Latin American Applied Research an International Journal of Chemical Engineering. 2014, vol. 44, 4, 61-66
(Accepted: March 17, 2014).

Supplementary Material:
ANALYSIS OF THE CONNECTING ZONE BETWEEN CONSECUTIVE SECTIONS IN DISTILLATION COLUMNS COVERING MULTIPLE FEEDS, PRODUCTS AND HEAT TRANSFER STAGES

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***Abstract*— A complementary analysis of particular cases where the compositions of the streams developed in the rectification column coincide with one of the vapor (y_{GFk}) or liquid (x_{GFk}) portions generated from the G_{Fk} can be found in this supplementary material.**

***Keywords*— Distillation; Side Stream; Process Design; Heat Stages; Lateral Product.**

I. Systematic analysis of the changes of sector in the McCabe-Thiele Method. Complementary particular cases: $y_{GFk}=y_{k+1,1}$ or $x_{GFk}=x_{k,NTk}$

In this section, that is complementary to the general analysis done in section 2 of the main text, we will analyze the general situation of a mass feed stream ($M_{GFk}>0$) for different thermal conditions of the feed stream (q_{GFk}), but in specific cases where the compositions of the vapor (y_{GFk}) or the liquid (x_{GFk}) portion generated from the GF_k is coincident with one of both streams defining the stage of the change of sector (i.e. $y_{k+1,1}$ or $x_{k,NTk}$). Though these situations only happen by improbable coincidences, they can be interesting to be analyzed due to the relationships occurring among the streams developed in the column.

A. Mixture of a liquid and vapor in equilibrium ($0 \leq q_{GFk} \leq 1$)

In case the thermal condition of the feed allows the composition of that liquid stream ($x_{k,NTk}$) coincide with the x composition corresponding to IP_k, or the composition of the first vapor stream ascending from the next sector coincide with the y composition corresponding to IP_{k+1}, the composition of the feed stream vapor and liquid portions match exactly with that of one of the streams present in the column.

If the x composition of IP_k coincides with that of the liquid falling from the last stage above the feed, then V_{GFk}, $V_{k,0}$ and $V_{k+1,1}$ have the same composition and $L_{k+1,0}$ is in the intercept of OL_{k+1} with $y_{k+1,1} = y_{GFk}$ (Figure S.1a).

If the y composition (Figure S.1b) of IP_{k+1} is that coinciding with the vapor ascending from the tray below, the three liquids L_{GFk}, $L_{k,NTk}$ and $L_{k+1,0}$ have the same composition and $V_{k,0}$ is in the intercept of OL_k with $x_{k,NTk} = x_{GFk}$. The construction is obviously equivalent since the two situations represent both ends of the same equilibrium stage.

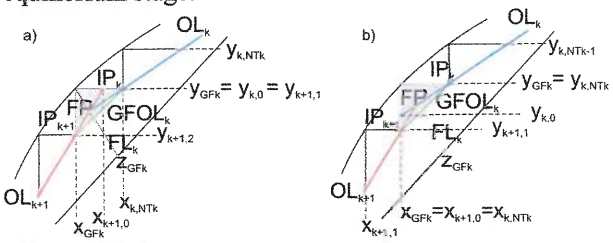

Figure S1. McCabe-Thiele y/x diagrams for a feed stream ($M_{GFk}>0$) and $0<q_{GFk}<1$: a) $y_{GFk}=y_{k+1,1}$; b) $x_{GFk}=x_{k,NTk}$

B. Superheated vapor ($q_{GFk} <0$)

Again, depending on the composition of the vapor feed, two situations can occur that allow y_{GFk} or x_{GFk} match exactly with one of the streams present in the column.

According to Figure S2a, if the feed vapor fraction coincides with the composition of the vapor ascending from the first stage of the subsequent sector, all vapor stream compositions generated in the change of sector coincide: $y_{GFk}= y_{k+1,1}= y_{k,0}$.

On the other hand, if we accept that the composition of the liquid streams developed in the change of sector stage where identical (Figure S2b), and then the liquid falling from the last tray of the previous sector had the same x composition as the liquid arriving to the first tray of the next sector ($x_{GFk} =x_{k,NTk} = x_{k+1,0}$), then it must be accomplished that the feed vapor composition fraction coincides with the vapor ascending from the last stage of sector k: $y_{GFk} = y_{k,NTk}$. The V_{GFk} joins the vapor coming from the stage below: $V_{k,0} = V_{k+1,1} + V_{GFk}$ and the corresponding diagram (Fig. S2b) shows that $y_{k,0}$ is located between $y_{k+1,1}$ and y_{GFk}.

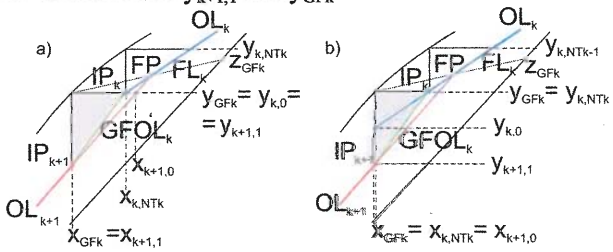

Figure S2. McCabe-Thiele y/x diagrams for a superheated vapor feed stream ($M_{GFk}>0$ and $q_{GFk}<0$): a) $y_{GFk}=y_{k+1,1}$; b) $x_{GFk}=x_{k,NTk}$

C. Saturated vapor (q_{GFk} =0)

In the case represented in Figure S3a, the composition of the feed vapor fraction coincides with the composition of the vapor ascending from the first stage of the subsequent sector (y_{GFk}= $y_{k+1,1}$= $y_{k,0}$), the composition of the liquid $L_{k+1,1}$ in equilibrium with $V_{k+1,1}$ coincides with the liquid composition in equilibrium with the feed (x_{GFk}=$x_{k+1,1}$) as expected, and the liquid falling from the last tray of sector k has the same x composition as the liquid arriving to the first tray of the next sector ($x_{k,NTk}$= $x_{k+1,0}$). In the case where x_{GFk}=$x_{k,NTk}$ (Figure S3b), as for the superheated vapor feed, it can be observed that: $y_{k,0}$ is aligned between $y_{k+1,1}$ and y_{GFk}, y_{GFk}=$y_{k,NTk}$ and the liquid composition in equilibrium with y_{GFk}, together with the composition of the liquid streams generated ($L_{k,NTk}$, $L_{k+1,0}$), coincide: $x_{k,NTk}$= x_{GFk}= $x_{k+1,0}$. Both cases, shown in Figures S3a and S3b lead, obviously, to the same number of steps.

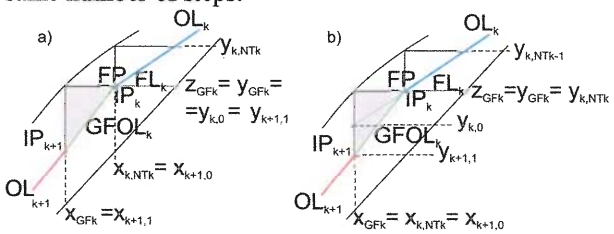

Figure S3. *McCabe-Thiele y/x diagrams for a saturated vapor feed stream (M_{GFk}>0 and q_{GFk}=0): a) y_{GFk}=$y_{k+1,1}$; b) x_{GFk}=$x_{k,NTk}$*

D. Saturated liquid (q_{GFk} =1)

In the case where y_{GFk} = $y_{k+1,1}$ (Figure S4a) the compositions of the all the vapor streams generated are the same: y_{GFk} = $y_{k,0}$ = $y_{k+1,1}$, x_{GFk}=$x_{k+1,1}$ and the relationship between the liquid streams is fulfilled ($L_{k+1,0}$ = L_{GFk} + $L_{k,NTk}$). For the case represented in Figure S4b when the feed liquid composition x_{GFk} coincides with the liquid composition descending from sector k ($x_{k,NTk}$), the composition of the vapor $V_{k,NTk}$ in equilibrium with $L_{k,NTk}$ coincides with the vapor composition in equilibrium with the feed (y_{GFk}= $y_{k,NTk}$) and, analogously to Figure S4a, $y_{k,0}$= $y_{k+1,1}$ despite the y_{GFk} being different.

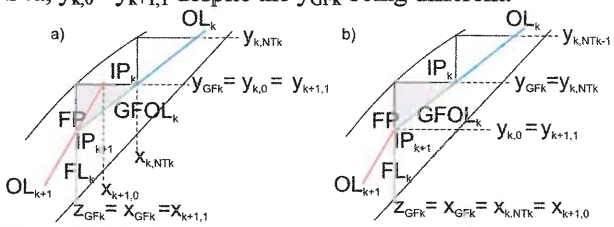

Figure S4. *McCabe-Thiele y/x diagrams for a saturated liquid feed stream (M_{GFk}>0 and q_{GFk}=1): a) y_{GFk}=$y_{k+1,1}$; b) x_{GFk}=$x_{k,NTk}$*

E. Undercooled liquid (q_{GFk} >1)

According to Figure S5a, if we accept that the composition of the vapor streams in the change of sector does not vary (y_{GFk}= $y_{k,0}$= $y_{k+1,1}$), then the feed liquid composition (x_{GFk}) must coincide with $x_{k+1,1}$. The L_{GFk} joins the liquid coming from the stage above: $L_{k+1,0}$ = $L_{k,NTk}$ + L_{GFk}, so $x_{k+1,0}$ is aligned between $x_{k,NTk}$ and x_{GFk}.

If the composition of the liquid feed coincides with the composition of the liquid descending from the last stage of sector k (x_{GFk}= $x_{k,NTk}$= $x_{k+1,0}$), the y composition of IP_{k+1} coincides with that of the vapor coming up from the first stage below the feed (Figure S5b). In this case $y_{k,0}$ is aligned with $y_{k+1,1}$ and y_{GFk} but not in between because $y_{k+1,1}$ is higher than $y_{k,0}$ since the undercooled liquid stream addition yields a poorer separation.

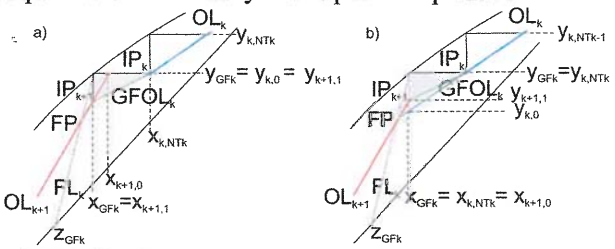

Figure S5. *McCabe-Thiele y/x diagrams for a undercooled liquid feed stream (M_{GFk}>0 and q_{GFk}>1): a) y_{GFk}=$y_{k+1,1}$; b) x_{GFk}=$x_{k,NTk}$*

REMARK

A review and extension of the McCabe Thiele method and the completed deduction of the generalized equations can also be found in the Open Academic Repository of the University of Alicante (RUA) (http://hdl.handle.net/10045/23195). Additionally, a website of self-learning about the McCabe-Thiele method for the design of distillation columns can be consulted: http://iq.ua.es/McCabe-V2/ (http://hdl.handle.net/10045/2283).