

# EngrD 2190 – Lecture 27A

Concept: Graphical Models for Mass Balances

Context: Operating Lines for Distillation, cont'd.  
The McCabe-Thiele Method.

Defining Question: How to graphically model  
unconventional multi-stage distillation?

Read Chapter 5 pp. 423-431.

Dimensional Analysis & Dynamic Scaling

# Homework

- Homework 7 due today at noon.

Write team code and names of all *contributing* team members on all solutions. Indicate this week's Team Coordinator.

Submit *after* lecture or deliver to the EngrD 2190 mailbox in a cabinet in the hallway outside 116 Olin Hall (ChemE Business Office). **Not to my mailbox.**

- Homework 8 due Friday 11/14.
  - 4.67 & 4.68** analysis of distillation columns.
  - 4.108** design with distillation columns.
  - 4.103** design with ternary diagrams.

Download blank graphs and phase data from EngrD 2190 homepage:  
Textbook → Textbook Graphs and Figures →  
Graphs for Chapter 4 Exercises.

*Homework is your chief means of assessing your command of the material.*

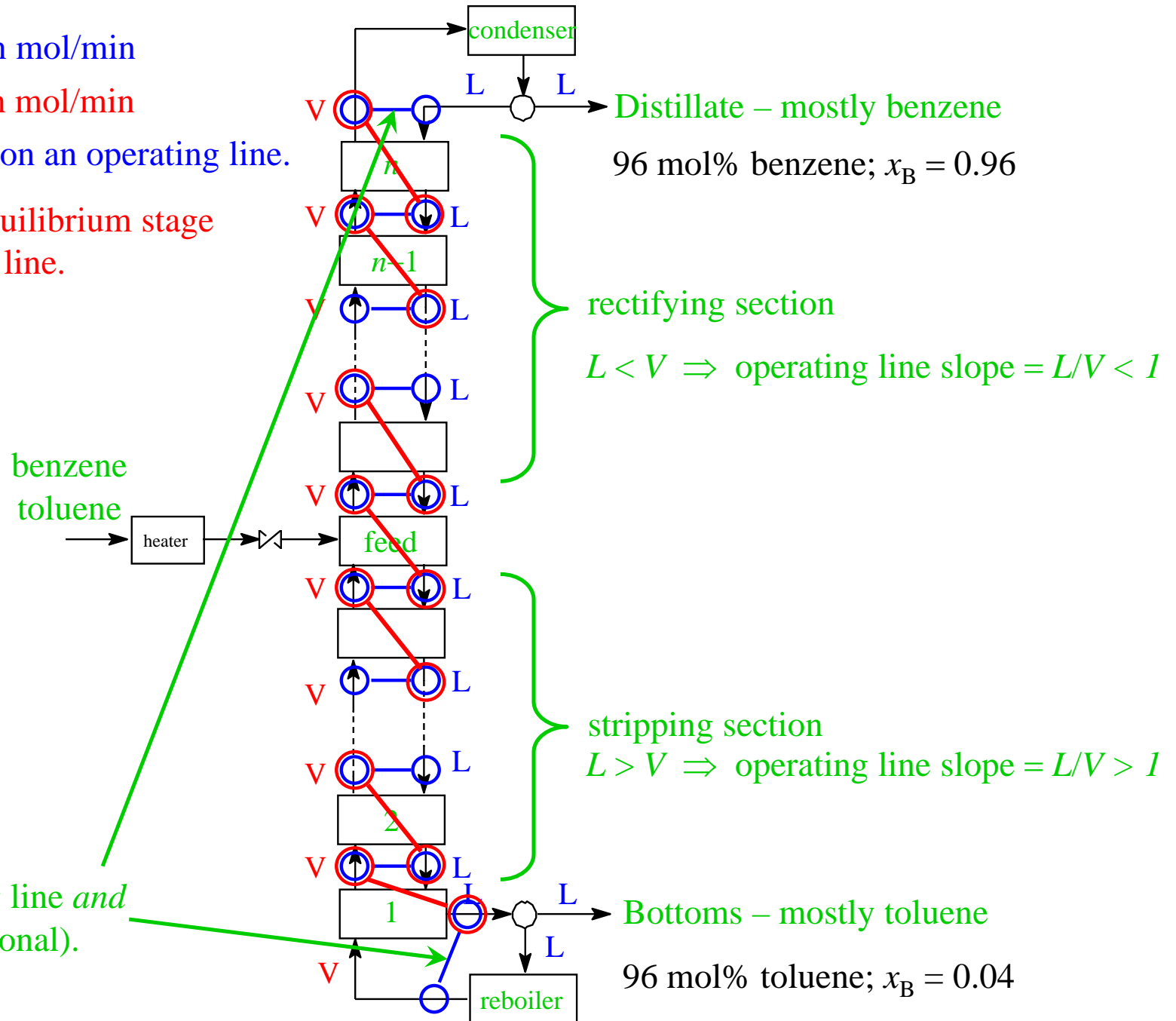
# A Distillation Column

$L \equiv$  liquid flow rate, in mol/min

$V \equiv$  vapor flow rate, in mol/min

Adjacent  $x$ - $y$  pairs are on an operating line.

$x$ - $y$  pairs leaving an equilibrium stage are on the equilibrium line.



$x$ - $y$  pair on operating line *and* on  $x=y$  line (the diagonal).

# A Graphical Model of a Distillation Column

vapor-liquid diagram  
for benzene+toluene  
mixtures at 1 atm

mol fraction  
benzene  
in vapor

pure  
toluene

plotting pair  
at bottom  
of column

mol fraction benzene in liquid

pure  
benzene

plotting pair  
at top  
of column

$x=y$  diagonal

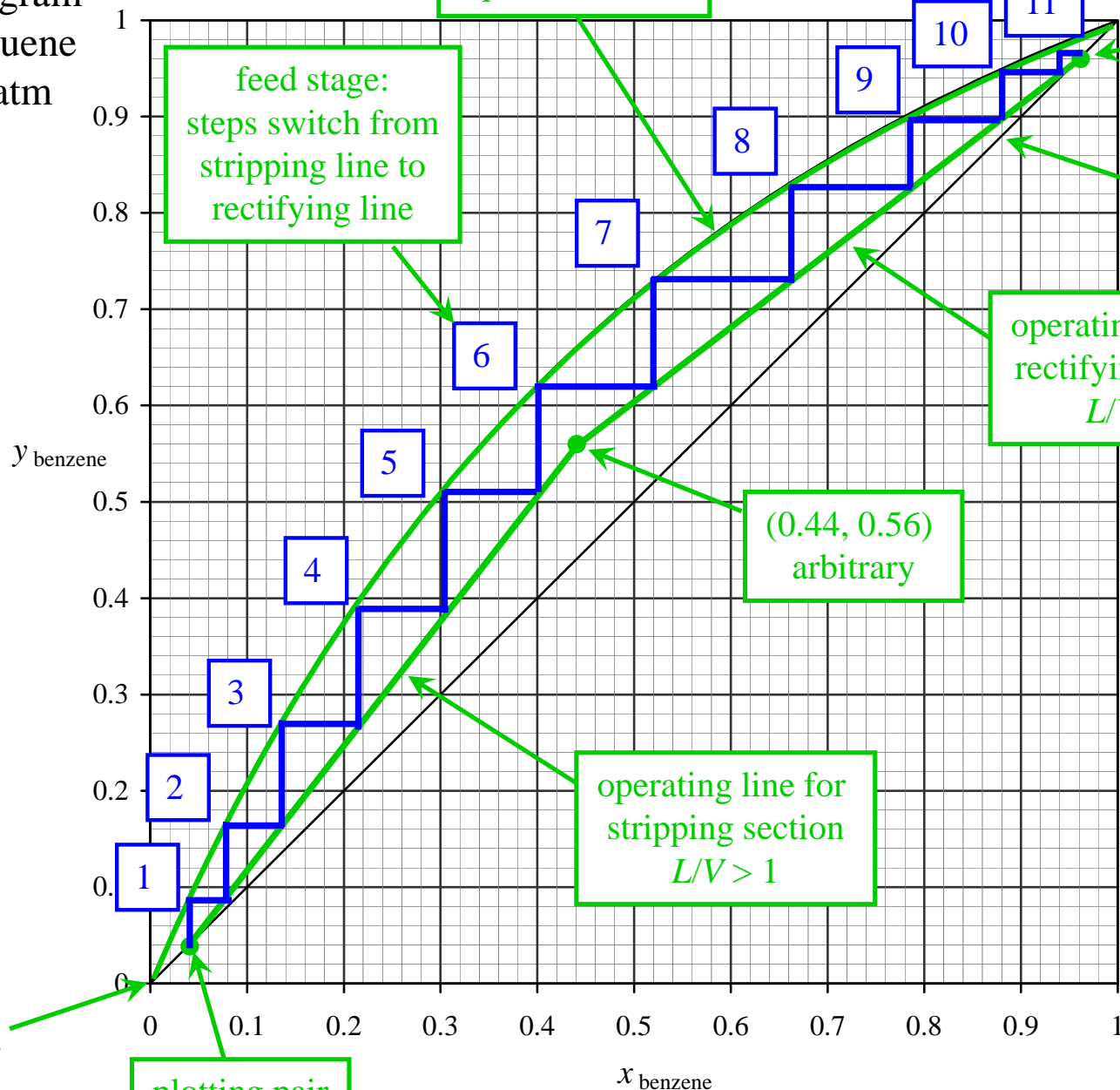
operating line for  
rectifying section  
 $L/V < 1$

(0.44, 0.56)  
arbitrary

operating line for  
stripping section  
 $L/V > 1$

feed stage:  
steps switch from  
stripping line to  
rectifying line

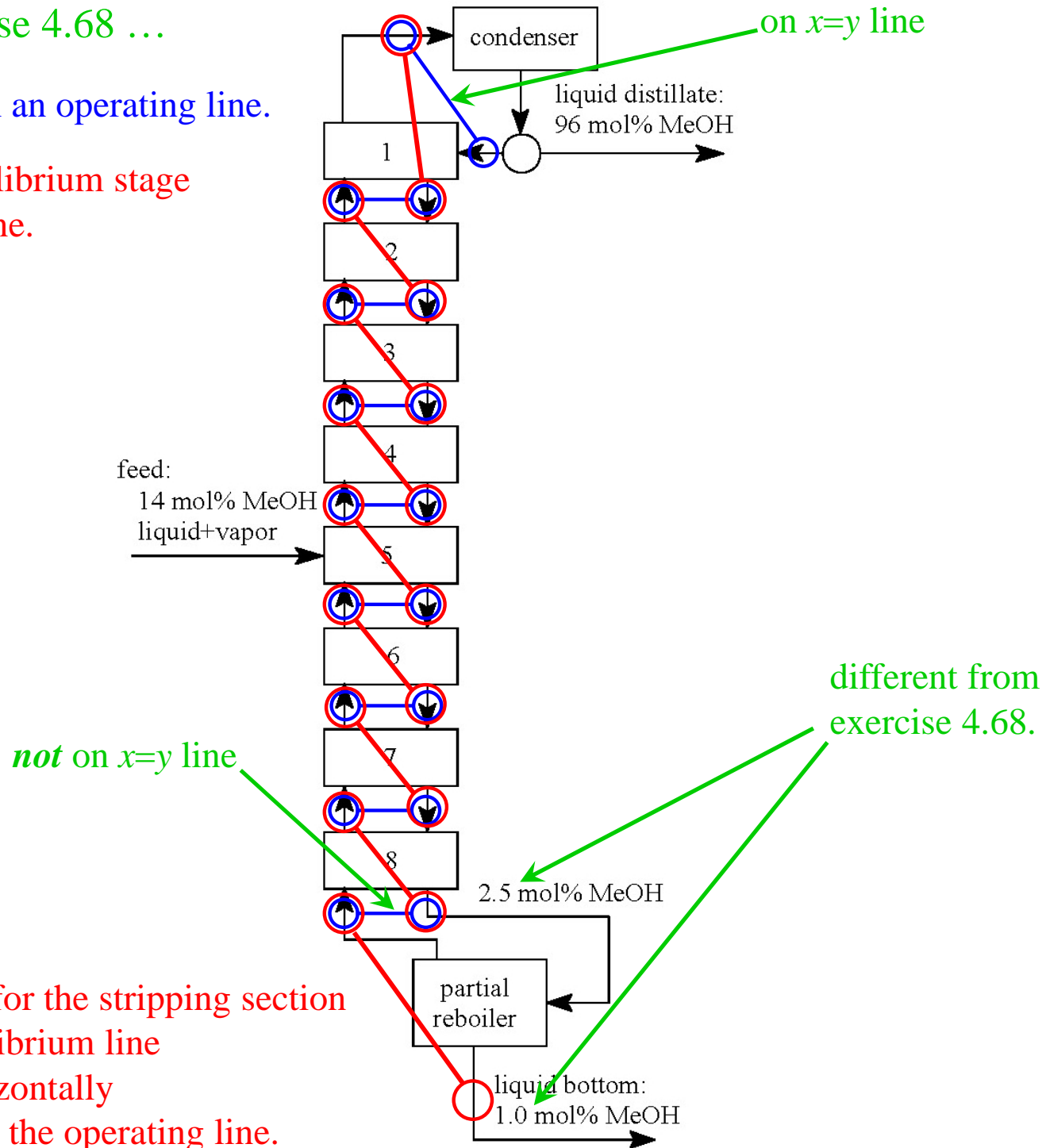
equilibrium line



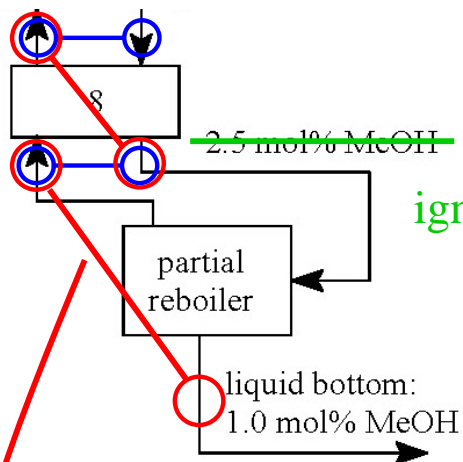
Some hints for exercise 4.68 ...

Adjacent  $x$ - $y$  pairs are on an operating line.

$x$ - $y$  pairs leaving an equilibrium stage are on the equilibrium line.



graphical analysis for the stripping section  
begins on the equilibrium line  
and then steps horizontally  
to the first point on the operating line.

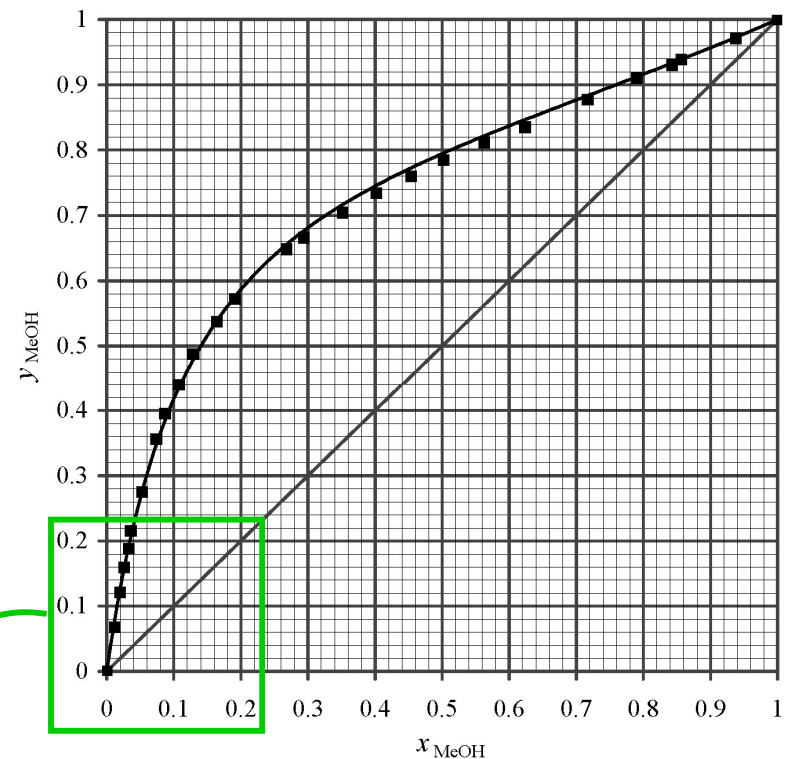


on an operating line.

on the equilibrium line.

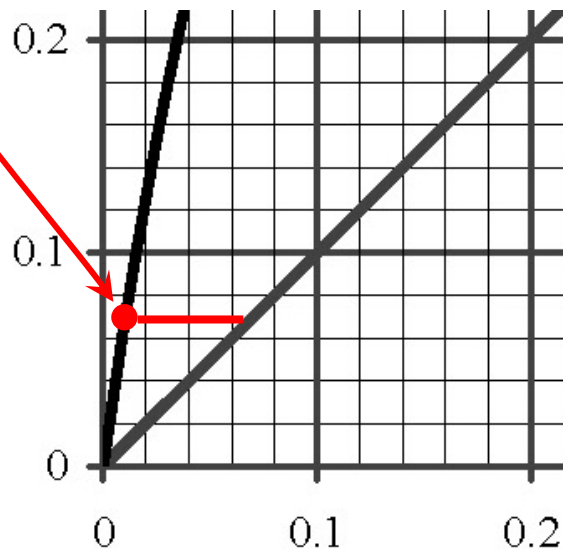
ignore for now.

graphical analysis for the stripping section begins on the equilibrium line and then steps horizontally to the first point on the operating line.

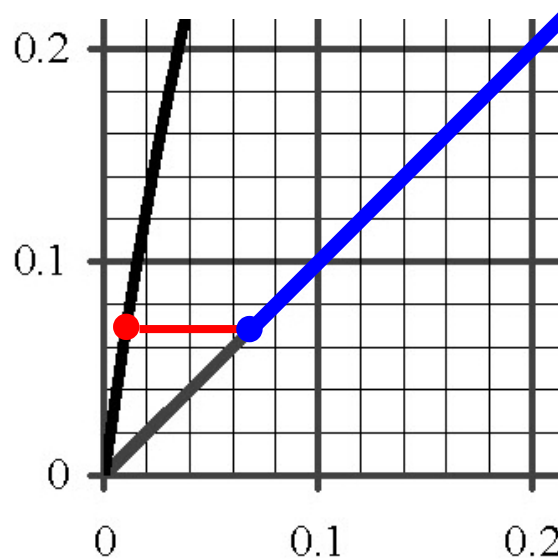


One extreme: no output  
 $\Rightarrow x = y, L = V, L/V = 1$

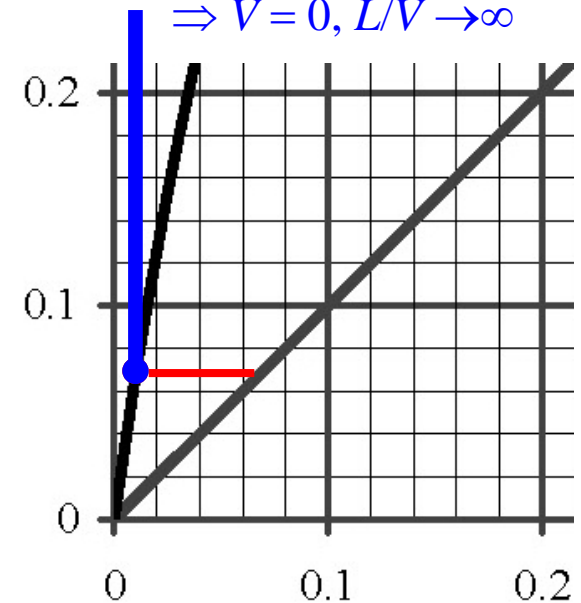
Another extreme: no reflux  
 $\Rightarrow V = 0, L/V \rightarrow \infty$

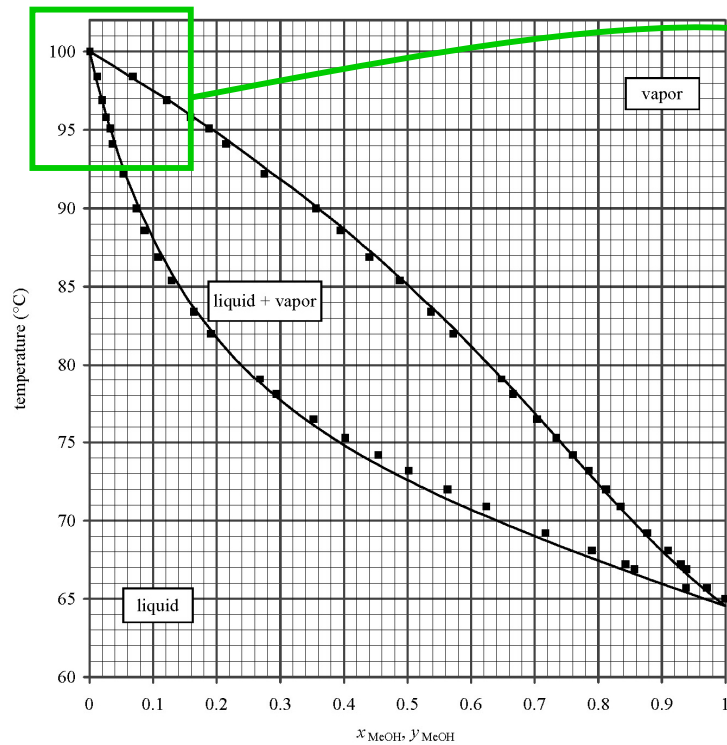


Where is 1<sup>st</sup> point on operating line?



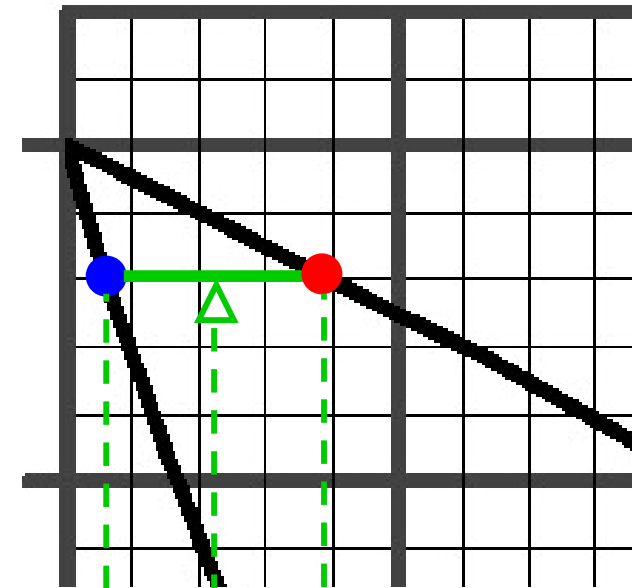
Location of 1<sup>st</sup> point sets the slope of the operating line.





100

95



$x_{\text{product}} = 0.01$

$y$  into stage 8

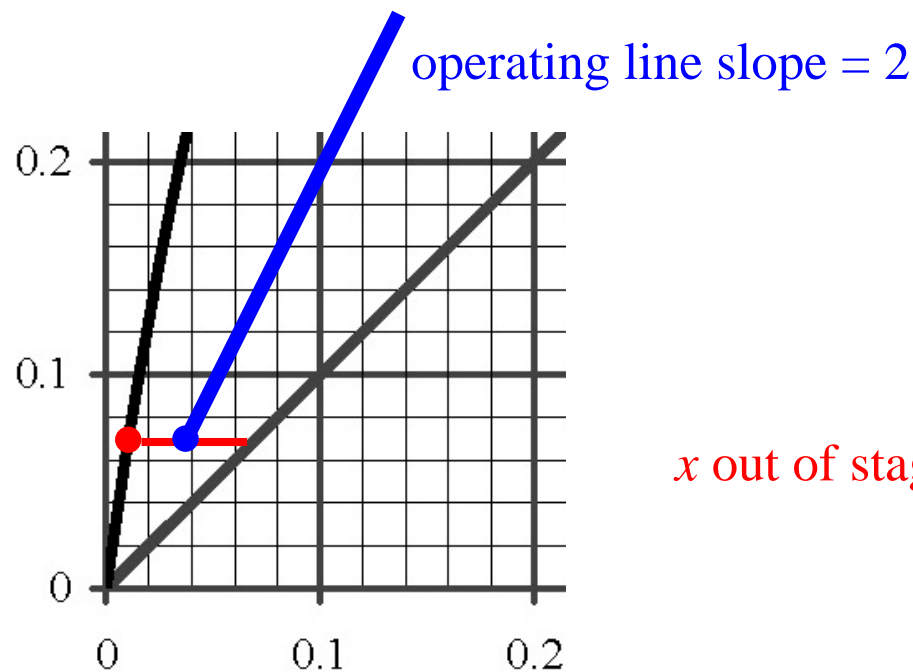
assume  $x$  out of stage 8 is at midpoint of tie line.

$\Rightarrow V$  into stage 8 =  $\frac{1}{2}L$  out of stage 8

$\Rightarrow L/V = L/(\frac{1}{2}L) = 2$

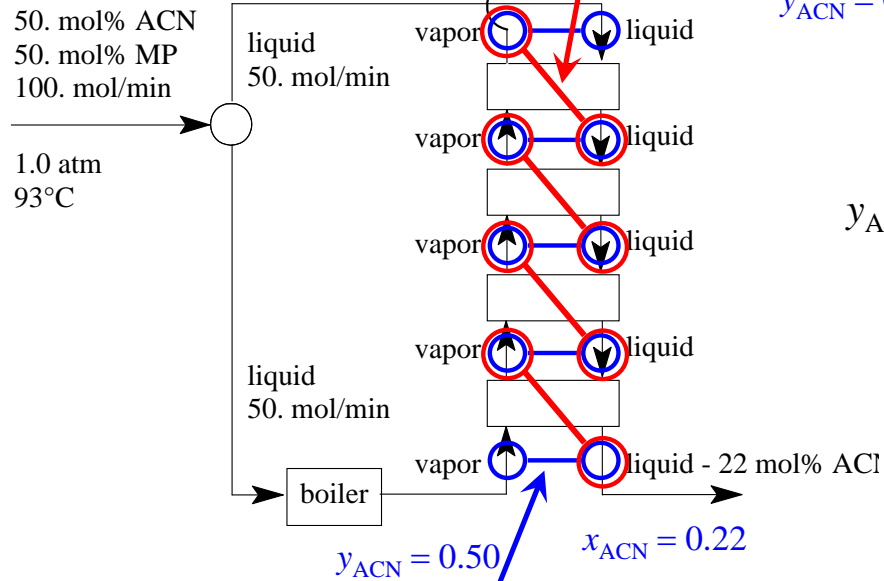
$x$  out of stage 8 determines the operating line slope.

and vice versa.



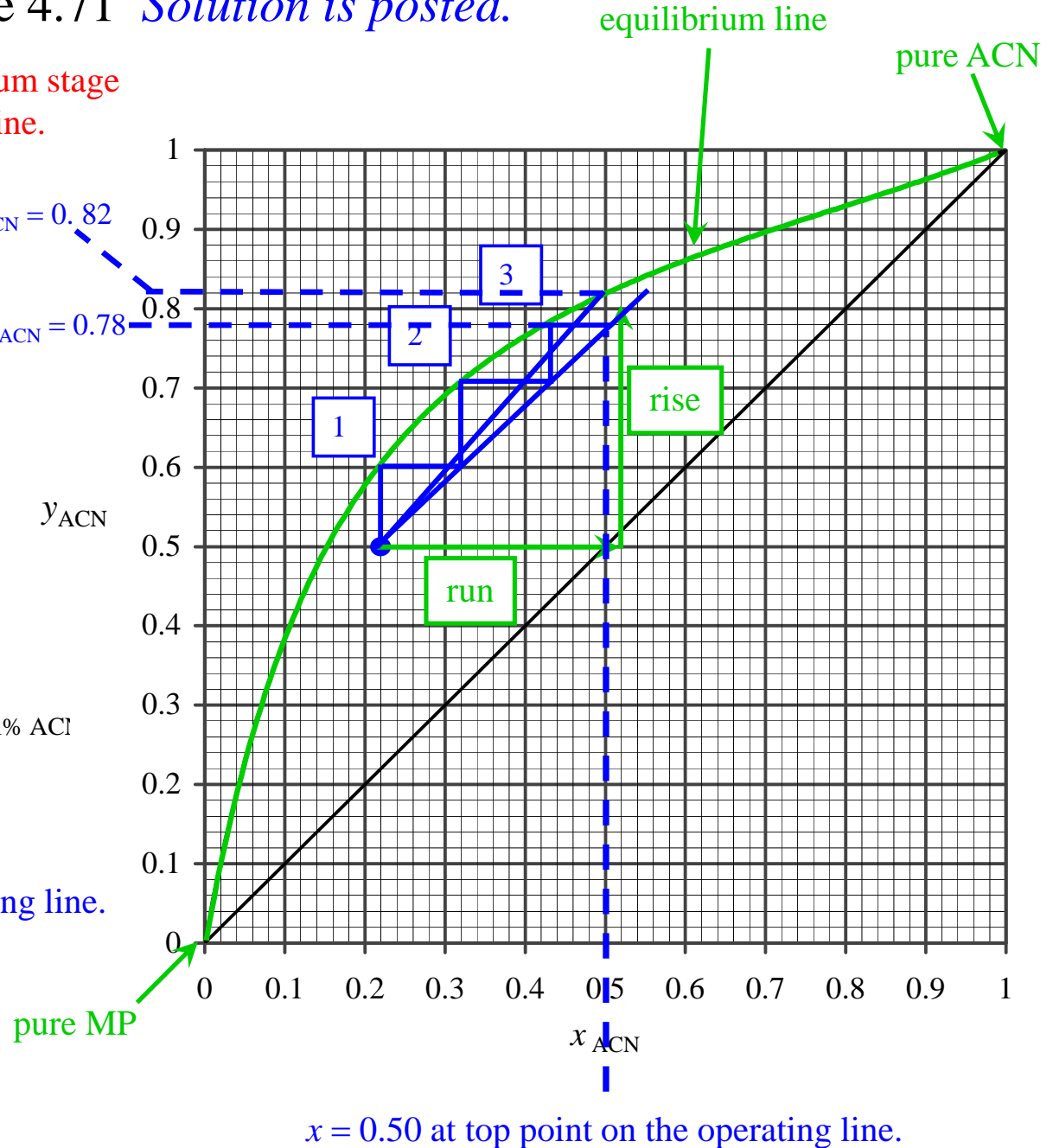
# Exercise 4.71 *Solution is posted.*

*x-y pairs leaving an equilibrium stage are on the equilibrium line.*



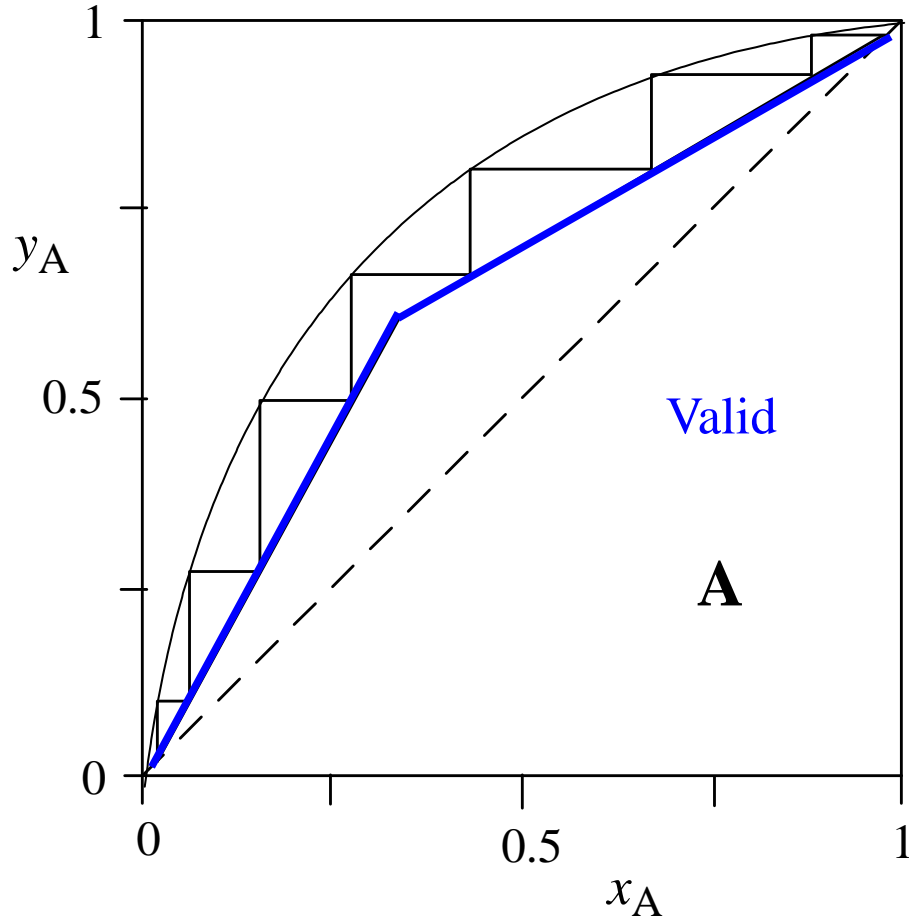
*Adjacent x-y pairs are on an operating line.*

$$\text{operating line slope} = \frac{L}{V} = \frac{50 \text{ mol/min}}{50 \text{ mol/min}} = 1$$



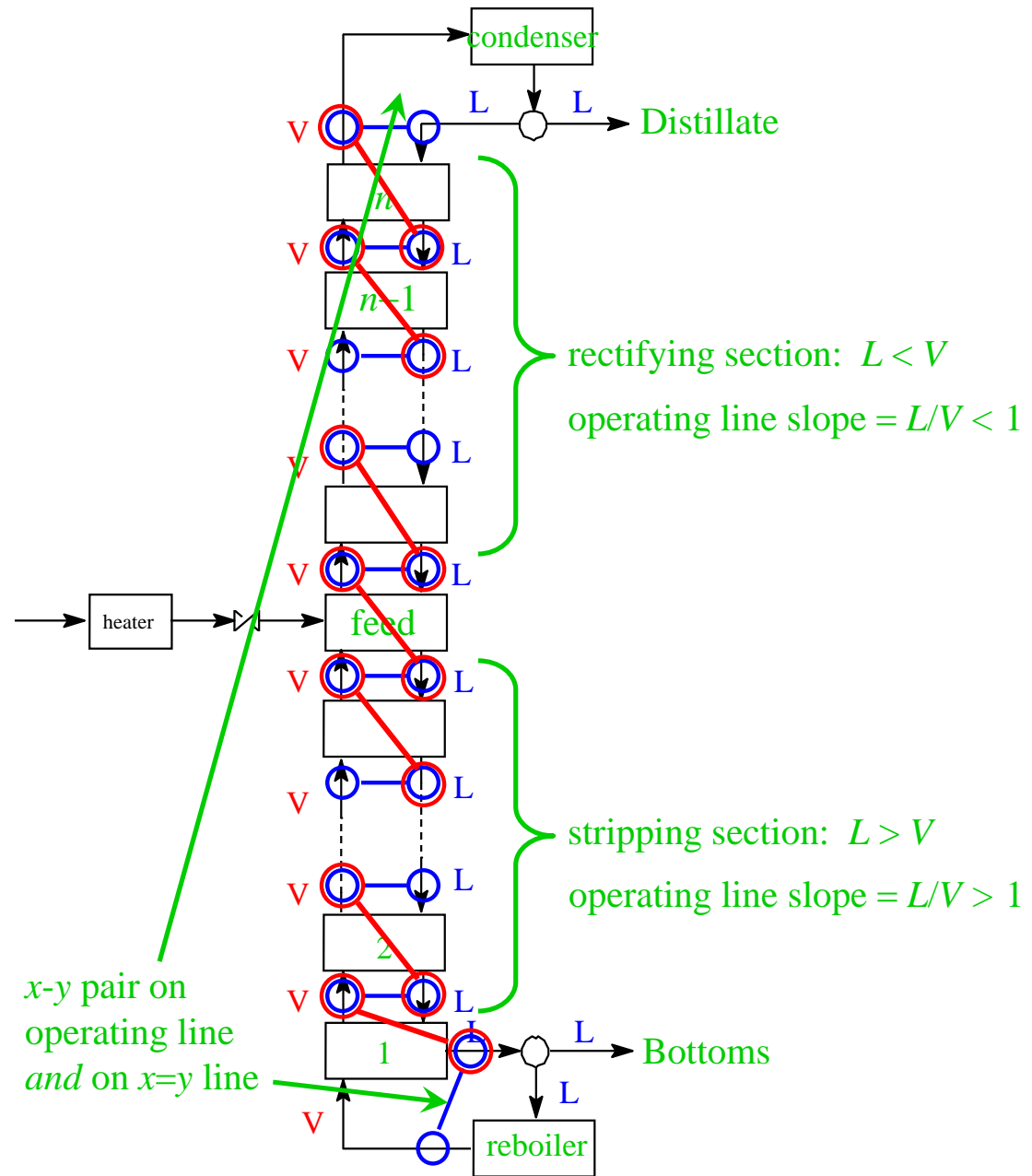


Exercise 4.60 *Solution is posted.*

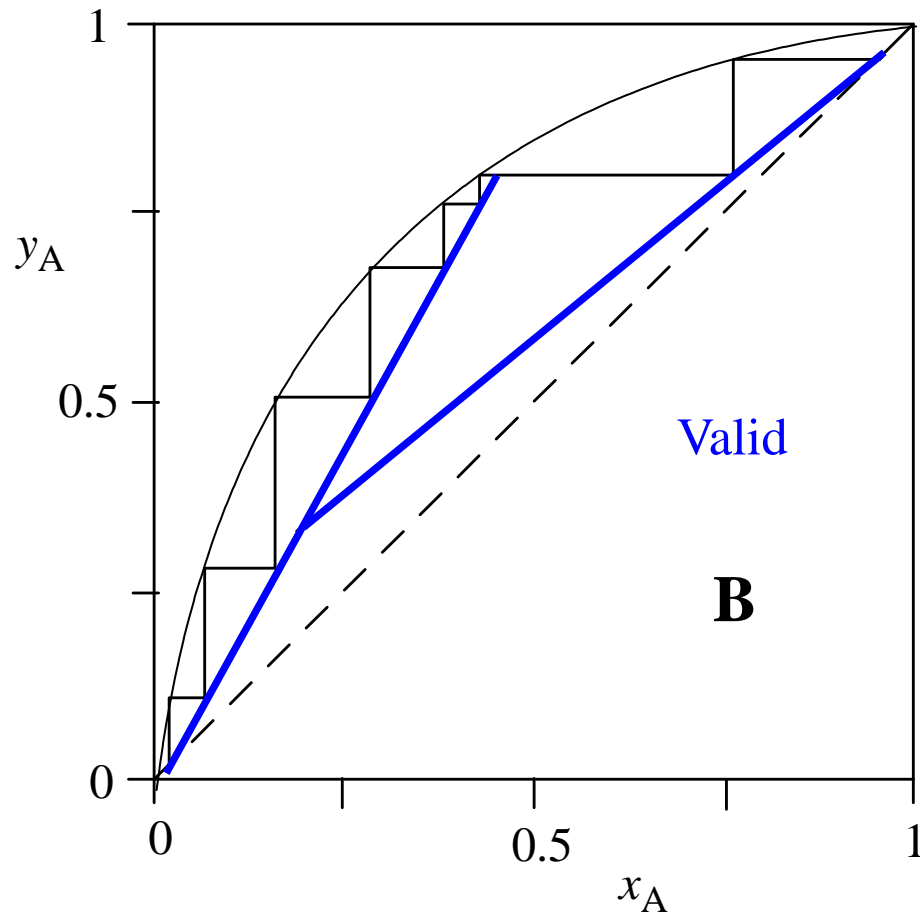


Decide if the operating lines and the steps are consistent with a distillation column with one feed stage and finite output from both the top and the bottom.

A Distillation Column

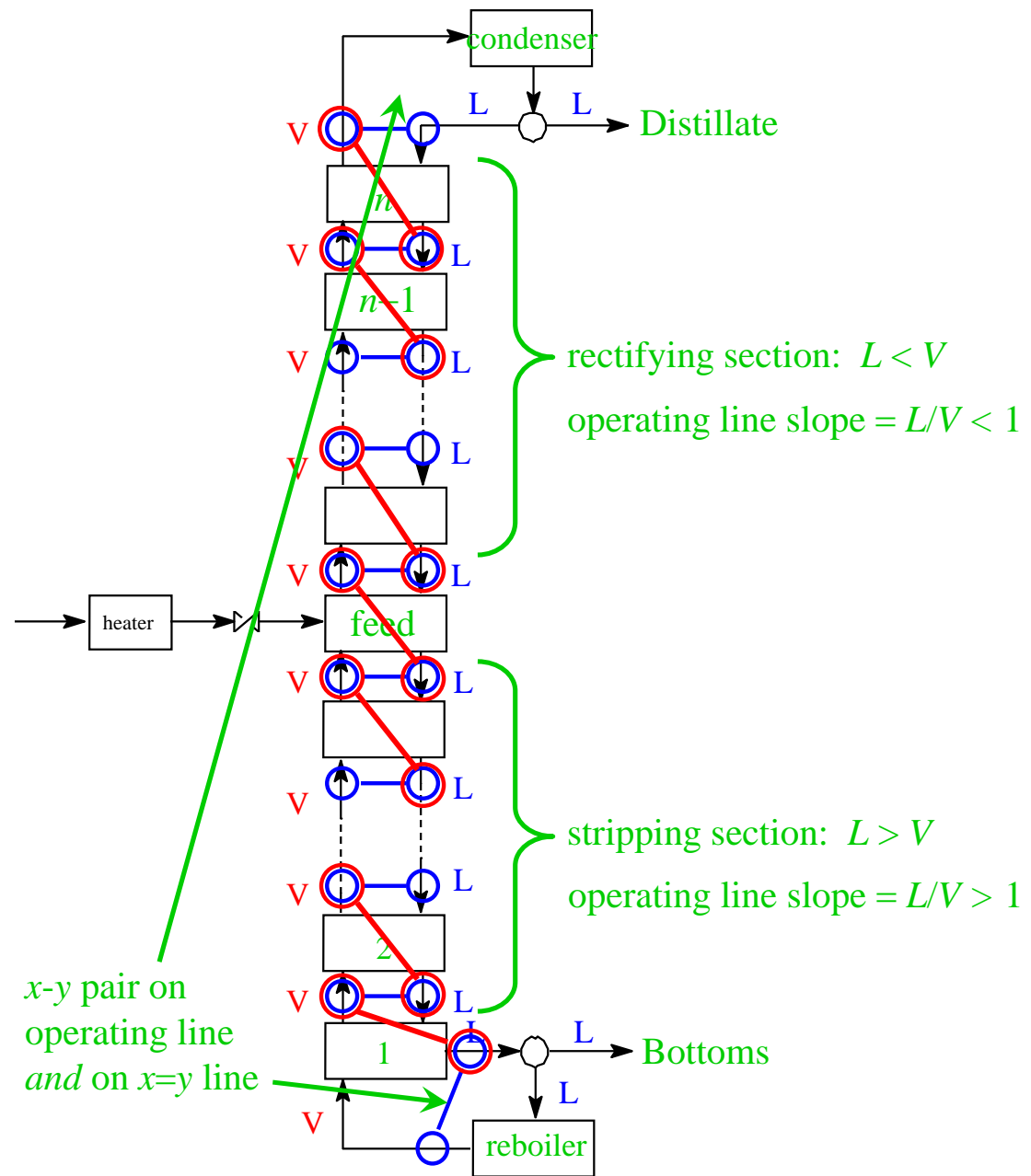


Exercise 4.60 *Solution is posted.*

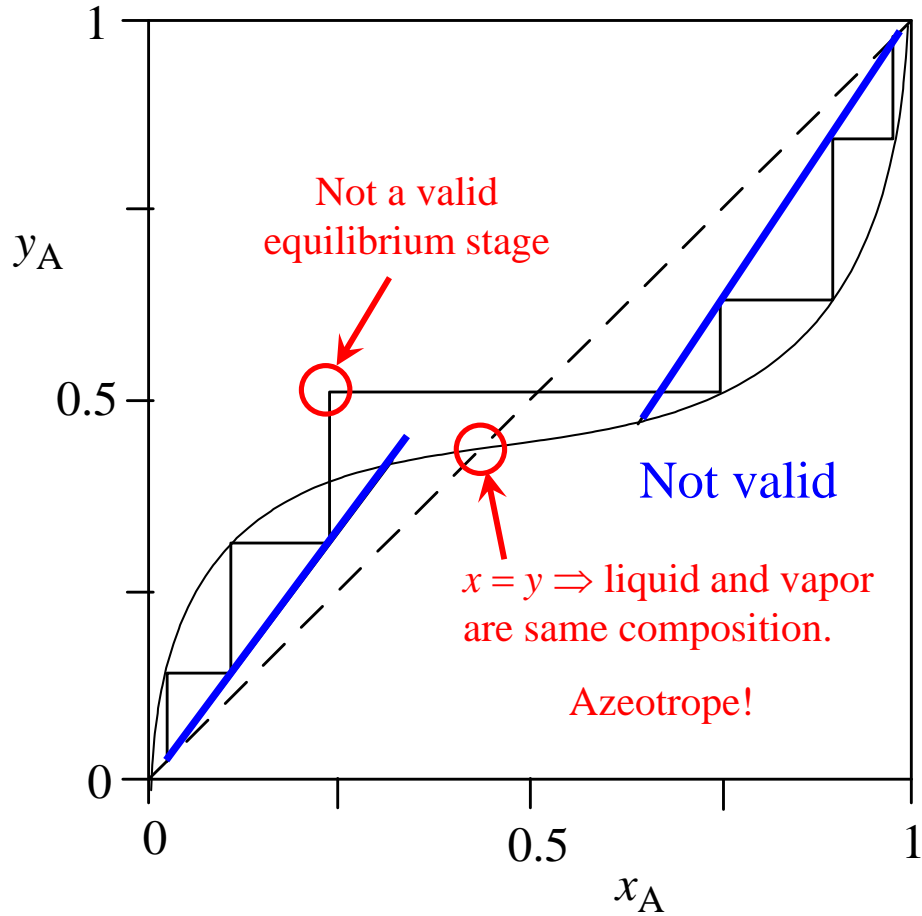


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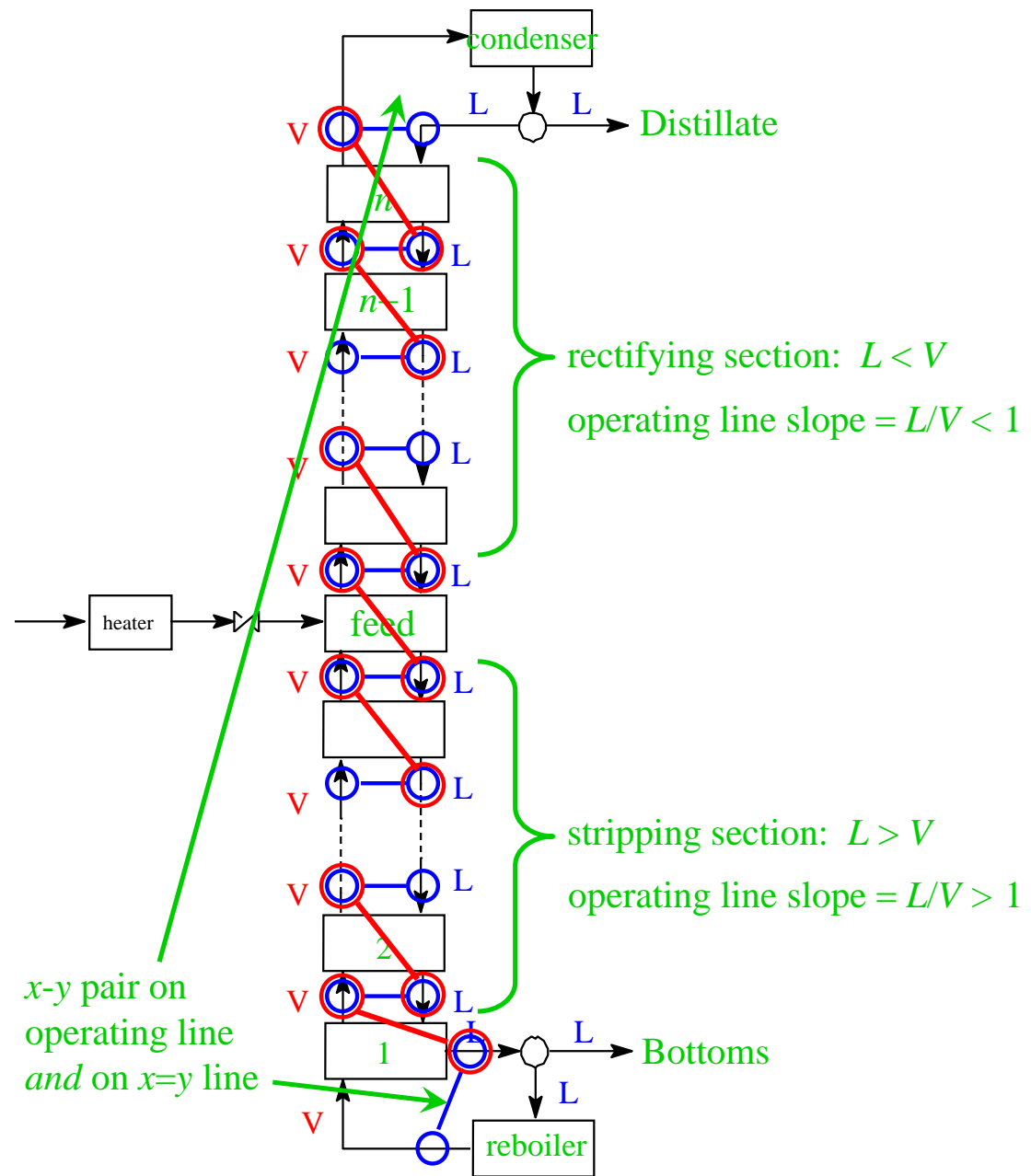


# Exercise 4.60 *Solution is posted.*

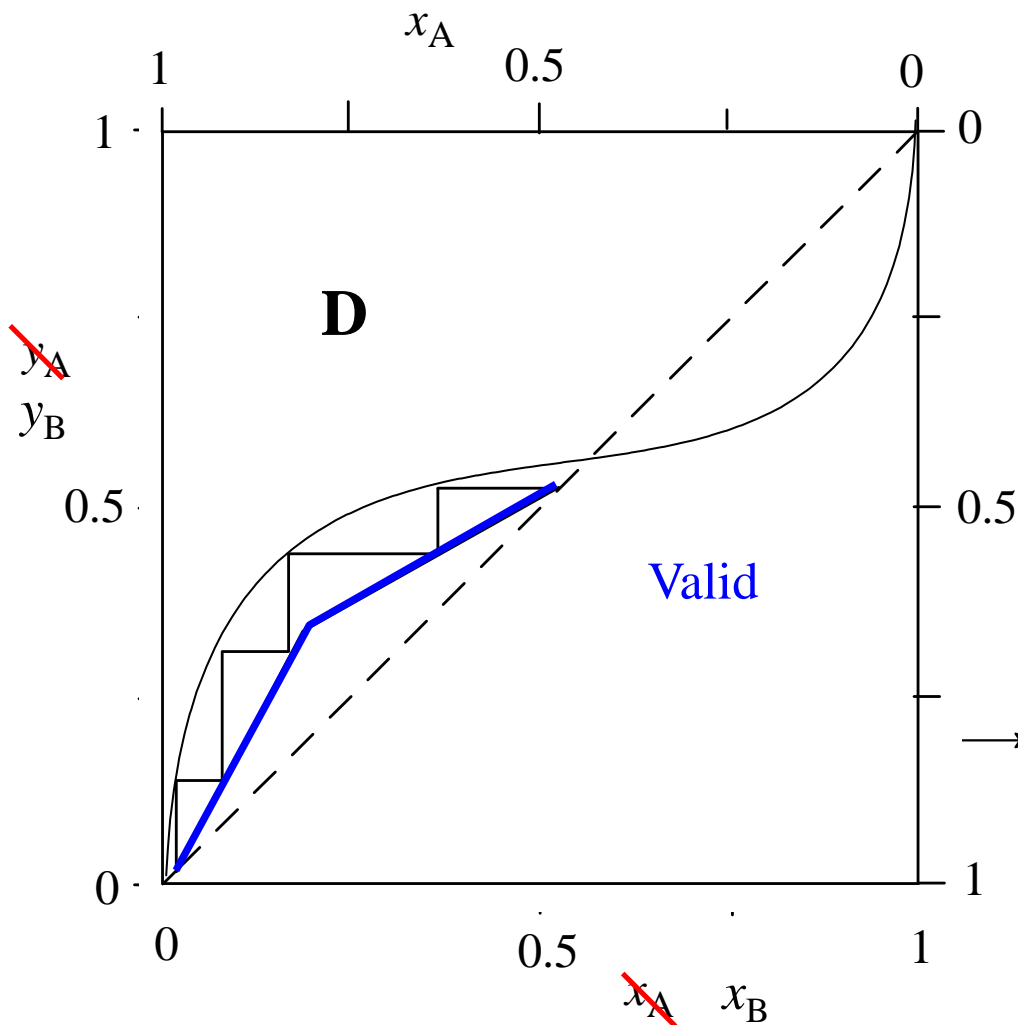


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## A Distillation Column

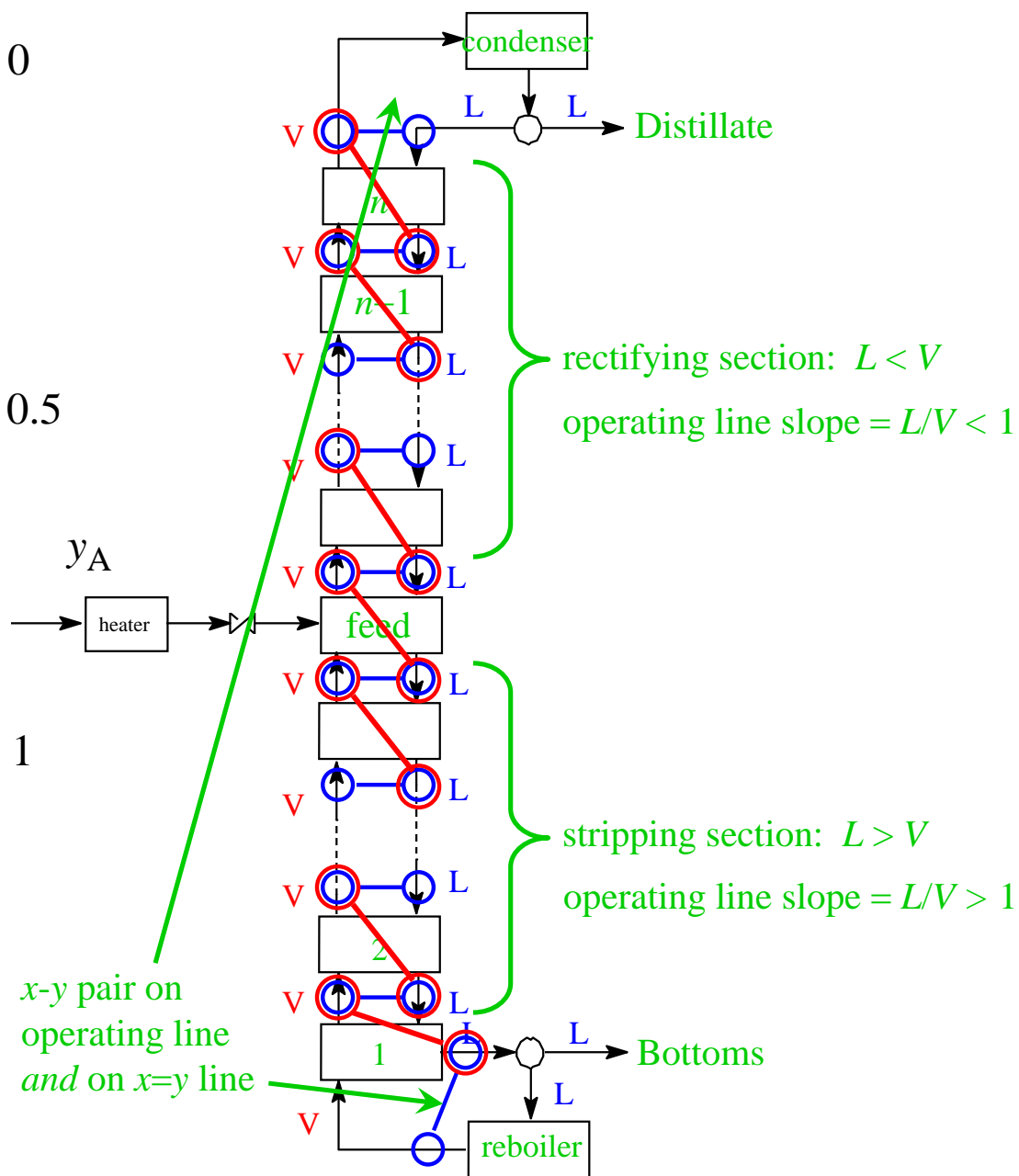


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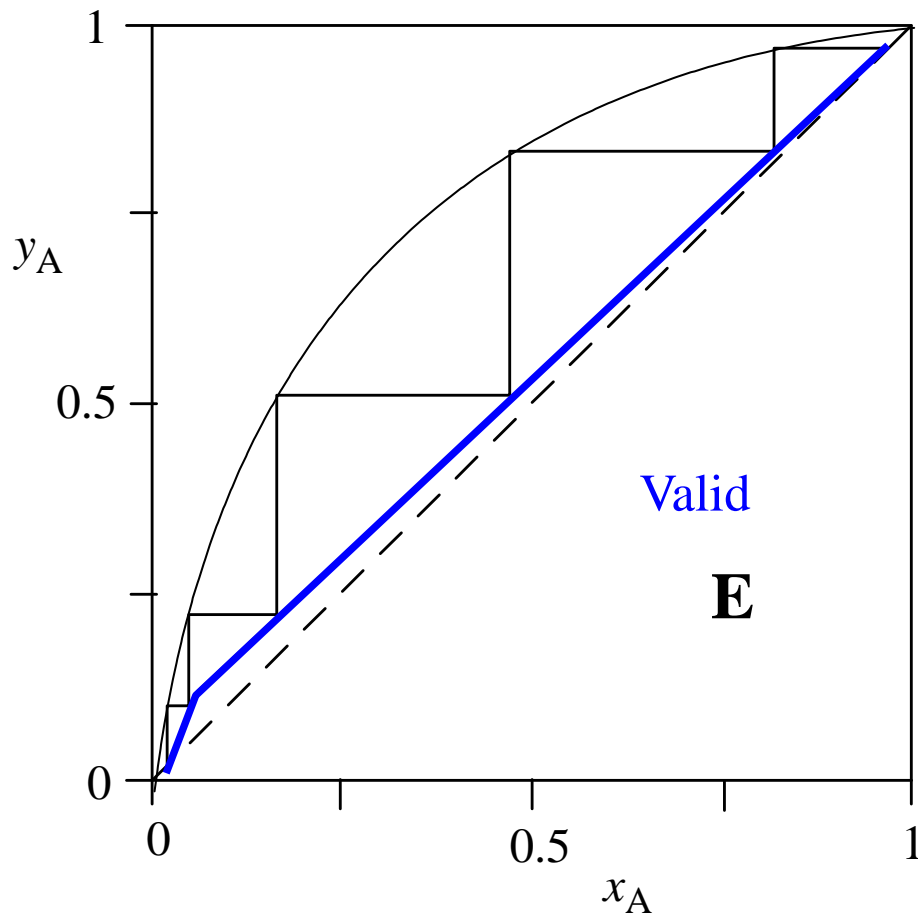


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A Distillation Column

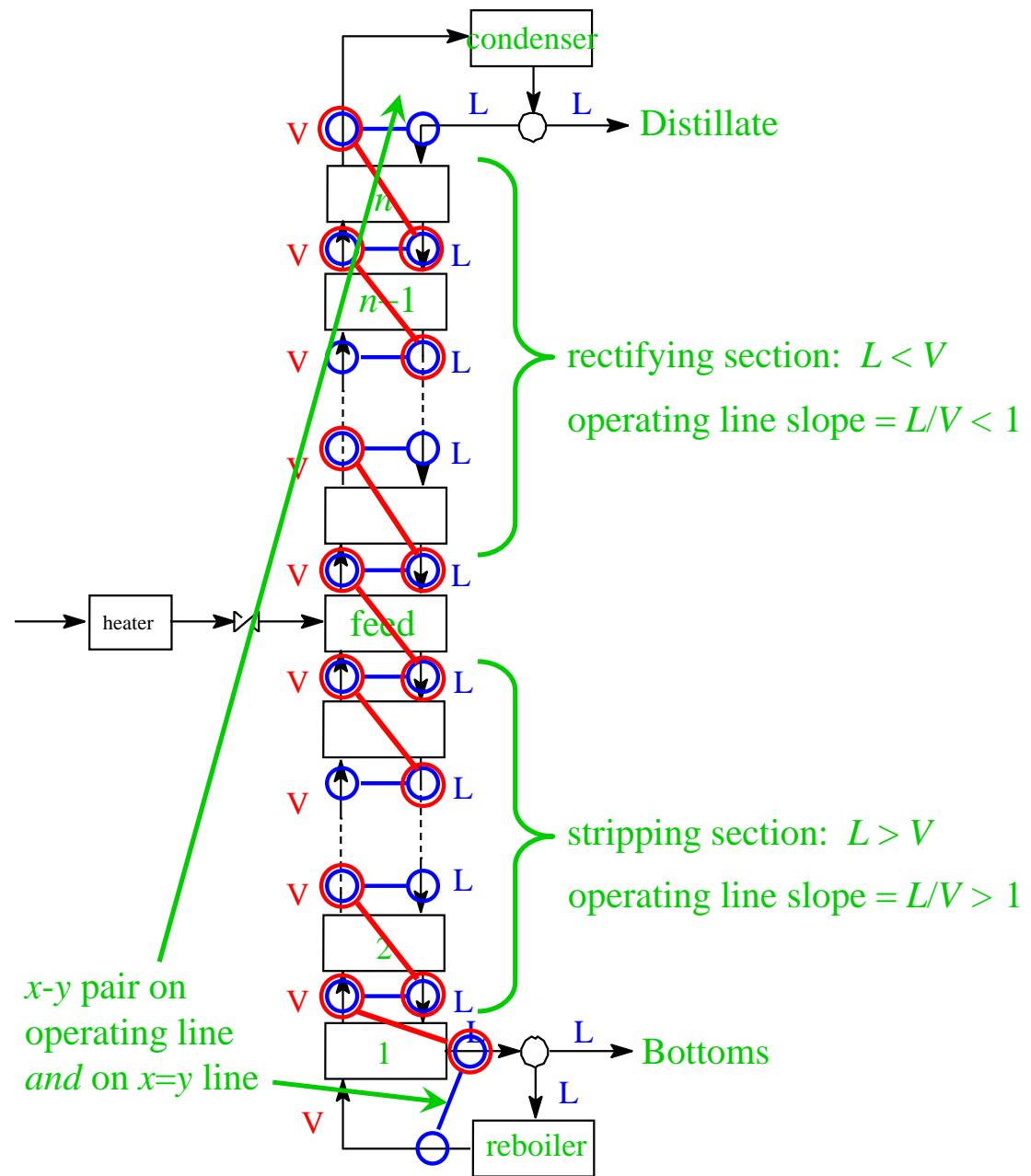


Exercise 4.60 *Solution is posted.*

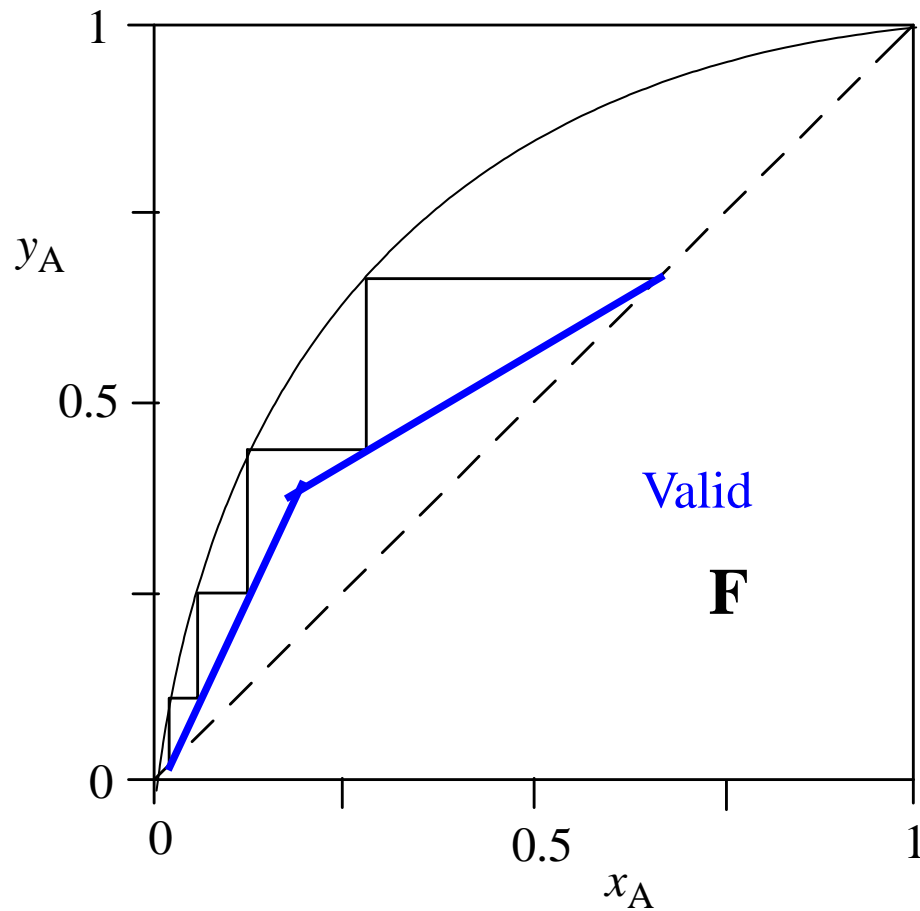


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A Distillation Column

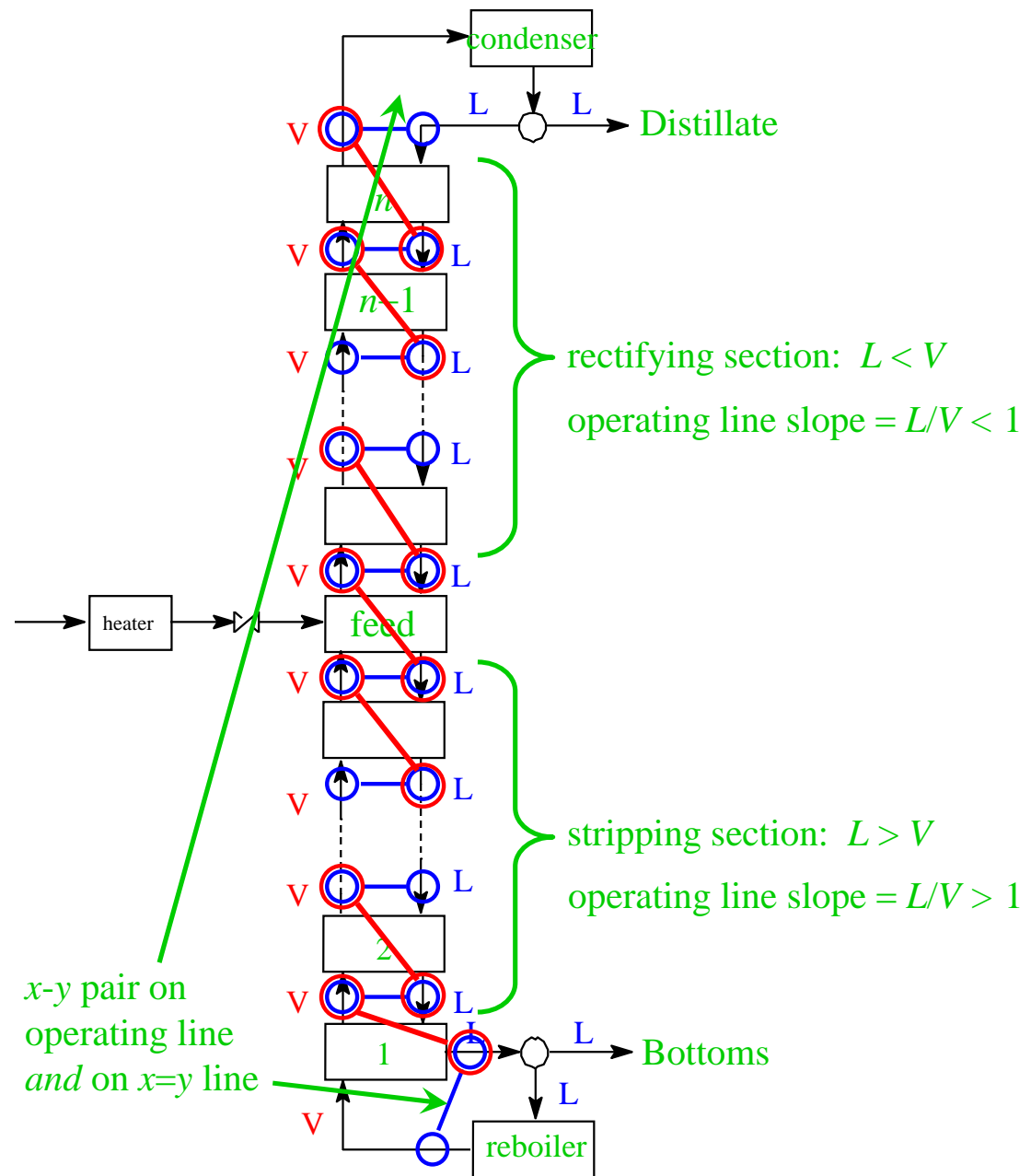


Exercise 4.60 *Solution is posted.*

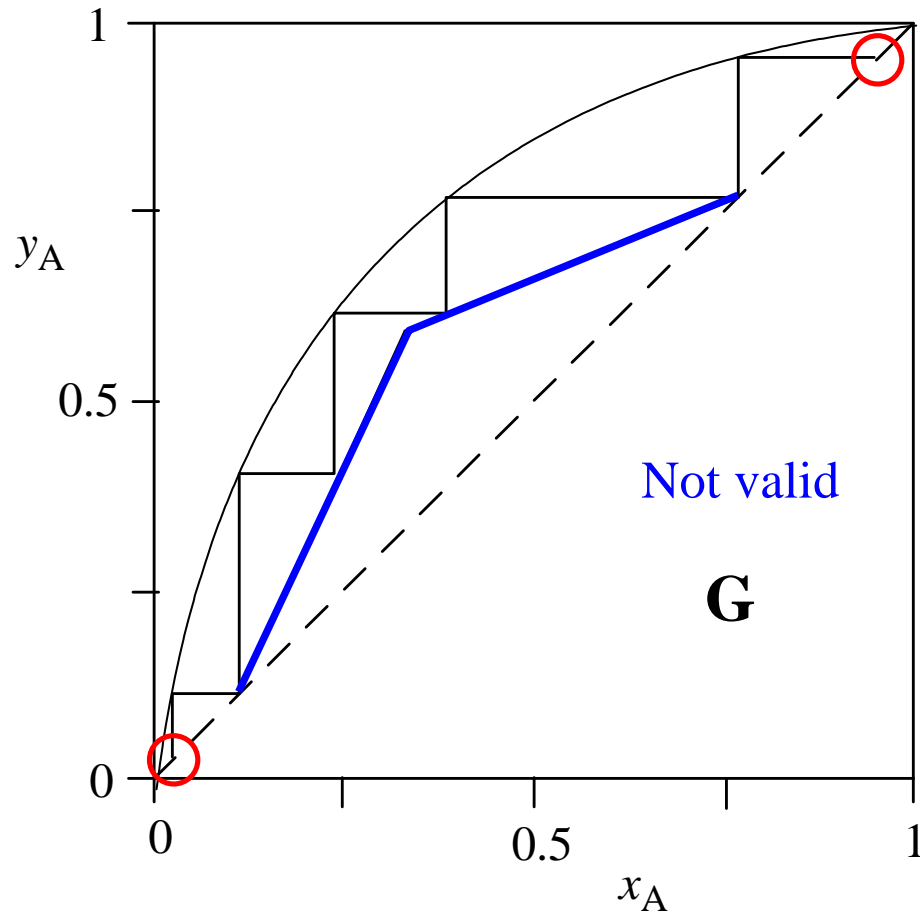


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A Distillation Column

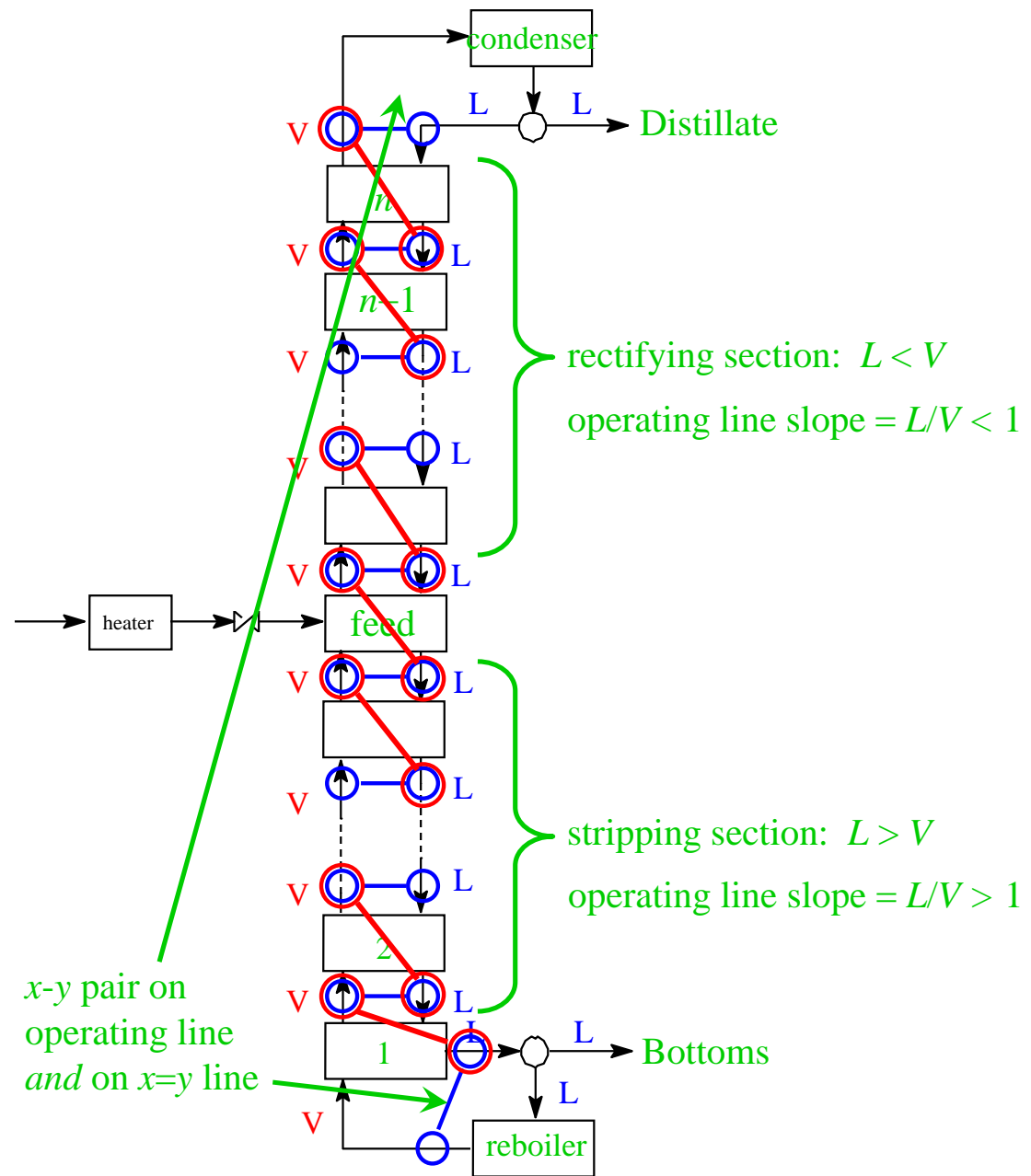


Exercise 4.60 *Solution is posted.*

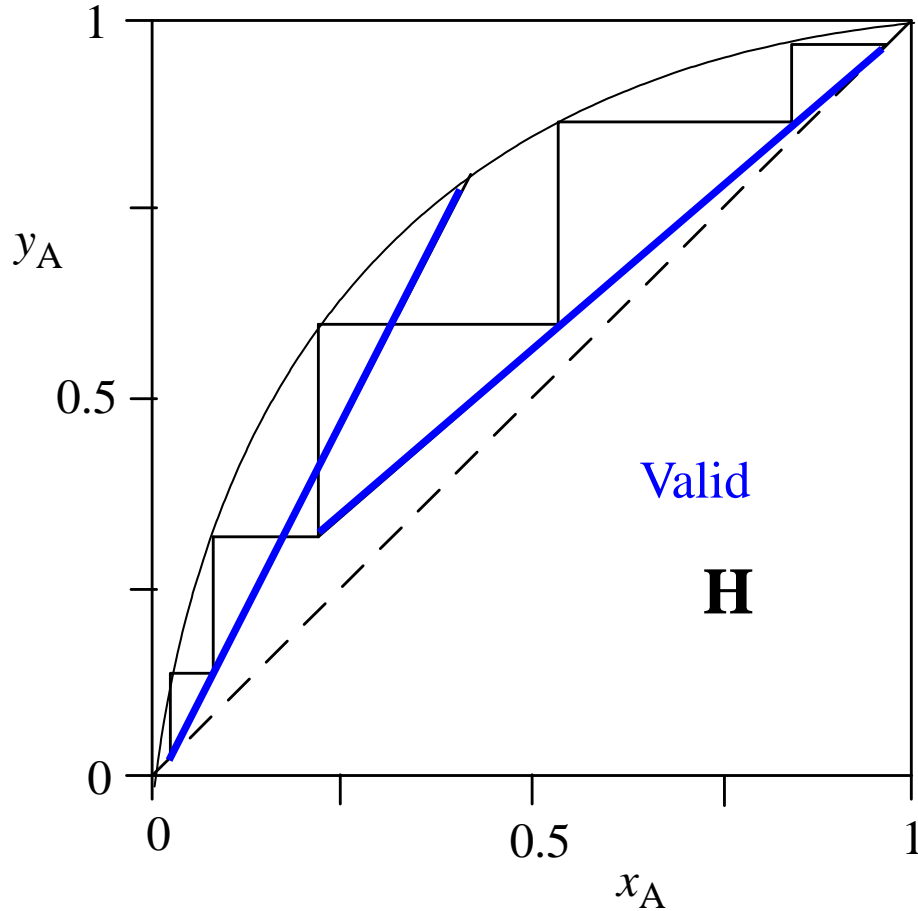


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A Distillation Column



Exercise 4.60 *Solution is posted.*



Decide if the operating lines and the steps are consistent with a distillation column with one feed stage and finite output from both the top and the bottom.

A Distillation Column

