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Evaporation Retardation by Monolayers

MacRitchie (*1*) presented data for the evaporation of water from a liquid surface and also studied the retardation of evaporation by monolayers of hexadecanol. Using laminar boundary layer theory, he analyzed both systems. We reexamined MacRitchie's data and found that the mass of water vapor transferred in the absence of hexadecanol is proportional to $U_0^{0.8}$ (where U_0 is the air velocity), which would indicate a turbulent boundary layer (*2*). MacRitchie justified his application of laminar boundary theory, which would yield a $U_0^{0.5}$ dependence (*2*), by noting that the maximum value of the Reynolds number ($\mathrm{Re} = LU_0/\nu$, where L is length and ν, kinematic viscosity) is only 28,800. However, the use of a fan in these experiments may introduce a complicated rotational motion, with vortices starting from the ends of the blades, unless shrouds, straighteners, and appropriate entry sections are provided; there is no mention of these. It is therefore not surprising that one obtains experimental data for this system which is consistent with results obtained for turbulent flows.

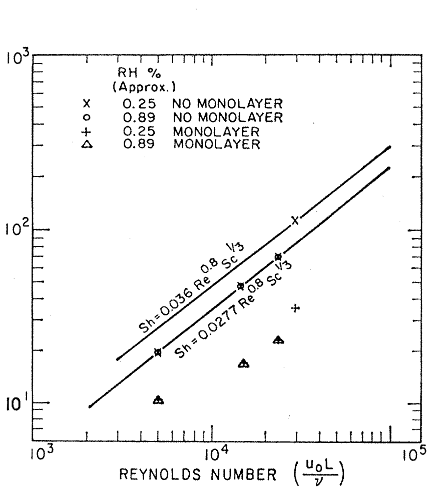

Fig. 1. Variation in Sherwood number with Reynolds number.

Data from previous experiments on turbulent flow have been correlated by the relation

$$\mathrm{Sh} = C\,\mathrm{Re}^{0.8}\,\mathrm{Sc}^{1/3} \qquad (1)$$

where Sh, the Sherwood number, is defined by $\dot{m}RTL/D\Delta P$, with $\dot{m}$ being the mass transferred; R, the universal gas constant; T, temperature; D, diffusivity; and ΔP, partial pressure difference (*2*); the Schmidt number Sc is defined by ν/D; C is equal to 0.036 although there is significant scatter in the data. The experimental results for the velocities and relative humidities reported (*1*) are in good agreement with Eq. 1 with C equal to 0.0277 (Fig. 1).

MacRitchie's experiments with hexadecanol monolayers showed that the "evaporation retardation ratio" $\dot{m}_{\mathrm{II}}/\dot{m}_{\mathrm{I}}$ is independent of the relative humidity at a given Reynolds number where $\dot{m}_{\mathrm{II}}$ and $\dot{m}_{\mathrm{I}}$ are the evaporation rates with and without hexadecanol, respectively. From this result he concluded that the hexadecanol produces no barrier to the vaporization step (the migration of water molecules from the liquid water phase into the vapor phase) but exerts its sole effect by altering the hydrodynamic boundary layer. However, the presence of a vaporization step with hexadecanol does yield results which are consistent with the above experimental observation. In detail, the presence of two resistances in series, that is, both in the vaporization step and in the hydrodynamic boundary layer, yields the relation

$$\frac{\dot{m}_{\mathrm{II}}(x)}{\dot{m}_{\mathrm{I}}(x)} = \frac{h_{V,\mathrm{II}}\,h_{H,\mathrm{II}}}{h_{V,\mathrm{II}} + h_{H,\mathrm{II}}} \cdot \frac{1}{h_{H,\mathrm{I}}} \qquad (2)$$

which is also independent of the relative humidity, where $h_{V,\mathrm{II}}$ and $h_{H,\mathrm{II}}$ are the vaporization and hydrodynamic conductances, respectively, with hexadecanol present, and $h_{H,\mathrm{I}}$ is the hydrodynamic conductance without hexadecanol. Equation 2 is a local relation, so that the (total) retardation ratio is obtained by integrating it over the length of the plate. The integrated result would also be independent of the relative humidity at a given Reynolds number.

To obtain the total retardation ratio we assume that the hydrodynamic conductances $h_{H,\mathrm{I}}$ and $h_{H,\mathrm{II}}$ are equal and given by the turbulent boundary layer results $Ax^{-0.2}$ where $A = D(C/0.8)(U_0/\nu)^{0.8}/\mathrm{Sc}^{1/3}$ (*2*) with $C = 0.0277$.

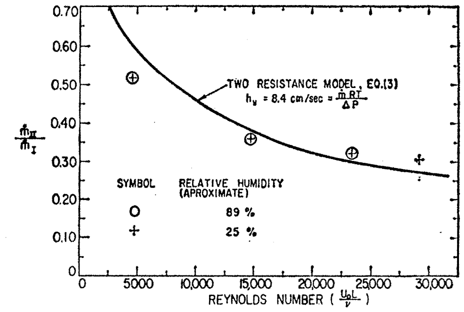

Fig. 2. Evaporation retardation ratio as a function of Reynolds number.

This relation is consistent with Eq. 1. We also take the vaporization step conductance

$$h_V = \dot{m}RT/\Delta P$$

to be constant; upon integrating Eq. 2, we obtain

$$\frac{\dot{m}_{\mathrm{II}}}{\dot{m}_{\mathrm{I}}} = \int_0^1 \frac{d(x/L)}{1 + (A/h_V L^{0.2})(x/L)^{-0.2}} \qquad (3)$$

Based on the experimental results of MacRitchie (*1*) a value of h_V equal to 8.4 cm/sec has been chosen and the results are shown in Fig. 2.

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References and Notes

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Ecological Succession

E. P. Odum (*1*) asserts the need of an understanding of ecological succession. He offers three parameters of succession, one being that, "It results from modification of the physical environment by the community; that is, succession is community-controlled even though the physical environment determines the pattern, the rate of change, and often sets limits as to how far development can go." Succession is certainly one of the key principles of ecology and requires examination, but the parameter quoted needs clarification. Odum asserts that succession "results from modification of the physical environment by the community" and "refers to changes which are brought