Effects of Internal and External Diffusion for the Hydrogenation of Ethylene in a Porous Nickel Catalyst

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In connection with a paper by Fulton and Crosser (*1*), it may be interesting to know that the same conversion data [fully reported in Fulton's thesis (*1*)] can be correlated successfully in a different way. The data were reevaluated with the use of different *J* factor correlations to calculate the convective heat and mass transfer resistances in the catalytic bed and, what is more important, accounting for internal diffusional resistances and for the radiational contribution to the heat transfer.

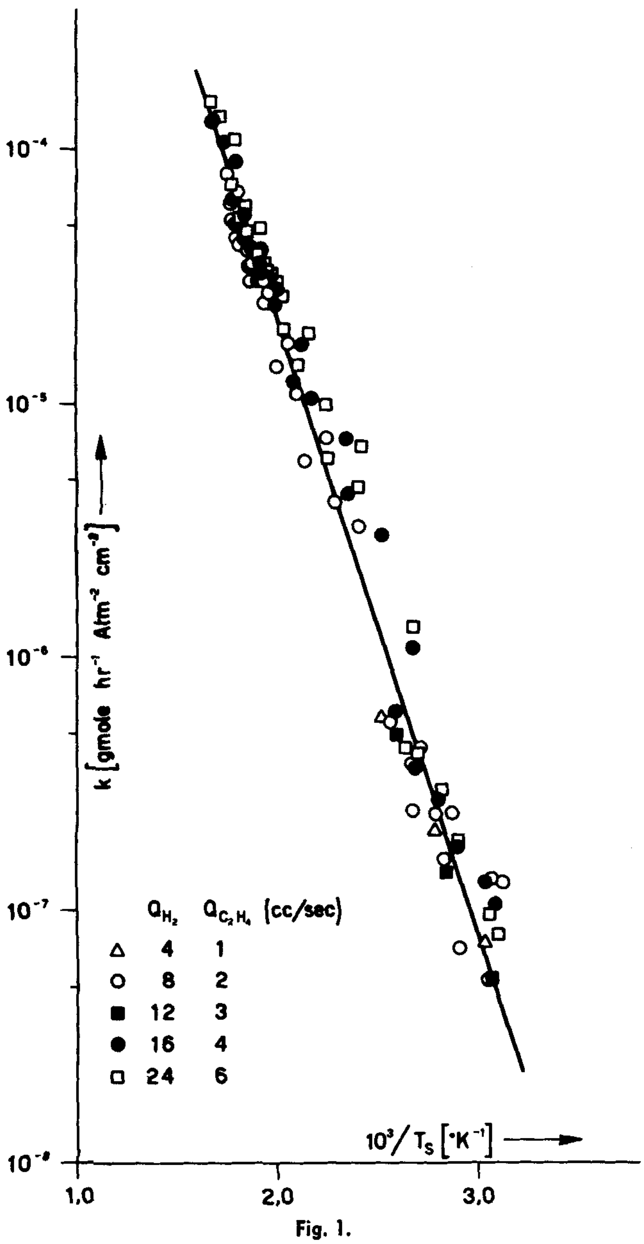

Fig. 1.

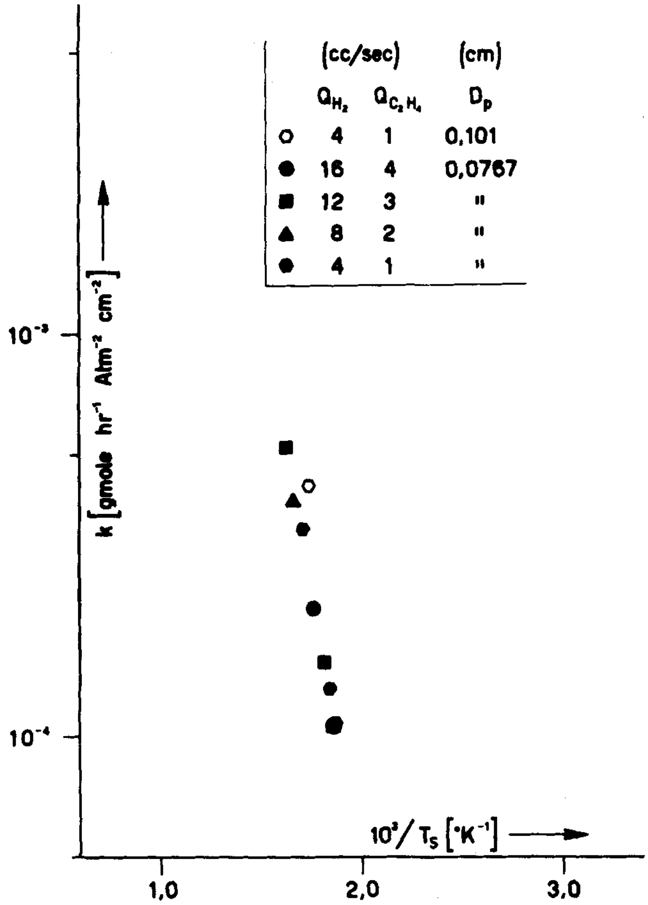

Fig. 2.

The external heat transfer convective resistance was determined with a *J* factor correlation experimentally derived by Eichhorn and White (*2*). A correlation derived by Bar-Ilan and Resnick (*3*) was used for the external mass transfer resistance. [Some anomalies in the *J* factor curve of these last authors are discussed by Williamson et al. (*4*).] The above correlations were chosen among those available for Reynolds number ranges as close as possible to the one occurring in Fulton's experiments ($0.16 < N_{Re} < 5.13$).

The internal mass transfer resistance was calculated by using a correlation that gives the effectiveness factor as a function of a modulus containing only observable quantities (*5*). The contribution of the internal resistance was substantial for most particle diameters. Calculational checks were also made for possible temperature gradients in the catalyst particles; these proved in all cases to be negligible.

The radiational contribution to the external heat transfer coefficient was accounted for by assuming that this additional heat transfer mechanism takes place only between solid particles. It proved to be a significant contribution.

The results of these calculations led to the Arrhenius plot of Figure 1, where a single straight line reasonably correlates Fulton's data. The slope of this line gives an activation energy of 11.4 kcal./g.-mole. According to the present interpretation, no shift in the reaction mechanism need be invoked.

In Figure 2 some data taken by the author are reported. They show a higher frequency factor than that obtained by Fulton, although the data were taken with the use of a catalyst containing approximately the same nickel percentage as in Fulton's work. This apparently higher frequency factor may be due to an improved purification system used in the present experimental work. The complete procedure outlined above as well as a description of the equipment are reported in reference *6*.

ACKNOWLEDGMENT

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Cocurrent Flows of Two Immiscible Viscous Fluids Over a Flat Plate

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Consideration is given to the laminar boundary-layer flow over a permeable flat surface through which an immiscible foreign fluid is released into the boundary layer. Thus, there is formed a buffer between the surface and the main stream, that is, there coexist two boundary layers. The drag reduction characteristics of the two-phase boundary layer were investigated by Sparrow et al. (*1*) through the use of the series expansion method. The present analysis extends the study to include its heat transfer characteristics; other literature pertinent to the work includes references *2*, *3*, and *4*.

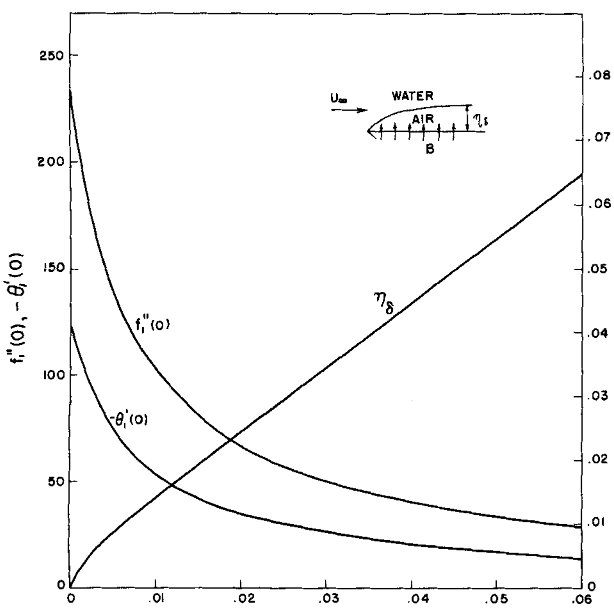

Fig. 1. Effects of the release rate of air into water stream on heat transfer and skin friction.

The application of the conservation principle of energy produces two laminar boundary-layer equations, one for the main stream fluid and the other for the foreign fluid. Each equation is reduced to an ordinary differential equation by similarity transformation

$$\theta'' + N_{Pr} f\theta' = 0 \qquad (1)$$

for both boundary layers. The matching and boundary conditions are

Plate surface:

$$\theta_1(0) = 1 \qquad (2a)$$

Interface:

$$\theta_1(\eta_\delta) = \theta_2(0)$$

$$\theta_1'(\eta_\delta) = (k_2/k_1)(\nu_1/\nu_2)^{1/2}\theta_2'(0) \qquad (2b)$$

Free stream:

$$\theta_2(\infty) = 0 \qquad (2c)$$

The Nusselt number N_{Nu} at the plate surface may be expressed in dimensionless form as

$$N_{Nu}/N_{Re}^{1/2} = -1/2\,\theta_1'(0) \qquad (3)$$

Consideration was given to two cases: the release of water into air stream and vice versa. Fluid properties corresponding to 100°F. were used. With the solutions for f_1 and f_2 obtained in reference *1*, as input data, Equations (1) for both inner and outer boundary layers were numerically integrated for θ_1 and θ_2 by the Runge-Kutta method with an IBM 7090 digital computer. The results are illustrated in Figures 1 and 2 for the release of air into water stream corresponding to $[(\rho\mu)_2/(\rho\mu)_1]^{1/2} = 177$ and $(k_2/k_1)(\nu_1/\nu_2)^{1/2} = 117$ and that of water into air stream corresponding to $(\rho_2\mu_2/\rho_1\mu_1)^{1/2} = 0.00565$ and $(k_2/k_1)(\nu_1/\nu_2)^{1/2} = 0.00853$, respectively. $f_1''(0)$ represents the skin friction grouping $4\,N_{Re}^{1/2}/\rho_1 U_\infty^2$ as obtained in reference *1*. The figures show that the release of foreign fluids to form a buffer between the main stream and the wall affects appreciably the transport phenomenon, caus-