because the experimental range of Sc by Patel et al. is very narrow ($Sc = 3\,100 \sim 4\,050$) in view of the scatter of their data. Thus, only the different dependence on Re is admitted from their experiments. This, we infer, is not due to some sources of error suggested by them but rather to their misuse of an input signal as follows.

To make the flow pulsation, Patel et al. change a liquid level in the head tank using an oscillating displacement device immersed in the liquid. They measured the oscillation of the displacement device and tacitly regarded its amplitude and phase as being identical to those of a pressure gradient at test section. In unsteady state, however, the steady state relation between the displacement length of device and the pressure gradient does not hold because of dynamic behaviors of fluid in the flow system from the head tank to the test section. In particular, the dynamics of fluid in the head tank and through contraction, elbow and two valves largely affect the relation in unsteady state. Hence, the discrepancy in measurements by Patel et al. increased with increasing frequency of pulsation, and it depended on the flow rate, thus on Re.

Evidently the dynamic relation between the oscillation of the displacement device and that of the pressure gradient is peculiar to their flow system and is suspected to be too complex to clarify analytically for the use of their study. Accordingly, it is recommended that one avoids this complexity and measures directly the pressure difference or the wall shear stress at the test section as described in the paper of the commentators (Mizushina et al., 1973).

NOTATION

l = length of mass transfer section
L = dimensionless length = $l/(2r_0 Re Sc)$
Re = Reynolds number
r_0 = radius of circular tube
Sc = Schmidt number
Sn = Stokes number = $r_0^2\omega/\nu$
ν = kinematic viscosity
ω = angular frequency

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Mizushina, Tokuro, Toshiro Maruyama, S. Ide, and Y. Mizukami, "Dynamic Behaviour of Transfer Coefficient in Pulsating Laminar Tube Flow," *J. Chem. Eng. Japan*, 6, 152 (1973).

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Reply to the Note of Maruyama and Mizushina

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Maruyama and Mizushina are quite correct that the work of Mizushina et al. (1973) predates our study of mass transfer in pulsatile laminar flow (Patel et al., 1975). Their data do show excellent correlation with the variable $SnScL^{2/3}$, which is the variable X_1 in the notation of our paper.

There is no question that direct measurement of the fluctuating pressure difference in the tube is preferable in order to calculate the amplitude ratio and phase lag of the fluctuating transfer coefficient. However, in our work we did not take the amplitude and phase of the displacement device to be identical to those of the pressure gradient in the test section as stated by Maruyama and Mizushina. A dynamic analysis of the flow from the variable head tank through the valves and flow straighteners was done. This analysis yielded a relation between the amplitude and phase of the displacement device and those of the pressure gradient in the tube. Details are given in the thesis by McFeeley (1972). While this procedure is not as accurate as direct measurements of the pressure gradient, the error is not as large as the assumption of identical amplitudes and phases for the pressure gradient and the height of the displacement device. It is conceivable that the predicted pressure gradients of our analysis deviate from the true pressure gradients as a function of Reynolds number and frequency and that this may be the cause of the deviation of our data from the theoretical predictions.

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