Effect of Entrance Shape on Flow Between Parallel Plates

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Whan and Rothfus (3) reported measurements of pressure drop and mean local fluid velocities for transition flow of water in a smooth rectangular duct of large aspect ratio. Their conduit was 0.70 in. high, 14 in. wide, and 20 ft. in horizontal length and was fitted with a bell-shaped entrance 3 ft. long. Velocity profiles were measured by means of a calibrated impact probe situated at the center line of the duct and 3 ft. from the downstream end. Bulk average linear velocities were calculated by integrating under the experimental profiles. Reynolds numbers and Fanning friction factors were expressed in the usual way, based on an equivalent diameter equal to four times the half-clearance between the broad sides of the duct, since infinitely wide parallel planes were approximated. No attempt was made at the time to establish the possible effect of entrance shape on the temporal mean behavior of the fluid.

Additional experiments have now been performed with the same apparatus, unchanged except for replacement of the bell-shaped entrance by a square-edged one. The isothermal flow of water at essentially room temperature has been investigated at seven Reynolds numbers between 3,270 and 9,590. Again both pressure drop and local velocities have been measured in the same manner as before.

Fanning friction factors and ratios of average to maximum velocities for the two types of entrances are compared in the following table. The data have been smoothed so that even values of the Reynolds number can be shown.

Reynolds number	Fanning friction factor square	Fanning friction factor bell	Average velocity ÷ maximum velocity square	Average velocity ÷ maximum velocity bell
2,750	—	—	(0.667)	0.667
3,000	—	—	(0.740)	0.738
3,500	0.0094	0.0094	0.798	0.780
4,000	0.0093	0.0093	0.825	0.802
5,000	0.0091	0.0090	0.848	0.828
6,000	0.0090	0.0088	0.853	0.841
8,000	0.0088	0.0086	0.859	0.854
10,000	0.0086	0.0084	0.862	0.860

Velocity ratios, but not friction factors, could be extended smoothly to the critical Reynolds number of 2,750 reported by Whan, and the extrapolated values are shown in parentheses.

Installation of the square-edged entrance appears to have affected the friction factors very little over the investigated range. The ratios of average to maximum velocity on the other hand are at least measurably higher for the square-edged entrance than for the bell. The region of difference is limited however, since both entrances yield about the same values at the extremities of the reported Reynolds numbers. At a given average velocity an increase in the velocity ratio is of course associated with a flattening of the velocity profile over the main-stream portion of the fluid. A small change in the velocity ratio can therefore reflect considerable changes in the local velocity gradients.

Mache (2) has pointed out that in transition flow intermittent turbulent fluctuations appear with greater frequency for a sharp-edged entrance than for a bell-shaped one. Lindgren (*1*) has pictured the transition process in terms of random bursts of turbulence resulting from the collapse of certain entrance disturbances. The present data also suggest that the transient patterns associated with different entrance shapes influence ordinary temporal mean velocity measurements in transition flow at long distances from the entrance. Nothing more definitive can be said about the mechanism however, since no relationship between instantaneous velocities and the action of the impact probe was investigated in the present case. The principal points to be noted are that there does seem to be an effect of entrance shape on the velocity profiles in the transition range and that the velocity data of Whan and Rothfus are therefore limited, strictly speaking, to the case of the bell-shaped entrance.

LITERATURE CITED

1. Lindgren, E. R., *Archiv fur Physik*, **12**, 1 (1955).
2. Mache, H., *Forsch. Gebiete Ing.*, **14**, 77 (1943).
3. Whan, G. A., and R. R. Rothfus, *A.I.Ch.E. Journal*, **5**, 204 (1959).

Velocity and Temperature Distributions About a Horizontal Cylinder in Free Convection Heat Transfer

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Some interesting results became apparent in the process of correlating velocity and temperature profile measurements taken about a single horizontal tube (*1*).

These measurements were taken at the plane of maximum diameter of a single, tapered, horizontal 1-in. diameter copper tube. Cooling water was passed through the tube while it was immersed in a volume-heated liquid.

All runs were made at the following single set of conditions:

Bulk temperature, 75.0°F.
Wall temperature, 63.8°F.
Volume heat source, 0.10 B.t.u./cu.ft.-sec.
Grashof number, 2.19 x 10^5

Velocity profiles were determined by measuring the motion of suspended 0.2 mm oil droplets (sp. gr. = 1.00), with an optical system which provided a 10x magnified image on a polar coordinate screen. The temperature field was obtained with a calibrated thermocouple probe, constructed from No. 36 chromel-alumel wire and supported