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MASS TRANSFER INVESTIGATION IN TURBULENT FLOW DOWNSTREAM OF SUDDEN ENLARGEMENT OF A CIRCULAR PIPE FOR VERY HIGH SCHMIDT NUMBERS

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Abstract—This paper reports the results of an experimental investigation, which employs the technique of "Diffusion-Controlled Electrolysis", for the determination of mass-transfer rates in the separated and redeveloping regions downstream of a sudden enlargement of a circular pipe. The data are presented for Schmidt number of 1400 and 2500 and for Reynolds number ranging between 2500 and 89000.

The results are compared with some other existing data and it is concluded that the mass-transfer behaviour is strongly influenced by the boundary conditions but its dependence on Schmidt number is rather weak. Finally it is shown that the reattachment-zone mass-transfer rates show a simple power-law dependence on the Reynolds number.

NOMENCLATURE

(All the dimensional quantities are assumed to be in SI units.)

d_N,	diameter of the nozzle;
d_P,	diameter of the pipe;
D,	diameter ratio ($\equiv d_P/d_N$);
D_S,	height of the step formed at enlargement $[\equiv (d_P - d_N)/2]$;
g_m,	mean mass-transfer coefficient;
G_m,	mean mass velocity in the pipe;
I_m,	mean diffusion-controlled limiting-current density;
Pr,	Prandtl number ($\equiv \mu/\rho\Gamma_h$);
Re,	Reynolds number ($\equiv G_m d_P/\mu$);
Sc,	Schmidt number ($\equiv \mu/\rho\Gamma_c$);
St,	Stanton number ($\equiv g_m/G_m$);
$St_{\max}$,	maximum value of Stanton number;
St_{∞},	value of Stanton number for fully developed pipe flow;
z,	axial distance measured from the sudden enlargement;
Z,	non-dimensional axial distance ($\equiv z/D_S$).

Greek symbols

Γ_c,	diffusivity for mass-species;
Γ_h,	diffusivity for enthalpy;
μ,	dynamic viscosity;
ρ,	mass density;
ϕ,	mass-concentration of ferricyanide ions per unit mass of the electrolyte.

1. INTRODUCTION

PIPES are perhaps the most widely used carriers in engineering industry. Flow in such pipes is frequently interrupted by pipe-joints or monitor and control devices. This often provokes flow separation and local recirculation, and has considerable influence on the momentum-, heat- and mass-, transfer behaviour. In general, recirculating flows are characterized by the occurrence of regions of high levels of turbulence,

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low shear stresses and high heat- and mass-transfer rates.

The available experimental data for heat/mass transfer immediately downstream of a sudden enlargement of a pipe is scarce. The data that are available, show large discrepancies in their qualitative nature (see, e.g. [1]). Moreover almost all of the existing data were obtained with air or water as the working medium and hence, they represent a rather limited range of Prandtl number (or, its mass-transfer equivalent, Schmidt number).

The series of experiments reported in this paper was designed to provide information about the mass-transfer behaviour of fluids at very high Schmidt numbers for turbulent incompressible flow behind a sudden enlargement of a pipe. The experimental technique which was used is commonly termed, the "Diffusion-Controlled Electrolysis"; although this technique is well-established for boundary-layer type of flows. its potential of application to separated flows is only beginning to be realized.

2. THE EXPERIMENTAL TECHNIQUE

The use of Diffusion-Controlled Electrolysis to obtain the wall-fluxes for high Schmidt numbers is well-documented. A comprehensive account of the technique is available, for example, in [2]; therefore only a brief description of its essential features is given here.

According to the concept of the ionic theory, the molecules of a binary electrolyte in solution dissociate into two types of ions: the cations possessing a negative charge and the anions possessing a positive charge. When an electromotive force (e.m.f.), above a certain critical value, is applied between two electrodes in such a solution, there is a transfer of electrons to the anions from the cathode and a transfer of electrons to the anode from the cations. This sets up an ionic current. In the steady state, the reacting ions must be continuously supplied to the electrodes from the solution. In general three mechanisms take part in this exchange: (a) *migration* under the influence of the potential gradient, (b) *diffusion* under the influence of the concentration gradient, and (c) *convection*.

Migration of ions can be eliminated by reducing the potential gradient in the flow, almost, to zero by adding a high concentration of a non-reacting electrolyte with high electrical conductivity. The ionic-transfer theory states that, for such a flow, the rate of the electrochemical reaction increases, at first, exponentially with the applied e.m.f., but when the e.m.f. is sufficiently high, the rate of reaction is independent of it and is determined only by the rate of ionic-transport to the electrodes [3]; the reaction is then termed "diffusion-controlled" and the current flowing through the cell is termed the "limiting-current". If, in addition, the flux of ions at the cathode is much greater than that at the anode, then the limiting-current conditions are first reached at the cathode and the reaction is then "cathode-controlled". For such a reaction, the ions transported to the cathode react very rapidly and their concentration at the electrode surface falls almost to zero.

In the series of experiments reported here the limiting-current was cathode-controlled by making the surface area of the cathode much smaller than that of the anode. The reaction employed was that between the ferricynide and ferrocynide ions:

$$\mathrm{Fe(CN)}_6^{3-} + \mathrm{electron}^{1-} \underset{\text{anode}}{\overset{\text{cathode}}{\rightleftharpoons}} \mathrm{Fe(CN)}_6^{4-}. \quad (2.1)$$

It can be shown that for this reaction g_m (see Nomenclature) is given by [4]:

$$g_m = 2{\cdot}196 \times 10^{-6}\, I_m/\phi. \quad (2.2)$$

3. THE APPARATUS

3.1. *The flow circuit*

A schematic diagram of the apparatus used is shown in Fig. 1. A centrifugal pump (2) maintains a supply of liquid from the reservoir

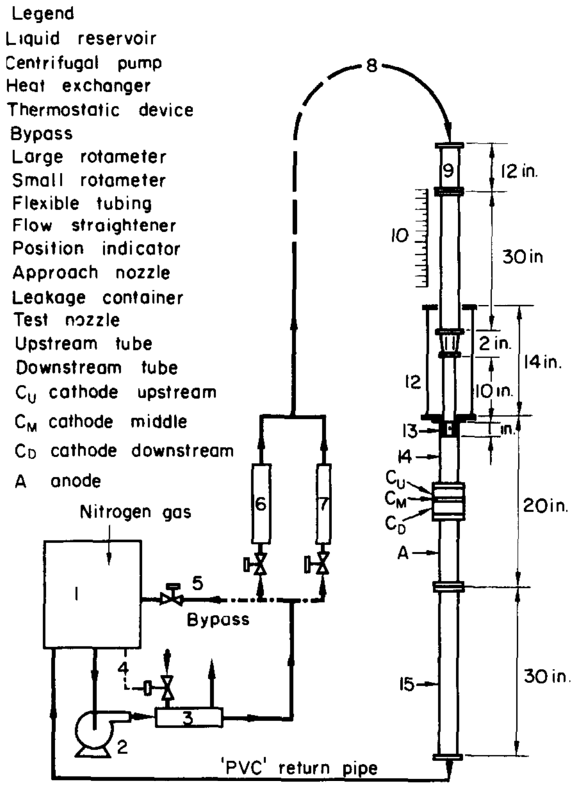

FIG. 1. Schematic diagram of the apparatus.

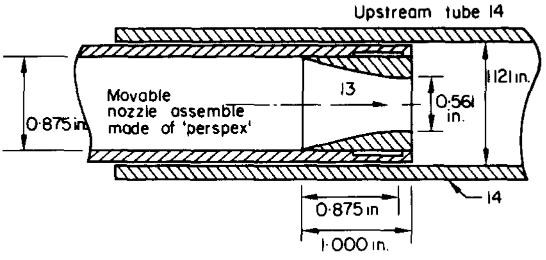

FIG. 2. Nozzle assembly detail.

(1) to the Rotameters (6, 7) via a thermostatically controlled heat exchanger (3). The liquid from the Rotameters is led through a flow-straightner device (9) and an approach nozzle (11) to the test nozzle (13). The jet of fluid issuing from the test nozzle expands into the test section and then returns to the reservoir. The test section contains three cathodes named C_U, C_M and C_D; their axial lengths are 0·498, 0·091 and 0·498 in. respectively. Further details and photographs of the apparatus have been presented by the author elsewhere [4].

The test nozzle assembly (Fig. 2) was designed to be movable along the upstream tube (14) of the test section made of six mutually insulated lengths of nickel tubing (Fig. 1); the movement being absorbed by the flexible tubing (8) at the top. The relative position of the nozzle in the test-section was obtained with a scale-and-pointer device (10) as shown in Fig. 1. The lower part of the nozzle assembly was surrounded by a leakage container (12) which could be partially, or completely, filled with the electrolyte to counterbalance the leakage-pressure through the sliding joint between the nozzle and the test-section. The necessity of a movable nozzle arose from the fact that the measurements were required at a number of positions downstream of the sudden enlargement. With a fixed nozzle this can be achieved only by employing a large number of cathodes along the length of the pipe; with a movable nozzle the same purpose can be served even by a single cathode.

The electrolyte employed consisted of equimolar concentrations of potassium ferricyanide, $K_3Fe(CN)_6$, and potassium ferrocyanide, $K_4Fe(CN)_6$, in aqueous solution of sodium hydroxide, NaOH. High purity "analar" chemicals and distilled water were used for the above purpose. Details of composition of the electrolyte are given later in Table 1. It is to be noted that only ferricyanide and ferrocyanide ions take part in the electrolysis as described by equation (1); sodium hydroxide merely provides a supporting electrolyte of high electrical conductivity.

To prevent oxidation of the ferricyanide ions, special precautions were taken during the construction, assembly and operation stages. The exposure to light and oxygen was minimized;

an oxygen-free-nitrogen atmosphere was maintained in the reservoir and the transparent parts of the apparatus were covered with deep orange celluloid paper. All the inner surfaces and joints of the test section and the test nozzle assembly were carefully smoothed and polished; the mean roughness on the electrode surfaces was less than 10^{-5} in. and the steps at joints were less than 5×10^{-3} in. The electrolyte was maintained at 25 ± 0·1°C by a thermostatic device. Further details are given in [4].

3.2. *The electrical circuit*

The essential features of the electrical circuit are shown in Fig. 3. The circuit was designed to allow the operation of the electrochemical cell with any combination of the cathodes. It also enabled measurement of the current through, and potential-drop across, any of the cathodes individually or in combination with others.

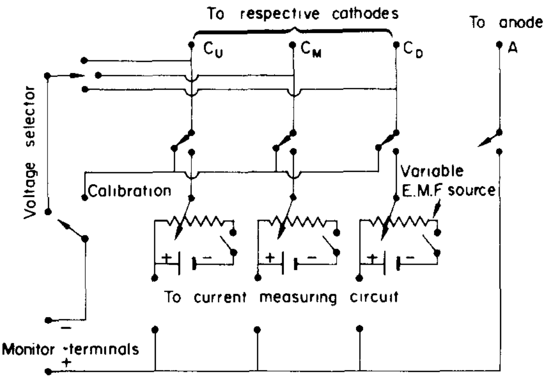

FIG. 3. Essential features of the electrical circuit.

The current through the circuit was obtained by measuring the potential-drop across a standard one-ohm resistor with a high-precision Digital Voltmeter*. An external resistance-capacitance filter-cum-integrater with a variable time period (50 μs–10 s) was used to even-out the strong fluctuations in, and to obtain a time-mean value of, the signal; most of the readings were taken with this filter set between 2 and 5 s.

A calibration circuit, consisting of a motor-driven potential divider and a chart recorder, was used to check the diffusion-control characteristics of the system from time to time.

3.3. *The choice of cathode combinations*

The choice of cathode combination has an important bearing on the mass-transfer behaviour of a cathode-controlled system such as the present one. It should be recalled from section 1 that the concentration of ferricyanide ions at the cathode surface will fall to zero; at an inactive surface preceding or succeeding such a cathode the concentration of ferricyanide ions is equal to that in the bulk flow. An active cathode thus implies a step-change in the boundary condition; and the mass-transfer behaviour of the cell depends upon which of the cathodes are made active.

The number of cathodes available is three (Fig. 1) and various types of boundary conditions can be simulated by electrically connecting some or all of these cathodes to the circuit. After a preliminary investigation [4], the following two cathode groups were selected for final series of tests:

Group I—with C_M alone active with C_U and C_D disconnected from the electrical circuit. This corresponds to a small locally active surface.

Group II—with C_M, C_U and C_D all active. This corresponds to a zone of active surface.

For both groups, it was the current generated by C_M alone that was measured. The length of this cathode was small enough ($\frac{1}{12}$th the pipe diameter) to justify the assumption that it represented the local value of mass transfer.

4. THE RESULTS AND DISCUSSION

4.1. *The experimental data*

The data were obtained for two values of the Schmidt number: 1400 and 2500; the range of Reynolds number investigated was from 2550 to

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* "Fenlow" DVM 301-A; 10 μV–1000 V range with 0·01 per cent DC accuracy.

88500. Concentrations of the corresponding solutions and other details are given in Table 1. The mass-transfer rates were measured at various locations downstream of the sudden enlargement; in terms of the non-dimensional distance Z, the range investigated was from 1·7 to 34·8.

Table 1. Fluid-property data of the solutions employed for the mass-transfer experiments

Solution no.	NaOH (g-moles/l)	$K_3Fe(CN)_6$ (g-moles/l)	Sc	Re range	Data appear in
1	0·520	0·00515	1400 ±7%	3550–88500	Figs. 4 and 5
2	2·056	0·00504	2500 ±7%	2550–65300	Figs. 6 and 7

The data is displayed graphically in Figs. 4–7 as plots of St vs. Z for various Reynolds numbers. Also shown are the asymptotic values, for fully developed pipe flow obtained by Gosman [5].

The present data far downstream of the enlargement compare favourably with the asymptotic values. The data for the separated and the redeveloping regions of the flow follow the well-established pattern of behaviour in its general trends: the mass-transfer rate rises rapidly to a maximum in the reattachment zone and then decays to its asymptotic values. However, there are two features of the present data which do not seem to have been reported in the existing literature. The first is a shift in the location of the Stanton number maxima with the boundary condition: the data for the cathode

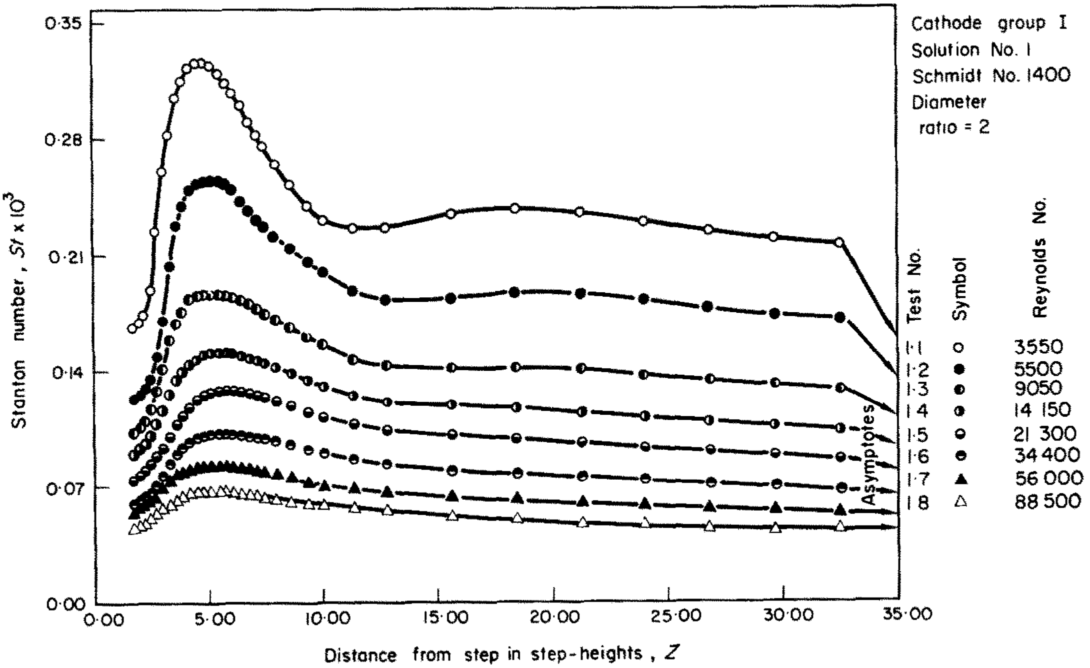

FIG. 4. Mass transfer downstream of the sudden enlargement with a small active zone at the point of measurement for Schmidt number of 1400.

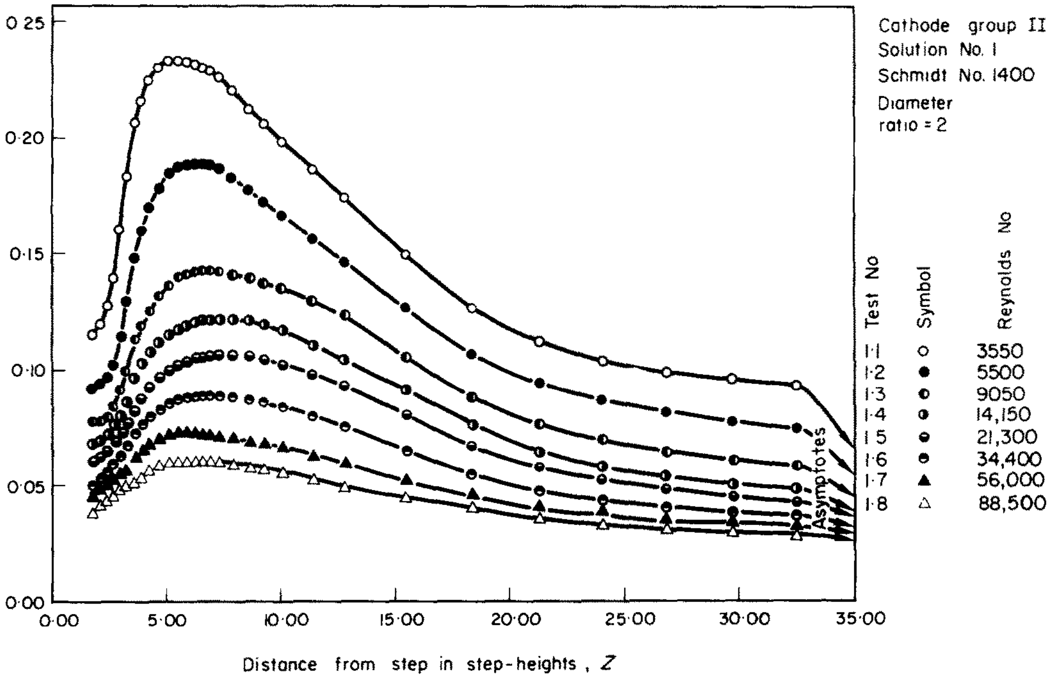

FIG. 5. Mass transfer downstream of the sudden enlargement with the point of measurement in the middle of a large active zone for Schmidt number of 1400.

group I exhibit maxima, on the average, in the vicinity of $Z = 5{\cdot}6$, whereas the maxima for the cathode group II are located near $Z = 7{\cdot}0$. The second novel feature is the appearance of a second maximum for the data of the cathode group I at low Reynolds number.

It is generally agreed that the location of the maximum heat/mass transfer is in the vicinity of, or at, the reattachment point; however, reattachment point itself is known to show strong oscillations about the mean position with time (e.g. [6]). Since the instantaneous values at a certain location are a function of the boundary conditions, it is conceivable that these two special features of the data, reported above, are caused by the time and space averaging process since both the time-interval of the measurements and the size of the cathode are finite. Another strong possibility is that the inactive cathode C_D for cathode group I may act as a pseudo-anode by providing a short circuit path for the electron flow between the cathode C_M and the anode A. This will cause a local increase in the concentration of the ferricyanide ions at C_D according to equation (2.1) and will result in increased rates of mass transfer at C_M whenever the local direction of flow is from C_D to C_M; this is likely to happen when C_M is situated within the reversed flow region so that C_D is situated locally upstream. If this is the cause of the appearance of a second maxima then it must be considered a limitation of the present experimental technique in its application to reversed flow situations. It can be shown [4] that this local increase in mass transfer will not exceed 5 per cent or so for cathode group I, whereas it is completely absent for cathode group II. It will be interesting to know exactly

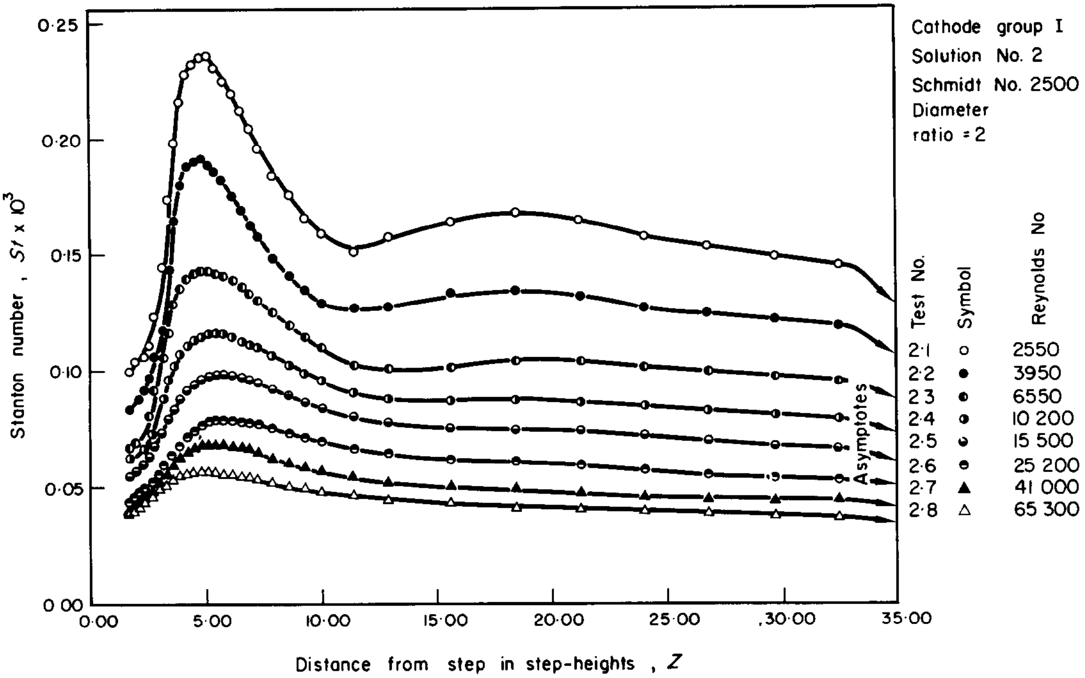

FIG. 6. Mass transfer downstream of the sudden enlargement with a small active zone at the point of measurement for Schmidt number of 2500.

why this second maximum appears on the scene for a boundary with a local step-change in boundary condition and also whether any similar effect has been noted in other heat-transfer problems.

In the existing literature, the maxima in heat/mass transfer and the reattachment points are reported to lie between Z value of 4 and 12 [1]. The most frequent values quoted in this respect are between the Z values of 6 and 8. It is interesting to note that almost identical values have been quoted for some external flow such as the flow past a step [7]. The present data, especially those for cathode group II, are thus consistent with the data obtained by earlier workers. It should be noted that all of the earlier data were obtained with uniform (temperature or heat-flux) boundary conditions for a considerable length downstream of separation: the boundary conditions of the cathode II are nearer to this situation than those of the cathode group I (see section 3.3). For the present problem, the thermal boundary condition can in no way influence the fluidynamic behaviour; it follows that the reattachment point for both the cathode group I and the cathode group II experiments must be the same. In view of the existing literature, and the discussion in previous paragraph, it seems that the results of cathode group II should be taken as indicative of the reattachment point location; which will then be in the vicinity of Z of 7.

4.2. *Correlation of the data*

A small locally active surface: *cathode group I*. For very high Schmidt numbers and small mass-transfer surfaces, the concentration boundary layer is likely to lie entirely within the viscous sub-layer. It can be shown [8] that away from the reattachment point:

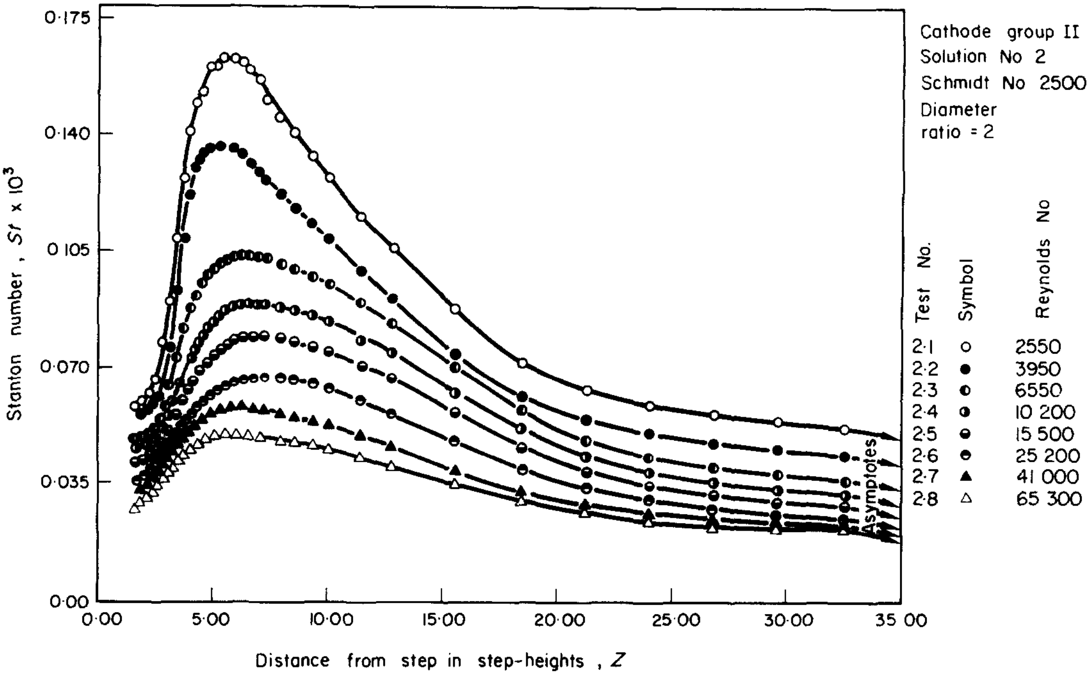

FIG. 7. Mass transfer downstream of the sudden enlargement with the point of measurement in the middle of a large active zone for Schmidt number of 2500.

$$St \propto Sc^{-\frac{2}{3}}, \tag{4.1}$$

and therefore, for purposes of correlation, let us say,

$$St = \text{const. } Re^{-q}\, Sc^{-\frac{2}{3}}. \tag{4.2}$$

Figure 8 presents plots of Re vs. $StSc^{\frac{2}{3}}$ for two locations downstream of the sudden enlargement: the location of the mass-transfer maxima and a location far downstream of the enlargement. In both cases, the data can be well correlated with q of 0·45.

According to Spalding [8], the value of q for a fully developed pipe flow at high Schmidt and Reynolds numbers is 0·417. In the vicinity of the reattachment point in a turbulent separated flow Spalding [9] deduced the value of q to be 0·40. The value 0·45 obtained above is thus in reasonable agreement with these deductions. The departure is, perhaps, partly due to the fact

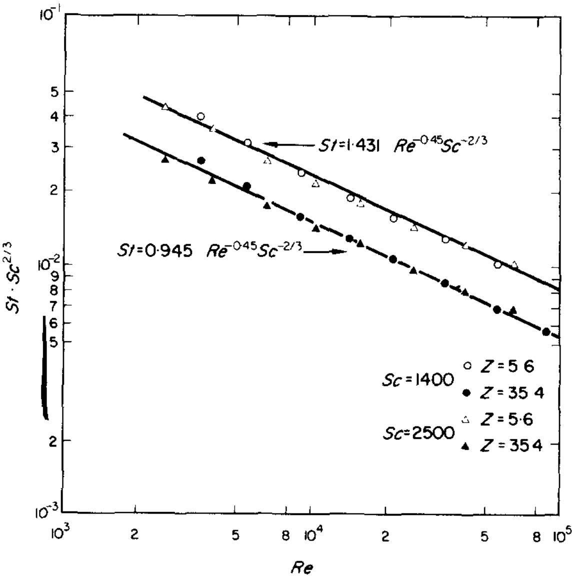

FIG. 8. Correlation of the experimental data for the small locally active surface: cathode group I.

that the deductions of Spalding were based upon one-dimensional models.

A zone of active surface: *cathode group II*. For fully developed turbulent flow at high Schmidt and Reynolds numbers, it can be shown [10] that:

$$St = \text{const. } Re^{-\frac{1}{8}} Sc^{-\frac{3}{4}}. \tag{4.3}$$

Though the boundary conditions of the cathode group II are unlikely to yield a fully developed flow, it is convenient to employ the following generalization of the above relation:

$$St = \text{const. } Re^{-q} Sc^{-\frac{3}{4}}. \tag{4.4}$$

Figure 9 displays Re vs. $St.Sc^{\frac{3}{4}}$ for two locations similar to the ones for the cathode group I. In this case, however, the data can be correlated as a simple power law only far the location of the maximum mass transfer; the index of the power law, q, is equal to 0·35. The values far downstream cannot be represented by a simple power law; in fact, even the dependence on Schmidt number does not appear to be a simple power of $\frac{3}{4}$. However, for Re greater than $2{\cdot}5 \times 10^4$, q in the above equation may be chosen as 0·20.

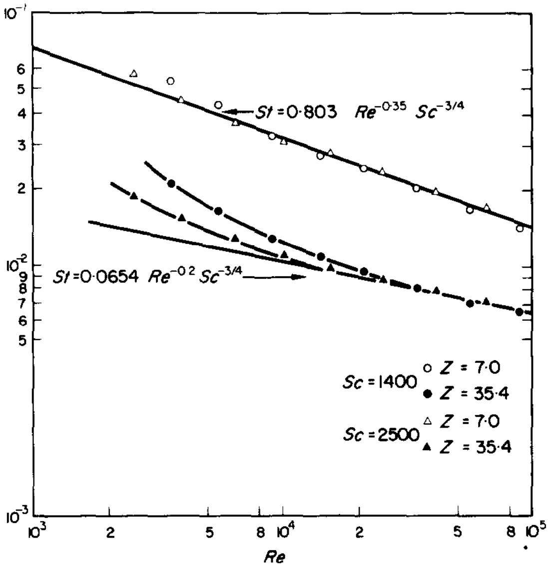

FIG. 9. Correlation of the experimental data for the zone of active surface: cathode group II.

It is to be noted, in comparison, that the values reported by earlier research workers, for uniform heat-flux, at the wall are close to q of 0·33 in the reattachment region. The value of q predicted by Spalding [9] for this region is 0·40.

4.3. *Comparison with previous investigations*

A number of investigations have now been conducted into the behaviour of the separated flows, and some of these have already been referred to in the preceding sections; however, none is directly comparable with the present one in both the geometrical arrangement and the experimental conditions.

Figure 10 presents the data of Krall and Sparrow [1] and Ede *et al.* [11] along with some data from the present investigation. All these data were obtained for sudden enlargement in a circular pipe for a diameter ratio of two; however the experimental conditions varied considerably. Krall and Sparrow induced separation by inserting an orifice into a pipe with fully developed upstream flow; the pipe was heated electrically and the tests were conducted at Prandtl number of 3 and 6. The data of Ede and co-workers was obtained for the sudden expansion of a fully developed pipe flow into a bigger pipe; electric heating and a Prandtl number of 9 were employed. In Fig. 10, St_{∞} for the data of Ede *et al.* was obtained from a correlation recommended by Knight [12] for similar data, which is:

$$St_{\infty} = 0{\cdot}0109\, Re^{-0{\cdot}116}\, Pr^{-0{\cdot}6}. \tag{4.5}$$

It should be noted that the slopes of $-0{\cdot}033$ and $-0{\cdot}225$ were derived from the correlation of the maxima and the asymptotic solutions recommended in [8] and [10].

Figure 10 shows that the effect of Prandtl or Schmidt number on $St_{\max}/St_{\infty}$, especially at high Reynolds numbers, is small. The differences between the results of Krall and Sparrow and

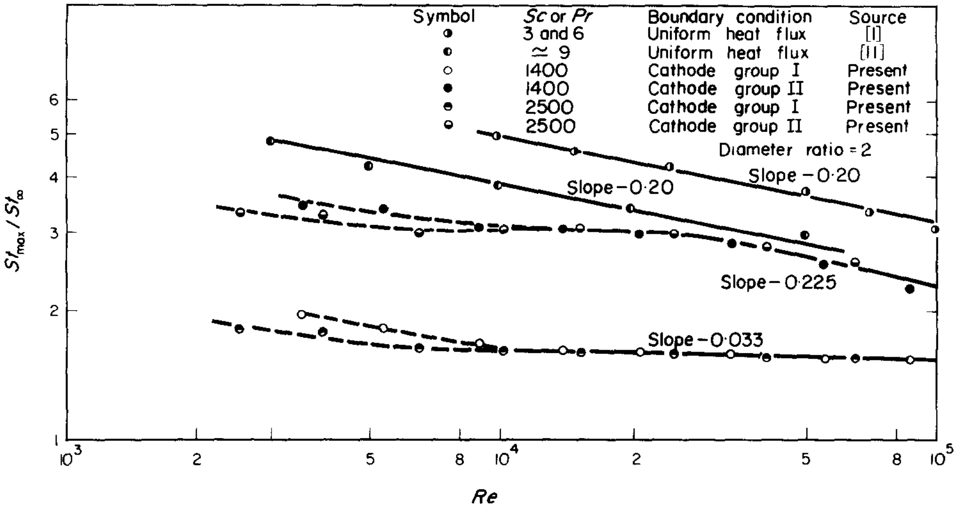

FIG. 10. Comparison of experimental data for the maximum heat/mass transfer downstream of a sudden enlargement of a circular pipe.

those of Ede and co-workers can, then, only be ascribed to the differences in the experimental conditions, such as the increased turbulence in the incoming flow in the case of Krall and Sparrow because of the presence of an orifice in the pipe.

The Reynolds number dependence of St_{max}/St_{∞} is considerably influenced by the boundary condition as can be seen from a comparison of the data for the cathode group I with those of the cathode group II. Also, the data show a large variation in the magnitude of St_{max}/St_{∞} at any fixed Reynolds number.

5. CONCLUSIONS

1. Effect of Schmidt number on St_{max}/St_{∞}, especially at Reynolds numbers above 10^4, is small.
2. Boundary conditions exert a considerable influence on the Reynolds number dependence of St_{max}/St_{∞}.
3. The flow reattachment, as inferred from mass-transfer behaviour, occurs between 6–8 step-heights (about $1\frac{1}{2}$–2 large pipe-diameters from enlargement).
4. The data in the reattachment zone can be well correlated as a simple power law dependence of the Stanton number on the Reynolds number. However, the value of the exponent of the Reynolds number is a function of the boundary condition and varies from −0·45 for a locally active surface to −0·33 for uniform boundary condition over a large zone.
5. A comparison of the measurements with the corresponding asymptotic value for fully developed pipe flow shows that the recovery of flow from the effects of separation is faster as the Reynolds number increases.

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REFERENCES

1. K. M. Krall and E. M. Sparrow, Turbulent heat transfer in the separated, reattached and redevelopment regions of a circular tube, *J. Heat Transfer* **88**, 131 (1966).
2. C. W. Tobias, M. Eisenberg and C. R. Wilke, Diffusion and convection in electrolysis—A theoretical review, *J. Electrochem. Soc.* **99**, 359c (1952).
3. V. G. Levich, *Physico-Chemical Hydrodynamics*. Prentice-Hall, New York (1962).
4. A. K. Runchal, Transfer processes in steady two-dimensional separated flows, Ph.D. Thesis, London University (1969).
5. A. D. Gosman, Diffusion-controlled electrolysis in two-phase flows, Ph.D. Thesis, London University (1969).
6. D. E. Abbott and S. J. Kline, Experimental investigation of subsonic turbulent flow over single and double backward facing steps, *J. Basic Engng* **84**, 317 (1962).
7. T. J. Mueller and J. M. Robertson, A study of the mean motion and turbulence down-stream of a roughness element, *Proc. 1st Southeastern Conf. Theoret. and Appl. Mech.*, Gatlinburgh, Tenn. May 3–4 (1962).
8. D. B. Spalding, Contribution to the theory of heat transfer across a turbulent boundary layer, *Int. J. Heat Mass Transfer* 7, 743 (1964).
9. D. B. Spalding, Heat transfer from turbulent separated flows, *J. Fluid Mech.* **27**, 97 (1967).
10. R. G. Diessler, Analysis of turbulent heat transfer, mass transfer, and friction in smooth pipes at high Prandtl and Schmidt numbers, NACA Rep. 1210 (1955).
11. A. J. Ede, R. Morris and E. S. Birch, The effect of abrupt changes of diameter on heat transfer in pipes, NEL Rep. 73 (1962).
12. H. R. Knight, Heat transfer in separated flows, Imperial College, Mech. Eng. Dept. SF/TN/3 (1966).

ETUDE DU TRANSFERT MASSIQUE POUR DES NOMBRES DE SCHMIDT TRÈS GRANDS DANS UN ÉCOULEMENT TURBULENT EN AVAL D'UN BRUSQUE ÉLARGISSEMENT D'UN TUYAU CIRCULAIRE

Résumé—Ce mémoire apporte les résultats d'une recherche expérimentale employant la technique "d'électrolyse contrôlée par diffusion", afin de déterminer les flux massiques dans les régions séparées et de réorganisation en aval d'un brusque élargissement d'un tube circulaire. On présente les résultats pour des nombres de Schmidt de 1400 et 2500 et un nombre de Reynolds compris entre 2500 et 89000.

Les résultats sont comparés à quelques résultats déjà existants, et on en conclut que le comportement du transfert massique est fortement influencé par les conditions limites mais que sa dépendance au nombre de Schmidt est plutôt faible. Finalement on montre que les flux de transfert massique dans la zone de réattachement dépend par une loi de puissance simple du nombre de Reynolds.

UNTERSUCHUNG DES STOFFAUSTAUSCHES IN EINER TURBULENTEN STRÖMUNG HINTER EINER PLÖTZLICHEN ERWEITERUNG EINES KREISFÖRMIGEN ROHRES BEI SEHR HOHEN SCHMIDT-ZAHLEN

Zusammenfassung—Die Arbeit berichtet über die Ergebnisse einer experimentellen Untersuchung, in der mit Hilfe der "diffusionskontrollierten Elektrolyse" die Anteile des Stoffaustausches in der abgelösten und in der sich wieder anlegenden Strömung hinter einer plötzlichen Erweiterung eines kreisrunden Rohres bestimmt wurden.

Ergebnisse werden angegeben für Schmidt-Zahlen von 1400 bis 2500 und für Reynolds-Zahlen zwischen 2500 und 89000. Die Ergebnisse werden mit einigen vorhandenen Daten verglichen. Daraus ergibt sich die Folgerung, dass das Stoffaustauschverhalten von den Randbedingungen stark beeinflusst wird, dass seine Abhängigkeit von der Schmidt-Zahl jedoch ziemlich gering ist. Schliesslich wird gezeigt, dass die Stoffaustauschanteile der wieder angelegten Strömung eine einfache Potenzgesetz-Abhängigkeit von der Reynolds-Zahl besitzen.

ИССЛЕДОВАНИЕ МАССООБМЕНА В ТУРБУЛЕНТНОМ ПОТОКЕ ЗА РЕЗКИМ РАСШИРЕНИЕМ КРУГЛОЙ ТРУБЫ ПРИ ОЧЕНЬ БОЛЬШИХ ЧИСЛАХ ШМИДТА

Аннотация—В работе приводятся результаты экспериментального исследования с применением методики «электролиза, зависящего от диффузии,» по определению скорости массообмена на отрывных и вновь развивающихся участках за резким расширением круглой трубы.

Представлены данные для чисел Шмидта 1400 и 2500 и для чисел Рейнольдса в диапазоне от 2500 до 89 000.

Результаты сравниваются с имеющимися данными и делается вывод, что режим массообмена сильно зависит от граничных условий, в то время как его зависимость от значений чисел Шмидта невелика. И, наконец, показано, что для скорости массопереноса в зоне воссоединения характерна простая зависимость от чисел Рейнольдса.