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On measurement of velocity by Pitot tube

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With 4 figures in the text

1. We know several paradoxal results from theoretical hydrodynamics which are incompatible with practical experience. Obviously such a paradox can be explained by an unpermitted simplification in the theorizer's assumptions. If e.g. all boundary conditions in a problem are stationary or the boundary has some symmetry properties, it is plausible to assume the same character for the solution of the hydrodynamical equations. Sometimes it is a good approximation to neglect the viscosity, e.g. by calculation of the velocity outside an airfoil in a homogeneous flow, but the supposition is an over-simplification if we seek the resistance of the body (d'Alembert paradox). For further examples of this kind I refer to a famous book by GARRETT BIRKHOFF [1]. Here I shall discuss a problem where the effects of viscosity are problematical.

A real fluid is viscous, and this fact may cause accumulation of fluid in "wakes". In some cases a wake may have a rather well defined boundary zone which on idealization to non-viscous fluid tends to a surface, called a "free" boundary, where the velocity is discontinuous. Sometimes the wake is bounded by a turbulent "mixing zone", and the turbulence produces motions in the wake, which are practically inaccessible for theoretical analysis. Evidently it is difficult to predict the existence of wakes, and without a condition of stability, we get an infinite number of solutions to a given problem. On account of the difficulty of surveying the stability problem for all conceivable cases, we must in general supplement the theoretical speculations with experimental experiences.

2. A long, straight, circular tube with thin walls is closed by a wall inside the tube. The tube is immersed in an incompressible fluid, and at a great distance from the end of the tube the flow is homogeneous, stationary and parallel to the tube axis. The velocity is so great that we may, as a first approximation, neglect the viscosity.

If no wakes were accumulated the calculation of the flow (Fig. 1) should be a classical problem for harmonic functions. In reality we may expect that fluid is accumulated in the tube and eventually forms a stable wake before the wall. Perhaps it is plausible that the free boundary has rotational symmetry about the tube axis and forms a peak on the axis (Fig. 2). We shall not try to make a stability analysis of this flow, but it is obvious that internal friction will break down the peak at an arbitrary small deviation from the symmetric arrangement.