in the heat exchanger to produce incomplete condensation, is taken as negative. On the upper part of Fig. 9.14, point $F$ is then either a saturated or superheated vapor.

**Illustration 9.4** A liquid mixture containing 50 mol % $n$-heptane (A), 50 mol % $n$-octane (B), at 30°C, is to be continuously flash-vaporized at 1 std atm pressure to vaporize 60 mol % of the feed. What will be the composition of the vapor and liquid and the temperature in the separator for an equilibrium stage?

SOLUTION *Basis*: $F = 100$ mol feed, $z_F = 0.50$. $D = 60$ mol, $W = 40$ mol, $-W/D = -40/60 = -0.667$.

The equilibrium data were determined in Illustration 9.1 and are plotted in Fig. 9.15. The point representing the feed composition is plotted at $P$, and the operating line is drawn with a slope $-0.667$ to intersect the equilibrium curve at $T$, where $y_D^* = 0.575$ mole fraction heptane and $x_W = 0.387$ mole fraction heptane. The temperature at $T$ is 113°C.

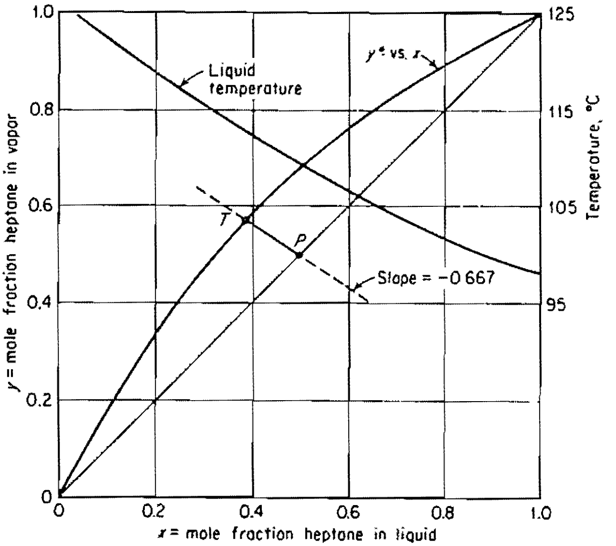


**Figure 9.15** Solution to Illustration 9.4.