Equipment for G-L MT operations

G-L contactors

- Gas Dispersed
  - Mechanically agitated contactor (MAC)
  - Sparged vessel
  - Tray towers
    - Sieve Tray
    - Valve Tray
    - Bubble cap Tray
- Liquid Dispersed

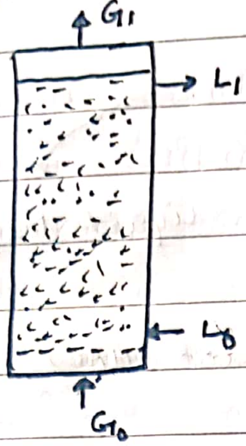
Mechanical agitator is used to create turbulence in the system, which will intimately mix the gas which is dispersed in the form of bubbles through dispersion.

Baffles are used to prevent vortex formation. Cooling jackets are used to remove the excessive heat.

Bubble colum doesn't have the agitator and hence can be operated either in semi-batch or cont. (can't be operated in batch mode)

Agitated and sparged vessels: Gas and Liq. can conveniently be contacted, with gas dispersed as bubbles, in agitated vessels whenever multistage counter-current effects aren't req.

Types of Bubble Columns

① 

Cascade Bubble column (Oxidation of Acetaldehyde to Acetic acid)

② Bubble Column with Internal Loop (Biological Wastewater Purification (Aerobic))

③ Bubble column with external loop (Hydrogenation of Benzene to Cyclohexane)

④ Slurry Bubble Column (Fischer Tropsch Synthesis in liquid phase)

Tray Towers

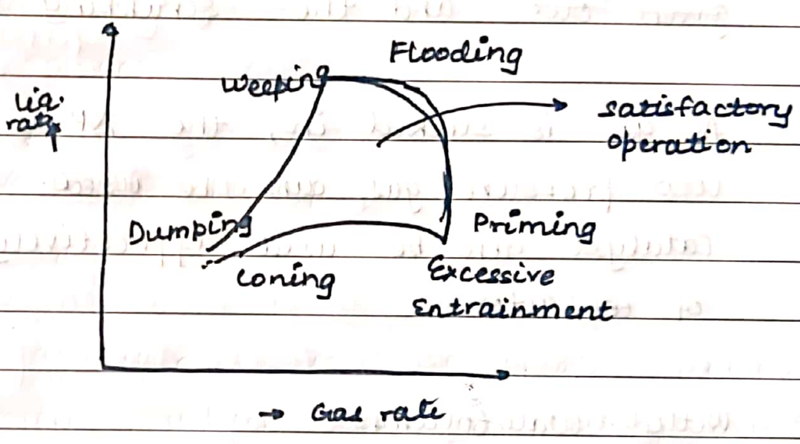
Tower consists of several trays. Gas and liq flow counter-currently

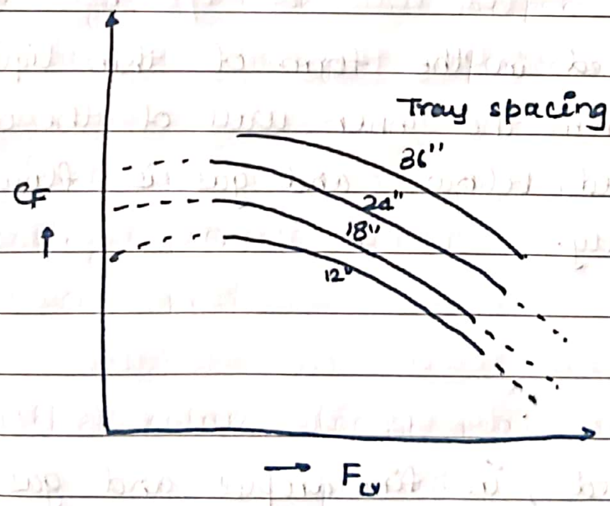
	Bubble cap	Valves	Sieves
Rel. cost	2	1.2	1
Pressure drop	H	I	L
efficiency	H	H	L
Vapor capacity	L	H	H
Turndown Ratio	5	4	2

For high MT efficiency :

① Deep pool of liquid for good contact time
② High gas velocity for more turbulence
③ (Gas ΔP will be more)

Tray performance constraints





capacity parameter

$$C_F = C_{sb}$$

$$= U_n \left(\frac{\rho_g}{\rho_L - \rho_g}\right)^{0.5}$$

$$F_{LV} = \frac{L}{G}\left(\frac{\rho_g}{\rho_L}\right)^{0.5}$$

Net Superficial gas flow rate under flooding

liq and vapour flow rate parameter

F_{LV} → (Flooding velocity)

C_F → (Perorated plate colmn)

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Liquid Disperesed Type Gas-Liquid Contractors

① Venturi Scrubber:

Gas is sucked in by scrubbing liquid in the convergent section, where gas mixing takes place and finally in the divergent section they will be seperated and the gas is ~~given out~~ released and the scrubbing liq is collected.

As gas is sucked in, the ΔP is low, so low pressure gas can be used.
Catalyst can be used effecitively in this type of contactor

② Wetted-wall column

Liquid is dropped in the form of thin liquid film, comes down from the inner wall of the contactor and is collected below, and gas is flow counter-currenty.

③ Spray Tower

Liquid is dropped, in fine droples and gas is blown from below, the gas coming out may contain these fine droplets, which is collected by the entrainment eliminator.

Pre-heating, humidification, internal heater and finally re-heating to the droom temp (?) and then left into the condensation space.

(4) Packed Towers

Most versatile. There is packing with a material and liquid is sprayed from top. Liquid is again dispersed in thin liquid film surrounding the packing material. Packing material is fully wetted by the liq film. Gas is blown from below and the mixing take place.

Rings → Raschig Ring
→ Lessing Ring
→ Cross Partition Ring
→ Pall Ring

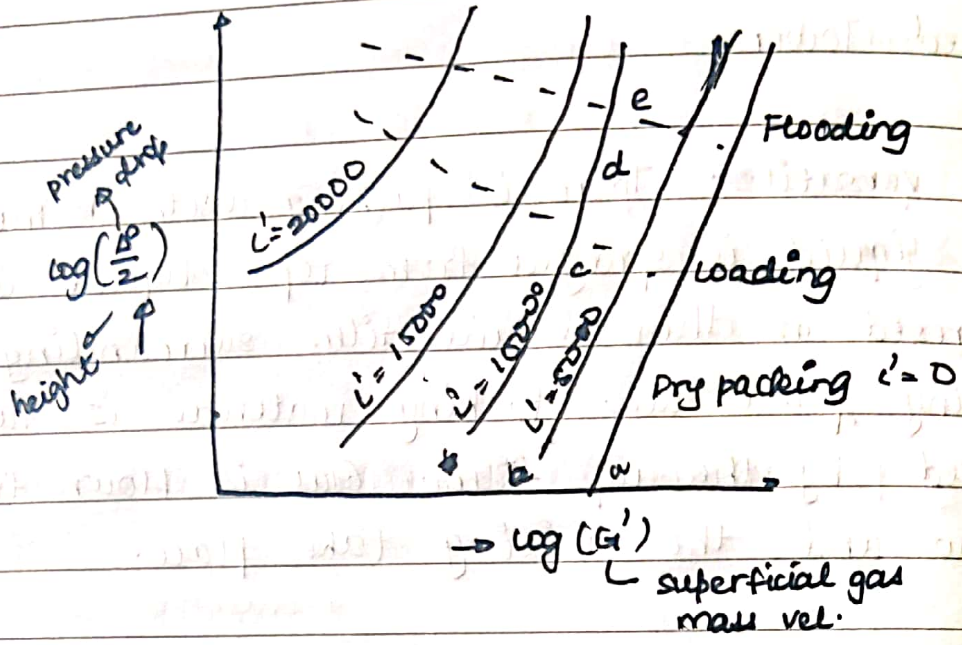
Saddle → Berl Saddle
→ Intalox saddle

To create extra surface for liq. and gas

Tellerettes → Metal
→ Plastic

A tower packing or fill should possess the following characteristics:

→ Provide large interfacial surface b/w liq and gas. The surface of packing per unit vol of packed space should be large.
→ Possess desirable fluid flow char.
→ Be chemically inert to fluids being processed
→ Have str. strength to permit easy handling and installation.
→ Rep. low cost.



Tray Tower v/s Packed Tower

Gas ΔP : Packed tower needs smaller ΔP

Liquid hold-up : Packet tower provides sustainability smaller liq. hold up.

Liq / Gas ratio : Low value of L/G ratio are best handled in tray towers

Liquid cooling : More readily removed in tray tower.

Foaming systems : Packed towers are more suitable.

Corrosion : Packed towers are suitable

Cleaning : Tray towers are easier to clean.

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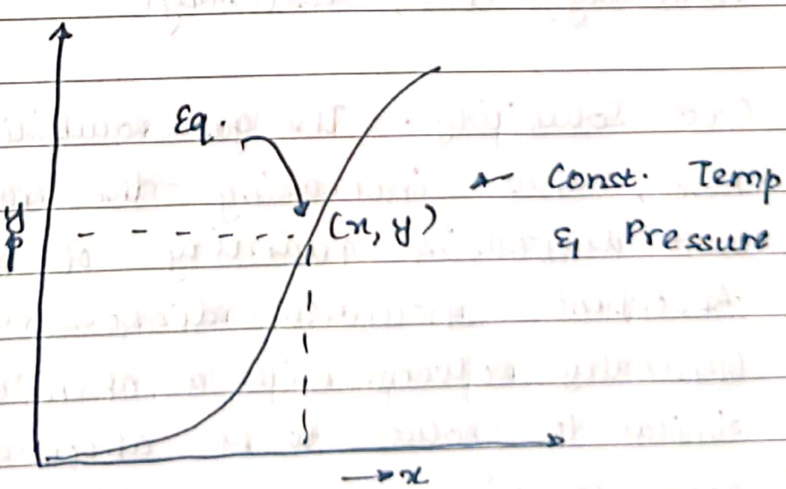
Gas Absorption - Desorption

Gas Absorption - Operation in which a gas mix. is contacted with a liq. for the purposes of pref. dissolving one or more comp. of gas and to provide a soln. of them in the liq.

Absorption requires MT from gas to liquid when MT happens in opp direction, i.e, liq to gas, the operation is called desorption or stripping

Eq. Distn: (solubility) Curve

The gas absorption process involves the re-distn. of solute between the gas and liquid phase, and between the 2 phases must come into close contact.



Henry's law
when the gas mixture in eq. with an ideal liq. soln. follows the ideal gas behaviour

$$p^* = P\bar{x} \rightarrow \text{liq}$$

$$\text{gas} \leftarrow y^* = p^*/P_T = mx$$

when soln. is non-ideal, Raoult's can be applied

$m \rightarrow$ Henry's law const.

Solvent selection

→ If principal purpose of absorption is to produce a specific soln., the solvent is specified by nature of pdt

→ If principle purpose is to remove some comp. from the gas, then factors like gas solubility volatility, cost, viscosity

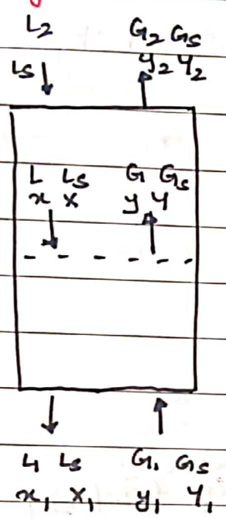
Gas Solubility - The gas solubility should be high, thus increasing the rate of absorption and decreasing quantity of solvent req.
· Absorbent shouldn't dissolve in carrier gas
Generally solvent with a chemical nature similar to solute to be absorbed will provide good solubility. A chemical rxn. of solvent with the solute will freq. result in very high gas solubility

Volatility - solvent should have low volatity and low v.p

Corrosiveness - Solvent shouldn't be corrosive, else spoils the equipment

Viscosity - low viscosity of solvent for rapid absorption rates, good heat transfer char.

Design of Absorber / stripper



Height is obtained by material balance and eq. considerations

$$Y = \frac{y}{(1-y)} \qquad X = \frac{x}{1-x}$$

$$G_s = G(1-y) = \frac{G}{(1+Y)}$$

G_1 (mol / time) is the total gas coming up

G_s is the solute free gas flow rate

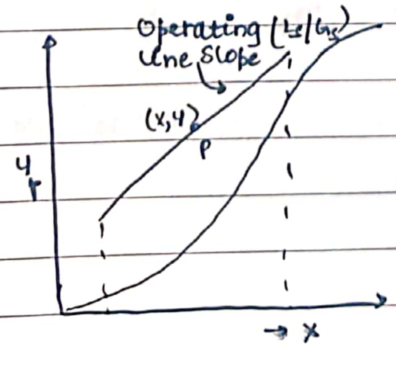
Overall solute balance

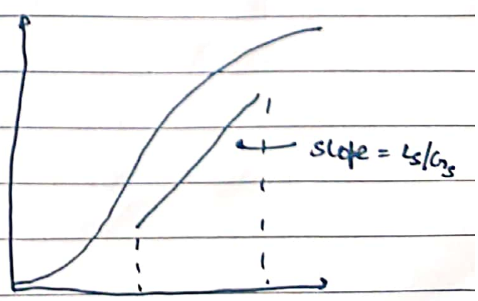
$$G_s(Y_1 - Y_2) = L_s(X_1 - X_2)$$

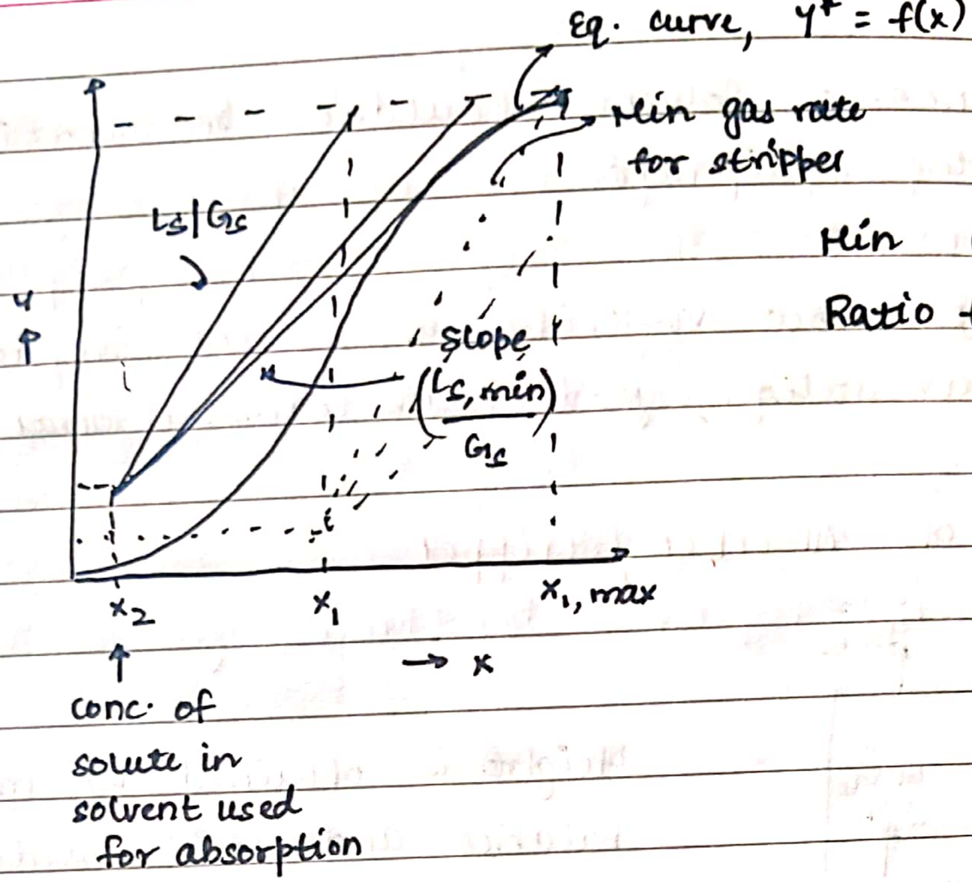
Material balance in lower part,

$$G_s(Y_1 - Y) = L_s(X_1 - X)$$

Operating lines for Absorber and stripper

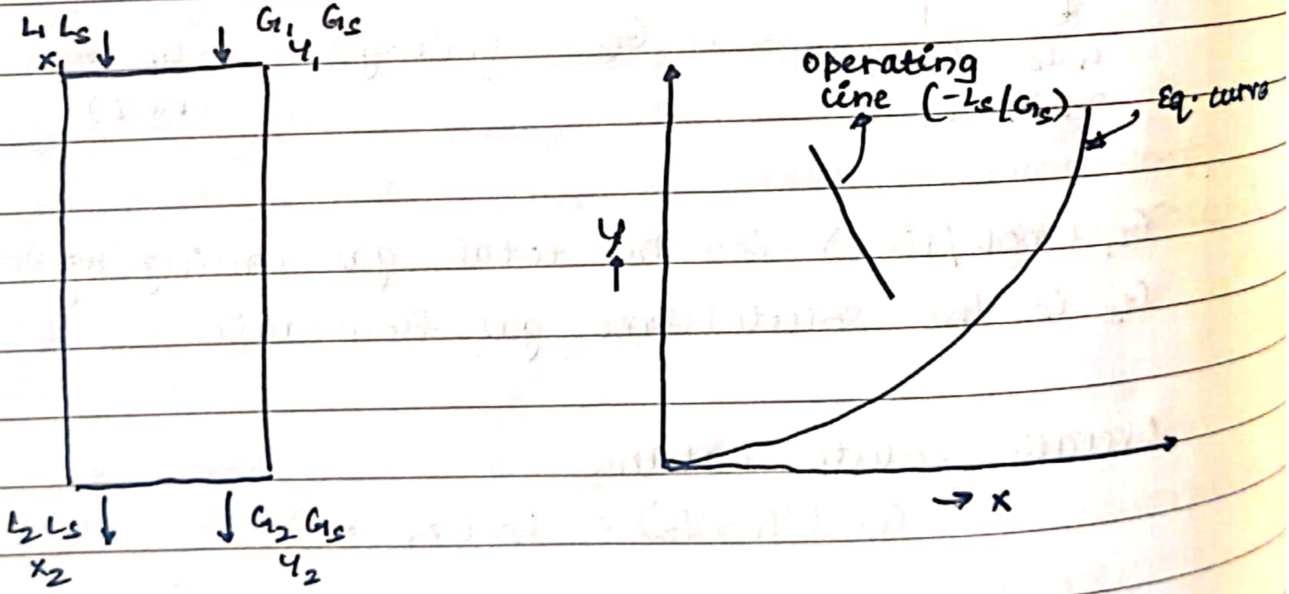




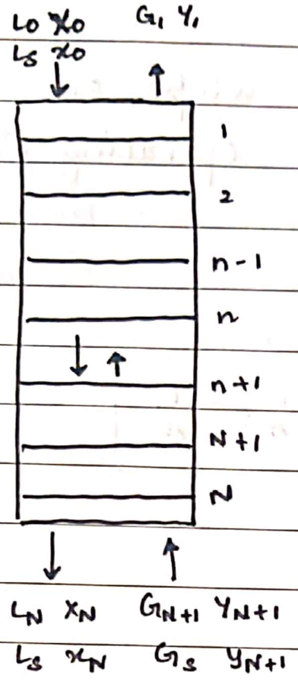


Min liquid / Gas Ratio for Absorption

Co-current Absorber



Counter-Current Multistage Gas Absorption:



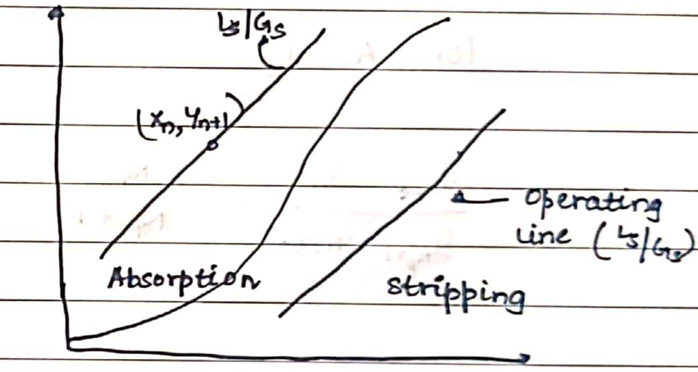
Material Balance over env 1:

$$G_s (Y_{n+1} - Y_1) = L_s (X_n - X_0)$$

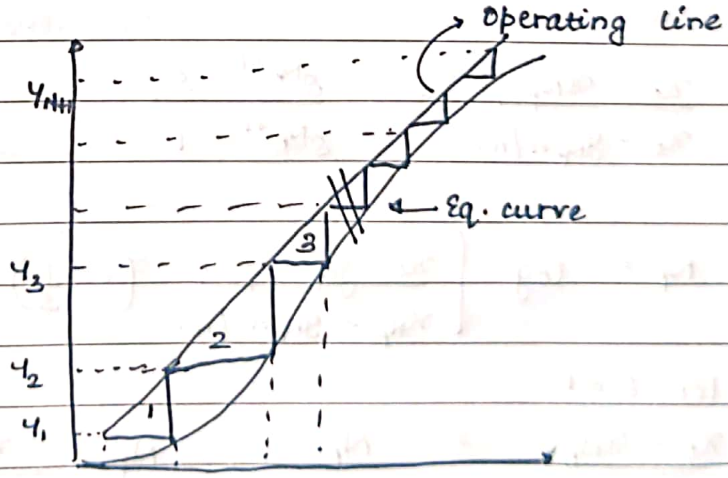
$$(Y_{n+1} - Y_1) = \frac{L_s}{G_s} (X_n - X_0)$$

Overall Material Balance (over E-2):

$$(Y_{N+1} - Y_1) = \frac{L_s}{G_s} (X_N - X_0)$$



Determination of no. of stages in counter current multi stage absorber



$$\text{No. of Trays} = \frac{\text{No. of Ideal Trays}}{\text{Tray Efficiency}}$$

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Kremser - Brown - Souders Eqn's

Absorption $(A \neq 1)$ $A \rightarrow$ Slope of Operating line

$$\frac{y_{N_p+1} - y_1}{y_{N_p+1} - mx_0} = \frac{A^{N_p+1} - A}{A^{N_p+1} - 1}$$

$$N_p = \frac{\log\left[\frac{y_{N_p+1} - mx_0}{y_1 - mx_0}\left(1 - \frac{1}{A}\right) + \frac{1}{A}\right]}{\log A}$$

For $A = 1$,

$$\frac{y_{N_p+1} - y_1}{y_{N_p+1} - mx_0} = \frac{N_p}{N_p + 1} \qquad N_p = \frac{y_{N_p+1} - y_1}{y_1 - mx_0}$$

Stripping .

For $(S \neq 1)$

$$\frac{x_0 - x_{N_p}}{x_0 - y_{N_p+1}/m} = \frac{S^{N_p+1} - S}{S^{N_p+1} - 1}$$

$$N_p = \log\left[\frac{x_0 - y_{N_p+1}/m}{x_{N_p} - y_{N_p+1}/m}\left(1 - \frac{1}{S}\right) + \frac{1}{S}\right] \times \frac{1}{\log S}$$

For $S = 1$

$$-\frac{x_0 - x_{N_p}}{x_0 - y_{N_p+1}/m} = \frac{N_p}{N_p + 1} \qquad N_p = \frac{x_0 - x_{N_p}}{x_{N_p} - y_{N_p+1}/m}$$

$N_p \rightarrow$ No. of theoretical trays

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Overall heights of Transfer units

when overall no. of transfer units are appropriate, the overall heights of transfer units can be synthesized from those for the individual phases through relation b/w overall transfer co-eff and individual transfer co-eff

$$H_{tOG} = \frac{G'}{K_y\, a\, y^*_{BM}} = \frac{G'}{y^*_{BM}}\left[\frac{1}{k_y a} + \frac{m}{k_x a}\right]$$

$$H_{tOG} = H_{tG}\frac{y_{BM}}{y^*_{BM}} + \frac{mG'}{L'} H_{tL} \frac{x_{BM}}{y^*_{BM}}$$

$$\frac{1}{N_{tOG}} = \frac{1}{N_{tG}}\frac{y_{BM}}{y^*_{BM}} + \frac{mG'}{L'}\frac{1}{N_{tL}}\frac{x_{BM}}{y^*_{BM}}$$

For gases,

$$H_{tOG} = H_{tG} + \frac{mG'}{L'} H_{tL} \frac{x_{BM}}{y^*_{BM}}$$

For dilute soln,

$$H_{tOG} = H_{tG} + \frac{mG'}{L'} H_{tL}$$

$$\frac{1}{N_{tOG}} = \frac{1}{N_{tG}} + \frac{mG'}{L'}\frac{1}{N_{tL}}$$

In similar fashion, use of liquid phase overall co-eff yields

$$H_{tOL} = H_{tL} + \frac{L'}{mG'} H_{tG}$$

$$\frac{1}{N_{tOL}} = \frac{1}{N_{tL}} + \frac{mG'}{L'}\frac{1}{N_{tG}}$$