Multieffect Distillation for Thermally Coupled Configurations

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A systematic method presented draws multieffect configurations for any thermally coupled multicomponent distillation scheme. For ternary mixtures, all the resulting double-effect configurations are presented for each of the five known thermally coupled configurations. For most feed conditions, some of these configurations often require substantially lower heat duty than the double-effect configurations derived from conventional distillation schemes, such as direct and indirect splits and prefractionator. Essential features of the resulting multieffect configurations are that some of the product streams are produced from more than one distillation column and the transfer of at least one mixture stream takes place between intermediate locations in the distillation columns. This method opens up many more multieffect distillation possibilities for multicomponent feed mixtures.

Introduction

In multieffect distillation, the overhead vapor from a column operating at a high pressure is condensed by supplying heat to the bottom reboiler of a second column operating at a lower pressure. This method of heat integration reduces the overall heat demand of a distillation process because heat supplied to the high-pressure column is also utilized for distillation in the low-pressure column. More than two distillation columns can also be used, whereby heat supplied to one or more high-pressure columns is ultimately transferred to two or more lower pressure columns. When only two distillation columns are heat integrated by this method, it is referred to as double-effect distillation. Double-effect distillation is used extensively in cryogenic separations, because it reduces the amount of heat input and heat removal at subambient temperature. One of the first such applications was for cryogenic air distillation to recover oxygen from nitrogen. Thousands of plants using this concept have been built in the past 100 years.

For binary mixtures, a large number of studies on multieffect distillation are available in the literature (Wankat, 1993). Luyben and coworkers found a 35 to 45% reduction in steam usage for a methanol/water and a propylene/propane splitter using double-effect distillation schemes (Tyreus and Luyben, 1975, 1976; Chiang and Luyben, 1983). An industrial example of double-effect distillation where xylol solvent was recovered from a mixture of other organics is given by O'Brien (1976). Wankat (1993) enumerated a large number of double-effect and multieffect configurations for binary mixtures, and concluded that multieffect distillation can lead to significant energy savings with only a modest increase in capital investment.

There are a number of studies using multieffect distillation configurations for mixtures containing more than two components (Rathore et al., 1974a,b; Kattan and Douglas, 1986; Kakhu and Flower, 1988). In each of the configurations described in these studies, every distillation column receives a feed, does sharp separation, and produces an overhead vapor and a bottom liquid stream. The overhead vapor streams from some of the distillation columns are condensed by heat exchange with the bottoms liquid of the other columns to provide multieffect distillation. Andrecovich and Westerberg (1985) have presented a method to select such multieffect distillation configurations quickly and easily. The details of the method are well explained in a book by Biegler et al. (1997).

Recently, a number of articles studying double-effect distillation for ternary separations have been published (Takama et al., 1982; Cheng and Luyben, 1985; Ding and Luyben, 1990). Three classical ternary schemes, direct, indirect and prefractionator, are heat integrated using the double-effect method. Each of these classical configurations uses two distillation columns, and every column has a bottom reboiler and a top condenser. Therefore, the condenser of one of the distillation columns can be heat integrated with the reboiler of the other column, and there are two possible ways to implement the double-effect method. All of these known configurations are shown in Figure 1. In these figures and throughout this article, components in a mixture are ranked according to their relative volatility, that is, for feed mixture ABC, A is the most volatile component and volatility decreases in

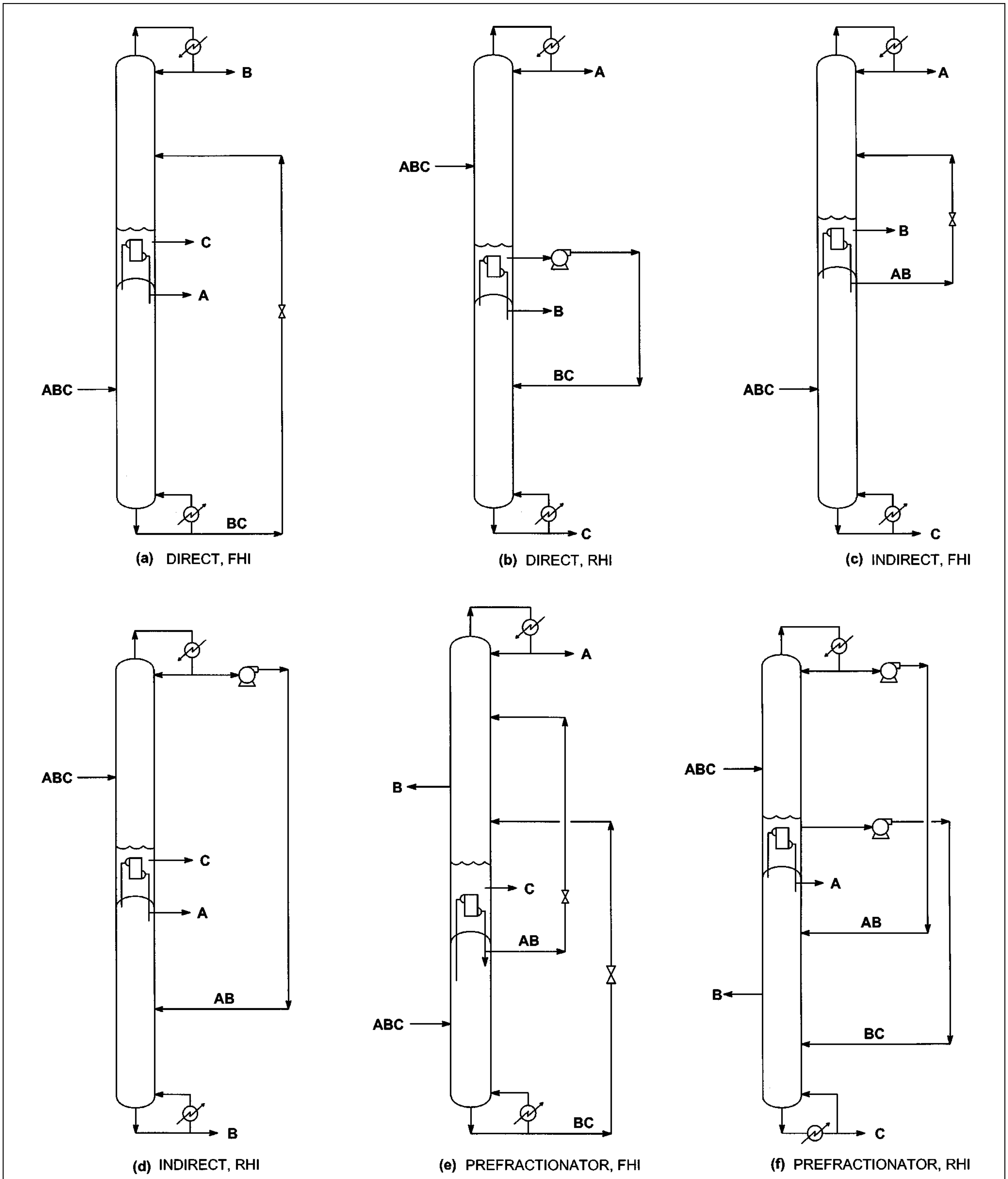

Figure 1. Double-effect distillations for classical configurations.

FHI is forward heat integration; RHI is reverse heat integration.

successive order, with C being the least volatile. When the condenser of the column receiving the feed is integrated with the reboiler of the other column, the feed column operates at a higher pressure and integration is known as forward heat integration. On the other hand, it is called reverse heat integration when feed is fed to the lower-pressure column and its reboiler is heat integrated with the condensing overhead vapor from the other distillation column.

Double-effect distillation has the potential to reduce heat duty by almost 50% of the heat duty of classical ternary schemes. The level of savings will depend on the relative volatilities and the feed compositions. It is worth noting that these savings come with a cost of temperature levels at which utilities are needed. Either the temperature of the heat source supplying heat to the reboiler goes up and/or the temperature at which heat is rejected in the condenser goes down. Westerberg (1985) has referred to this as a tradeoff between the first law duty and the second law ΔTs. When there is a substantial decrease in the total heat duty, the increased unit cost of the utilities may be economically justifiable. Control studies of the double-effect configurations in Figure 1 have found them to be quite operable (Ding and Luyben, 1990; Mizsey et al., 1998; Bildea and Dimian, 1999).

For a ternary distillation, it is well known that thermal coupling between distillation columns operating at similar pressures can lead to a substantial decrease in heat duty (Fidkowski and Królikowski, 1987). The classical thermal coupling between two distillation columns requires two-way communication, whereby both vapor and liquid streams are transferred in opposite directions between one specific location in each of the distillation columns. For a ternary mixture, there are five known thermally coupled schemes: side stripper, side rectifier, fully-coupled (also known as the Petlyuk configuration), side stripper with direct liquid connection (SL), and side rectifier with direct vapor connection (RV). A description of these configurations can be found in Agrawal (2000).

Since thermally coupled configurations can often require up to 30 to 40% less heat duty than the conventional direct and indirect configurations, Annakou and Mizsey (1996) performed a parametric study comparing the performance of the fully-coupled configuration with the double-effect configurations of direct and indirect schemes. They found that

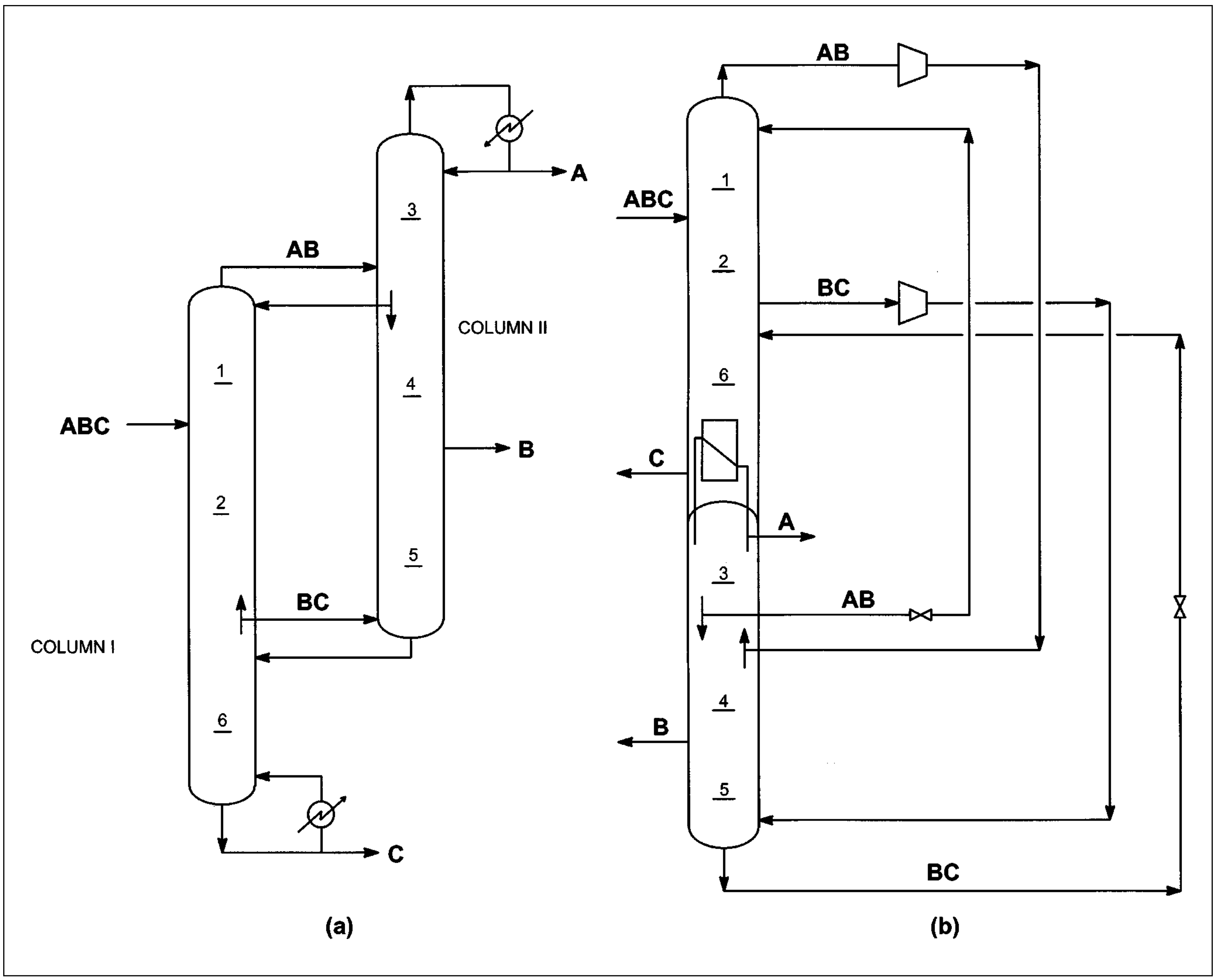

Figure 2. (a) Fully-coupled distillation; (b) initial attempt to draw a double-effect configuration.

double-effect configurations reduced the total heat duty by 10% to 50% when compared to the original direct and indirect schemes. However, a striking result of their parametric study is that the double-effect configurations are economical more frequently than the fully-coupled configuration, and in cases of sharp separations, they are always more economical. However, it would be more interesting to compare the results if double-effect versions of the thermally coupled configurations could be included in such parametric studies

Since a two-way communication in a thermally coupled scheme involves transfer of both vapor and liquid streams, researchers have concluded that both of the distillation columns in a ternary distillation must operate at similar pressures (Linnhoff et al., 1983). The heat integration in a double-effect distillation requires that one column operate at a significantly higher pressure than the other. Furthermore, the problem with the fully-coupled configuration, as originally proposed by Petlyuk et al. (1965), is that both the reboiler and condenser reside in the same distillation column.

The objective of this article is to present a generalized framework to draw multieffect distillation configurations for thermally coupled multicomponent separations. The method will first be illustrated for a ternary mixture and then extended to mixtures containing four or more components.

Ternary Distillation

Figure 2 shows an initial attempt to draw a double-effect configuration for a fully-coupled scheme. Figure 2a shows a fully-coupled scheme where the reboiler and condenser are on different distillation columns (Agrawal, 1999). The resulting double-effect version is shown in Figure 2b. The feed is fed to the low-pressure column. The two-way communications of the original configuration in Figure 2a requires that vapor streams from two different locations of the low-pressure column be compressed and sent to two locations of the high-pressure column, and two liquid streams are returned from the high-pressure column to the low-pressure column. All of the vapor flow to the high-pressure column is provided from the low-pressure column which in return gets its vapor flow through the condensation of the vapor from the high-pressure column. There is no external source of vapor generation shown in Figure 2b. Due to these connections, it will be very difficult to start and operate such a double-effect configuration. Generally, it is more desirable to have double-effect configuration where only liquid streams are transferred between the distillation columns and external heat and cold utilities are used for the distillation.

The trick to drawing double-effect configurations of thermally coupled distillations which are more convenient to start and operate is first to draw equivalent thermally coupled configurations with minimum or no vapor transfers between distillation columns. Such equivalent thermally coupled configurations are described in Agrawal (2000). In such cases, each of the distillation columns would have a bottom reboiler and a top condenser. For a double-effect configuration, the condenser of one column may be heat-integrated with the reboiler of the other column. This will lead to two possible double-effect configurations, one with forward heat integration and the second with reverse heat integration.

For a side stripper arrangement, the equivalent thermally coupled and the two resulting double-effect configurations are shown in Figure 3. Similarly, double-effect configurations for side rectifier and fully-coupled distillations are shown in Figures 4 and 5. When compared to the double-effect configurations of conventional distillation schemes in Figure 1, these new double-effect configurations produce pure product streams at both ends of each of the distillation columns. The binary mixture streams are not transferred from either the top or the bottom end of one distillation column to an intermediate location of another distillation column. The double-effect side stripper configurations in Figures 3c and 3d can be compared with the corresponding double-effect configurations for indirect split distillation in Figures 1c and 1d. For forward heat integration, a distillation section is added to the top of the high-pressure column in Figure 1c to obtain Figure 3c. Therefore, for the same pressure in the low-pressure column, the pressure of the high-pressure column will be greater in the new double-effect configuration of Figure 3c. This will lead to an increase in temperature of the bottom sump liquid in the high-pressure column and could require a higher temperature heat source for boilup. Similarly, when thermally coupled configurations in Figures 1d and 3d are compared, the columns can be operated at similar pressures, but the temperature at the top of the low-pressure column will be lower for the new configuration and could require a cold utility at a lower temperature. Also, the double-effect side rectifier configurations in Figures 4c and 4d can be compared with the corresponding double-effect direct split configurations in Figures 1a and 1b.

For an SL configuration, the equivalent and double-effect configurations are shown in Figure 6. The corresponding configurations for a side rectifier with direct liquid connection (RL) are shown in Figure 7. It is interesting to compare the double-effect configurations in Figures 5 through 7 with the double-effect configurations of a prefractionator scheme in Figures 1e and 1f. In all these double-effect configurations both the binary mixtures AB and BC are transferred from one column to the other column. The only difference is that in case of the double-effect prefractionator configurations, each of these streams are withdrawn from either end of a distillation column. Whereas in the double-effect configurations of Figures 6 and 7, one binary stream is withdrawn from one end of a column and the other binary stream is withdrawn from an intermediate location of the same column. The column pressures for the configurations in Figures 1e and 7c, and 1f and 6d can be similar. Whereas the high-pressure column pressure for the double-effect fully-coupled configuration in Figures 5c and 5d will always be at the highest value. It turns out that the double-effect configurations in Figures 5 through 7 could also be derived from the double-effect configurations of the prefractionator in Figures 1e and 1f by judiciously adding one or two distillation sections to the distillation column which provides both binary mixtures for the transfers.

Because a binary distillation can be performed in a single distillation column, the benefit of heat duty reduction in a double-effect configuration comes with the cost of an additional distillation column. Ternary distillation, however, generally requires two distillation columns and, therefore, heat duty reduction due to double-effect comes without any increase in the number of distillation columns. This can make the economics of double-effect distillation for ternary mixtures quite attractive. In this case, however, the reduction in heat duty due to double-effect comes at the cost of the temperature levels at which utilities are needed.

The overall savings in heat duty due to double-effect will

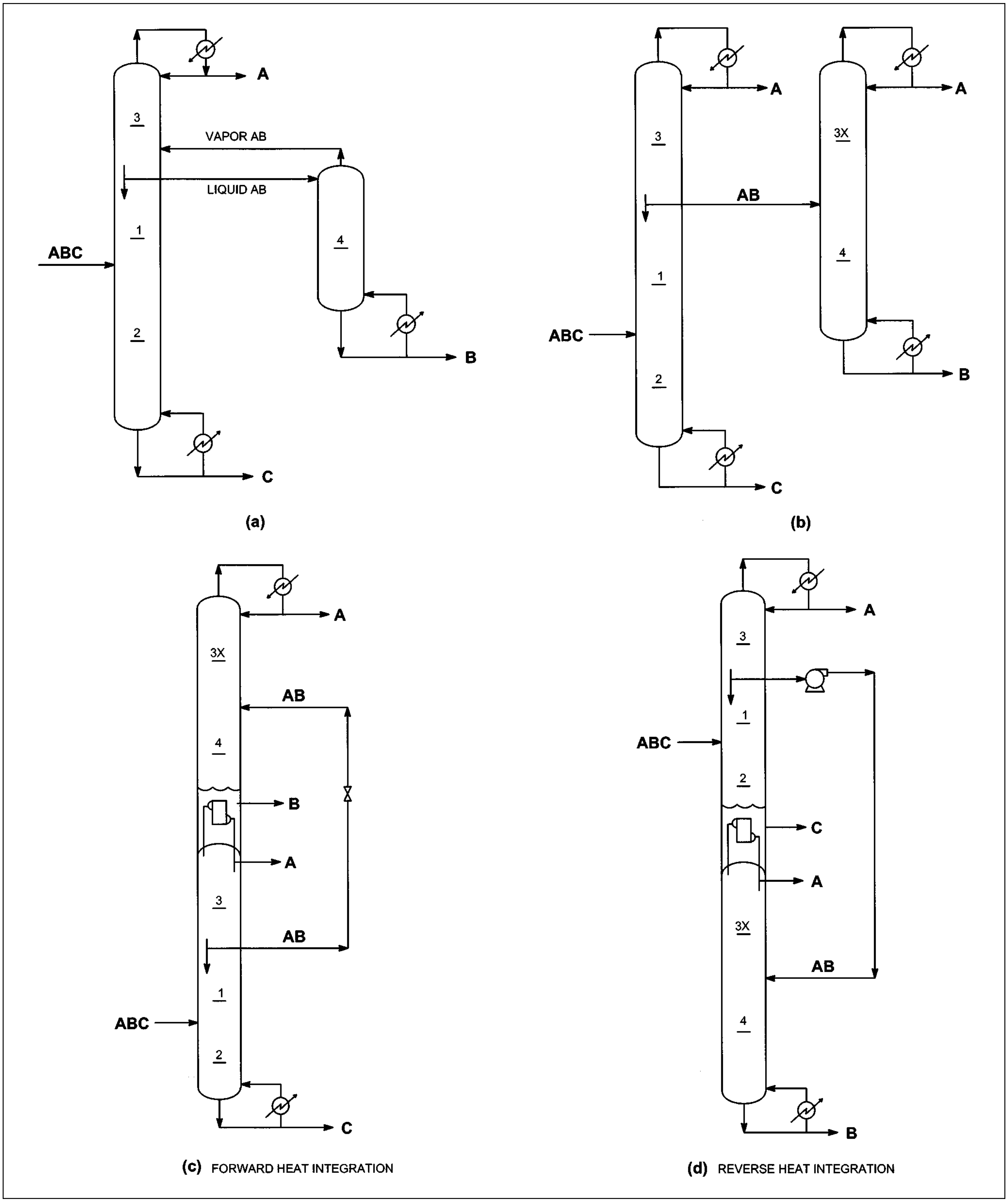

Figure 3. (a) Side stripper; (b) equivalent side stripper; (c) and (d) corresponding double-effect configurations.

depend on the magnitudes of the vapor flows in the two distillation columns of the original thermally coupled configuration. If the vapor flows are nearly equal, then an overall savings approaching 50% can be expected. On the other hand, if the vapor flows in the distillation columns are quite dissimilar, then the improvement due to the double effect will be

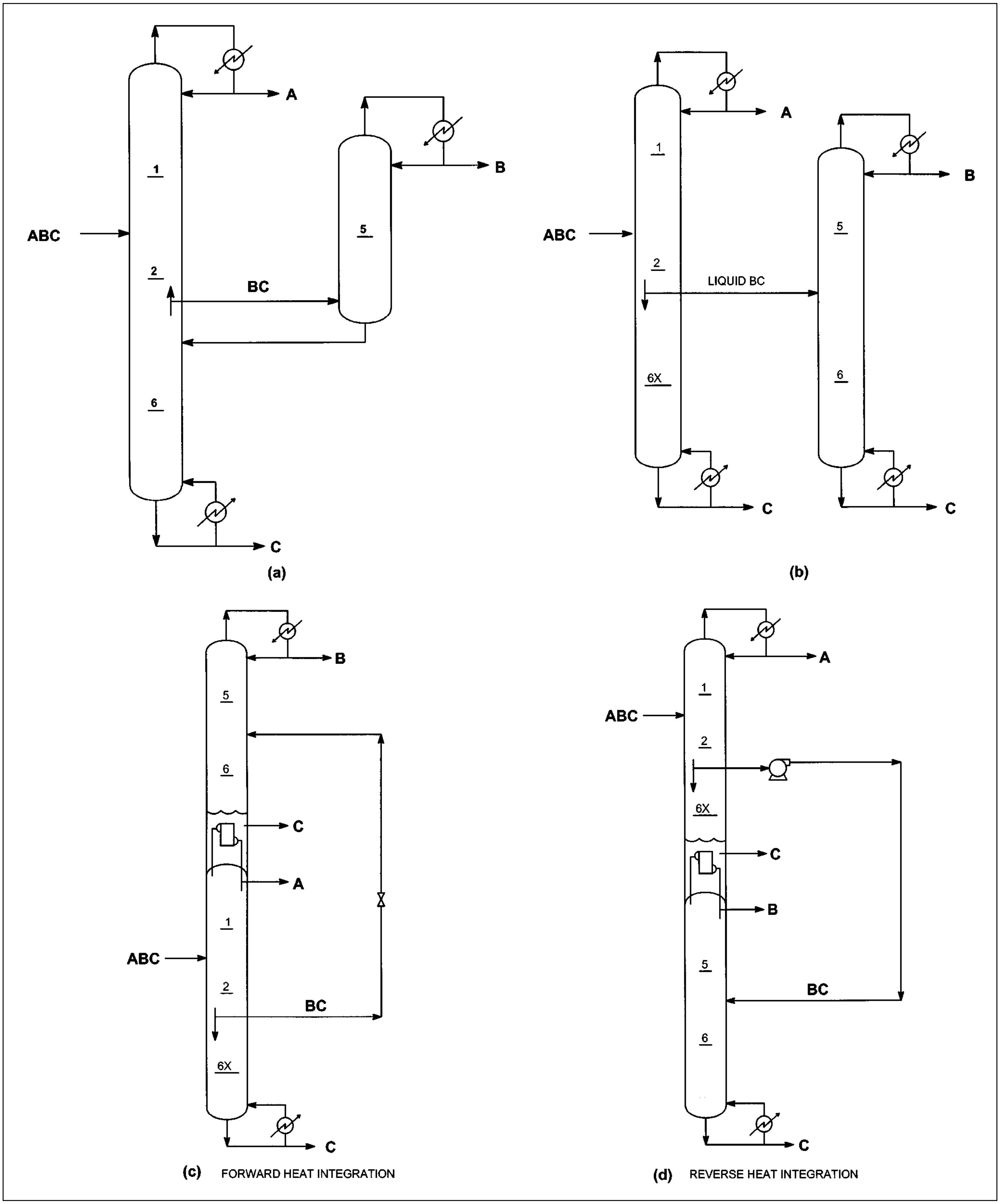

Figure 4. (a) Side rectifier; (b) equivalent side rectifier; (c) and (d) corresponding double-effect configurations.

low. It is well known that the thermally coupled configurations as a group require much lower heat duty than conventional direct and indirect split configurations. Therefore, it is logical to expect much lower heat duties of double-effect configurations derived from the thermally coupled configurations as compared to the double-effect configurations of di-

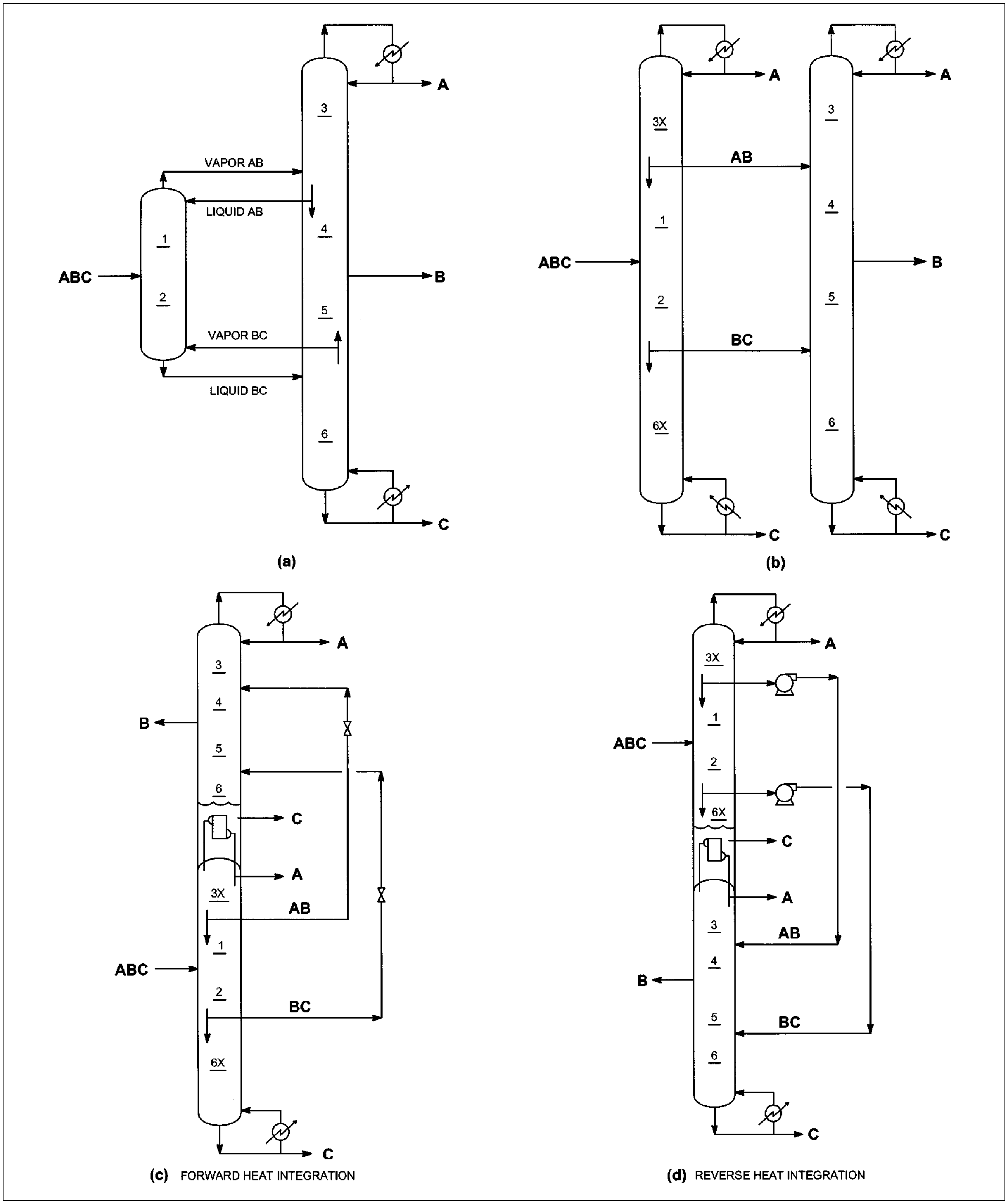

Figure 5. (a) Fully-coupled; (b) equivalent fully-coupled; (c) and (d) corresponding double-effect configurations.

rect and indirect schemes. However, the feed conditions for which the fully-coupled configuration gives much lower heat duty as compared to the other thermally coupled and prefractionator configurations is somewhat limited. Therefore, for a given feed, it is difficult to say if the double-effect fully-coupled configuration would require *significantly* lower heat duty as compared to other double-effect thermally coupled and double-effect prefractionator configurations. It is ob-

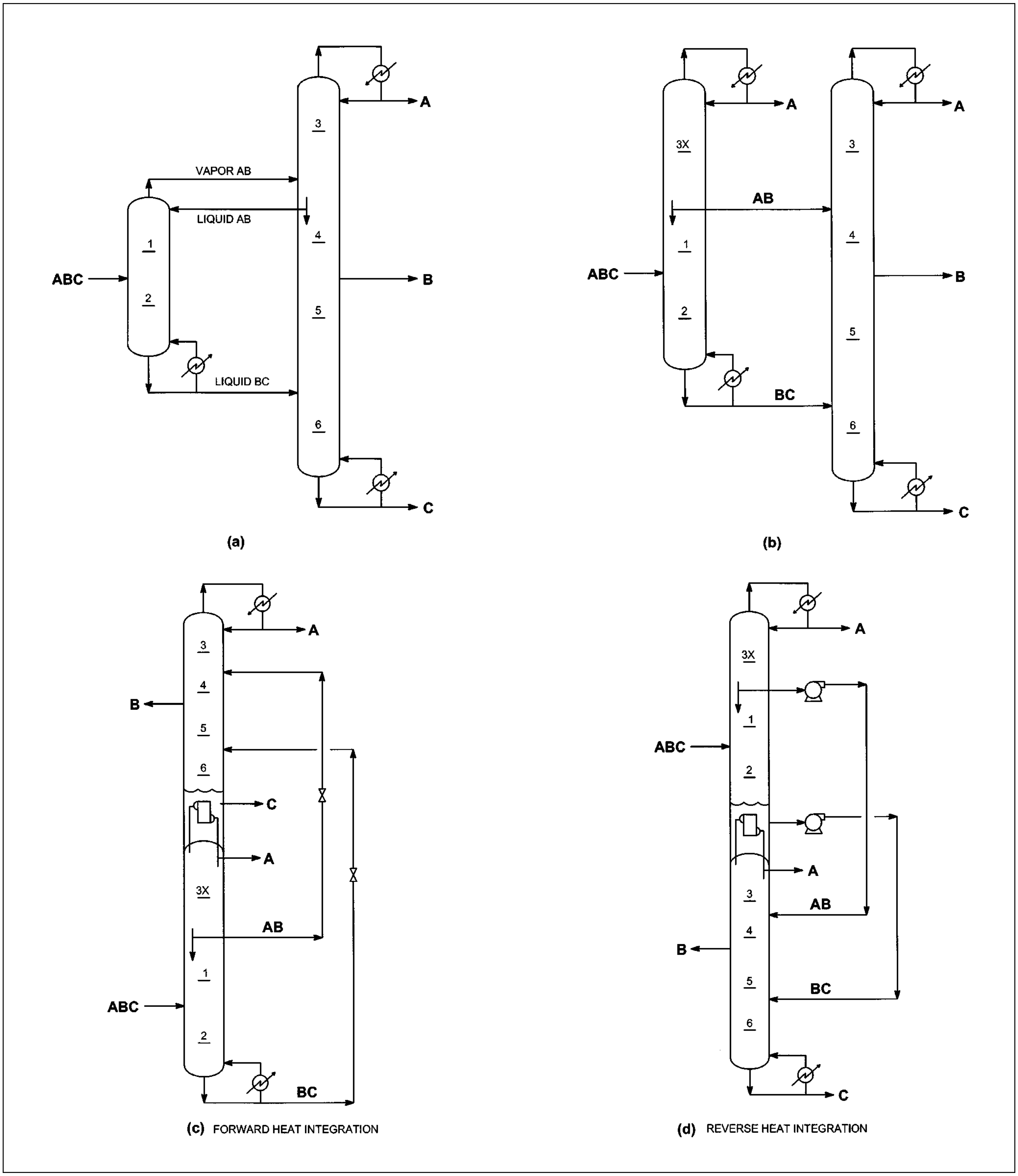

Figure 6. (a) SL; (b) equivalent SL; (c) and (d) corresponding double-effect configurations.

served that the double-effect configurations of Figures 1e, 3c, 4c, 6c and 7c are subsets of the double-effect fully-coupled configuration of Figure 5c. Therefore, unless relative volatilities are very sensitive to pressure, the double-effect fully-coupled configuration is expected to be the configuration with either the lowest or nearly the lowest heat duty of all the double-effect configurations. It is only the magnitude of savings with respect to other double-effect thermally coupled and double-effect prefractionator configurations that is uncertain.

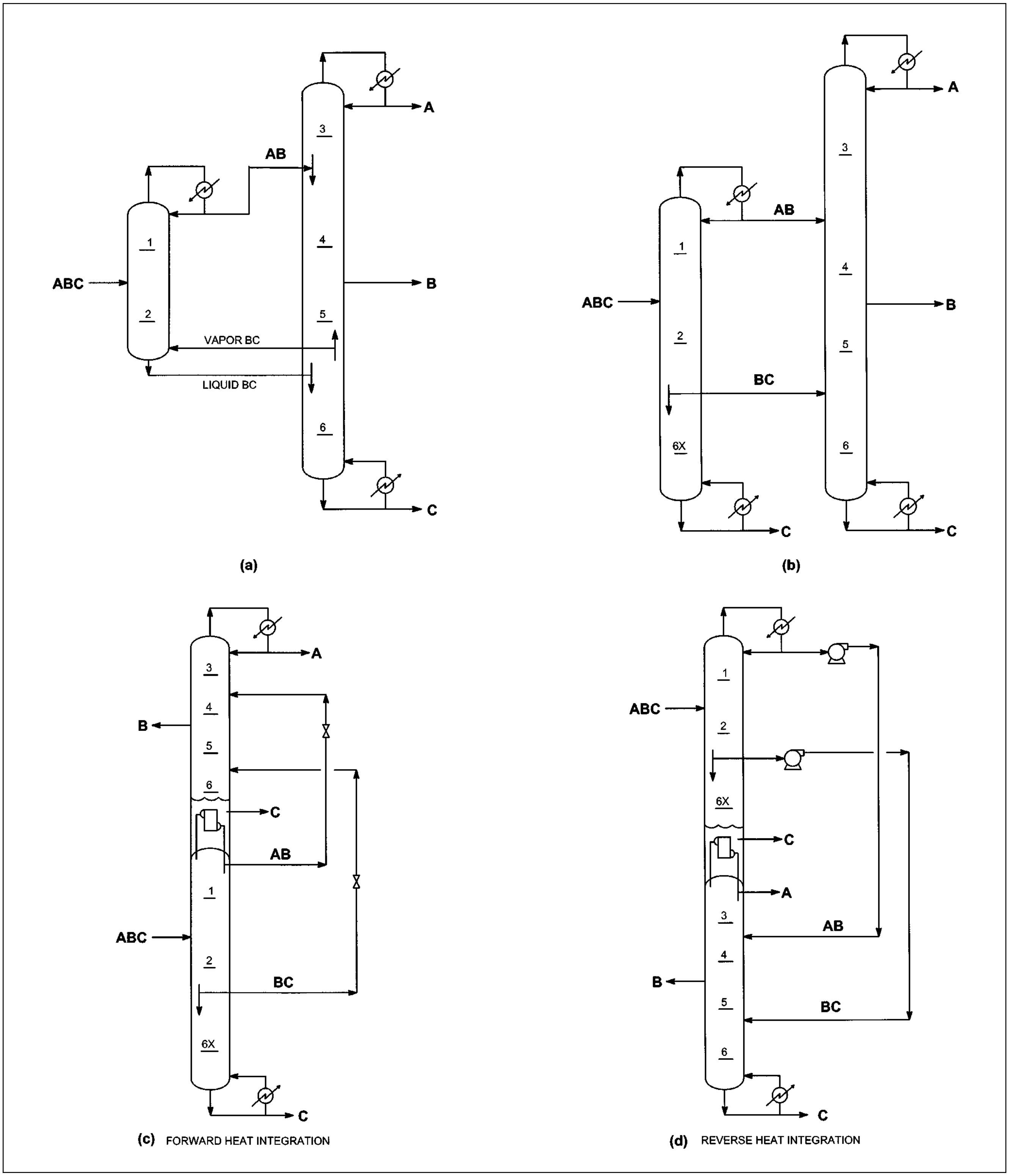

Figure 7. (a) RL; (b) equivalent RL; (c) and (d) corresponding double-effect configurations.

In order to get a glimpse of the relative merit of double-effect thermally coupled configurations, some very approximate calculations were done. In these calculations, feed and product streams were assumed to be saturated liquids and relative volatilities were taken as constant and independent of pressure. All the three components were assumed to have equal latent heats. For any configuration, the vapor flows in each of the distillation columns without any double-effect were calculated and the larger of the two flows was taken to represent the vapor flow for the corresponding double-effect configuration. The minimum vapor flow for the double-effect configuration was generally calculated by scanning different feasible vapor flows through each of the distillation columns without any double effect and observing when the vapor flow through the distillation column with higher vapor flow goes through a minimum. It is interesting to note that for the prefractionator, RL, and SL configurations, the minimum vapor flow for the double-effect configuration can occur when the corresponding configuration without double effect has a total vapor flow rate that is higher than the minimum needed. For the fully-coupled configuration, the minimum vapor flow for the double effect configuration was estimated from the minimum vapor case without any double effect. For this configuration, however, the minimum total vapor flow can sometimes occur over a wide range of relative flows in each of the distillation columns and a careful search had to be made to find the minimum value of vapor flow in the distillation column with higher vapor flow. Based on these approximate calculations, the following preliminary observations can be drawn:

(1) Double-effect fully-coupled configuration requires substantially lower heat duty than the double-effect direct or indirect configurations.

(2) There are a number of feed conditions for which double-effect can reduce the total heat duty of the fully-coupled configuration by nearly 50%. This is especially true when the relative volatilities between A and B (α_{AB}) and B and C (α_{BC}) are quite dissimilar.

(3) For all the feed conditions tested, there was always at least one double-effect configuration derived from the other thermally coupled configurations whose total heat duty was either the same as or similar to the double-effect fully-coupled configuration. This is an attractive result because the distillation columns in a double-effect fully-coupled configuration have the maximum number of distillation sections. An alternative double-effect configuration with similar total heat duty can therefore be easier and more economical to implement. Specifically, a double-effect configuration derived from a side rectifier or a side stripper with only one binary mixture transfer between the distillation columns can be quite attractive.

(4) For feed conditions when all three components are present in similar quantities and the relative volatilities α_{AB} and α_{BC} are similar, all the double-effect configurations derived from fully-coupled, SL, RL and prefractionator have similar total heat demand. This implies that any one of these configurations would be a candidate for choice. However, when a vapor stream with pure component condenses against a liquid stream with pure component, then it may be easier to control the pressure of the high-pressure column during feed disturbance. This may affect the final configuration choice.

(5) When the amount of B in a feed mixture is large and both A and C are present in small quantities, then the heat duties of double-effect configurations derived from fully-coupled and prefractionator are similar.

(6) A surprising observation was made for feeds that are low in B but have similar quantities of A and C, and the relative volatilities α_{AB} and α_{BC} are similar. For such feed conditions, a fully-coupled configuration gives a much lower heat duty than does any other configuration. For double-effect cases, however, the heat duty for the fully-coupled configuration turns out to be very similar to those for the RL, SL, and prefractionator configurations. This is due to the fact that the vapor flow rates in the two distillation columns of the equivalent fully-coupled configuration are quite dissimilar (Figure 5b), while this is not true for the three other configurations.

(7) There are feed conditions for which the double-effect prefractionator configuration requires much higher heat duty than does the double-effect fully-coupled configuration. This occurs when the amount of C in the feed is much higher and both A and B are present in smaller quantities. This also happens for an A-rich feed when both B and C are present in small quantities and the relative volatilities α_{AB} and α_{BC} are similar. This also holds for nearly equimolar feeds with much different values of the relative volatilities.

The above observations provide a glimpse of the usefulness of double-effect thermally coupled configurations in reducing overall heat demand for distillation. However, considering the rudimentary nature of calculations on which the above observations are based, for any given application, one should do detailed calculations for each double-effect configuration before making the final choice.

In the double-effect configurations of Figures 3 through 7, the distillation column with higher vapor demand controls the total heat duty requirement. This means that for some feeds, more vapor may flow through one of the distillation columns than is essential for separation in that column. In such cases, additional reboilers and/or condensers may allow the use of some lower level heat or of a higher temperature cold utility. For example, in Figure 3c, if the heat requirement of the high-pressure column, is greater than that of the low-pressure column, then a portion of the vapor, either from the top or from an intermediate location of the high-pressure column, may be condensed against an external cold source. This will also decrease the diameter of the low-pressure column due to decreased vapor traffic. On the other hand, if the heat demand of the low-pressure column is much higher than that of the high-pressure column, then a portion of the vapor need of the low-pressure column can be provided by using an external heat source through another reboiler located either at the bottom or at an intermediate location of this column. Now the diameter of the high-pressure column will decrease due to reduced vapor traffic through this column.

When the vapor need of the low-pressure column is much greater than that of the high-pressure column, vapor from the top of the high-pressure column may be condensed in a reboiler/condenser located at an intermediate location of the low-pressure column. The boilup at the bottom of the low-

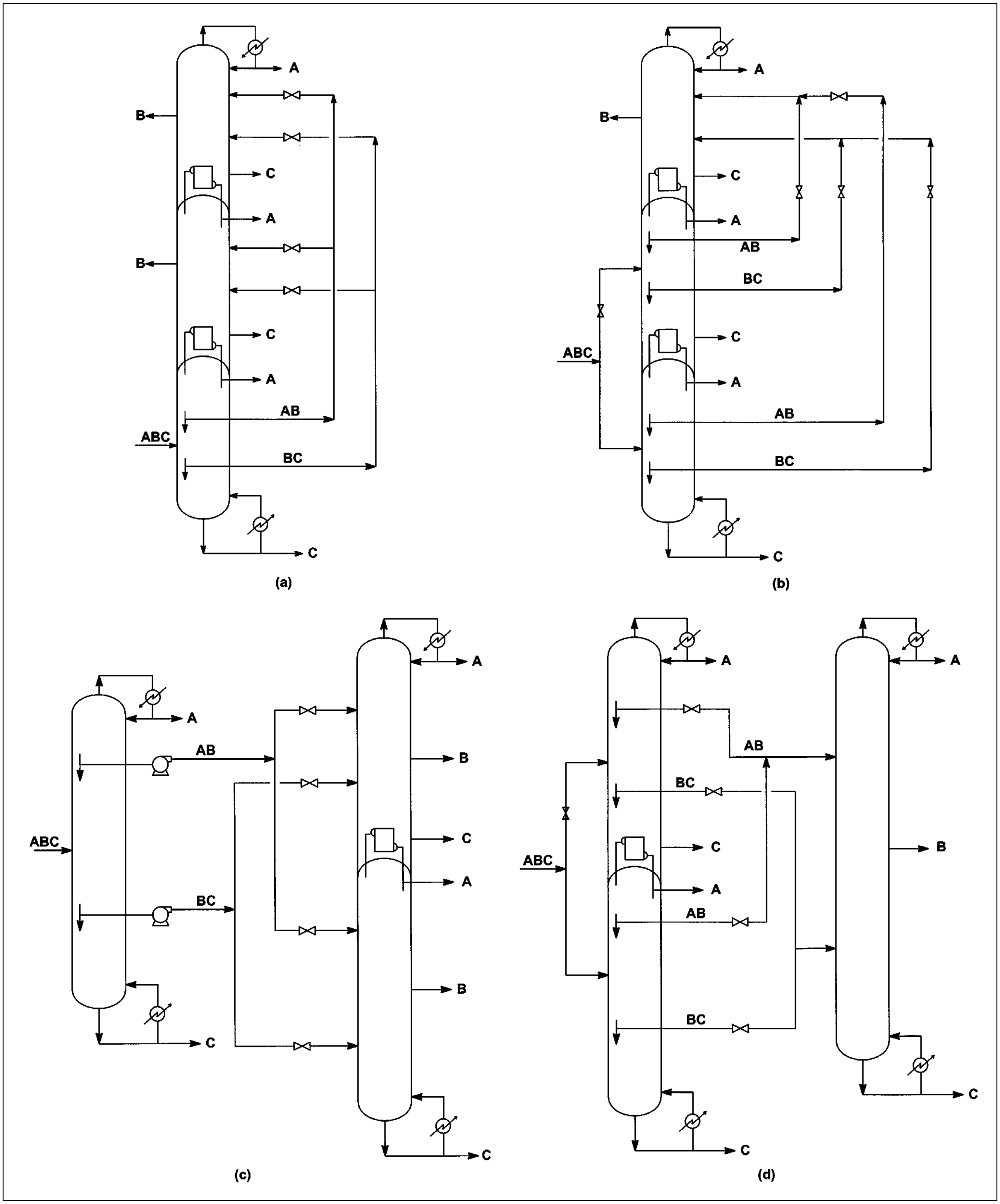

Figure 8. From fully-coupled ternary distillation: (a) and (b) multieffect configurations; (c) and (d) additional double-effect configurations.

pressure column is then provided from an external heat source. This will decrease the pressure of the high-pressure column.

Even though all of the double-effect configurations in Figures 3 through 7 show only liquid transfers between the distillation columns, if needed, a vapor stream may be transferred from one column to another. Specially, when the vapor need of the high-pressure column is much greater than the vapor need of the low-pressure column, a binary vapor mixture from the high-pressure column may be expanded in a turbo expander to recover energy and then be fed to the low-pressure column.

When an equivalent thermally coupled configuration such as the one in Figure 5b is drawn and vapor flow rates in the two distillation columns are greatly dissimilar, then the corresponding double-effect configuration does not provide substantial reduction in the total heat duty. This was observed to be the case for feeds that are low in B but which have similar quantities of A and C, and the values of two relative volatilities α_{AB} and α_{BC} are similar. For such feeds in the equivalent fully-coupled configuration in Figure 5b, the vapor flow rate in the distillation column producing component B is several fold more than the vapor flow in the feed distillation column. In such cases, a substantial reduction in the total heat duty can be realized by using a multi effect distillation configuration containing more than two distillation columns. Two feasible multi-effect distillation configurations derived from the fully-coupled configuration are shown in Figures 8a and 8b. In Figure 8a, the heat duty of the distillation column of Figure 5b producing component B is split into two distillation columns to reduce overall heat demand. This multieffect configuration can be attractive for the feed conditions just discussed. When in Figure 5b the heat demand of the feed column is much higher than that of the other column, then this feed column may be split into two distillation columns and arranged to provide the multi-effect distillation configuration of Figure 8b. The feed is now split between the two columns, one operating at high pressure and the other at medium pressure. In this figure, both high- and medium-pressure columns have been shown to produce each of the binary streams AB and BC of the same composition. If needed, the two columns may produce each binary stream of different composition and feed them at appropriate locations of the lowest-pressure column. Such multieffect configurations can also be easily drawn for other thermally coupled configurations.

One possible disadvantage of the multieffect configurations in Figures 8a and 8b is a much higher operating pressure of the highest-pressure distillation column. In situations where, in an equivalent thermally coupled configuration such as the one in Figure 5b, the vapor flow rate in one of the distillation columns is many times more than that in the other distillation column, the configurations in Figures 8c and 8d may provide more attractive options. In these configurations, the double effect is used for the distillation column with the much higher vapor flow, while the operation of the other dis-

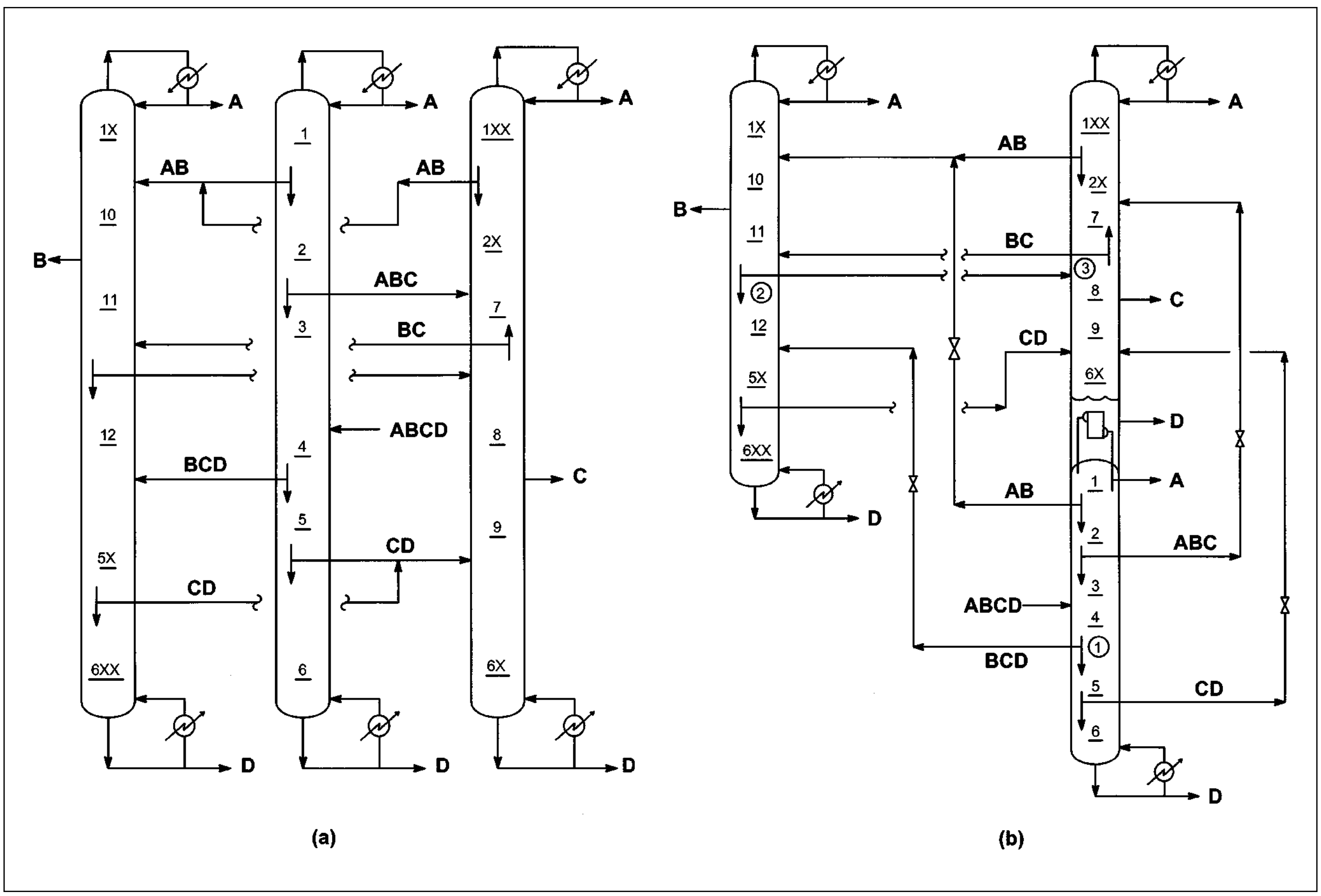

Figure 9. Four component distillation configurations: (a) an equivalent satellite column arrangement; (b) a corresponding double effect configuration.

tillation column is left unchanged. In Figure 8c, the feed column operates at a low pressure and provides feed to two columns that are linked together through double-effect heat integration. In this case, if the heat duty of the feed column is many times less than that of the other distillation columns, then a substantial reduction in the total heat duty will be obtained as compared to the fully-coupled scheme without the double effect. The corresponding scheme when the feed column in Figure 5b has several fold higher heat duty than the other column is shown in Figure 8d. The potential advantage of Figures 8c and 8d as compared to Figures 8a and 8b is that reduction in heat duty can be obtained without operating the highest pressure column at too high a pressure. Of course, such configurations can be drawn for any thermally coupled configuration.

More Than Three Component Distillation

Distillation of feed mixtures containing four or more components generally requires three or more distillation columns. For a four-component distillation, a thermally coupled configuration requires three distillation columns. When the equivalent thermally coupled configuration with minimal or no vapor transfer between the columns is drawn, then it contains three or four distillation columns (Agrawal, 2000). Figure 9a shows the equivalent configuration for a fully-coupled satellite column arrangement. With three distillation columns, many possible configurations exist for double-effect and multieffect distillations. Any two of these three distillation columns can be double-effect heat integrated. Furthermore, there can be forward, as well as reverse, heat integration. Alternatively, all the three columns could be multieffect heat integrated as low-pressure, medium-pressure and high-pressure distillation columns. The vapor from the top of the high-pressure column is condensed against the liquid from the bottom of the medium-pressure column, and the vapor from the top of the medium pressure column is condensed against the liquid from the bottom of the low-pressure column. In yet another option, one distillation column may be simultaneously heat integrated in double-effect mode with the other two distillation columns, that is, a portion of the vapor from the top of one of the distillation columns is condensed against the bottom liquid of the second column and the other vapor portion is condensed against the bottom liquid of the third column. Figure 9b shows one possible double-effect configuration. In this configuration, double-effect heat integration exists between the top of the feed column and bottom of the distillation column producing C-rich product stream. The distillation column producing B-rich product stream may be operated at any suitable pressure. It is clear from this discussion that the lessons learned from ternary distillation can be easily applied to thermally coupled configurations for any multicomponent feedstream.

Once a configuration such as the one in Figure 9b has been drawn, one or more streams and distillation sections may be eliminated to simplify the process. For example, one of the two mixture streams AB or ABC from the high-pressure column ① could be eliminated. Similarly, transfer of one of the two mixture streams BCD or CD could be eliminated. Also, the production of either one or both the product streams A or D could be eliminated from the high-pressure column ①. Production of product stream D from column ② and product stream A from column ③ could also be eliminated. In one option, for example, the transfer of both the ternary mixture streams ABC and BCD from the high-pressure column ① could be eliminated. Now, the low-pressure column ③ would get only one binary stream CD from the high-pressure column. All the distillation sections above the recovery point of product C would be eliminated from the low-pressure column. A condenser operating at the top of this column would be condensing a vapor stream enriched in C. Only the product streams enriched in C and D would be produced from the low-pressure column. Similarly, the distillation column ② would receive only binary mixture containing A and B from the high-pressure column ①. This distillation column would only produce product streams enriched in A and B. Clearly this represents only one simplified configuration. Many more simplified configurations could also be drawn from configurations such as the one in Figure 9b.

It is clear from all the discussions so far that the main feature of a double-effect or a multieffect configuration drawn for a thermally coupled distillation is that at least one mixture stream is withdrawn from an intermediate location of one of the distillation columns and transferred to an intermediate location of another distillation column. In the past it seems that within a multieffect configuration, mixture streams drawn only from the top and/or bottom of one distillation column were transferred to an intermediate location in another distillation column. Therefore, the main lesson from this exercise seems to be that the performance of a conventional multicomponent multieffect distillation may be improved by adding distillation sections to some of the distillation columns such that some of the product streams are produced from more than one distillation column and some of the mixture streams are transferred from intermediate locations of some of the distillation columns. Generally, it is expected that the addition of one or two distillation sections to one or two distillation columns with the associated transfer of one or two mixture streams from intermediate locations in these columns would provide most of the available benefit in heat duty reduction.

Conclusions

Multieffect distillation configurations derived from conventional multicomponent distillation schemes, such as direct and indirect split and prefractionator, are well known. These multieffect distillation configurations are known to substantially reduce the total heat demand for distillation. However, multieffect distillation configurations derived from thermally coupled distillation schemes have not been previously known. In this article, a systematic method is presented to draw double and higher effect configurations for any thermally coupled multicomponent distillation scheme.

All the double-effect configurations for each of the five known ternary thermally coupled configurations are illustrated in detail. In these configurations, two distillation columns with vapor from the top of one of the columns condensing against the bottom liquid of the other column are used. Using some very approximate calculations, it is found that the total heat duty of the double-effect fully-coupled configuration is always substantially lower than that of double-effect configurations derived from direct and indirect split schemes. It is also found that for all the feed conditions studied, there is always at least one other double-effect thermally coupled configuration whose total heat duty is either same or similar to that of the double-effect fully-coupled configuration. For some feed conditions, the total heat duty of the double-effect prefractionator configuration can be very similar to that of the double-effect fully-coupled configuration. As a result, for a given feed, economic calculations should be performed on more than one double-effect configuration in order to find the optimum solution.

A feature of the multieffect configurations derived from thermally coupled distillation schemes is that some of the product streams are produced from more than one distillation column. Also, at least one mixture stream is transferred from an intermediate location of one of the distillation columns to an intermediate location in the other distillation column. Based on this observation, the conventional known multieffect configurations may be modified to further decrease their heat duty.

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