Dear Editor:

Baer and McKelvey claim to have proved that the lower condensation coefficients obtained with air present are the result of a higher resistance at the interface, rather than the result of a diffusional resistance [*A.I.Ch.E. Journal*, 4, 218 (1958)]. The authors supported this conclusion by showing that their data could be represented by straight lines on the appropriate type of graph. However a typical set of data may appear to give straight lines on several plots, particularly if the data scatter slightly and do not cover a wide range. A straight line for the plot testing one theory does not rule out other theories.

The authors said that diffusion effects were negligible in their work because straight lines and not curves were obtained on Figures 5 and 6, the plots drawn to test their theory. However with only 6 to 8 points for each line, only a 1.5-fold range of abscissa values, and with an average error of about 10% of the range of ordinate values, it is possible that a slightly flexed curve would fit the data just as well or better. Rather than basing their conclusions on whether or not the graphs seemed linear, the authors should have prepared separate plots based on a linear form of the equation which did allow for diffusion.

To test the diffusion theory the interfacial resistance would be assumed small and the heat flux expressed as

$$\frac{q}{A} = h(t - t_s)$$

$$= h_N(t_i - t_s) = \lambda\, k_g(p - p_i)$$

If the mass transfer coefficient is constant, and if the driving force for diffusion, $(p - p_i)$, is assumed proportional to the temperature difference, $(t - t_i)$, the equation becomes

$$h(t - t_s) = h_N(t_i - t_s) = b(t - t_i)$$

or

$$\frac{1}{h} = \frac{1}{h_N} + \frac{1}{b}$$

Since $h_N = C(q/A)^{-1/3}$, a plot of $(1/h)$ vs. $(q/A)^{1/3}$ is suggested, but this is exactly the same plot as the authors' graph of $(\Delta T_1/\Delta T_2)$ vs. $(\Delta T_2)^{1/3}$, which was used to test for interfacial resistance! The mass transfer coefficient would actually not be constant because the natural convection would increase with increased heat flux, though this effect would be partially cancelled by the increase in the logarithmic mean pressure of the air in the diffusion layer. [For one-way diffusion, the Nusselt number becomes $(k_g P_{BM} D)/(RT D_v)$.] Even if the exact variation of k_g with (q/A) were known, it would not be much help here; because of the scatter of the data the assumption of either a slight increase or a slight decrease in k_g with (q/A) would still give apparently straight lines on the corresponding graphs. The conclusion is that the relative importance of diffusion and interface effects cannot be determined by graphical manipulation unless extremely accurate data and a more exact expression for the mass transfer rate are available.

There is a reliable way to show that diffusion must be at least partly responsible for the low condensing coefficients obtained with air. The mass transfer coefficient is predicted from the correlations for natural convection, with a trial-and-error method used to estimate the interface temperature. A calculation for methanol condensing at atmospheric pressure shows that the presence of 1% air could lower the apparent film coefficient to 40% of the normal value. The turbulence created by the injection of vapor into the condenser would generally make the mass transfer rate slightly higher than for natural convection, but not enough higher to eliminate the diffusion resistance completely. Since the authors did not include their complete data for methanol, the coefficients of Othmer for steam-air mixtures (taken from McAdams, "Heat Transmission") were used for a detailed comparison of theoretical and experimental coefficients.

Effect of Air on Coefficients for Film Condensation
Steam at 1 atm. condensing on a horizontal 3-in. cylinder

		Theory		Data of Othmer	
Δt	% Air	h	h/h_o	h	h/h_o
10°F.	0	2,390	1.0	2,200	1.0
	2		0.19		0.32
	4		0.14		0.21
	6		0.10		0.15
40°F	0	1,500	1.0	1,300	1.0
	2		0.30		0.44
	6		0.19		0.25

The measured coefficients are about 50% higher than those predicted, with published correlations for mass transfer by natural convection used. Therefore the primary effect of air is probably a result of a diffusion resistance; this could easily be demonstrated experimentally by comparing the coefficients for natural and forced convection. To measure the interfacial resistance in the presence of air would require elaborate apparatus designed to minimize both the diffusional resistance and the resistance of the condensate film.

Very truly yours,

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