The Momentumless Wake

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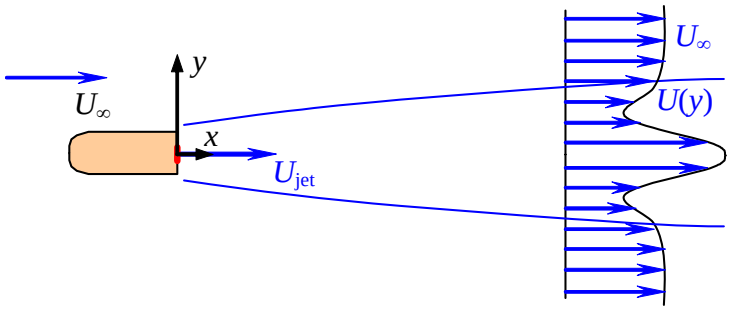
1. Introduction

- We examine the decay of turbulence downstream of a 2-D, incompressible, momentumless wake, as sketched.
- If the jet in the center of the wake is adjusted so as to provide a thrust that exactly balances the body drag, the net drag is zero, and the wake is said to be momentumless.
- We compare four cases: pure wake (no jet), weak wake (jet not strong enough to balance the drag), momentumless wake (jet adjusted to exactly balance the drag), and weak jet (jet too strong).



2. Experiments

- This was a Ph.D. project of Woon Jean Park, a student of John M. Cimbala at Penn State in the late 1980s.
- For velocity and turbulence measurements, Pitot-static probes and hot wires were used.
- For flow visualization, a smoke-wire was used to generate smoke streaklines in the experiments in a wind tunnel.
- In Figure 6, the mean velocity profiles are shown for all four cases at two different downstream locations. The mean shear in the momentumless wake case quickly decays, leaving a nearly uniform velocity profile far downstream.

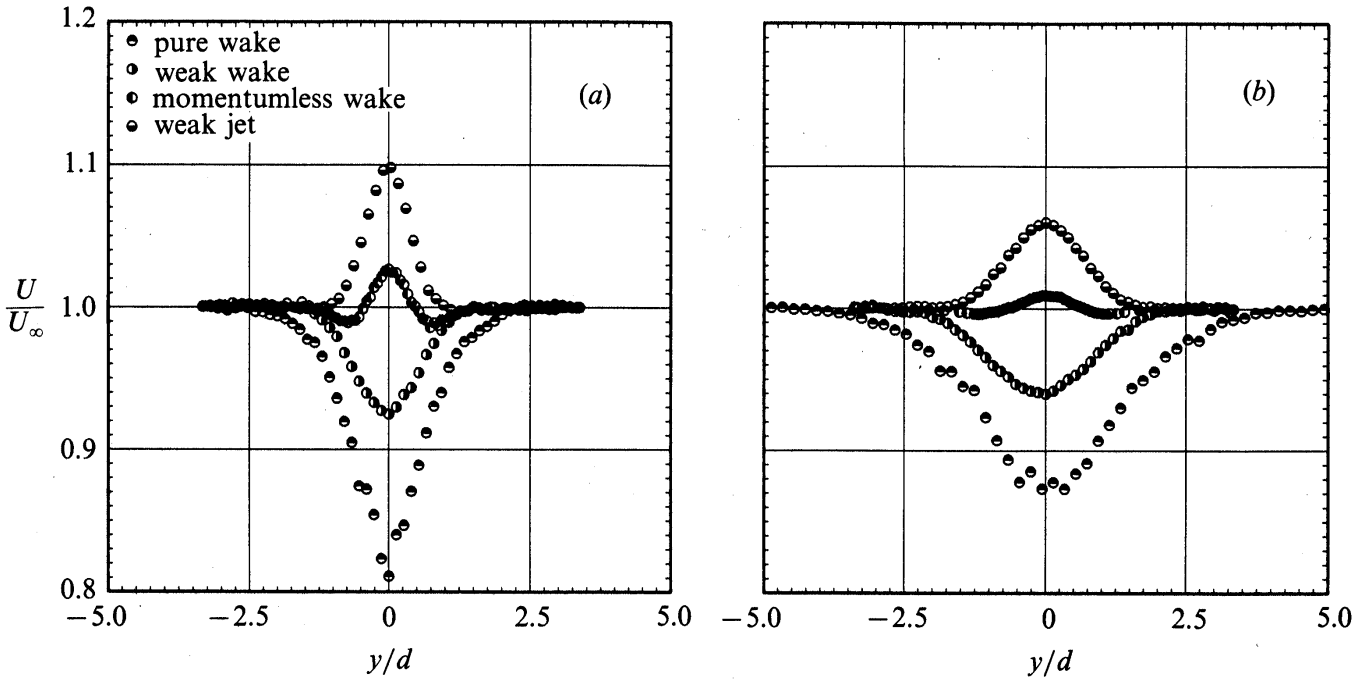


FIGURE 6. Mean velocity profiles at $Re = 5400$, and at (a) $x/d = 15$ and (b) 45.

All figures from: Cimbala, J. M. and W. J. Park. 1990. An Experimental Investigation of the Turbulent Structure in a Two-Dimensional Momentumless Wake. *Journal of Fluid Mechanics,* Vol. 213, pp. 479-509.

- In Figure 2, the smoke-wire was placed just downstream of the body. All four cases are shown. The pure wake reveals strong Kármán vortices, but the other three cases are hard to distinguish in this view.

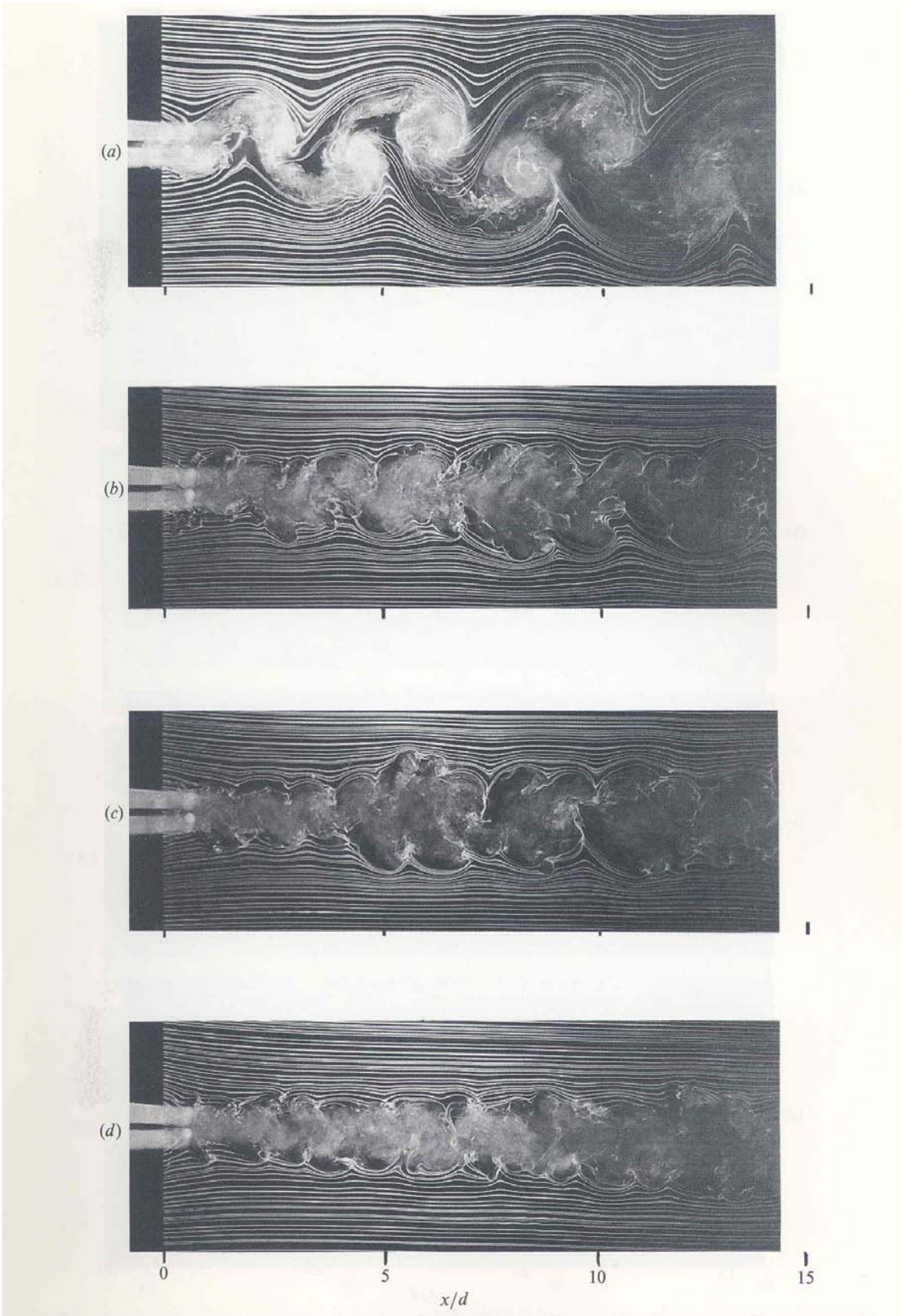


FIGURE 2. Flow visualization at $Re = 5400$, smoke-wire at $x/d = 0$: (a) a pure wake, (b) a weak wake, (c) a momentumless wake, (d) a weak jet.

- In Figure 3, the smoke-wire was placed 15 diameters downstream of the body. All four cases are shown. The large-scale turbulent eddies of the momentumless wake case are less organized compared to the other cases.

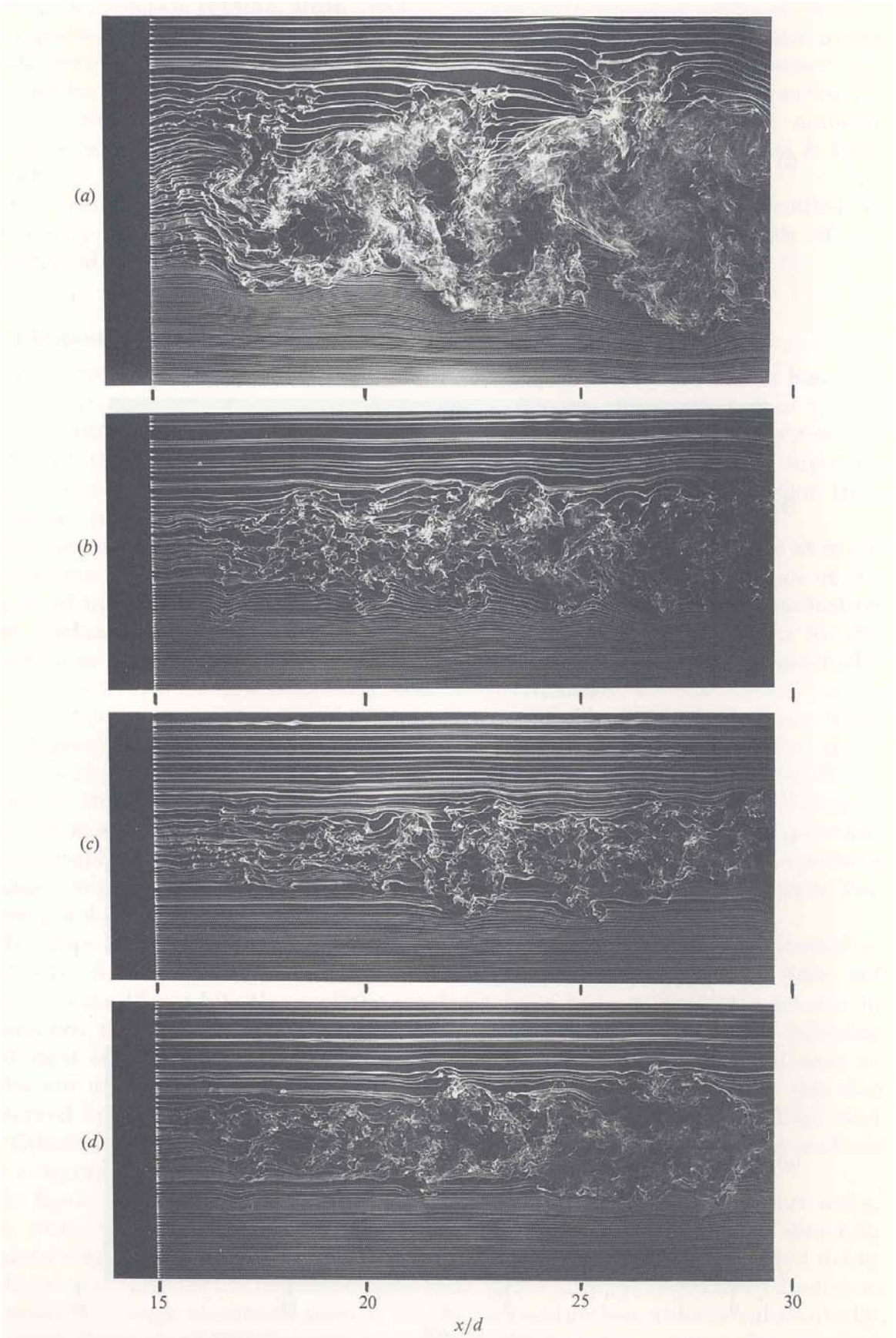


FIGURE 3. Flow visualization at $Re = 5400$, smoke-wire at $x/d = 15$: (*a*) a pure wake, (*b*) a weak wake, (*c*) a momentumless wake, (*d*) a weak jet.

- In Figure 4, the smoke-wire was placed 45 diameters downstream of the body. All four cases are again shown – the momentumless case shows that the turbulence has nearly died out.

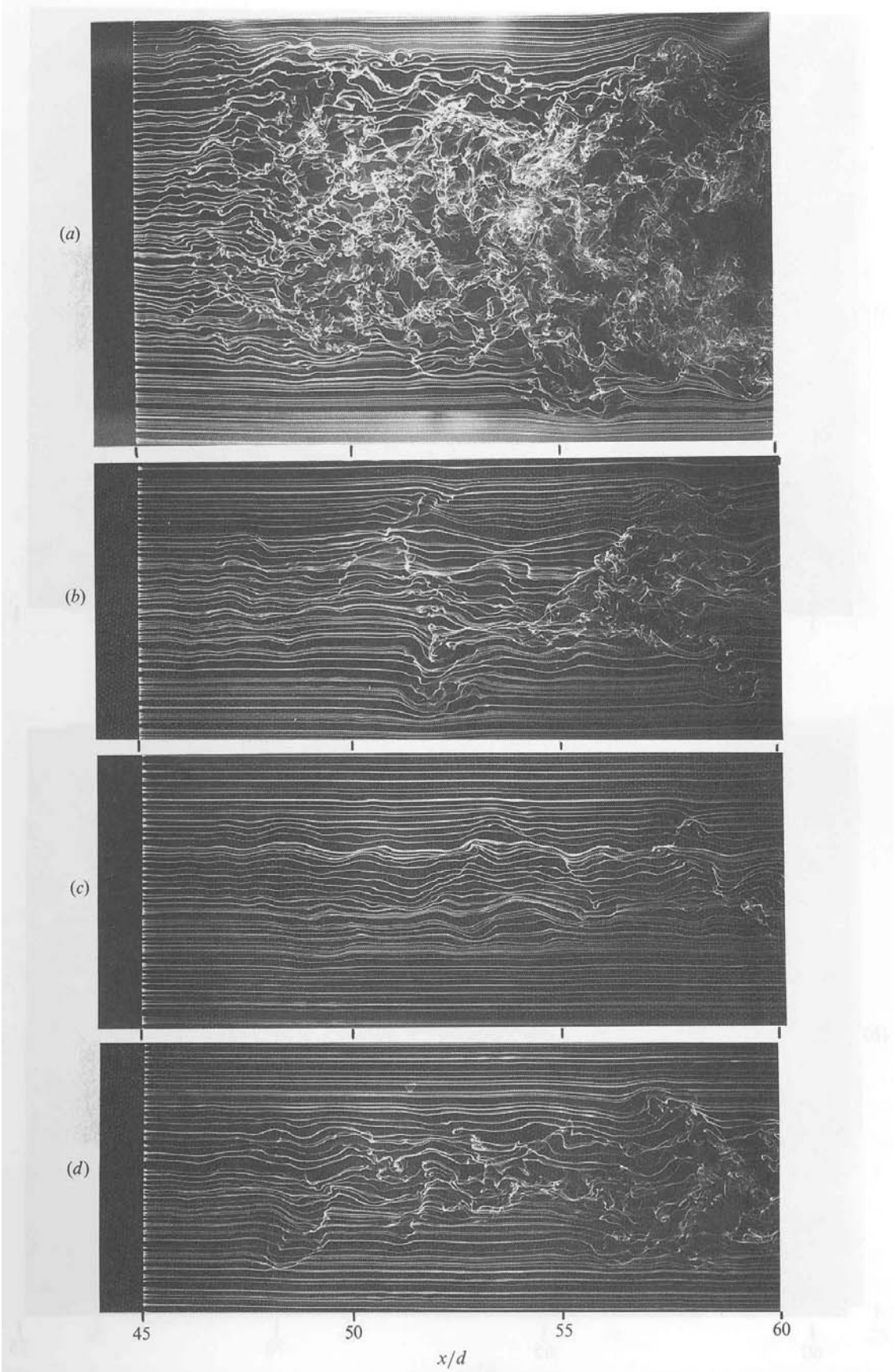


FIGURE 4. Flow visualization at $Re = 5400$, smoke-wire at $x/d = 45$: (*a*) a pure wake, (*b*) a weak wake, (*c*) a momentumless wake, (*d*) a weak jet.

- In Figure 5, the smoke-wire was placed 60 diameters downstream of the body. Only the pure wake and the momentumless wake cases are shown. The momentumless wake has nearly disappeared – the velocity profile is nearly uniform and the turbulence has all but completely decayed.

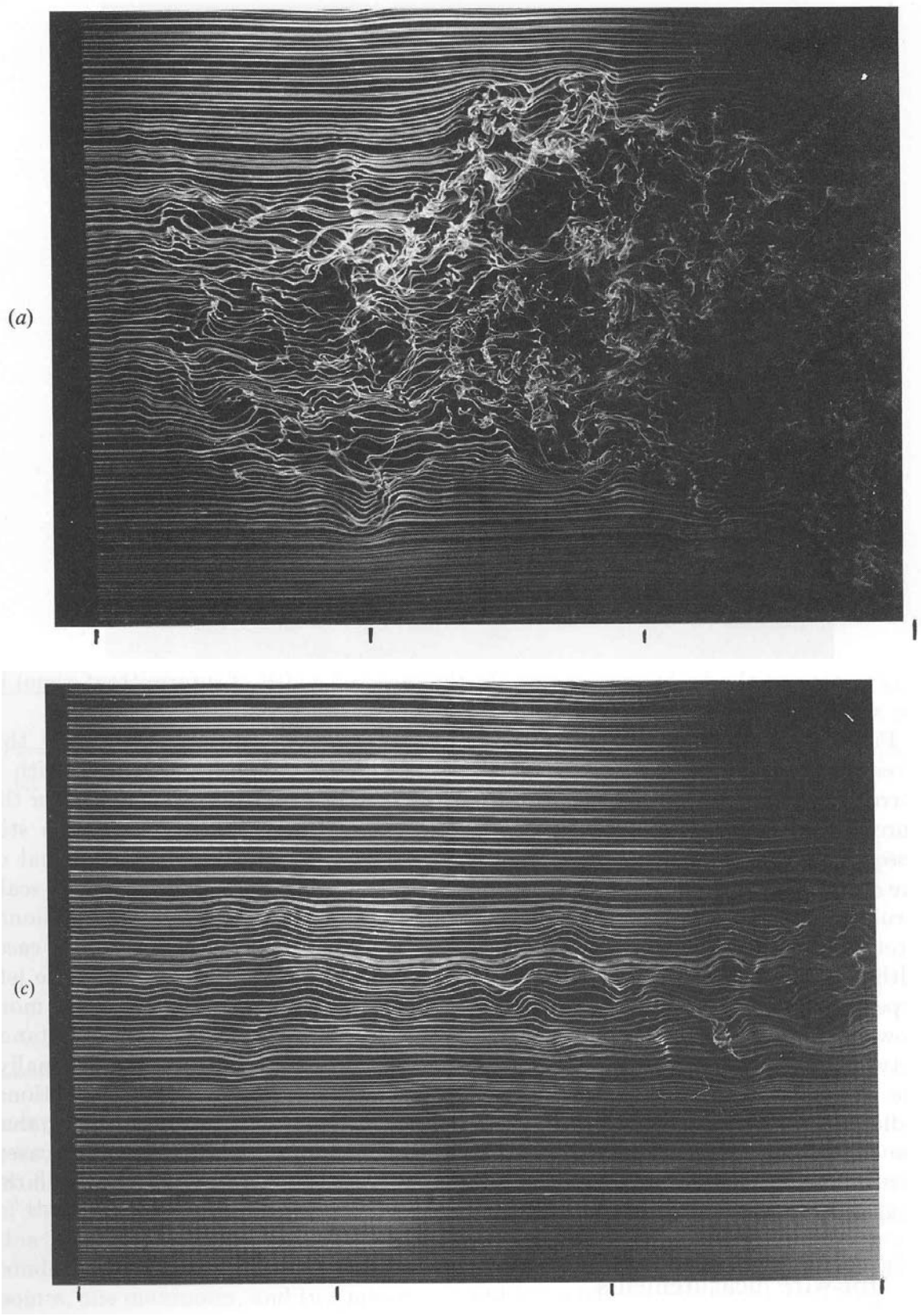


FIGURE 5. Flow visualization at $Re = 5400$, smoke-wire at $x/d = 60$: (a) a pure wake, (b) a weak wake, (c) a momentumless wake, (d) a weak jet.