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Software application for supporting of CAE in process engineering: Automated choice of the suitable reboiler type

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The most critical stage of reboiler design is the selection of the proper type of reboiler for a given service. This paper describes possibilities of selection suitable reboiler for given requirements of operation. It is introduced a list of advantages and disadvantages of the most used types and the list of suitability use. The simplified selection diagram is show also (Love, 1992).
The created selection algorithm is implemented into HGA – Hot Gas Application - database (Kilkovsky et al., 2008) with the use of Visual Basic for Application (VBA) environment in Microsoft Excel making developed software application comfortable and user-friendly. Developed software (the part of the selection of the suitable reboiler) is intended for implementation substantially speeding-up the selection of the right type of reboiler for given process application.

1. Introduction

Reboilers are the special kinds of heat exchangers. Their assignment is to generate a flux of vapor to feed to a destillation tower (or distillation column) (Hewitt, 1994). The vapor rises up the tower contacting a downward flowing liquid stream. The vapor is generated in the reboiler from the liquid stream leaving the lowest tray. The liquid is only partly evaporated; the remainder is partly recirculated through the reboiler and partly passed out of the system as the “bottom product” of the distillation tower (Hewitt, 1994). Proper reboiler operation is necessary to effective distillation.

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2. Types and configurations of reboilers

The most used reboilers are shell-and-tube heat exchangers. It is possible to use also internal reboiler, externally generated vapor, or feed preheat systems and others. Commonly used types are:

- Kettle reboiler;
- horizontal or vertical thermosyphon type;
- forced circulation.

If the Kettle reboiler is used, so the bottom product take from reboiler and the fluid back to column is single phase vapor. At horizontal and vertical thermosyphon is bottom product take from distillation column and fluid back to column is two phase.

The reboilers can to have some possible configurations. The major configurations are (The Distilllation Group, Inc., 2002):

- forced versus natural circulation;
- tube side versus shell side vaporization;
- once-through versus process recirculation;
- single-shell versus multiple-shell systems;
- vertical versus horizontal orientation.

The description and pictures of these reboiler types is possible to find in many technical literatures, for example (Hewitt, 1994; Love, 1992; Wikipedia, 2000). Advantages and disadvantages the most used types of reboilers are introduced in the Table 1 (Love, 1992).

*Table 1 Advantages and disadvantages the most used types of reboiler*s (Love, 1992)

Type of reboiler	Advantages	Disadvantages
Kettle type	One theoretical tray Ease of maintenance Vapor disengaging Low skirt height Handles viskosity greater than 5.10^{-4} Pa.s Ease of control No limit on vapor load	Extra piping and space High cost Fouls with dirty fluids High residence time in heat zone for degradation tendency of some fluids Low residence time surge section of reboiler
Vertical once-through type	Once theoretical tray Simple piping and compact Not easily fouled Less cost than kettle	Difficult maintenance High skirt height No control of circulation Moderate controllability
Vertical naturally circulation	Good controllability Simple piping and compact Less cost than Kettle	No theoretical tray Accumulation of high bowling point components in feed line, i.e., temperature may be slightly higher than tower bottom

		Too high liquid level above design could cause reboiler to have less capacity Fouls easier Difficult maintenance High skirt height
Horizontal once-through	One theoretical tray Simple piping and compact Not easily fouled Lower skirt height than vertical Less pressure drop than vertical Langer tubes possible Ease of maintenance Less cost than Kettle	No control of circulation Moderate controllability High skirt height
Horizontal naturally circulation	Ease of maintenance Lower skirt height than vertical Less pressure drop than vertical Longer tubes possible Less cost than Kettle	No theoretical tray Extra space and piping as compared to vertical Fouls easier as compared to vertical Accumulation of higher boiling point components in feed line, i.e., temperature may be slightly higher than tower bottom
Forced circulation	One theoretical tray Handles high viscous solids-containing liquids Circulation controlled Higher transfer coefficient	Highest cost with additional piping and pumps Higher operating cost Requires additional plant area

3. Selection criteria

Finding the criteria by which designers select a particular reboiler type, in practice, is not simple (Hewitt, 1994). It is many factors influences reboiler type selection. The most important factors are (The Distilllation Group, Inc., 2002):

- total duty required;
- fraction of tower liquid traffic vaporized;
- fouling tendency;
- temperature approach available;
- temperature approach required;
- working pressure;
- area available.

All this factors influence as well the configuration of reboilers. The decision which type of reboiler will be selected would be beginning with the list of advantages and disadvantages of each reboiler type. There are introduced the advantages and disadvantages of each individual reboiler in the Table 1.
The final selection would be carrying out on the basis of economic analysis. Often but is execute the selection on the basis of design difficulty and practice of the individual or company (Hewitt, 1994).
On the Figure 1 is showed the basic select algorithm (Love, 1992). This algorithm enables to choice easy the suitable type of reboiler in the few steps. Unfortunately this algorithm not covers all requirement of service and would be to use only as an auxiliary selection tool.
From Table 1 and Figure 1 it can be seen that for high viscous fluids or for solids-containing liquids to use of forced circulation type is preferred. If the viscosity is not too high can be use horizontal once-through reboiler. Other important factor of the selection is the equipment cost. The most expensive reboiler is the forced circulation and then Kettle reboiler.

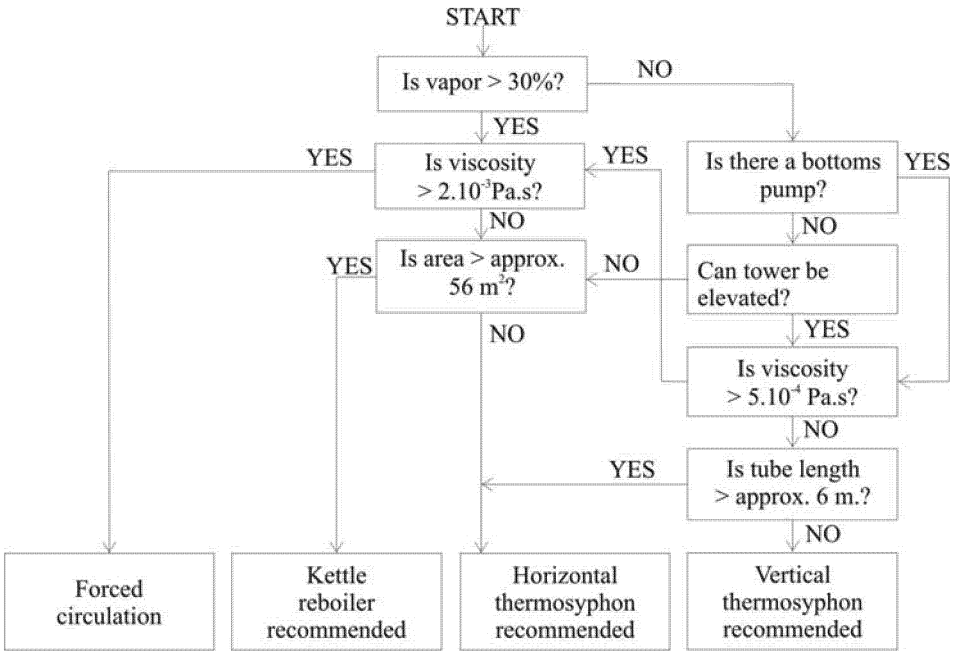

Figure 1 Basic reboiler design selection algorithm (Love, 1992)

Above described algorithm is the basic (instrumental) algorithm of reboiler selection. It is necessary to consider the other factors. The important factors that would probably be agreed by the most designers are as follows (Hewitt, 1994):

1. Most fouling fluid should be placed inside the tubes for easier cleaning. Thus, if the liquid being boiled tends to foul, a vertical thermosyphon reboiler should be used. Kettle reboilers tend to be the worst with regard to their fouling characteristics.
2. If the liquid being boiled is heat sensitive, a low residence time is required; a vertical thermosyphon is needed.
3. None of the reboilers is very suitable at very high pressures. A kettle will be very expensive because of the large-diameter shell, and the thermosyphon types may not operate satisfactorily because the density difference is too small. The circulation may be boosted by a pump in the inlet pipe to the reboiler.
4. For a vacuum system a horizontal thermosyphon reboiler is often preferred to a vertical thermosyphon because the bottom of the reboiler need not be so far below the liquid level in the distillation column. This will make the sensible heat duty lower.
5. A related point is that vertical thermosyphon reboilers may require the distillation column to be lifted to give the necessary working head. However, vertical thermosyphons require very little ground area.
6. Kettle reboilers are not suitable for foaming liquids.
7. Kettle reboilers are easier to design, at least on a rather crude basis. This is because the heat transfer aspects and the hydraulic factors are largely independent. Thermosyphons, however, need to be designed complete with the external pipework, or the required recirculation rate may not be attained.
8. Kettle reboilers are easiest to control and present no stability problems.
9. If the liquid is hazardous or toxicity, the internal reboiler is preferred.

The selection process (algorithm) was implemented on the basis of the flow chart (see Figure 1) and the additional criterions (recommendations) introduced in the paper into HGA database - Hot Gas Application (Kilkovsky et al., 2008) with use of Visual Basic for Application (VBA) environment in Microsoft Excel. This enables the selection of suitable type of reboiler.

The selection is conducted with the support table (like Table 2 below). The table contains given process requirements and the suitability is adding to each reboiler for given requirements. It can be use for example abbreviations according to: B – best; G – good operation; F – fair operation, but better choice is possible; Rd – risky unless carefully designed, but could be best choice in some cases; R – risky because of insufficient data; P – poor operation; E – operable but unnecessarily expensive.

In the software application is for each abbreviation assigned a numerical value – suitability for given application (0 – 100 %).

Table 2 Illustration of possible way of reboiler selection

	Reboiler Type			
Process Conditions	Kettle or Internal	Horizontal Thermopsiphon	Vertical Thermopsiphon	Forced Flow
Operating pressure Moderate	E	G	B	E
Design ΔT Moderate	E	G	B	E
Fouling Heavy	Rd	G	B	E
etc.	…	…	…	…

4. Conclusion

The paper deals with the description and selection of suitable reboiler type for given application. The main types used reboiler and their possible configurations are introduced. The possible selection algorithm working on the basis of advantages and disadvantages of individual reboiler type have been created.

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