But the heavy and light key material balances shown in Equations 5 and 6, result in Equation 7.

Equation 7 can be expressed in terms of mole fraction recovered, as shown in Equation 8.

When Equation 4 is substituted into Equation 1, expressing in terms of the light key component results in Equations 9 and 10. Expressing Equation 10 in terms of fractional recoveries results in Equations 11 and 12.

If Equations 1 and 2 are expressed in terms of the recoveries of the ith component, Equations 13-15 result. Therefore, the recovery of the ith component in the distillate is given by Equation 16, and the recovery of the ith component in the bottoms is given by Equations 17-19.

Fenske for total reflux

Fenske's equation for determining the minimum equilibrium stages at total reflux was based on an ideal mixture.[8] This suggests that the ratio of vapor pressures or the ratio of equilibrium vaporization of the key components is constant over the range of temperatures (the relative volatilities are constant).

Fenske expressed the minimum number of equilibrium stages by the use of Equation 20.

Gilliland method

The number of theoretical equilibrium stages required for a given separation at a given reflux ratio is often determined by empirical correlations.[9,10] The program uses the Gilliland correlation as shown in Fig. 2.

The abscissa, X, represents a reflux function $X = (R - R_m)/(R + 1)$, and the ordinate, Y, represents a stage function $Y = (N - N_m)/(N + 1)$.

The ratios used for the axes of abscissa and ordinate were chosen because they provide fixed end points for the curve ($X = 0.0$, $Y = 1.0$ and at $X = 1.0$, $Y = 0.0$). The two functions were found to give good correlations.

Gilliland's correlation has produced relevant results which offer the following advantages:

- They represent an optimum solution with regard to the location of the feed plate.
- The splitting for the two-key component is verified.
- The maximum deviation using Gilliland's correlation in terms of tray number is within a 7% range.[10]

Table 2

Example 1 results

INPUT

Input number of components?	4
Do you want equilibrium constants, Yes/No?	Y
Input feed and equilibrium K of each component?	0.06 2.15
	0.17 1.70
	0.32 0.835
	0.45 0.70
Input recoveries of light and heavy keys?	0.95 0.95
Input position of the heavy key component?	3
Input thermal feed condition Q?	1
Input factor for the reflux ratio?	1.3

OUTPUT
Multicomponent system fractionation

Component number	Feed moles	Rel. vol. alpha	Distillate %	Distillate Moles	Bottom, %	Bottom, Moles
1	0.0600	2.5749	99.2532	0.0596	0.7468	0.0004
2	0.1700	2.0359	95.0000	0.1615	5.0000	0.0085
3	0.3200	1.0000	5.0000	0.0160	95.0000	0.3040
4	0.4500	0.8383	1.2067	0.0054	98.7933	0.4446

The heavy key component number is:	3
Percentage recovery of the light key component in the distillate is:	95.00 %
Percentage recovery of the bottom key component in the bottoms is:	95.00 %
Minimum number of stages is:	8.3
Total moles in the distillate is:	0.2425
Total moles in the bottoms is:	0.7575
Underwood constant:	1.6213
Minimum reflux ratio:	2.8036
Actual reflux ratio:	3.6447
Number of theoretical plates in the column:	16.2
The position of the feed plate is:	6.7
Do you want to print the results of the program? yes/no	

Table 3

Stream composition, propane-butadiene separation

Number	Component	Feed, mol/hr	Rel. vol. α_i
1	Propylene	215.8	2.245
2	Propane (LK)	181.7	2.052
3	Butadiene (HK)	201.0	1.000
4	Butane	231.2	0.935
5	Pentane	170.3	0.433

Table 4

Example 2 results

INPUT

Input number of components?	5
Do you want equilibrium constants, Yes/No?	N
Input feed and relative volatility of each component	215.8 2.245
	181.7 2.052
	201.0 1.000
	231.2 0.935
	170.3 0.433
Input recoveries of light and heavy keys?	0.99 0.99
Input position of the heavy key component?	3
Input thermal feed condition Q?	1
Input factor for the reflux ratio?	1.37

OUTPUT
Multicomponent system fractionation

Component number	Feed moles	Rel. vol. alpha	Distillate rec. %	Distillate rec. Moles	Bottom, rec. %	Bottom, rec. Moles
1	215.8000	2.2450	99.6809	215.1115	0.3190	0.6885
2	181.7000	2.0520	99.0000	179.8830	1.0000	1.8170
3	201.0000	1.0000	1.0000	2.0100	99.0000	198.9900
4	231.2000	0.9350	0.4259	0.9847	99.5741	230.2153
5	170.3000	0.4330	0.0000	0.0000	100.000	170.3000

The heavy key component number is:	3
Percentage recovery of the light key component in the distillate is:	99.00 %
Percentage recovery of the heavy key component in the bottoms is:	99.00 %
Minimum number of stages is:	12.8
Total moles in the distillate is:	397.9892
Total moles in the bottoms is:	602.0107
Underwood constant:	1.3745
Minimum reflux ratio:	1.7441
Actual reflux ratio:	2.3895
Number of theoretical plates in the column:	24.2
The position of the feed plate is:	11.5