Distillation Separation Effect by Thermosiphon Reboiler

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Introduction

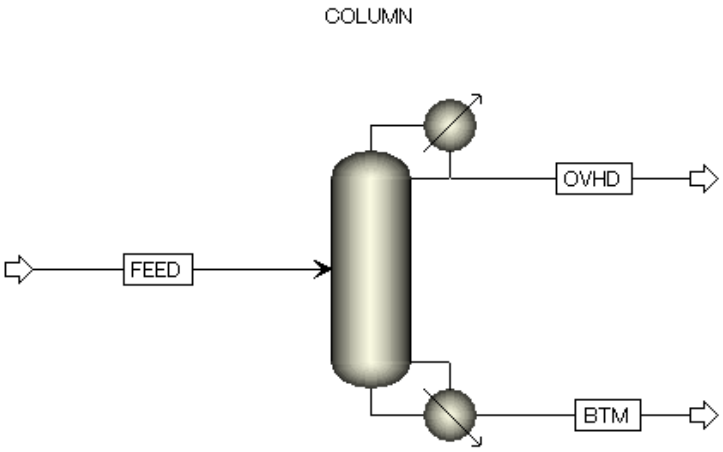
- When examining a distillation column using a general-purpose simulator, it is common practice to calculate the condenser and the reboiler as one with the distillation column. This is because the number of recycle loops is reduced, and improvement in convergence can be expected.
- There are roughly two types of classification for reboilers: the kettle type and the thermosiphon type. In the case of a thermosiphon type in which vapor and liquid return to the distillation column in a mixed phase state, the distillation separation effect is difficult to understand.
- In this study, we will create simple distillation column models to examine the distillation separation effect of the thermosiphon type and compare it with the kettle type.

Subject of Examination

Components:
Methanol (1)
Ethanol (2)

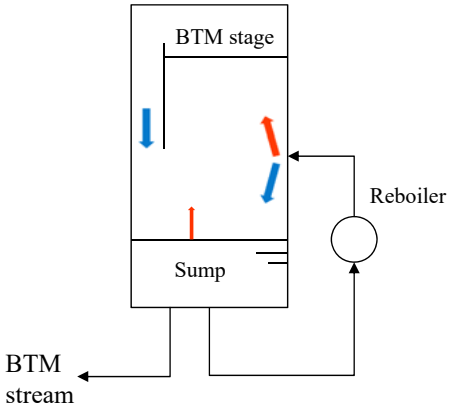
Feed:
Equimolar

Distillation Column
Operating Pressure:
1 ATM

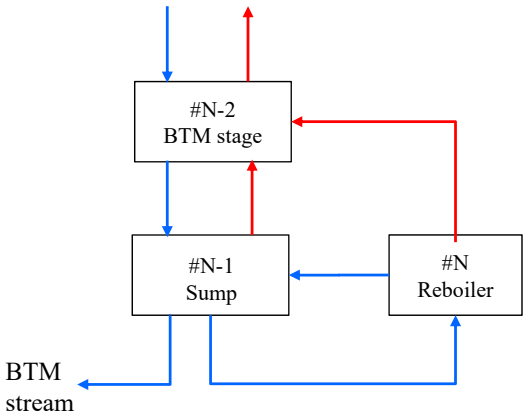


The number of theoretical stages is set to seven so that the impact of the separation effect by the reboiler can be more clearly understood. Also, Aspen Plus is used for the distillation calculation.

Thermosiphon Reboiler Model



Bottom Section of Actual Distillation Column

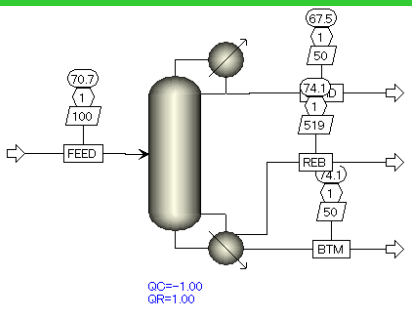


Thermosiphon Reboiler Study Model

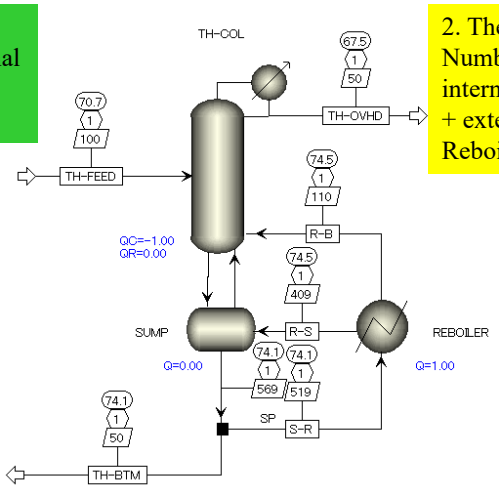
The left figure is the equipment configuration around the bottom of the actual distillation column. The right figure is a diagram for verifying the separation effect of the thermosiphon reboiler. The return liquid from the thermosiphon reboiler returns to the sump and the vapor returns to the distillation column BTM stage.

Simulation Model (Thermosiphon Model Verification)

1. Thermosiphon Model A:
Number of theoretical stages = 7+ (internal condenser & thermosiphon reboiler)
Reboiler outlet vapor fraction ≈ 0.36



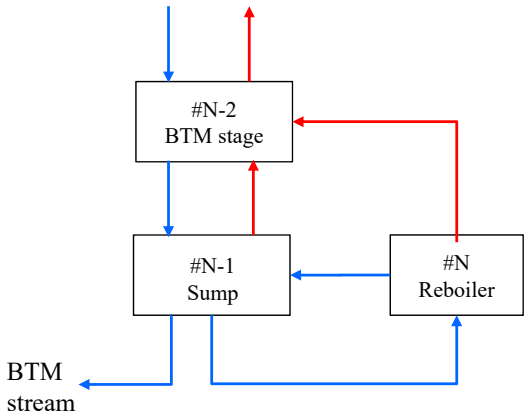
2. Thermosiphon Model B:
Number of theoretical stages = 7+ internal condenser
+ external sump & reboiler)
Reboiler outlet vapor fraction ≈ 0.36

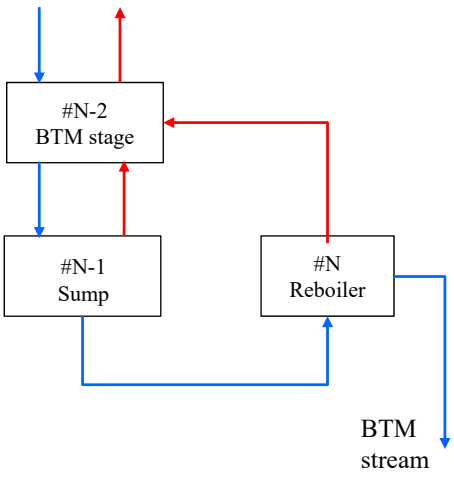


	FEED	OVHD	BTM	TH-OVHD	TH-BTM
Temperature C	70.7	67.5	74.1	67.5	74.1
Pressure bar	1.013	1.013	1.013	1.013	1.013
Mole Flow kmol/hr	100	50	50	50	50
Mole Flow kmol/hr					
MeOH	50	37.073	12.927	37.073	12.927
EtOH	50	12.927	37.073	12.927	37.073
Mole Frac					
MeOH	0.5	0.741	0.259	0.741	0.259
EtOH	0.5	0.259	0.741	0.259	0.741

- The results of model A (left figure), in which the distillation column and thermosiphon are calculated together, and model B (right figure), in which the thermosiphon is externally attached, agree with each other.
- It can be seen that the separation effect of thermosiphon can be evaluated by the external model.

Kettle Type Reboiler Model





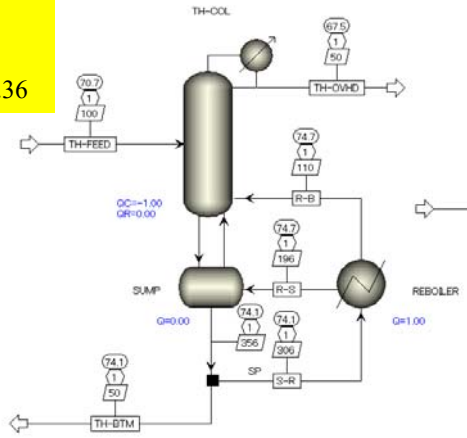
Thermosiphon Reboiler Study Model

Kettle Type Reboiler Study Model

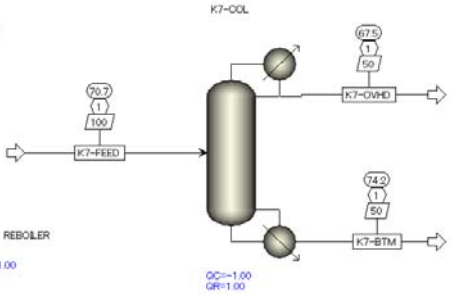
The right figure is a diagram of a kettle type reboiler model. After pool boiling, only steam returns to the distillation tower BTM stage. The separation efficiency is examined using the above model. In this study, the distillate flow rate and the reboiler heat load of the distillation column are set equal in all cases in order to have equal operating conditions.

Thermosiphon versus Kettle

2. Thermosiphon Model B:
Number of theoretical stages = 7+ internal condenser
+ (external sump & reboiler)
Reboiler outlet vapor fraction ≈ 0.36



3. Kettle Type Model:
Number of theoretical stages =7 + (internal condenser + kettle reboiler)

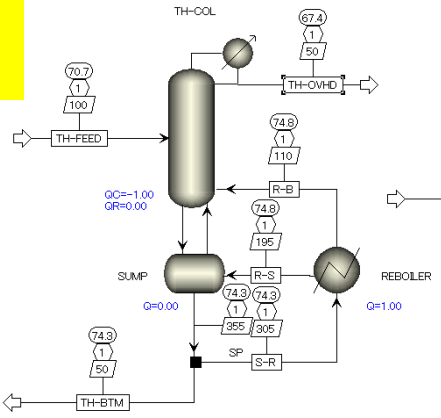


	FEED	TH-OVHD	TH-BTM	TH-OVHD	TH-BTM
Temperature C	70.7	67.5	74.1	67.5	74.2
Pressure bar	1.013	1.013	1.013	1.013	1.013
Mole Flow kmol/hr	100	50	50	50	50
Mole Flow kmol/hr					
MeOH	50	37.073	12.927	37.273	12.727
EtOH	50	12.927	37.073	12.727	37.273
Mole Frac					
MeOH	0.5	0.741	0.259	0.745	0.255
EtOH	0.5	0.259	0.741	0.255	0.745

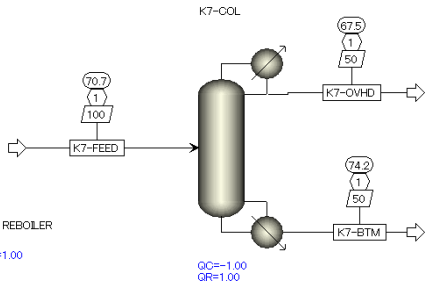
Overhead MeOH Concentration
Thermosiphon: 0.741
Kettle: 0.745
The thermosiphon (model B) has a poorer separation than the kettle type. In other words, it can be seen that the effect of one theoretical stage cannot be expected.

Thermosiphon versus Kettle -2

2. Thermosiphon Model C:
Number of theoretical stages = 8+ internal condenser
+ (external sump & reboiler)
Reboiler outlet vapor fraction ≈ 0.36



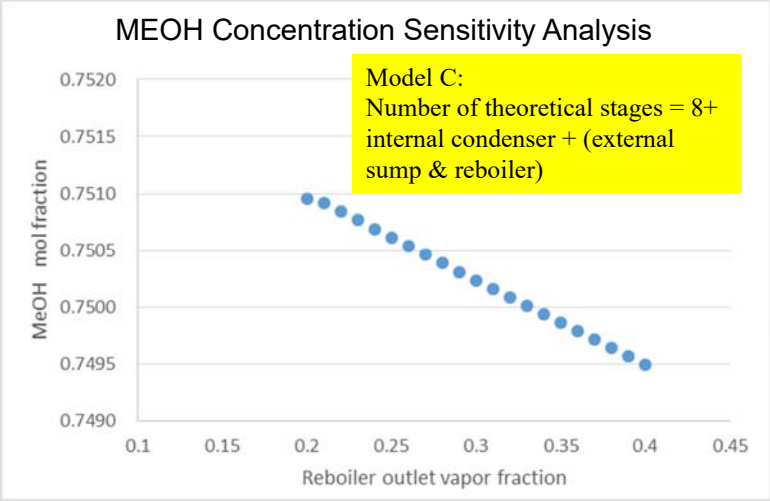
3. Kettle Type Model:
Number of theoretical stages =7 + (internal condenser + kettle reboiler)



	FEED	TH-OVHD	TH-BTM	K7-OVHD	K7-BTM
Temperature C	70.7	67.4	74.3	67.5	74.2
Pressure bar	1.013	1.013	1.013	1.013	1.013
Mole Flow kmol/hr	100	50	50	50	50
Mole Flow kmol/hr					
MeOH	50	37.489	12.511	37.273	12.727
EtOH	50	12.511	37.489	12.727	37.273
Mole Frac					
MeOH	0.5	0.750	0.250	0.745	0.255
EtOH	0.5	0.250	0.750	0.255	0.745

Overhead MeOH Concentration
Thermosiphon: 0.750
Kettle: 0.745
In the case where one theoretical stage is added to model B (model C), the thermosiphon has better separation.

Sensitivity Analysis of Thermosiphon Outlet Conditions



- It was found that the separation effect changes according to the outlet vapor fraction as a result of conducting a sensitivity analysis regarding the outlet vapor fraction change of the thermosiphon reboiler.
- Since the circulation rate of the thermosiphon reboiler is determined by the pressure balance, it can be seen that the outlet vapor fraction varies according to the pressure loss, and that the separation efficiency changes as a result.

Conclusion

- In this case study, the separation effect of a thermosiphon reboiler was discussed in comparison with a kettle type reboiler.
- Vertical thermosiphons are often preferred in new plant distillation columns due to advantages such as their smaller footprints. However, a thermosiphon is inefficient because liquid is recycled, so unlike a kettle type reboiler, it cannot be expected to have the separation effect of one theoretical stage.
- In the case of a thermosiphon, the separation effect changes depending on the circulation rate, but it is generally considered that there is a contribution of about 0.1 to 0.3 theoretical stages. For this reason, it is considered practical (safe) to consider adding one stage in combination with the bottom stage of the distillation column when carrying out distillation studies and the like.