CE 407 LECTURE NOTES 9/21/17

PLATE EFFICIENCIES

- IDEAL PLATE CALCULATIONS ASSUME THAT LIQUID AND VAPOR LEAVING EACH PLATE ARE IN EQUILIBRIUM, $y_n = y_n^*$

  y_n^* is vapor phase MOLE FRACTION IN EQUILIBRIUM with x_n

- Elroy is SAD TO REPORT THAT THIS IS NOT ALWAYS TRUE!

- PLATE EFFICIENCY IS A FUNCTION of the RATE of MASS TRANSFER BETWEEN LIQUID AND VAPOR PHASES

☆ η_o : OVERALL EFFICENCY   ENTIRE COLUMN

$$\eta_o = \frac{\text{\# IDEAL PLATES}}{\text{ACTUAL \# of PLATES REQUIRED}}$$

NO FUNDAMENTAL BASIS

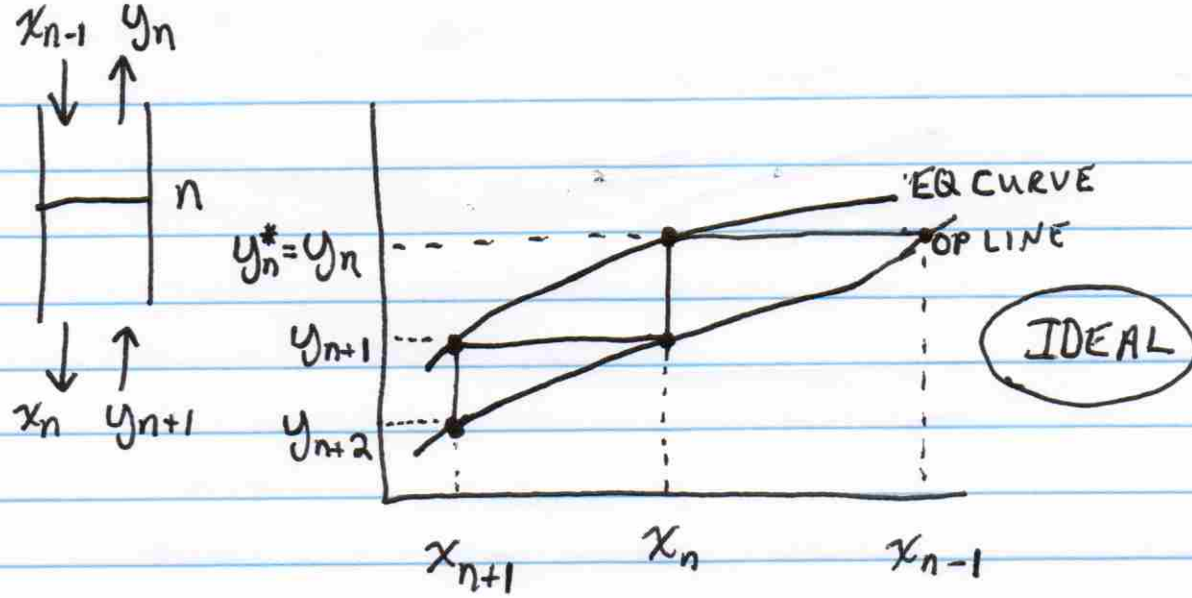
☆ η_M : MURPHREE EFFICIENCY   SINGLE PLATE

$$\eta_M = \frac{y_n - y_{n+1}}{y_n^* - y_{n+1}}$$

☆ η' : LOCAL - SPECIFIC LOCATION on SINGLE PLATE

$$\eta' = \frac{y_n' - y_{n+1}'}{y_{en}' - y_{n+1}'}$$

MURPHREE

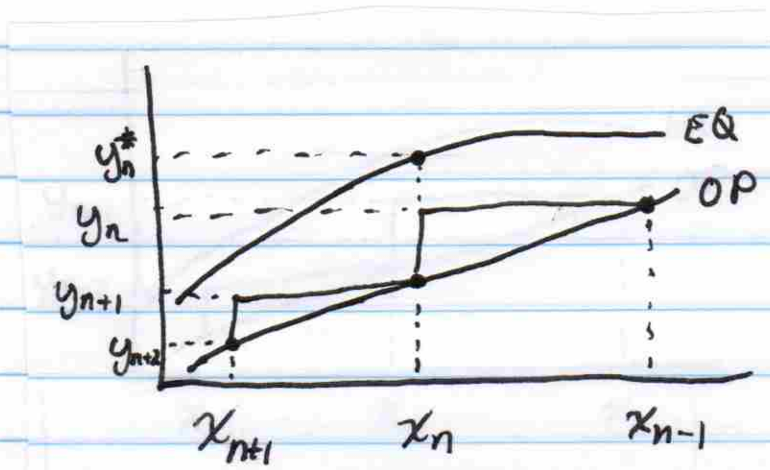


IDEAL

RECALL x_n and y_{n+1} reference a point on OP LINE
x_n and y_n reference a point on EQ CURVE

STEPS ABOVE Assume $y_n = y_n^*$ and lies on EQ CURVE

MURPHREE ACKNOWLEDGES IT MAY FALL SHORT



$\eta_M < 1$

$y_n^* \neq y_n$! NOTE $y_n^* - y_{n+1}$ IS THE CHANGE IN VAPOR PHASE COMPOSITION IF WE REACHED EQUILIBRIUM. $y_n - y_{n+1}$ IS WHAT WAS ACHIEVED

$$\eta_M = \frac{y_n - y_{n+1}}{y_n^* - y_{n+1}}$$

LOCAL EFFICIENCY

$$\eta' = \frac{y_n' - y_{n+1}'}{y_{en}' - y_{n+1}'}$$

y_n' CONCENTRATION OF VAPOR LEAVING SPECIFIC LOCATION on PLATE n

y_{n+1}' CONCENTRATION of VAPOR ENTERING PLATE n at the SAME LOCATION

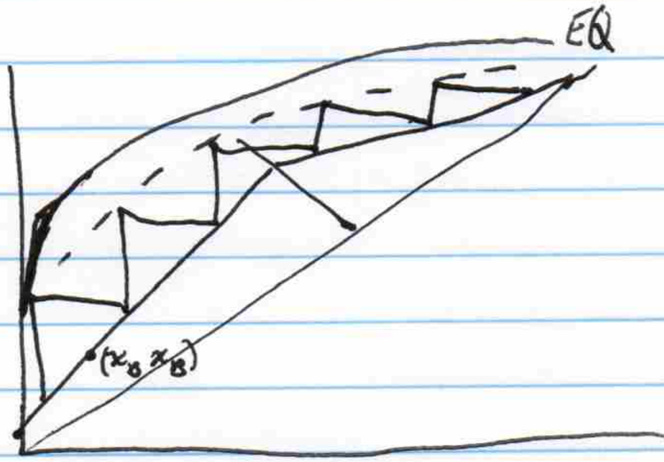
y_{en}' CONCENTRATION OF VAPOR IN EQUILIBRIUM WITH the LIQUID AT THAT SAME LOCATION

VALUES CAN VARY FROM POINT TO POINT ON A GIVEN PLATE DUE TO POOR MIXING, BAD FLOW PATTERNS, etc.

IN SMALLER COLUMNS WITH GOOD MIXING, etc.

$$\eta' = \eta_M$$

USE of η_M



Dotted curve is y' effective EQUILIBRIUM

NOTE: FOR Reboiler THE TRIANGLE IS DRAWN VS THE TRUE EQ CURVE

Plot $y_e' = y + \eta_M (y_e - y)$

FOR HIGH Purity Cases:

WHEN CALCULATING THE LINEAR APPROXIMATION TO EQ CURVE (Above cutoff)

EQ Line Passes through $(1,1)$

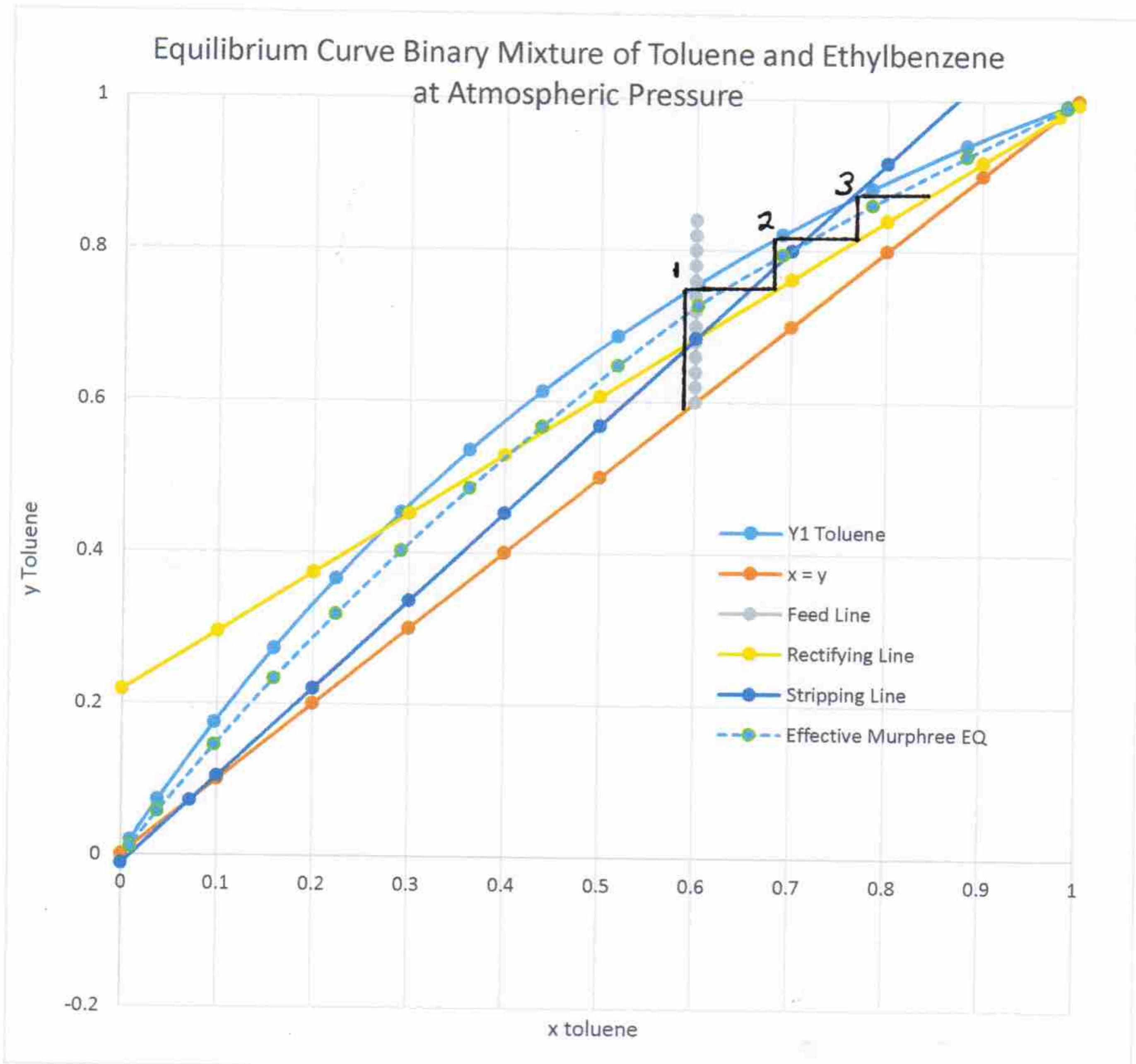
and $(x_{cutoff}, y^* \text{ at } x_{cutoff}) \Rightarrow$ CALCULATE $y^* = mx + b$ FROM THESE 2 points

y_a^* obtained at x_D

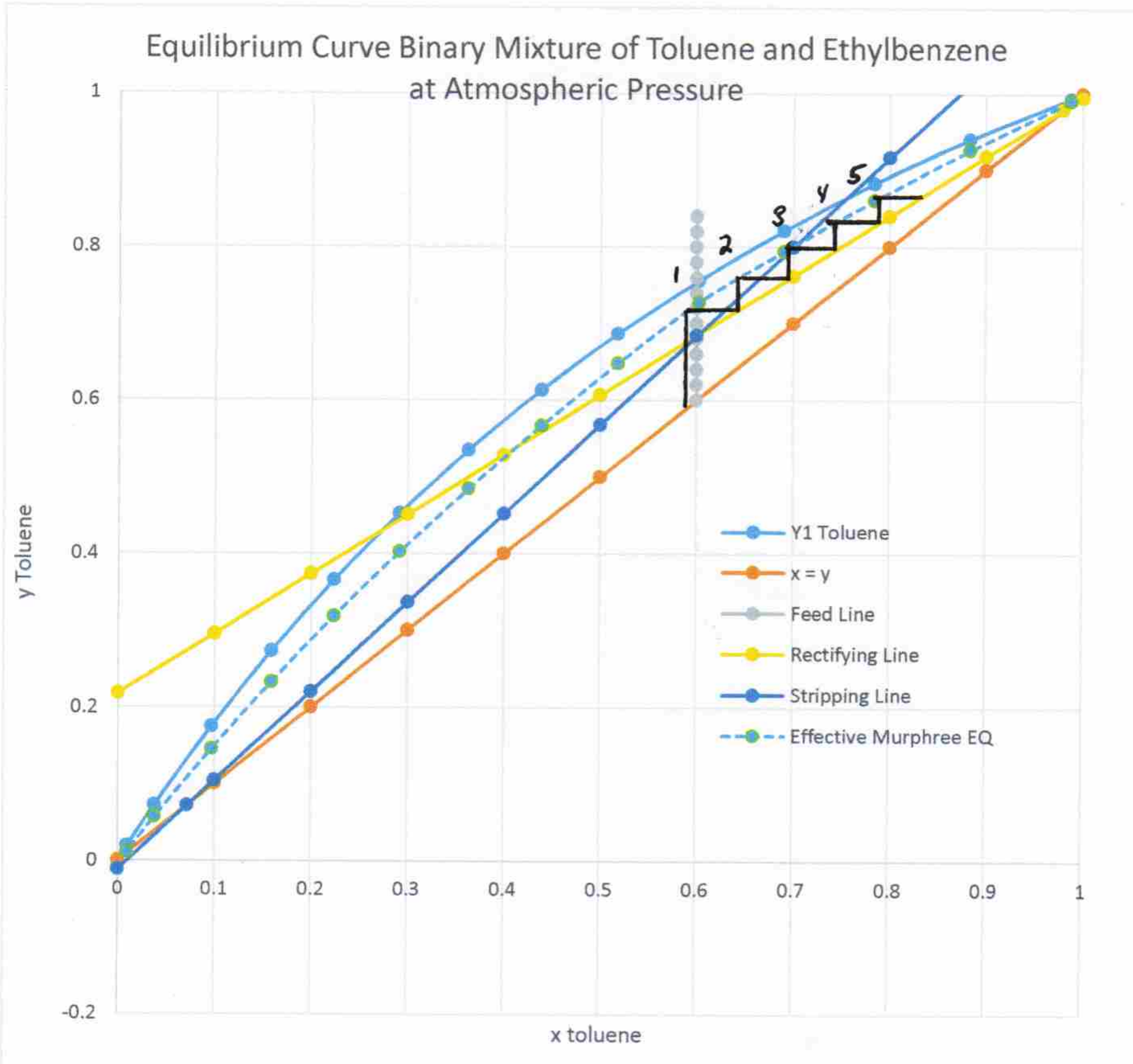
or $y_a^{*\prime} = y_a + \eta_M (y_a^* - y_a)$

$y_b^{*\prime} = y_b + \eta_M (y_b^* - y_b)$ y_b^* obtained at $x = x_{cutoff}$

IDEAL


Equilibrium Curve Binary Mixture of Toluene and Ethylbenzene
at Atmospheric Pressure
y Toluene
x toluene
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Y1 Toluene
x = y
Feed Line
Rectifying Line
Stripping Line
Effective Murphree EQ
1
2
3

$\eta_M = 0.6$ ↑ →



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Feed Line
Rectifying Line
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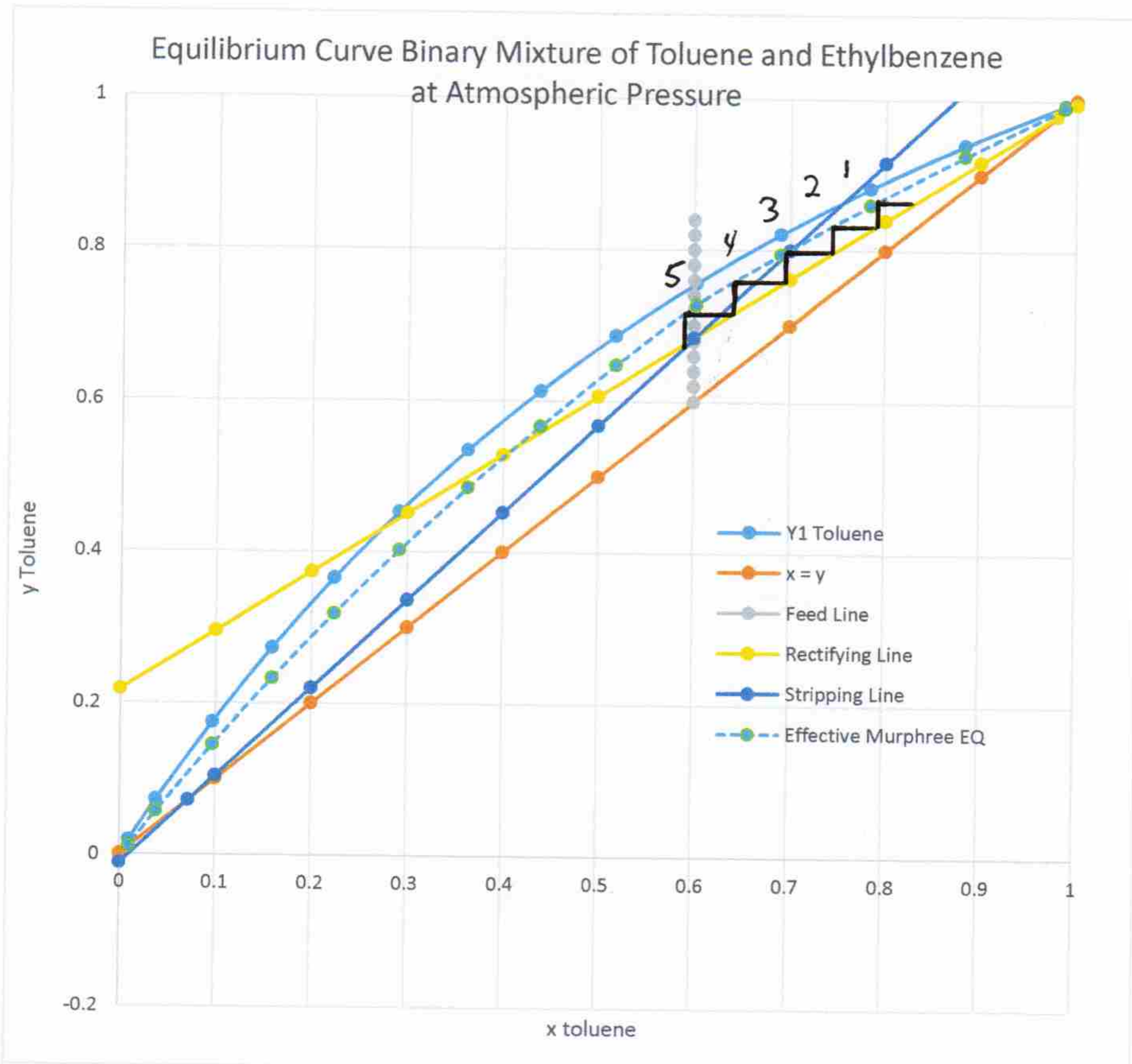
Effective Murphree EQ
1
2
3
4
5

$\eta_M = 0.6$



Equilibrium Curve Binary Mixture of Toluene and Ethylbenzene at Atmospheric Pressure
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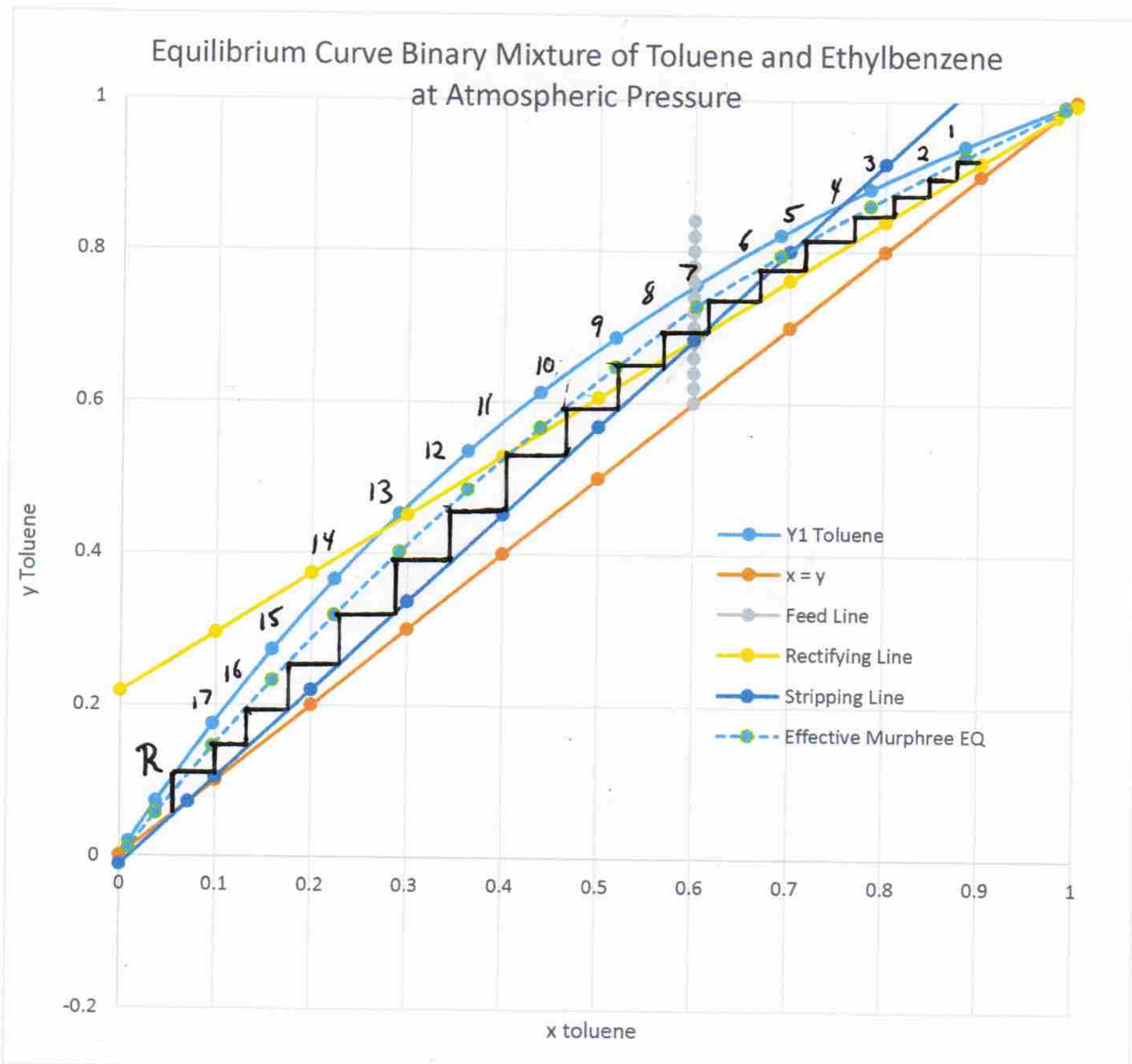
17 STAGES w/ $\eta_M = 0.6$

FROM $x = 0.1$ to $x = 0.9$

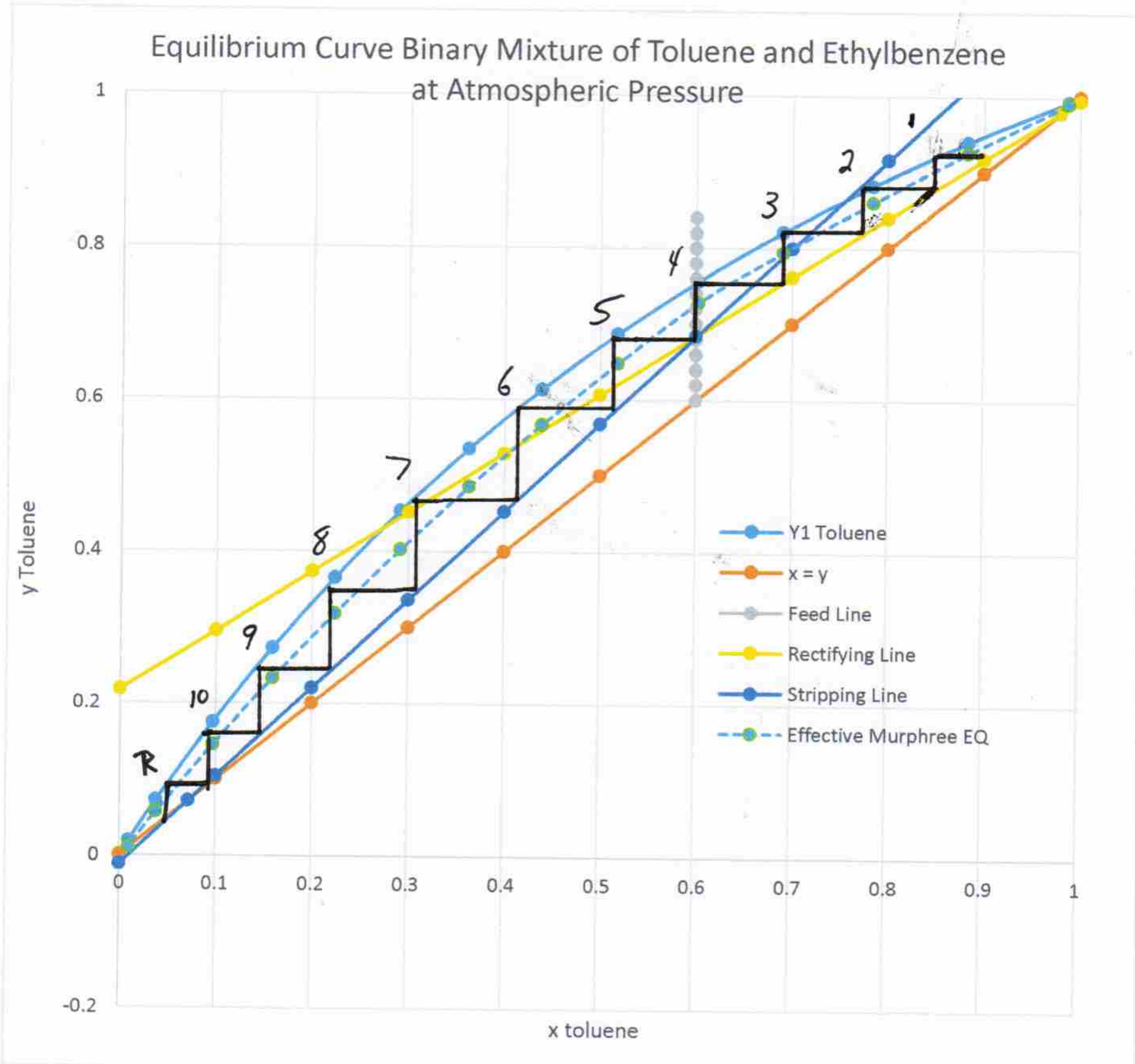


$$\eta_o = \frac{10}{17} = 0.59$$

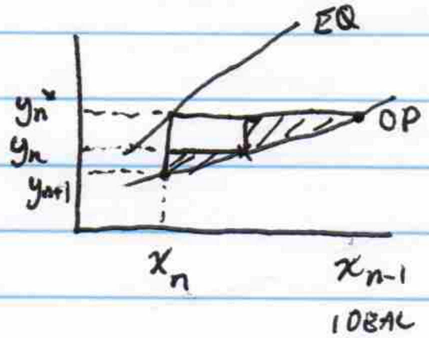
BUT IF WE HAD WORKED UP TO $x_D = 0.9794$, η_o would drop

10 IDEAL STAGES

FROM $x = 0.1$ to $x = 0.9$



$\eta_0 \neq \eta_M$ IN MANY CASES



ONE IDEAL STEP, TWO ACTUAL STEPS

$$\eta_0 = \frac{1}{2} = 0.5$$

$$\eta_M = \frac{y_n - y_{n+1}}{y_n^* - y_{n+1}} < 0.5$$

FACTORS INFLUENCING PLATE EFFICIENCY

$\mu_L, D_{vy}, D_{vx}, \rho_L, \rho_V \ldots\ldots$

"The BEST METHOD of PREDICTING EFFICIENCY IS STILL IN QUESTION"

"MOST COLUMNS ARE DESIGNED USING EFFICIENCIES MEASURED FOR SAME TYPE of PLATE AND SIMILAR SYSTEMS"

IT IS IMPERATIVE TO HAVE COLUMN DESIGNED SO THAT PLATES ACTUALLY FUNCTION PROPERLY (NO FLOODING, WEEPING, ETC.)

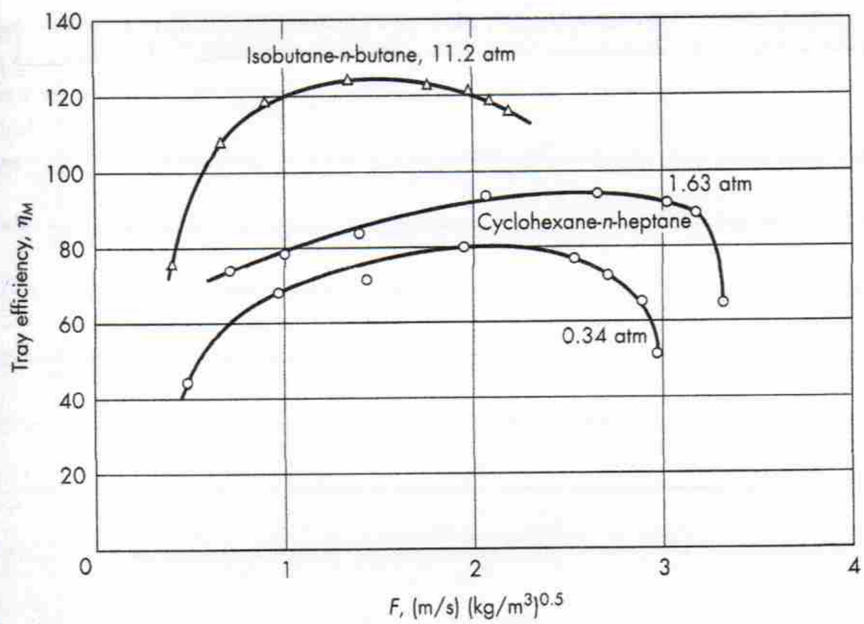


FIGURE 21.33
Efficiency of sieve trays in a 1.2-m column. (*From M. Sakata and T. Yanagi, 3rd Int. Symp. Dist.*, p. 3.2/21, *ICE*, 1979.)

$\eta_M > 1.0$?!?

THIS WAS DUE to LIQUID CONCENTRATION GRADIENTS

PACKED COLUMNS

INSTEAD of PLATES the IS A COLLECTION of PACKING, SMALL PIECES OF SPECIFIC SHAPES DESIGNED TO PROVIDE SURFACE AREA FOR LIQUID TO FLOW ACROSS

- USED IN LESS DEMANDING SEPARATIONS
- LESS EXPENSIVE
- LESS ΔP
- EVEN DISTRIBUTION OF LIQUID FLOW CAN BE A CHALLENGE

☆ ONE CALCULATES NUMBER of IDEAL STAGES USING McCABE-THIELE

☆ HEIGHT EQUIVALENT to a THEORETICAL PLATE

HETP the height of packing that achieves the same separation as an ideal stage

Although effective HETP will vary w/ position in column (DUE TO CHANGE is SLOPE of equilibrium curve), it balances out ACROSS COLUMN

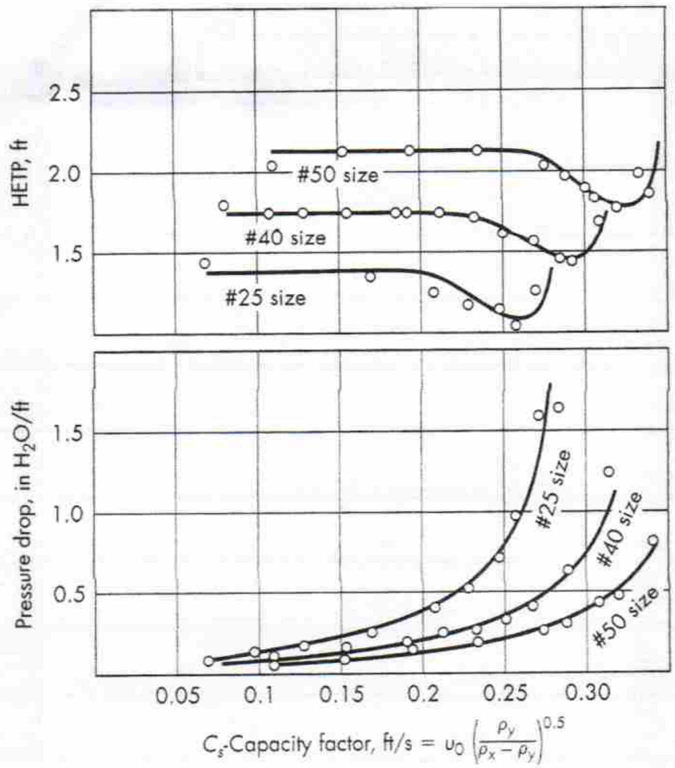


FIGURE 21.34
HETP and pressure drop in the distillation of isooctane and toluene in Intalox metal tower packings.[22]

EXAMPLE DATA for A SPECIFIC PACKING IN A SPECIFIC SYSTEM

COMMON 1½" or 2" PACKINGS HAVE HETP in range of 1 to 2 FEET