COMMUNICATIONS TO THE EDITOR

Liquid Mixing on Bubble Trays — A Correction

Dear Editor:

The paper by Oliver and Watson in your March, 1956, issue has been misinterpreted by Foss, Gerster, and Pigford in the June, 1958, issue.

In preparing a paper, one is faced with the necessity of being as brief as possible consistent with understandability. In view of the misunderstanding, our brevity was excessive in this instance. I, therefore, request publication of the analysis which follows:

We are stated by Foss, *et al.*, to "have assumed that a certain fraction of the liquid at the exit weir is recircuited to the inlet weir, where it is mixed with the incoming liquid. This mechanism is not explicitly stated by Oliver and Watson. . . ." This is incorrect. The statement in our paper "the assumption that the rate of mixing is uniform across the plate makes possible a solution. . ." was meant to indicate the derivation. The assumption is continuous, constant, back mixing across the plate.

NEW ASSUMPTIONS OF OLIVER AND WATSON

1. A constant fraction of the liquid flow is transferred bodily from downstream to upstream of a differential slab without mass transfer. Thus, the total liquid flow through the slab is $(1 + C)L$ in the direction of flow.

2. Volatile component concentration in liquid rises from x_n at the exit to x_e just downstream of inlet weir; x_{n-1} is higher than x_e (or equal if $C = 0$).

ASSUMPTIONS OF LEWIS CASE I (1)

3. Vapor enters a differential slab (which is transverse to liquid flow) with concentration y_{n+1} and leaves with concentration y'.

4. y_{n+1} is constant.

5. Total liquid and gas flows are constant.

6. The true point efficiency is constant on the tray.

7. Liquid concentration is vertically invariant.

By material balance the amount of volatile component entering the vapor equals that leaving the liquid:

$$(y' - y_{n+1})\, dG = (1 + C)L\, dx \qquad (1)$$

The assumptions are illustrated in Figure 1. By definition

$$E_{OGT} = \frac{y' - y_{n+1}}{y^* - y_{n+1}} \qquad (2)$$

Substituting in Equation (1) one gets

$$E_{OGT}(y^* - y_{n+1})\, dG = (1 + C)L\, dx \qquad (3)$$

Integrating and rearranging yields

$$E_{OGT} = \frac{(1 + C)L}{G} \int_{x_n}^{x_e} \frac{dx}{y^* - y_{n+1}} \qquad (4)$$

Now the liquid concentration change due to contacting vapor for a flow of $(1 + C)\, L$ is $1/(1 + C)$ times what it would be with flow of L. The total change without liquid mixing would be $(x_{n-1} - x_n)$. Thus

$$\int_{x_n}^{x_e} (1 + C)\, dx = x_{n-1} - x_n \qquad (5)$$

Integrating and rearranging, one obtains

$$1 + C = \frac{x_{n-1} - x_n}{x_e - x_n} \qquad (6)$$

By definition

$$F = \frac{x_{n-1} - x_e}{x_{n-1} - x_n} \qquad (7)$$

$$1 - F = \frac{x_e - x_n}{x_{n-1} - x_n}$$

$$\frac{1}{1 - F} = \frac{x_{n-1} - x_n}{x_e - x_n} = 1 + C \qquad (8)$$

and the substitution of (8) in (4) yields

$$E_{OGT} = \frac{L}{G(1 - F)} \int_{x_n}^{x_e} \frac{dx}{y^* - y_{n+1}} \qquad (9)$$

This is Equation (13) of our paper, from which the others readily follow.

The equations of our paper are thus not dependent on a patently false assumption about mixing which would cast doubt on their validity. While not demonstrably true, the assumption actually made is not unreasonable as an approximation.

It is clear that the relations are the same whether the mixing takes place continuously or in finite steps, provided the total flow subjected to mass transfer is constant, since recycling of liquid from exit to entrance gives the same result as localized mixing through a differential slab.

The mechanism postulated makes the rate of mixing independent of the concentration gradient, which is not uniform.

It is to be hoped and expected that the modern statistical methods employed by Foss, Gerster, and Pigford, coupled with concerted efforts at amassing data, will be more powerful than past approaches in investigating efficiency phenomena. Until efficiencies can be reliably correlated in terms of system properties, flow rates, and geometry for bubble cap as well as the more elementary sieve trays, the simple equations resulting from the fractional mixing concept may find use when the effect of liquid mixing can be adequately described by a constant. The accuracy may conceivably be as good as the application of the two-film theory to distillation, which depends on vertical constancy of liquid composition in order for the relation between point efficiency and transfer units to be valid.

NOTATION

C = fraction of liquid locally recirculated
dG = vapor entering differential slab.
E_{OGT} = true local efficiency
F = fractional mixing, defined as concentration drop across inlet weir divided by total concentration drop across plate
G = mass velocity of vapor
L = mass velocity of liquid
x = mole fraction of low boiler in liquid
y = mole fraction of low boiler in vapor
y' = mole fraction of low boiler in vapor leaving differential slab
y^* = mole fraction of low boiler in vapor in equilibrium with liquid of concentration x

Subscripts

e = entering tray, just downstream of inlet weir
n = tray number, down from top

LITERATURE CITED

1. Lewis, W. K., Jr., *Ind. Eng. Chem.*, **28**, 399 (1936).

Very truly yours,
Earl D. Oliver
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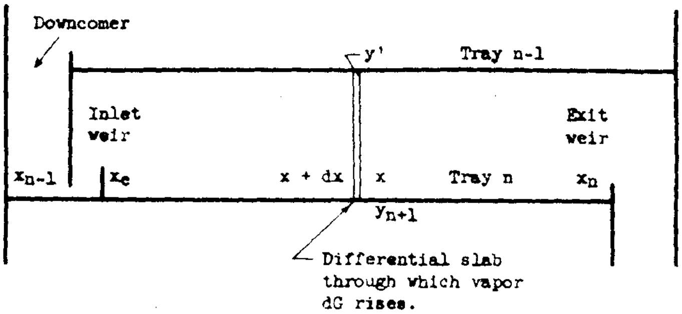

Fig. 1. Illustration of assumptions.