Diffusion Coefficients over Rough and Smooth Boundaries, obtained by Measuring the Concentration-Velocity Covariance

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DIFFUSION COEFFICIENTS OVER ROUGH AND SMOOTH BOUNDARIES, OBTAINED BY MEASURING THE CONCENTRATION-VELOCITY COVARIANCE

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ABSTRACT

A preliminary investigation of the coefficients of turbulent diffusion in an open channel was conducted by employing: 1) hot-film anemometry to detect the velocity fluctuation, 2) a platinized single-electrode conductivity probe to detect the concentration fluctuations, and 3) a digital computing system to evaluate the covariance and other statistical properties of the two output signals.

Data were collected downstream of a constant-discharge point source of neutrally-bouyant salt solution at stream temperature and velocity. Using current semi-empirical methods diffusion coefficients were obtained in the vertical and lateral directions as well as dispersion coefficients due to convection.

Using the concentration-velocity covariance data the longitudinal diffusion coefficient could be evaluated directly from basic principles. The necessary equation is derived from the conservation of mass and is referred to as the Eulerian diffusion equation,

$$\frac{\partial \bar{c}}{\partial t} + \bar{U}_i \frac{\partial \bar{c}}{\partial x_i} = - \frac{\partial}{\partial x_i} \overline{c'u'_i} . \qquad (1)$$

A coefficient of turbulent diffusion may then be defined as

$$\epsilon_{T_{ij}} \frac{\partial \bar{c}}{\partial x_j} \equiv - \overline{c'u'_i} . \qquad (2)$$

No simplifying assumptions have been made in these equations and it is thus felt to be a true representation of the diffusion process.

Diffusion coefficients obtained by the direct method are compared with those obtained by the semi-empirical methods. The comparison makes possible the evaluation of the validity of the assumptions made in obtaining diffusion coefficients by earlier methods.

The results also include intensities, autocorrelations and power spectra for the velocity and concentration signals at various selected points in the flow.

An evaluation and description of the equipment along with data reduction procedures are discussed in detail.

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SYMBOLS

$\bar{c}$	time average concentration
c'	fluctuating concentration
t	time
u'_i	fluctuating velocity in x_i - direction
$\bar{U}_i$	time average velocity
x_i, x_j	space coordinates
$\epsilon_{T_{ij}}$	coefficient of turbulent diffusion
$\overline{c'u'_i}$	covariance of concentration and velocity

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