

**Von Karman Institute for Fluid Dynamics
Chaussée de Waterloo, 72
B - 1640 Rhode Saint Genèse - Belgium**

VKI Lecture Series

**"Measurement Techniques in Fluid Dynamics
an Introduction"**

FLOW VISUALIZATIONS

Compiled by

M. Carbonaro

© 1994 by the von Karman Institute

The pictures in the pages that follow are examples of selected Flow Visualization Techniques, all applied (with one exception) at the von Karman Institute, by members of the Faculty, PhD researchers, Diploma Course members, and members of the Short Training Program. With the exception mentioned, they can be freely used and diffused, provided they are kept unmodified in the original form, that the VKI origin is duly acknowledged, and that these two conditions are imposed to any further recipient of the material.

The techniques are illustrated in the following order:

On a solid surface (limiting streamlines or skin friction lines):

- Oil flow
- Sublimation
- Sand erosion
- Wall tufts
- Oil dots
- Oil streaks
- Wall dye streaks

On a free surface (water table):

- Surface bubbles
- Hydraulic analogy (surface waves)
- Hydraulic analogy (Water colors)

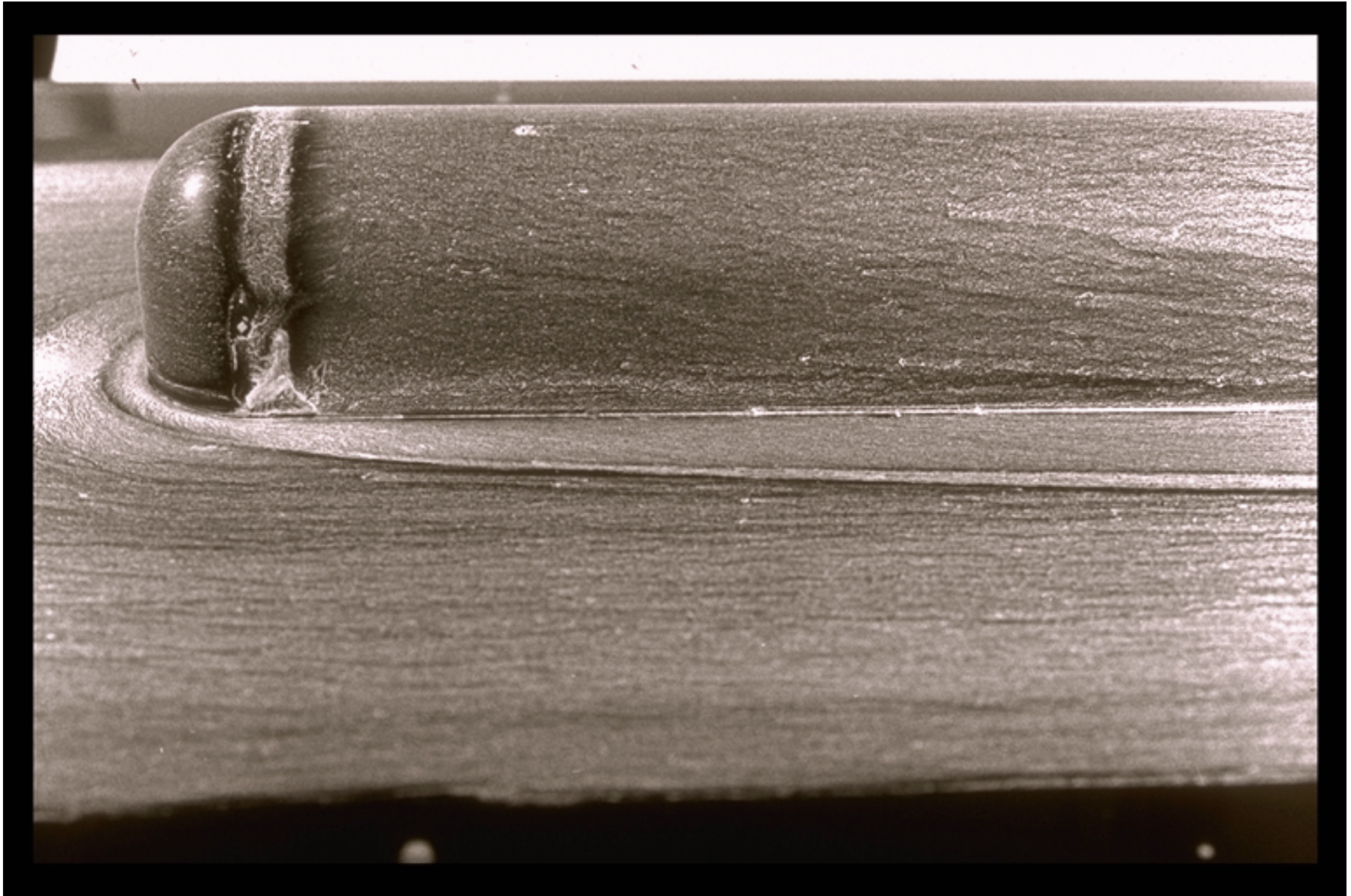
In a 3D space:

- Tufts in air (grid, pole)
- Smoke in air
- Colored smoke (smoke wire)
- Laser sheet & smoke
- Dye in water: color streaks, or all water
- Hydrogen bubbles

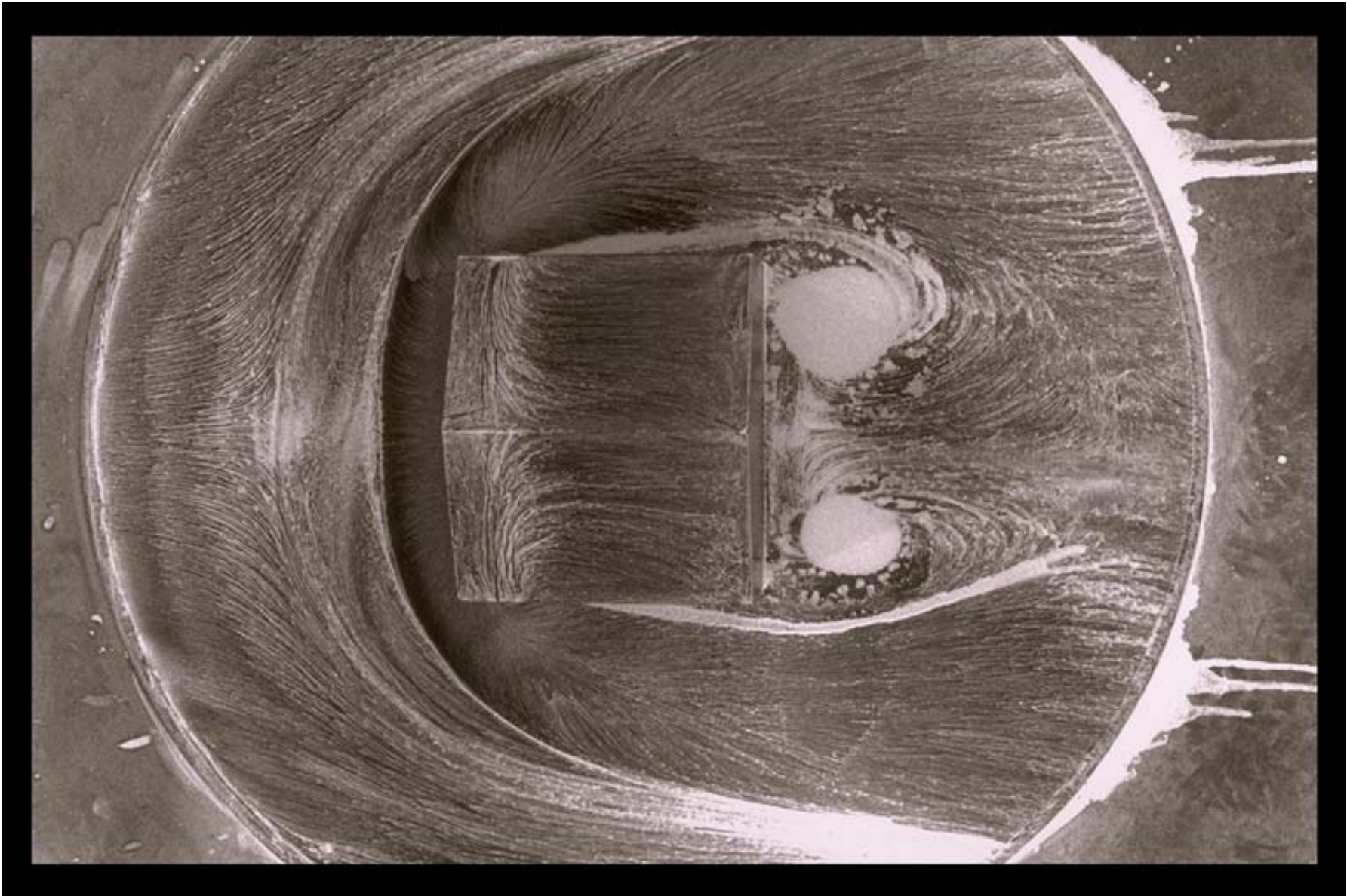
Of potential flow (Hele-Shaw analogy)



Oil flow visualization.
Airflow around a bluff protuberance mounted on a flat plate.
(top view, flow from left)



Oil flow visualization.
Airflow around a bluff protuberance mounted on a flat plate.
(side view, airflow from left)

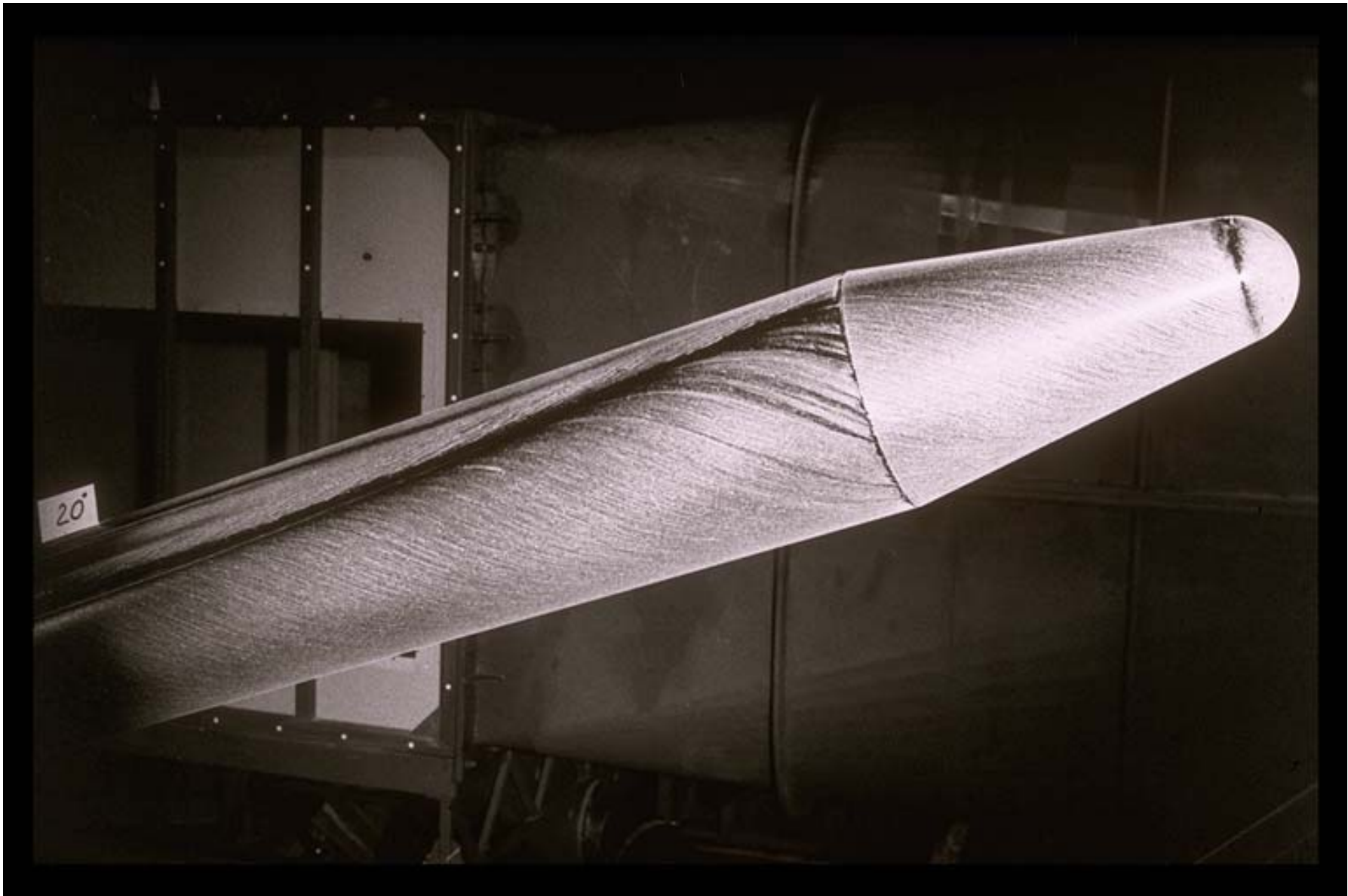


Oil flow visualization of flow around a house.
Top view, airflow from left.



Oil flow visualization.

Airflow on end wall of a turbine blade cascade.



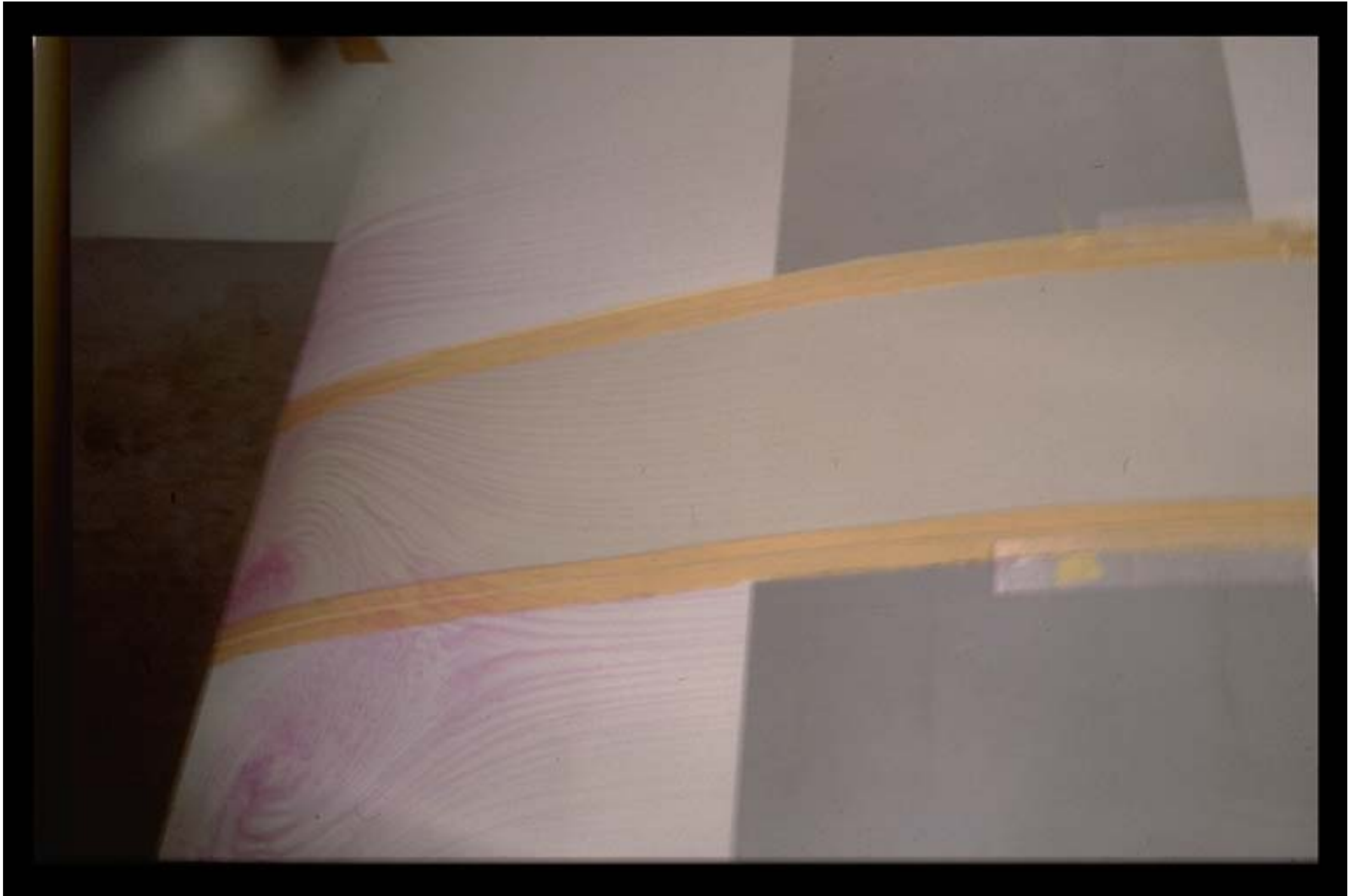
Oil flow visualization.
Airflow around a missile body at incidence.



Oil flow visualization.

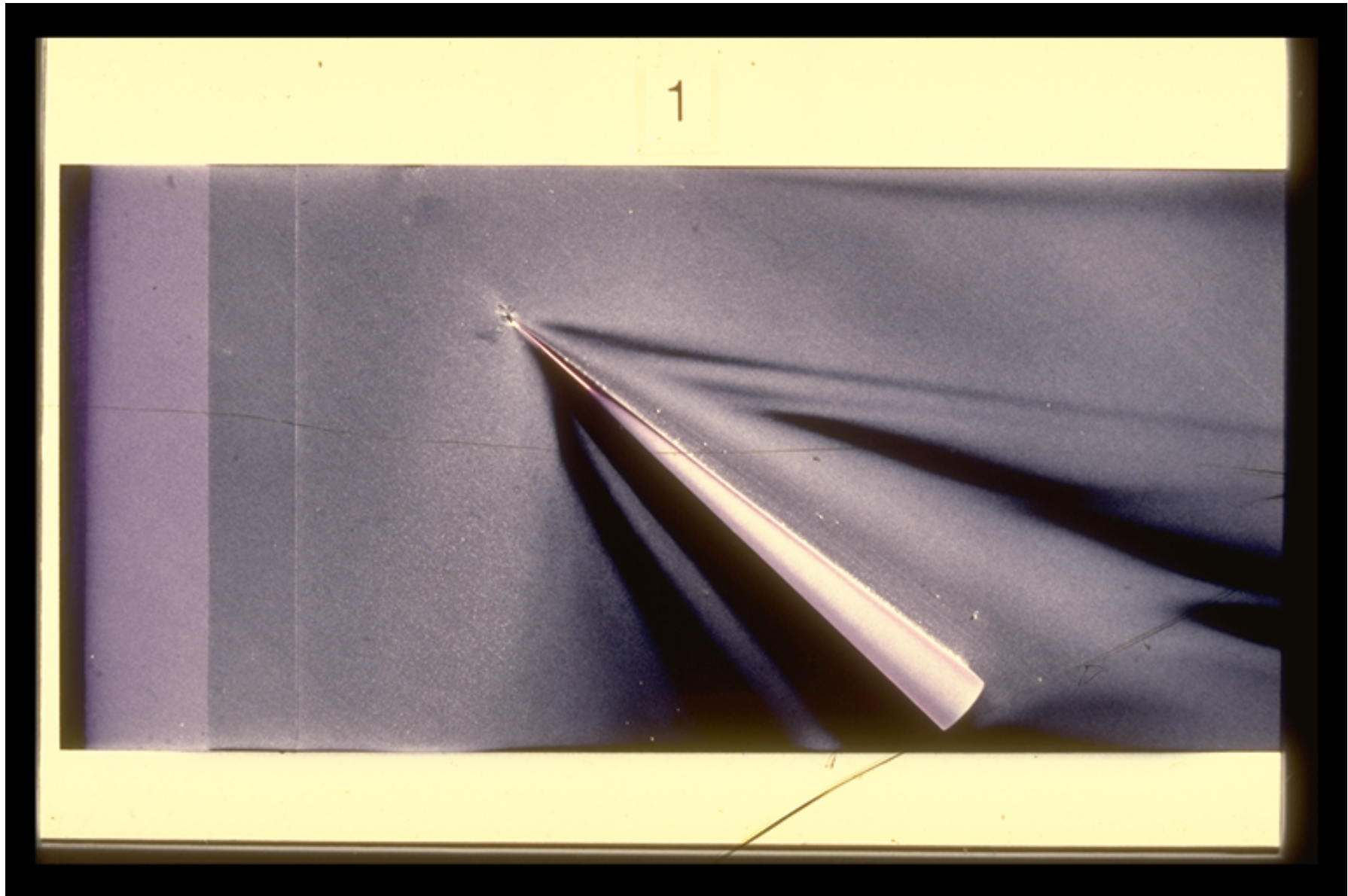
Airflow around a missile body at incidence.

Detail of flow near hemispherical front part of missile.

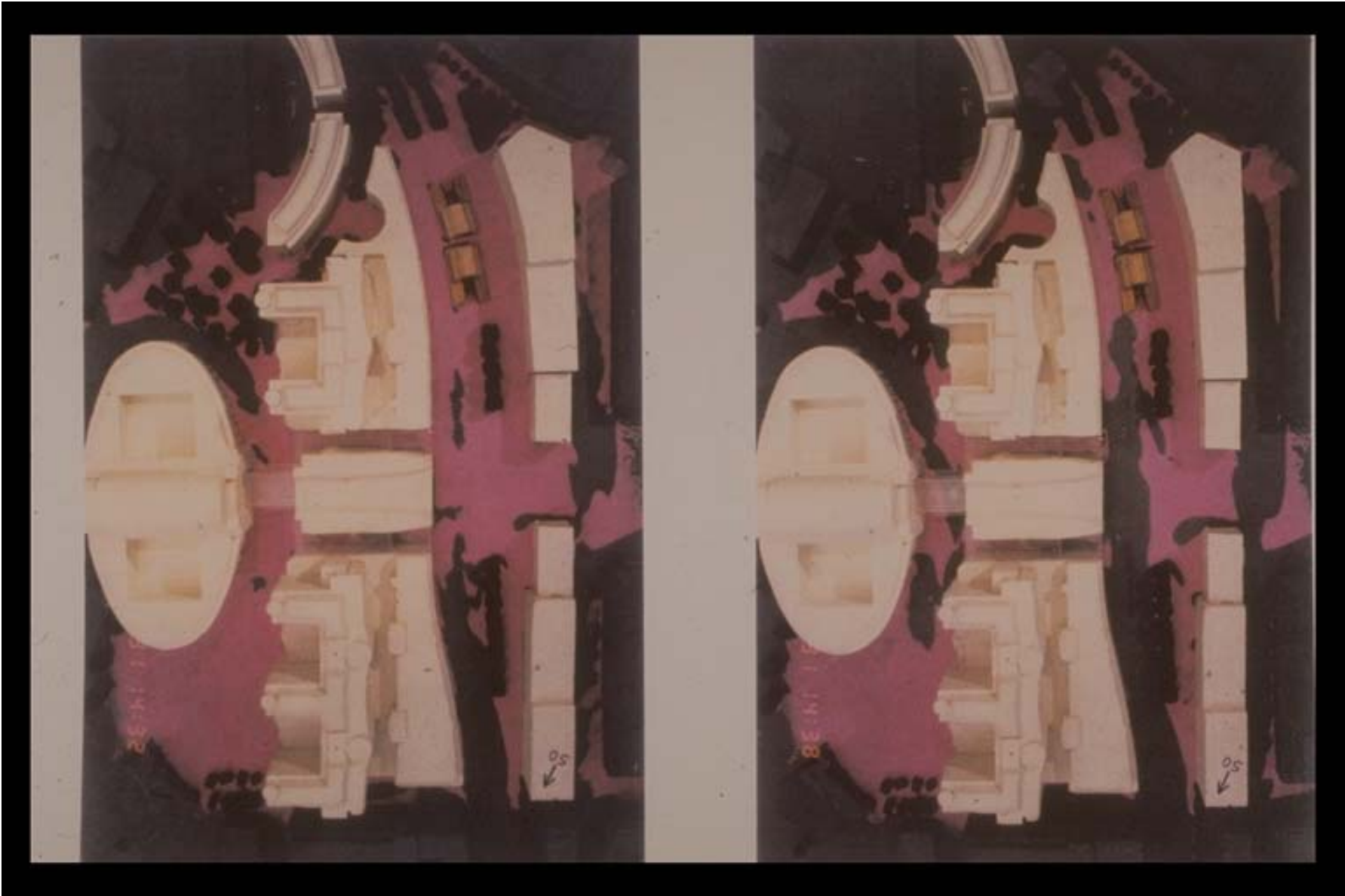


Surface flow visualization.

Incipient wing stall, showing saddle point and two focal points of vortical separation.



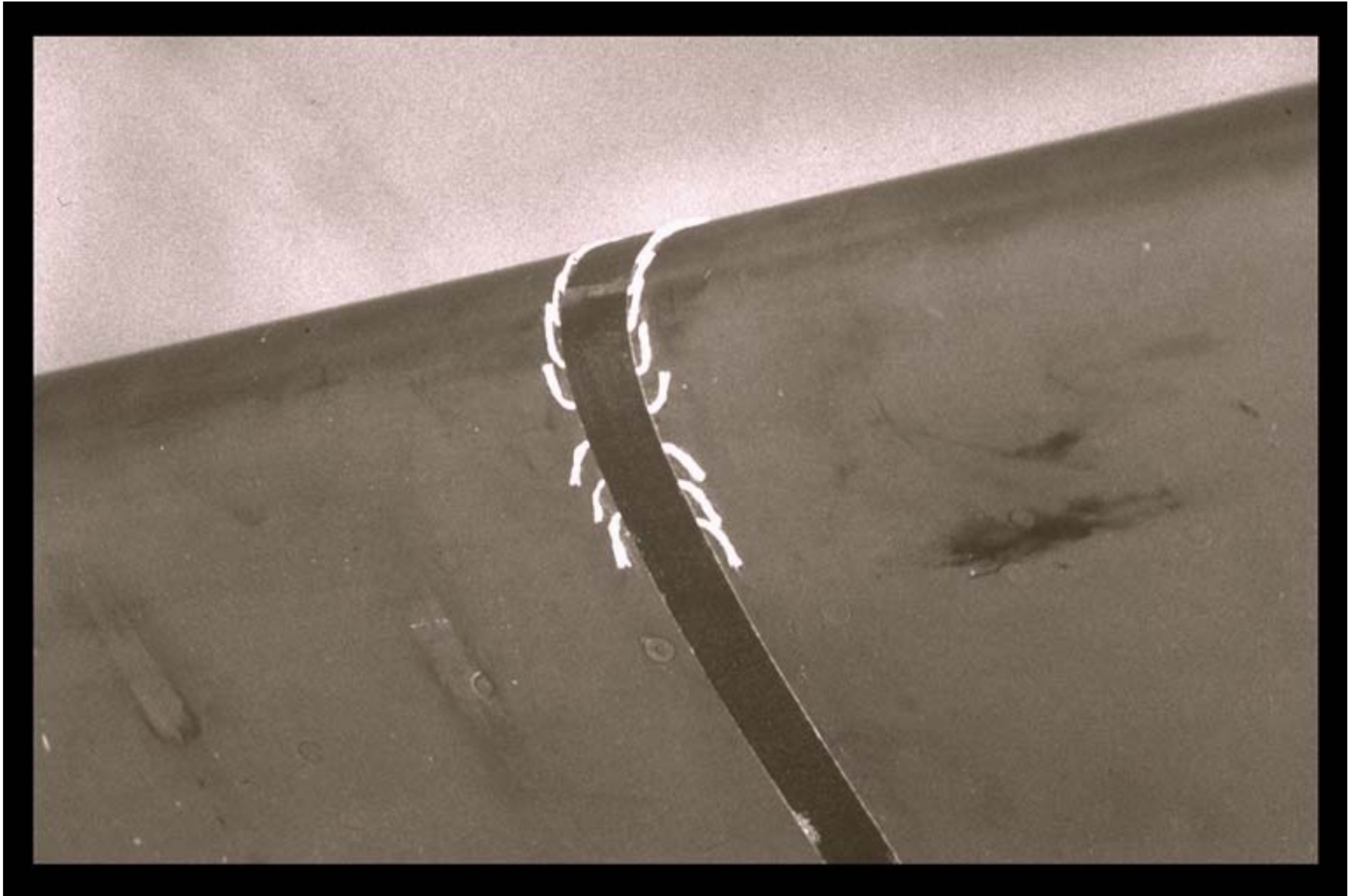
Sublimation technique in Mach 6 hypersonic tunnel.
Triangular fin mounted on a flat plate. Flow from left.



Sand erosion technique. Low speed visualization of urban microclimate patterns.

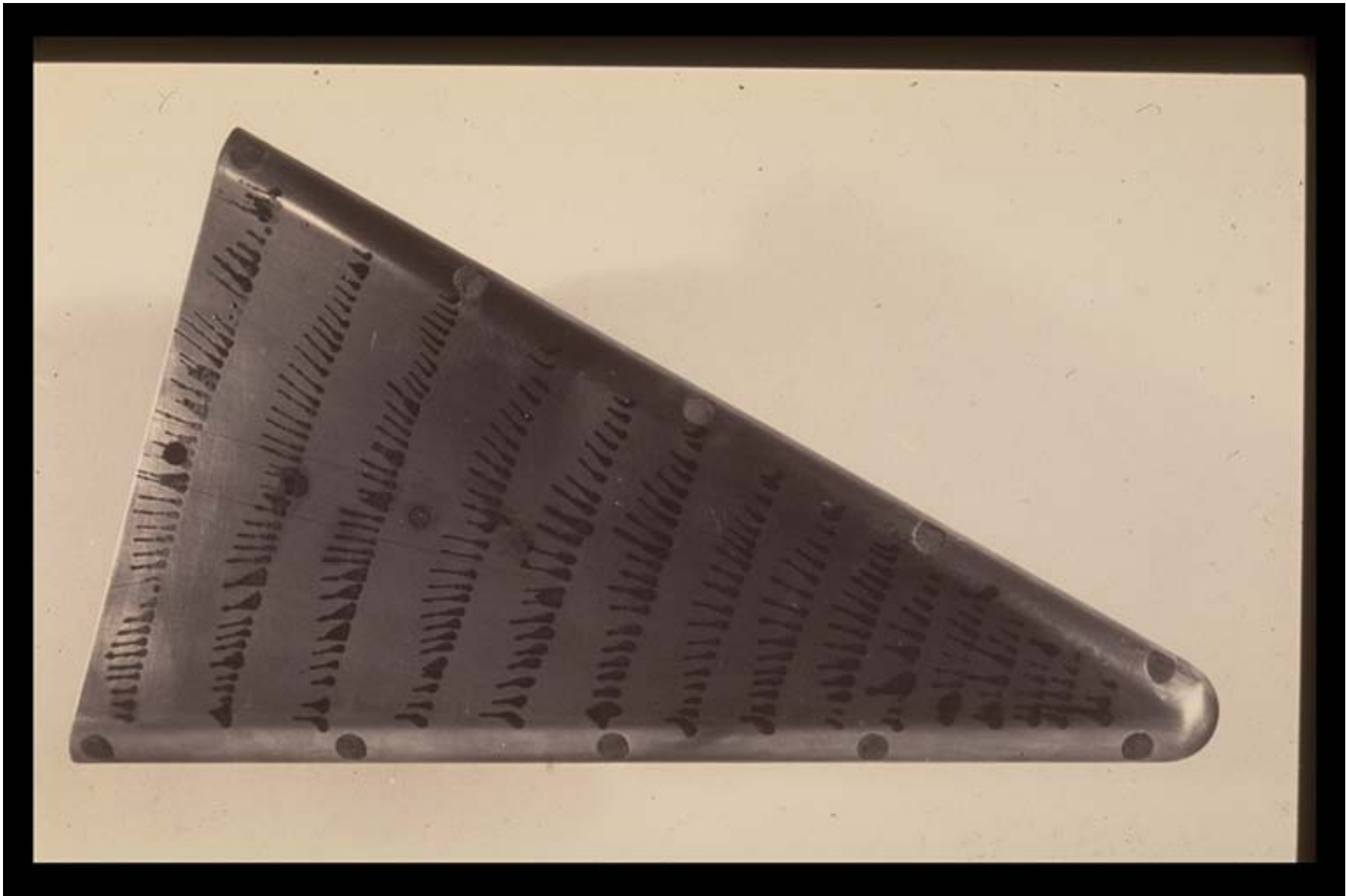


Wall tufts technique.
Surface flow on a turboprop aircraft engine pod.

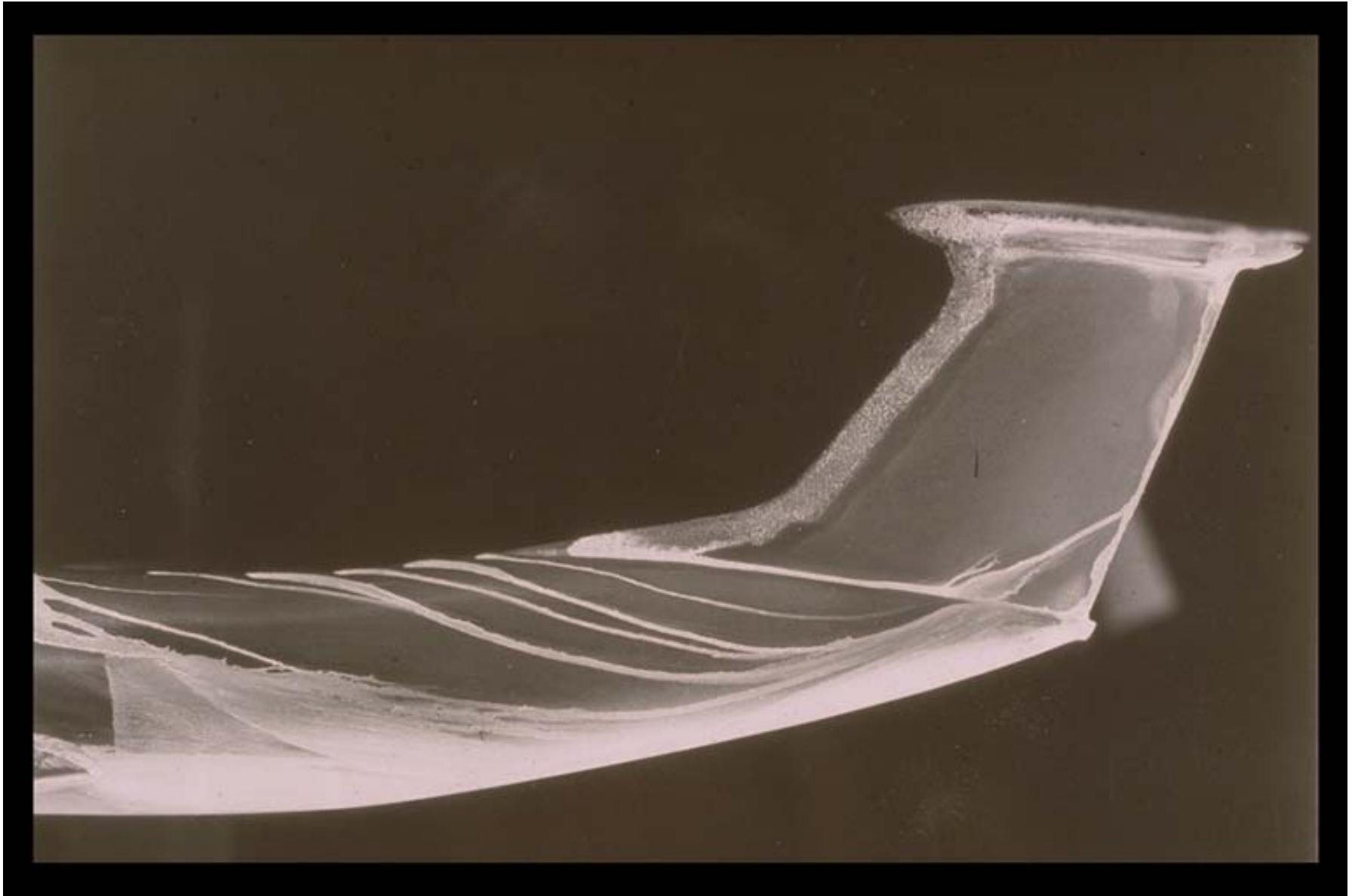


Wall tufts technique.

Determination of stagnation point position at leading edge of an aircraft wing.



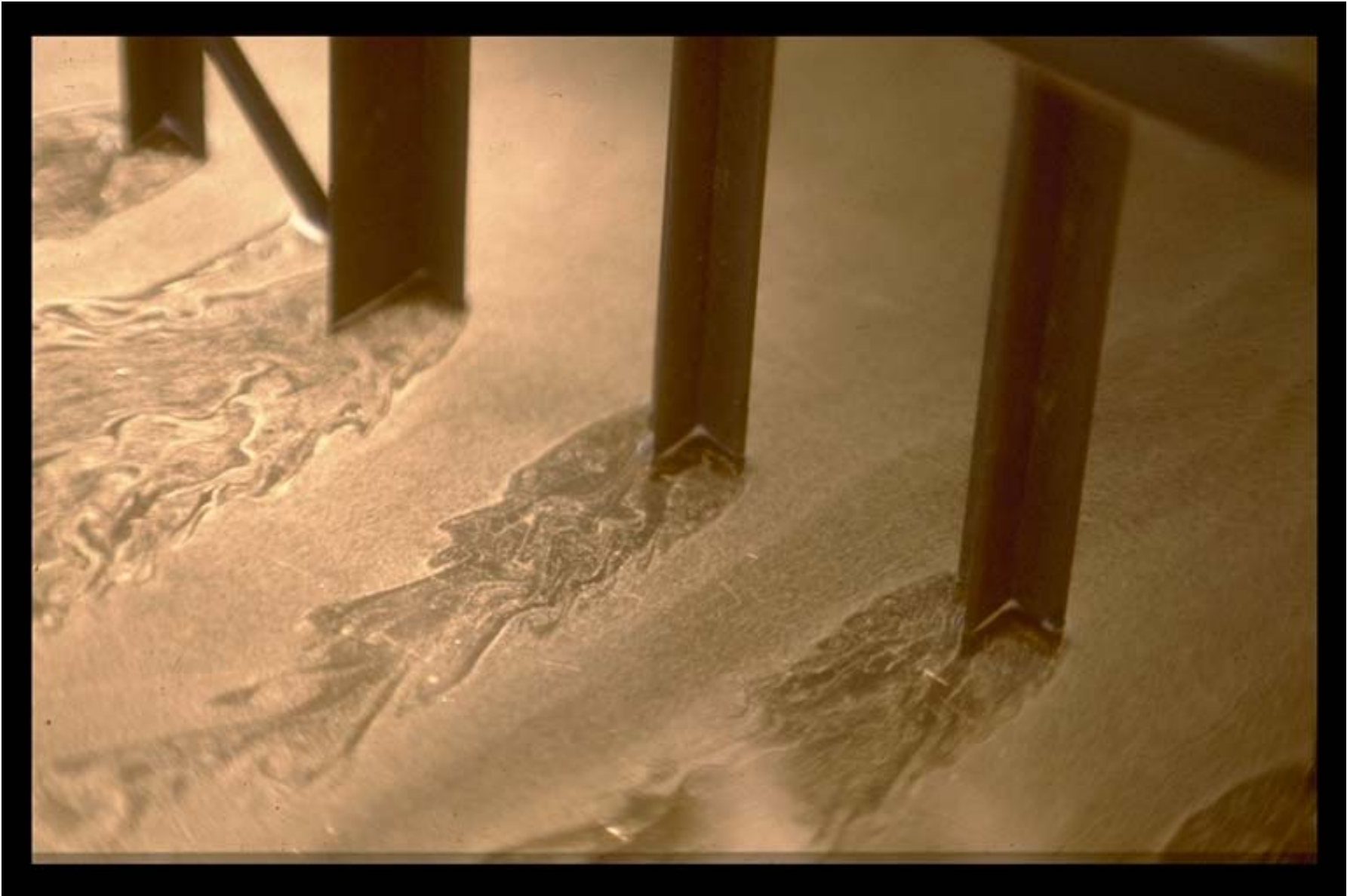
Oil dots technique. Hypersonic tunnel, Mach 15.
Visualization of velocity direction and magnitude on hypersonic delta wing.



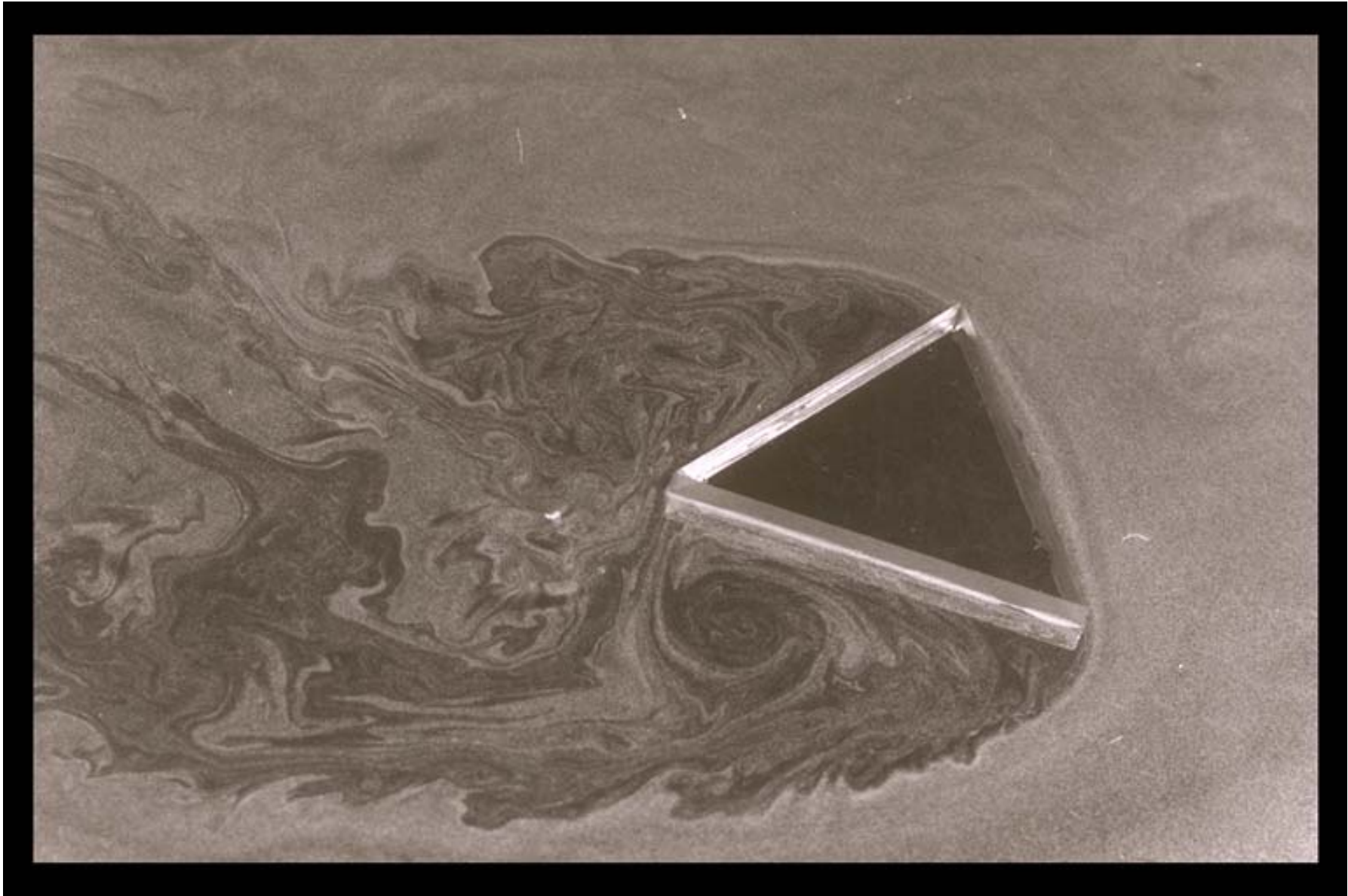
Oil streaks technique.
Visualization of streamlines on the upswept afterbody of a transport aircraft.



Water tunnel flow visualization by wall dye streaks.
Triangular fin mounted on a flat plate. Flow from left.

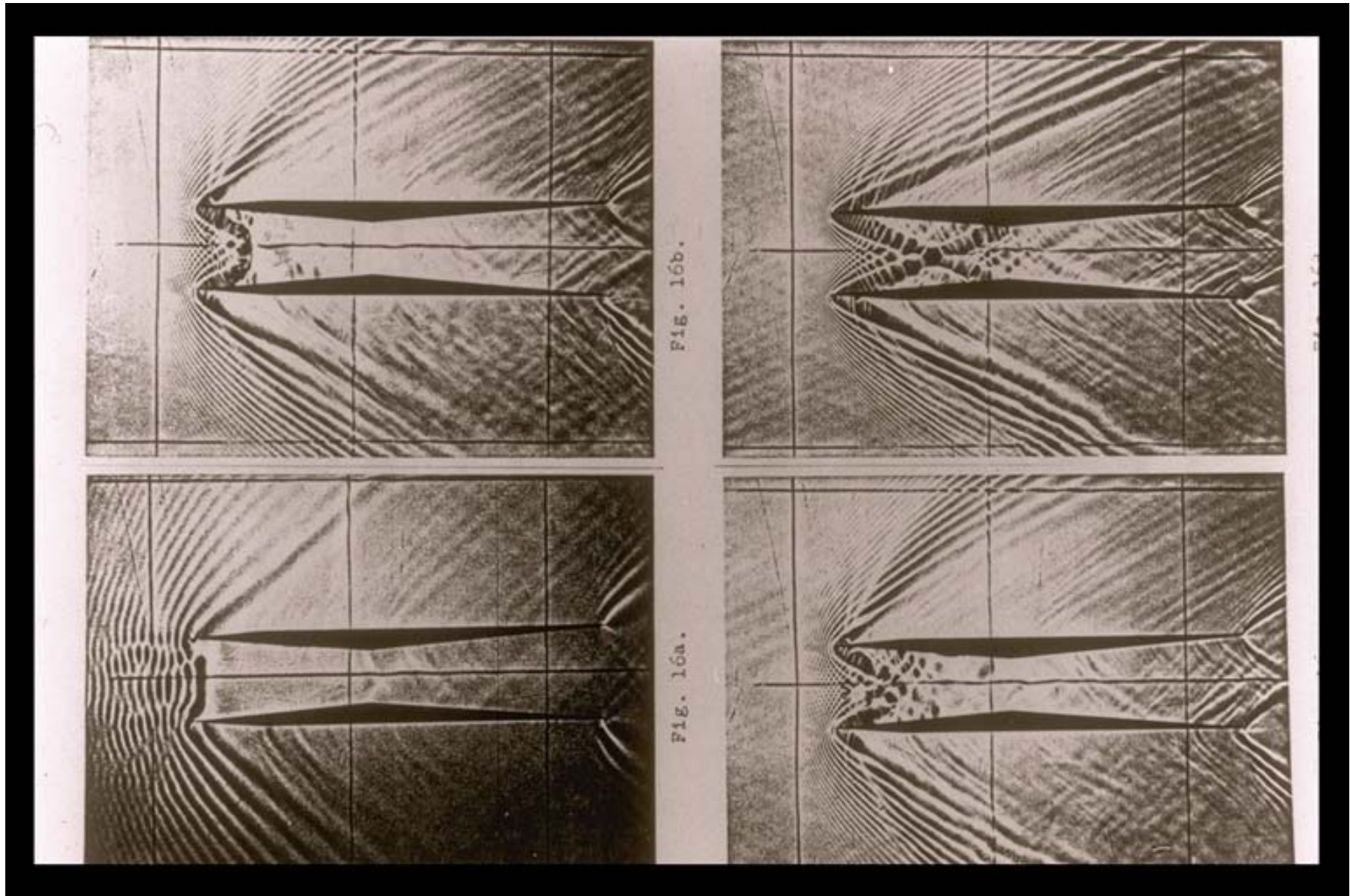


Surface bubbles flow visualization.
Water table, $Fr < 1$, turbulent wakes behind an array of bluff obstacles.



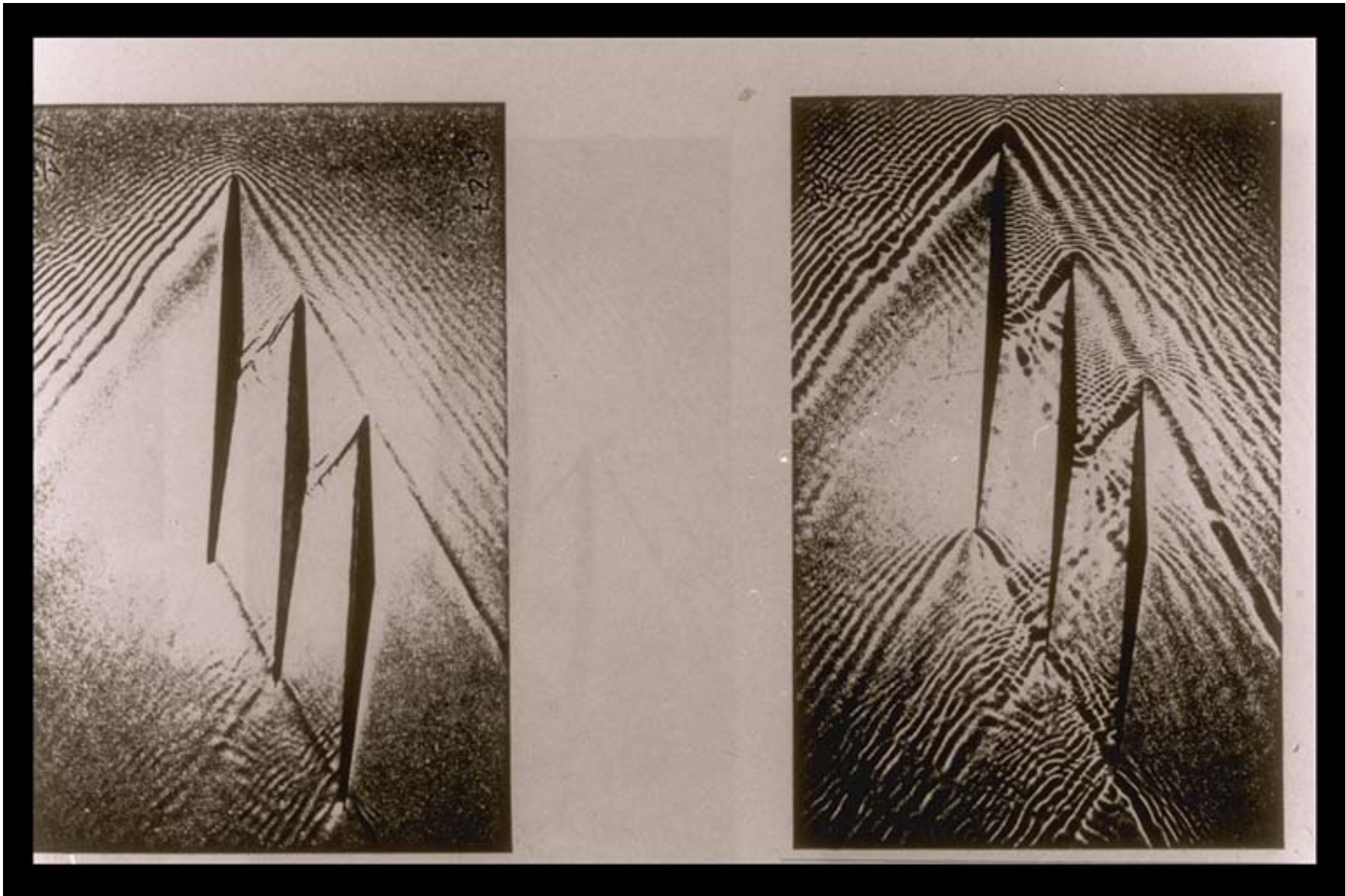
Surface bubbles flow visualization.

Water table, $Fr < 1$, separated flow and vortex formations behind bluff triangular body.



Hydraulic analogy in water table, $Fr > 1$.

Surface waves to visualize expansions and shock waves in a supersonic intake (choked or not).



Hydraulic analogy in water table, $Fr > 1$.
Expansion and shock waves in a supersonic compressor cascade.



Smoke flow visualization in air.
Reversed turbulent flow across an open door in a building.



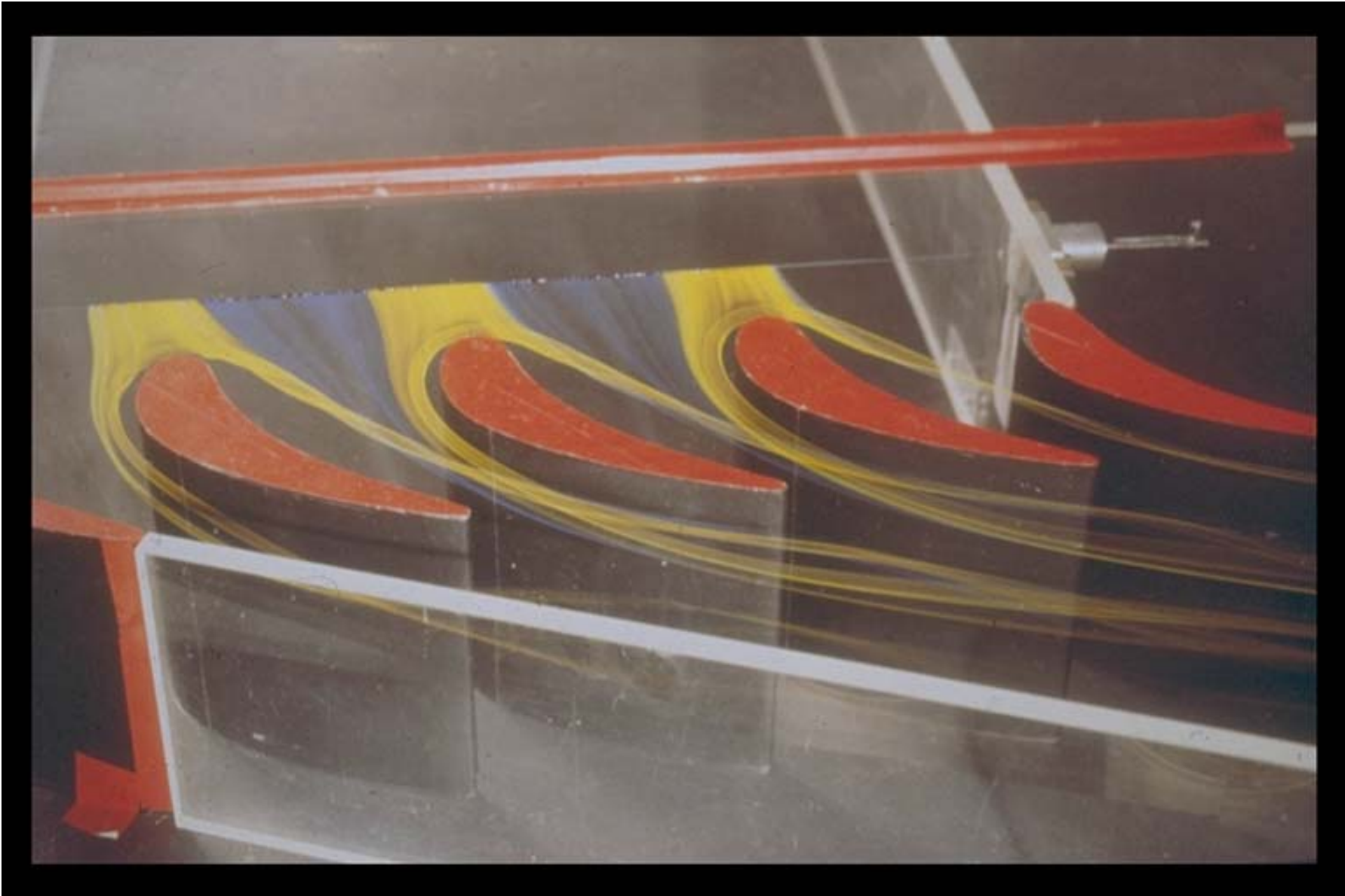
Smoke filaments flow visualization.
(copyright not belonging to VKI)



Smoke flow visualization of spoilers effectiveness in a truck to control flow separation on truck sides.



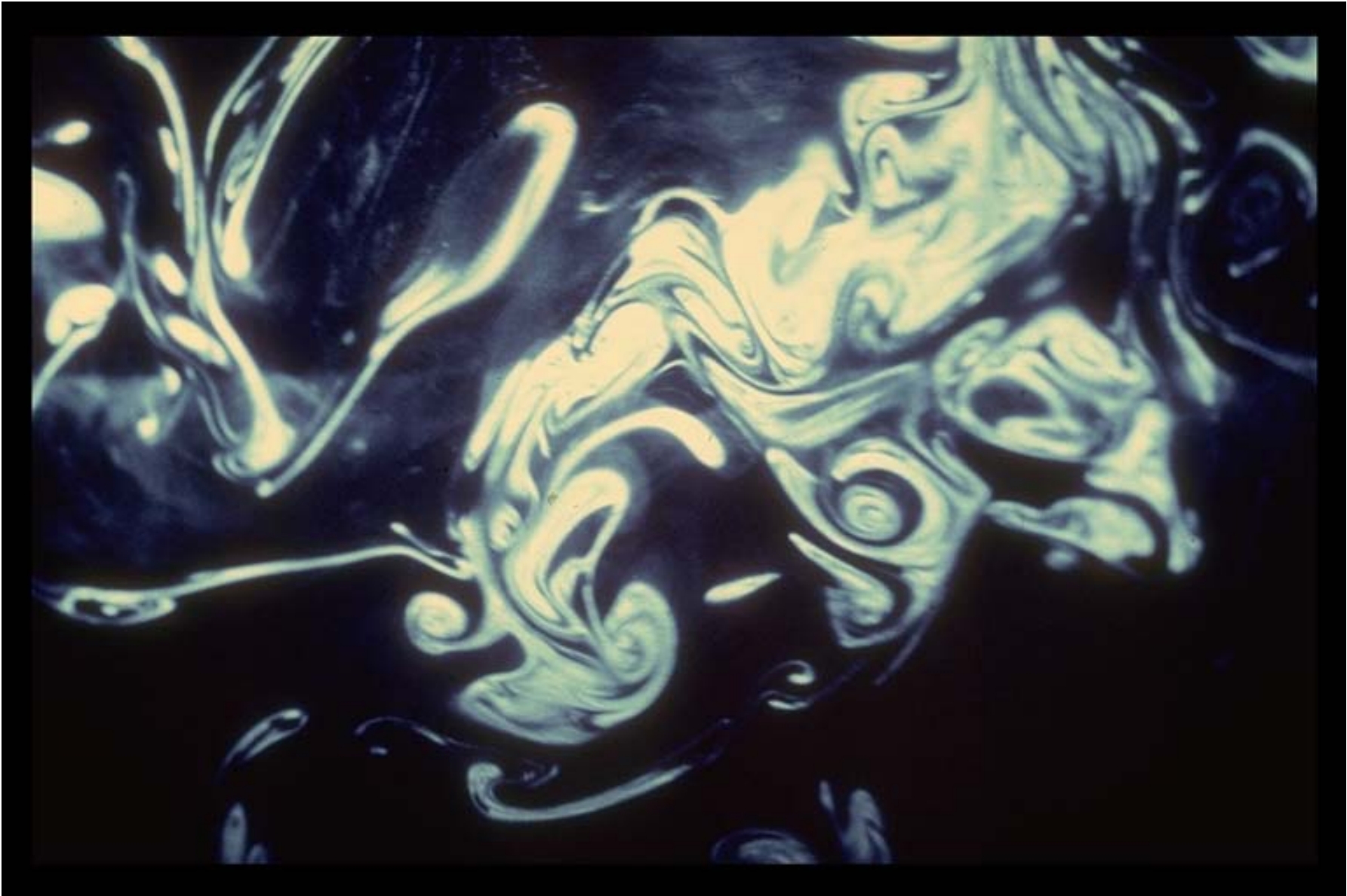
Smoke flow visualization of exhaust plume from forced draft cooling towers.



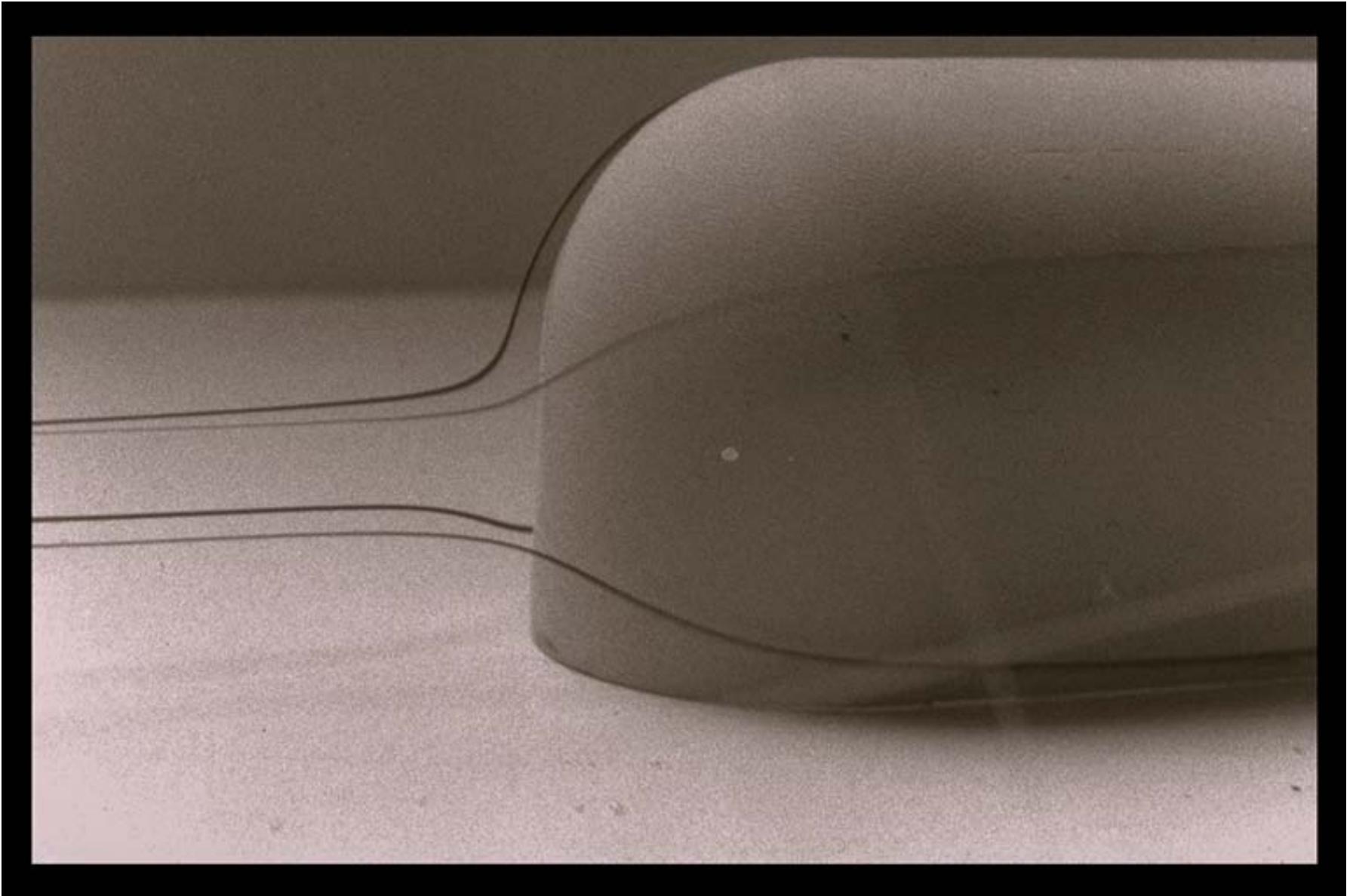
Smoke wire technique. Colored smoke to visualize horse shoe vortices on the end wall of a turbine blade cascade.



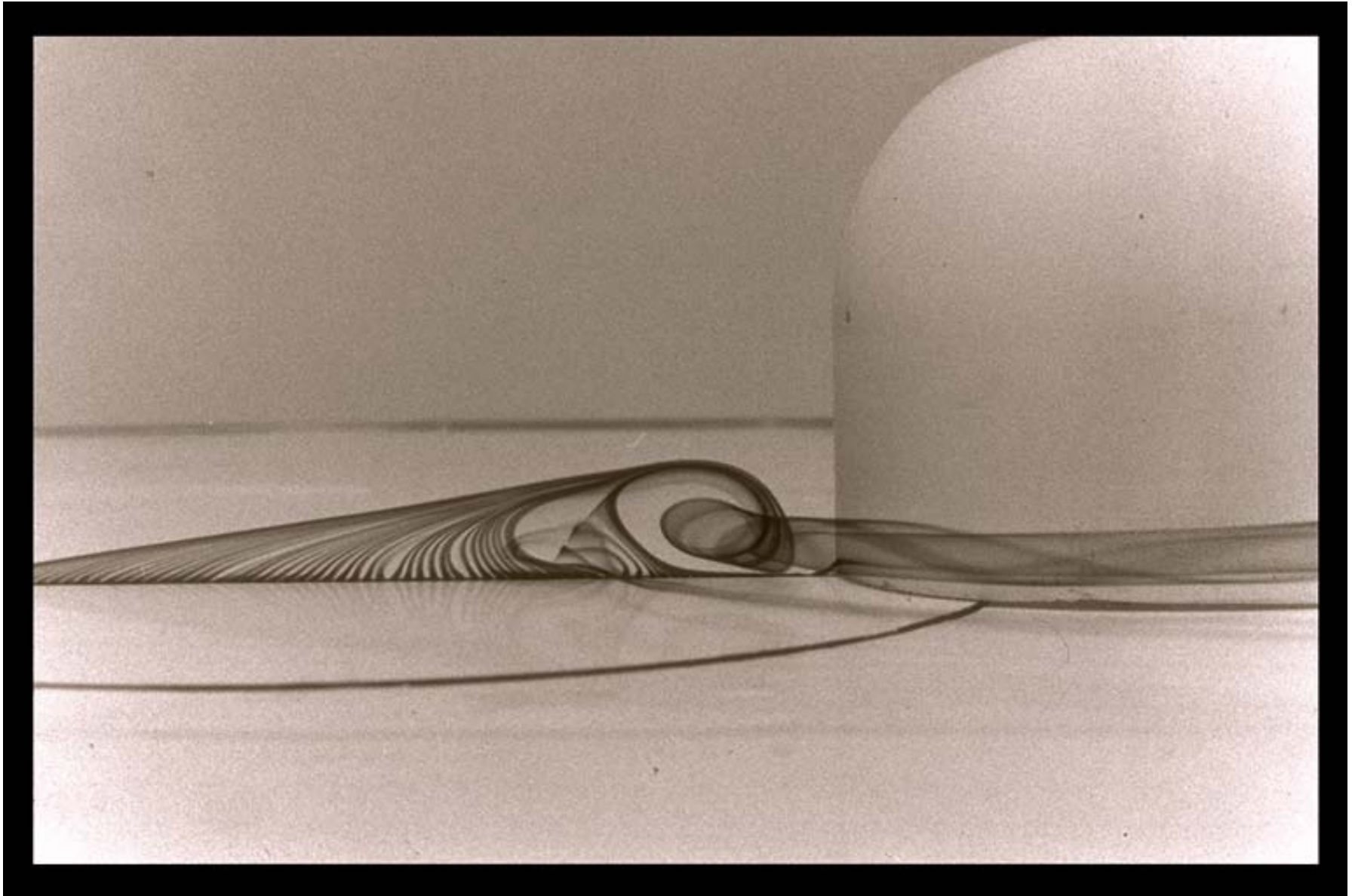
Smoke and laser sheet visualization of vortical flow on upper surface of delta wing.



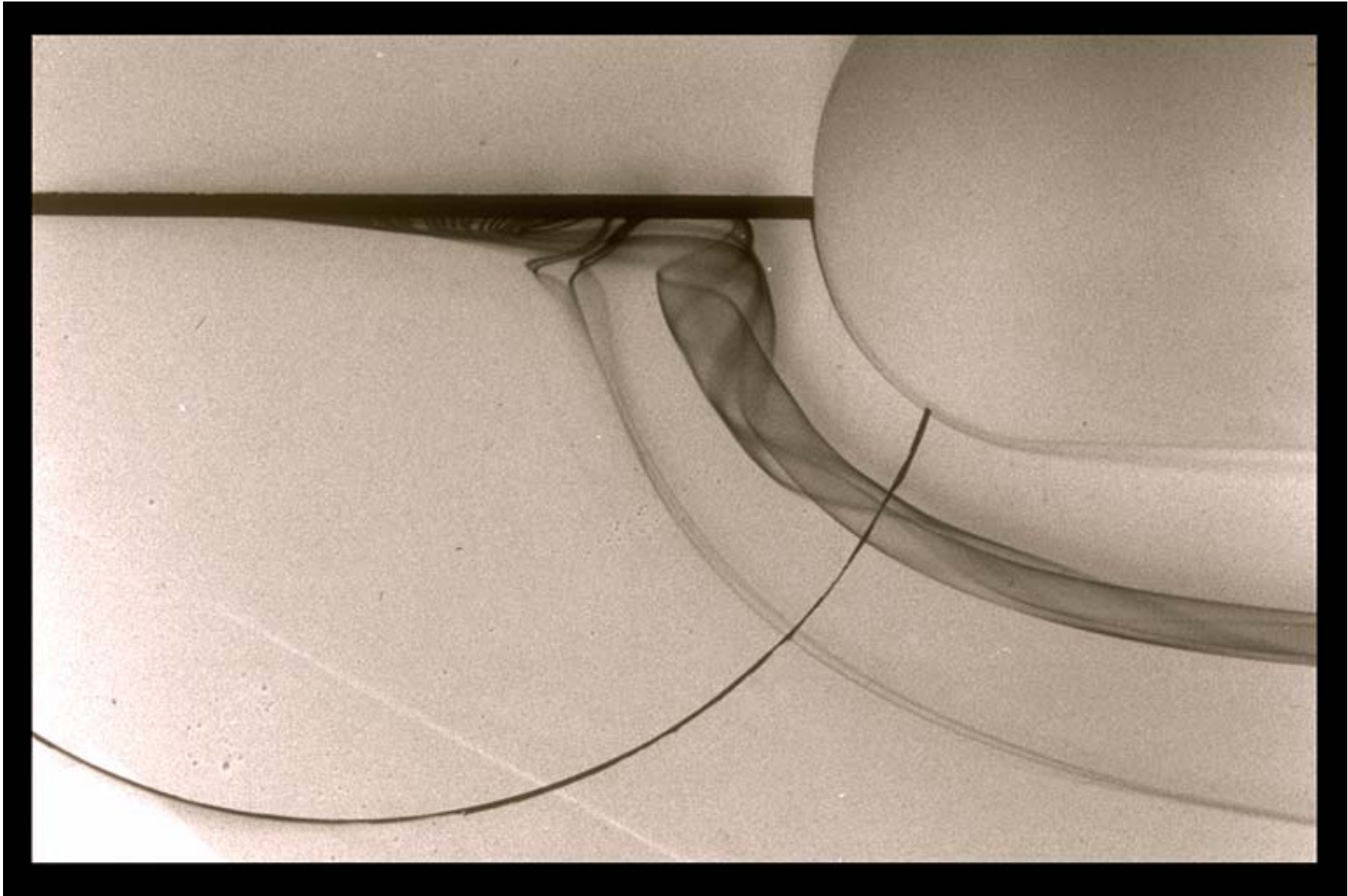
Smoke and laser sheet visualization of turbulent convection patterns.



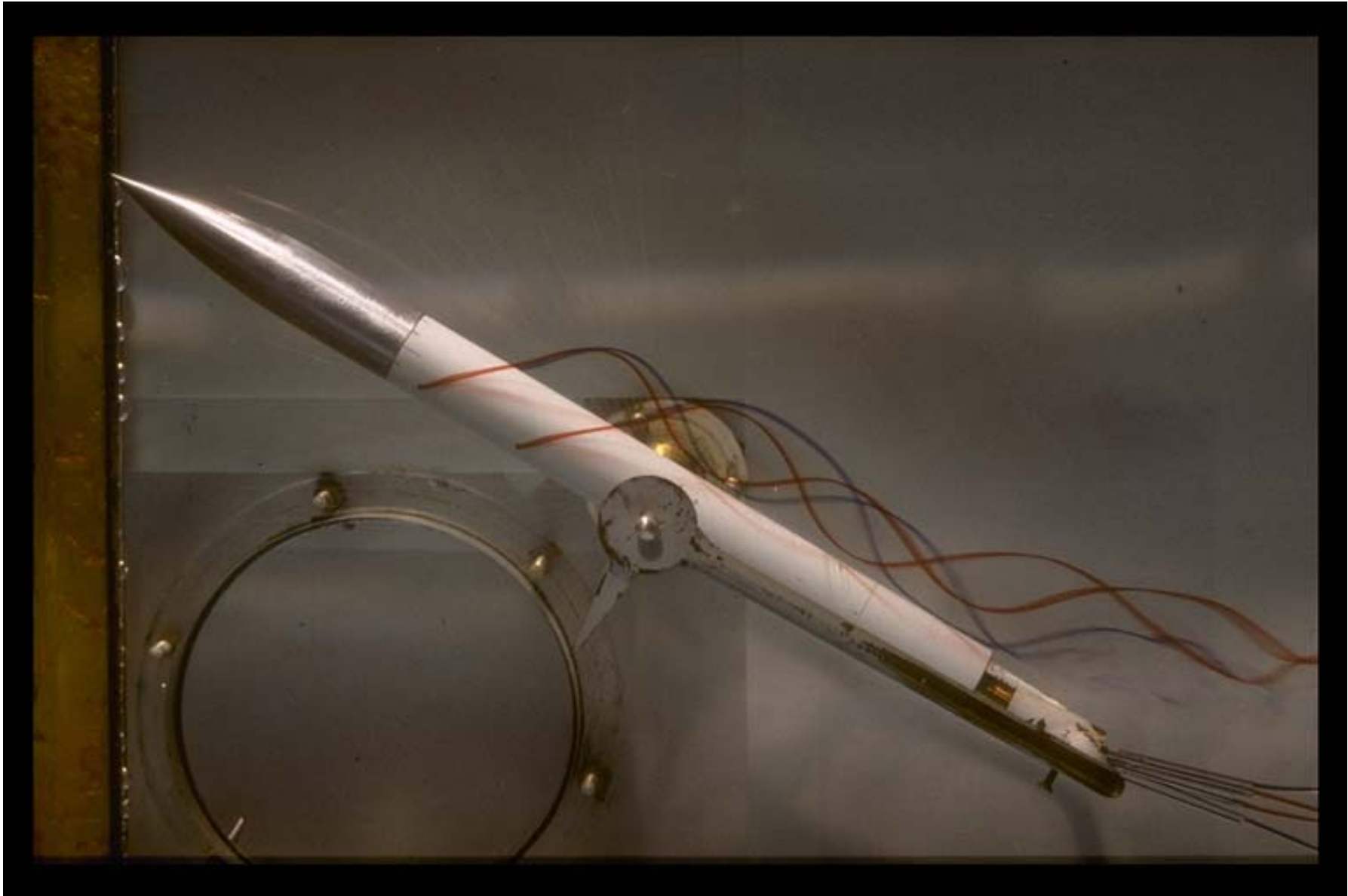
Color streaks in water, to visualize streamlines around a bluff protuberance mounted on a flat plate.



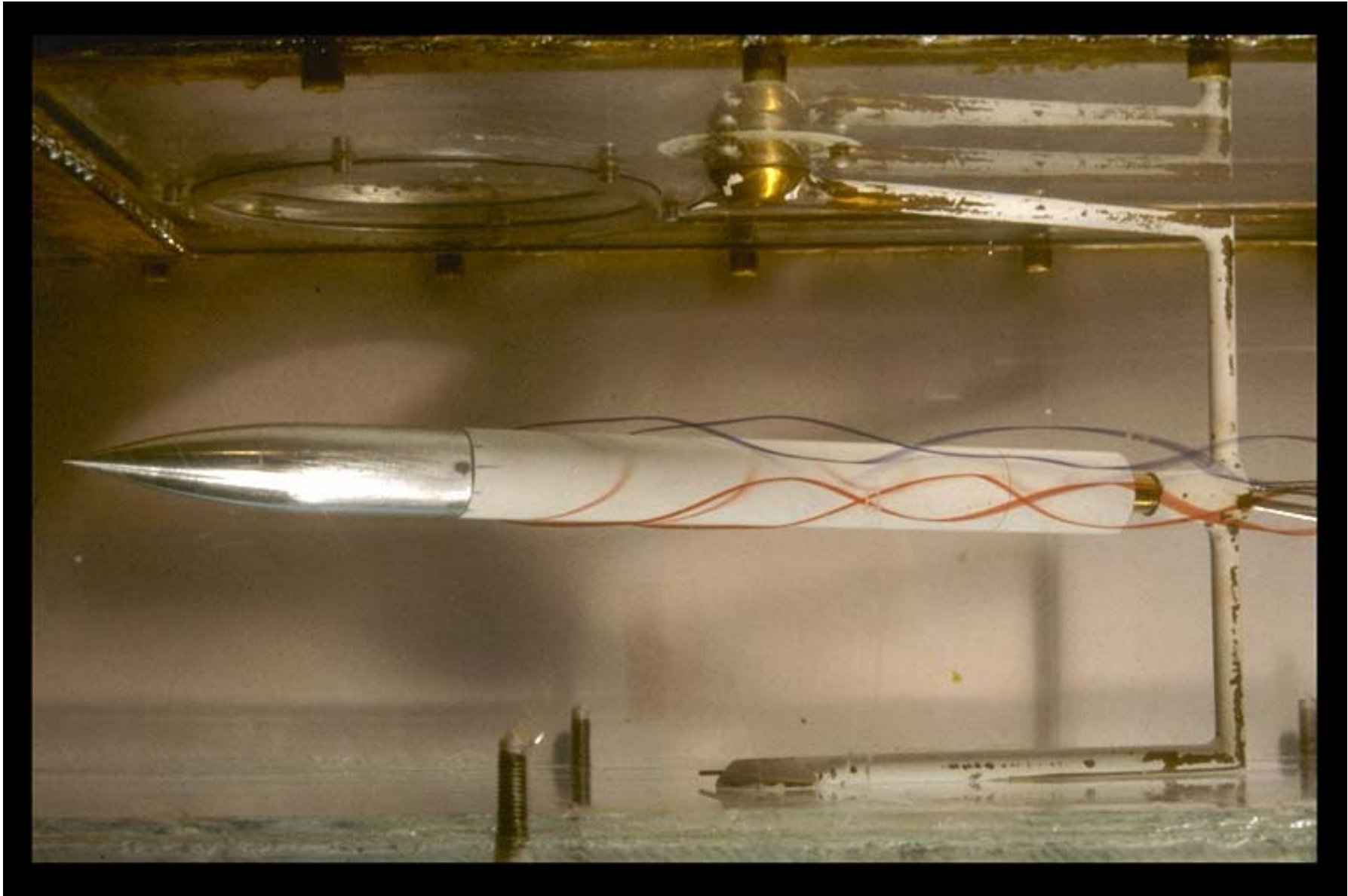
Color streaks in water, to visualize horse shoe vortex formation upstream of a bluff protuberance mounted on a flat plate (side view).



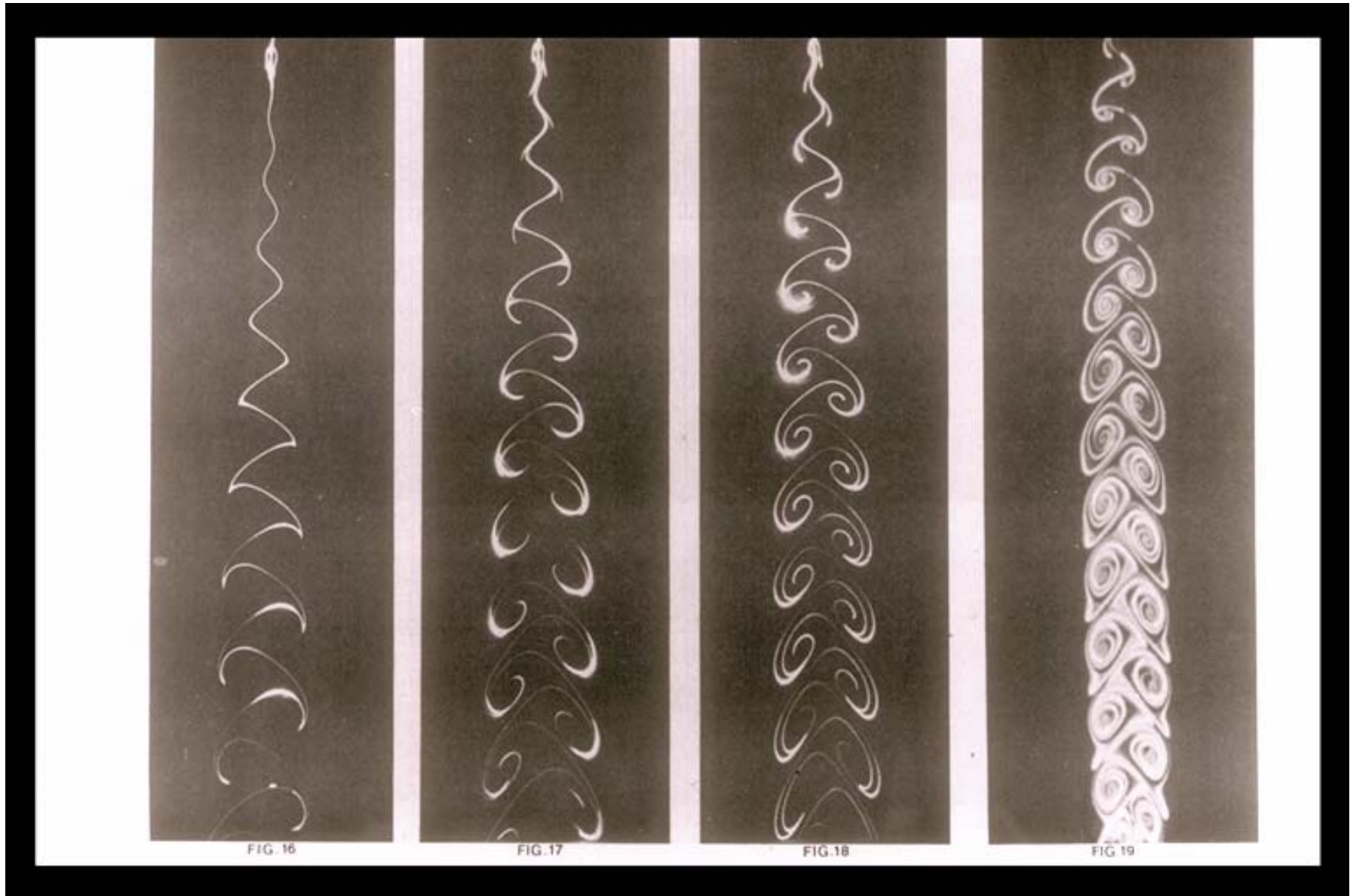
Color streaks in water, to visualize horse shoe vortex formation upstream of a bluff protuberance mounted on a flat plate (top view).



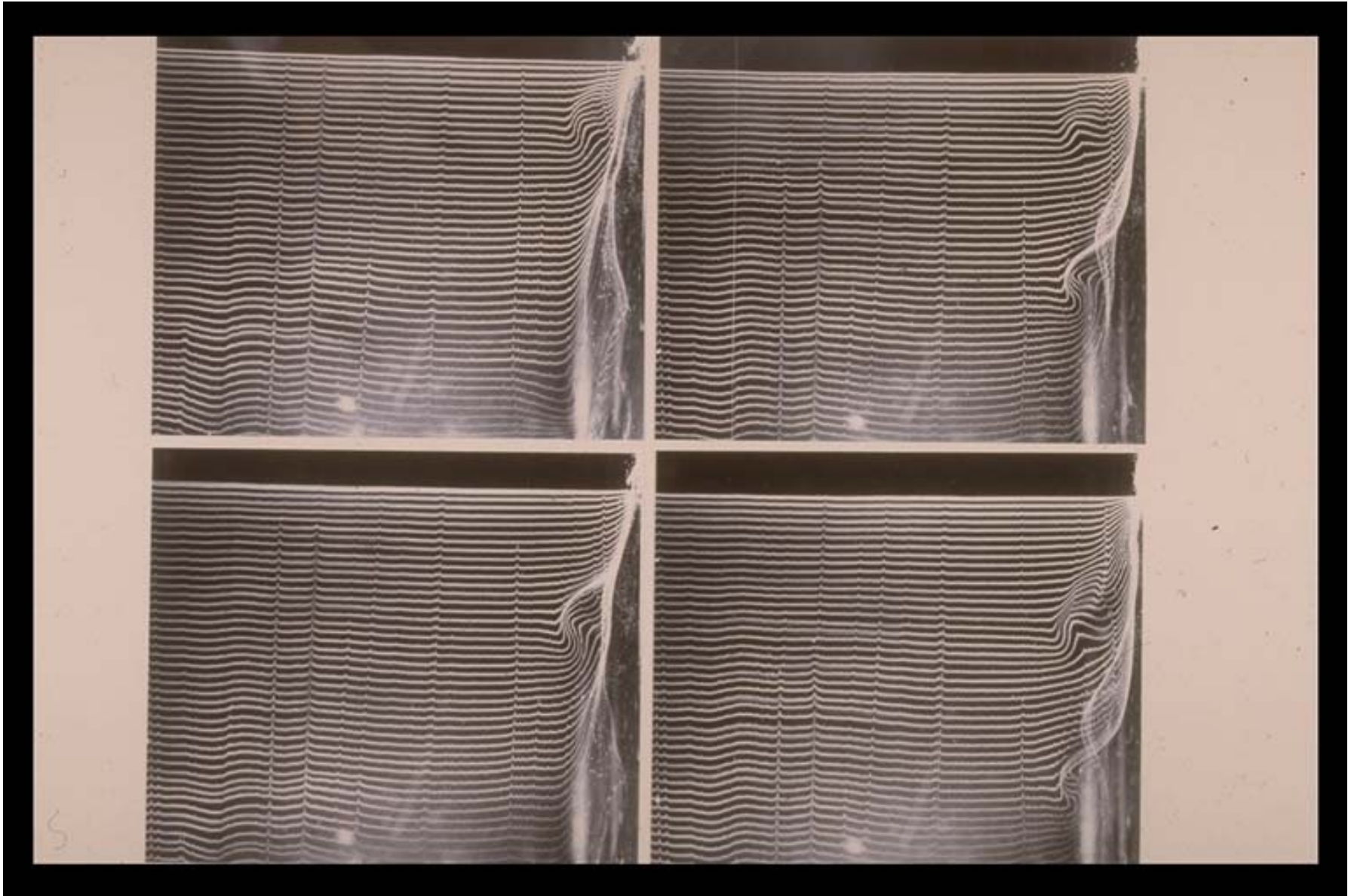
Water tunnel flow visualization with color streaks. Body vortices on leeward side of missile at incidence (side view).



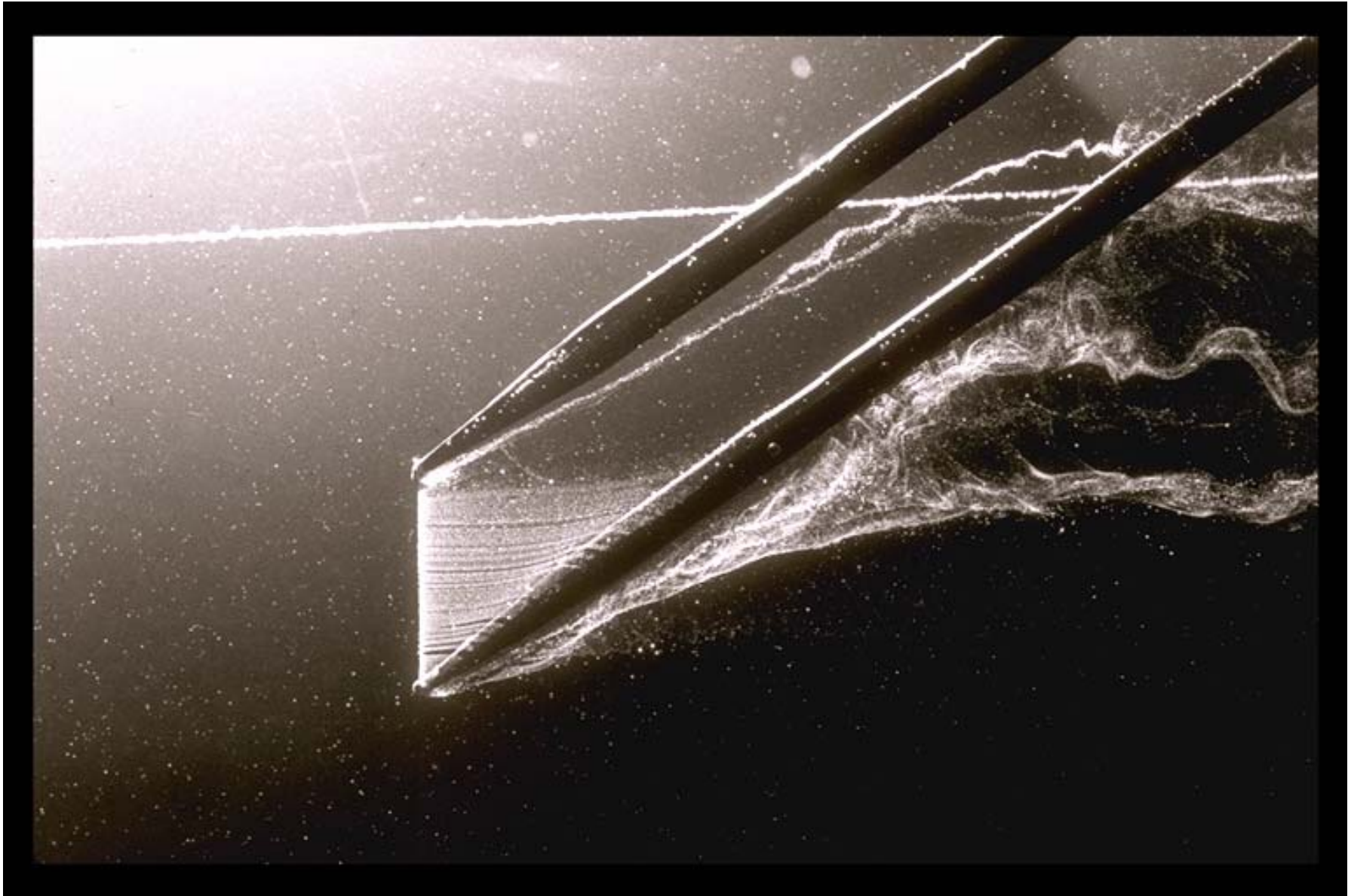
Water tunnel flow visualization with color streaks. Body vortices on leeward side of missile at incidence (top view).



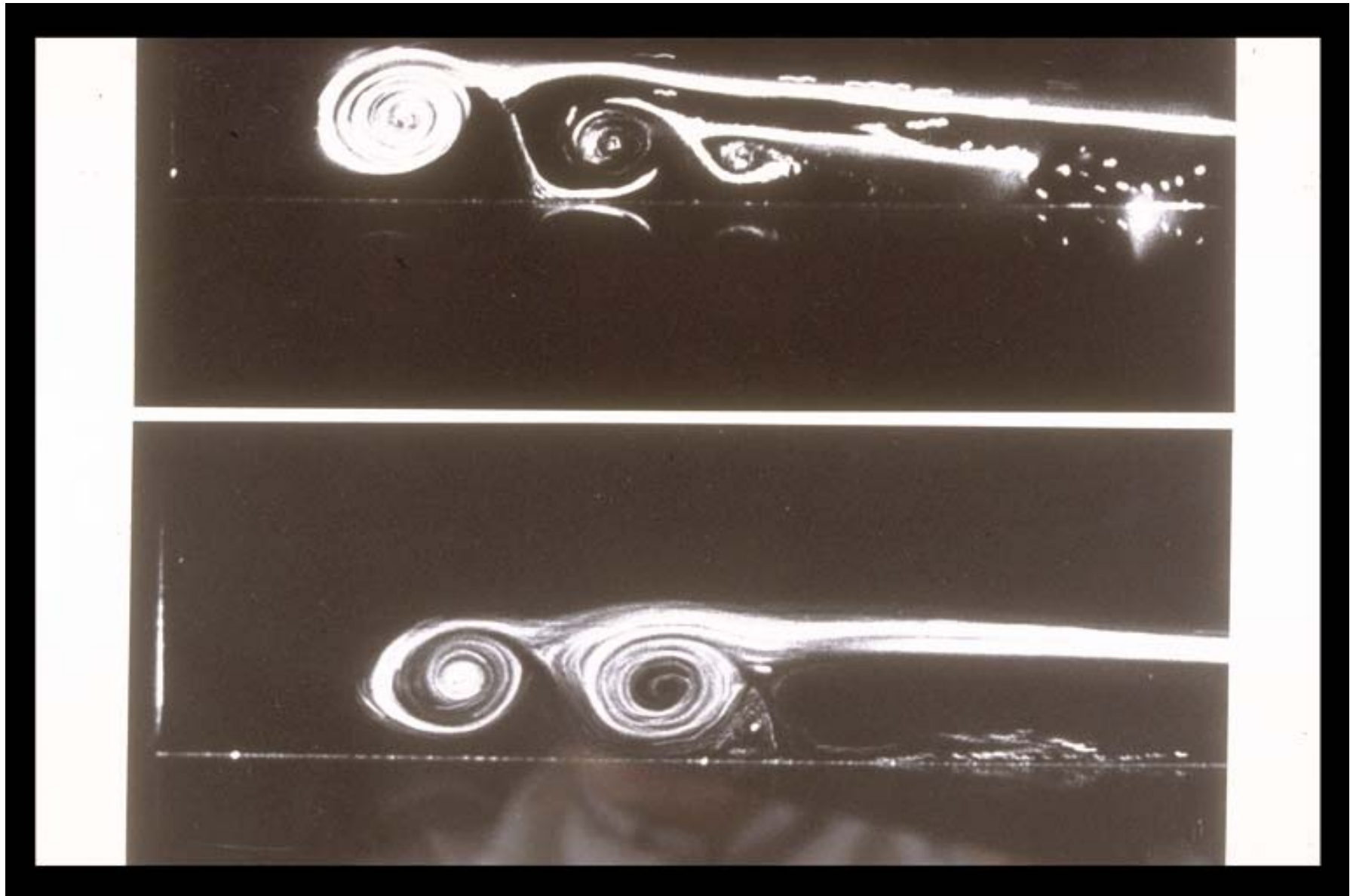
Water tunnel flow visualization of Karman vortex street behind a cylinder at increasing Re number. Fluorescent dye, and laser sheet.



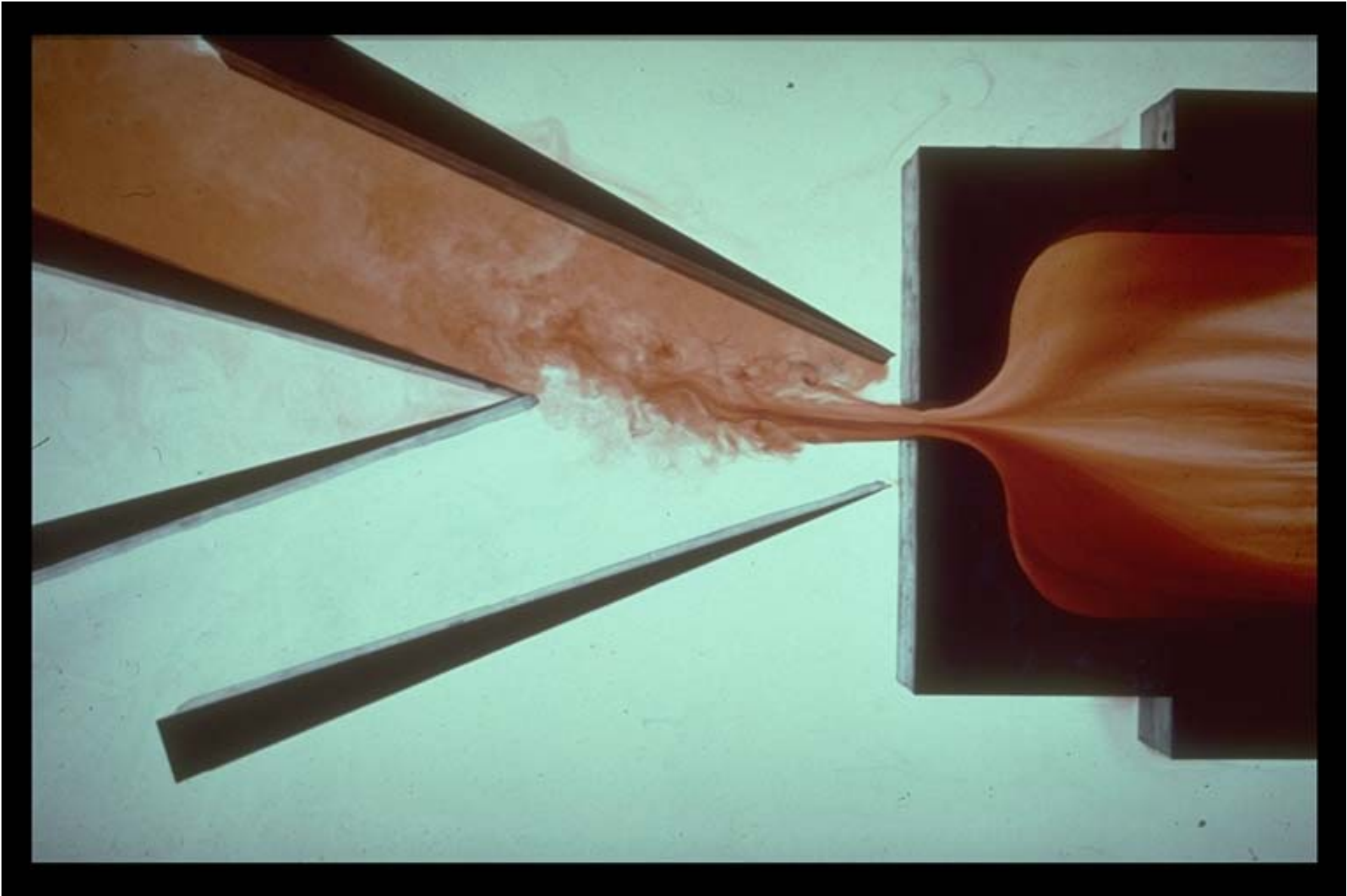
Hydrogen bubbles flow visualization in water tunnel.
Transitional boundary layer profiles on a flat plate, behind a vibrating ribbon.



Hydrogen bubbles flow visualization in a water channel.
Flow around the prongs of a scaled-up hot wire anemometer.



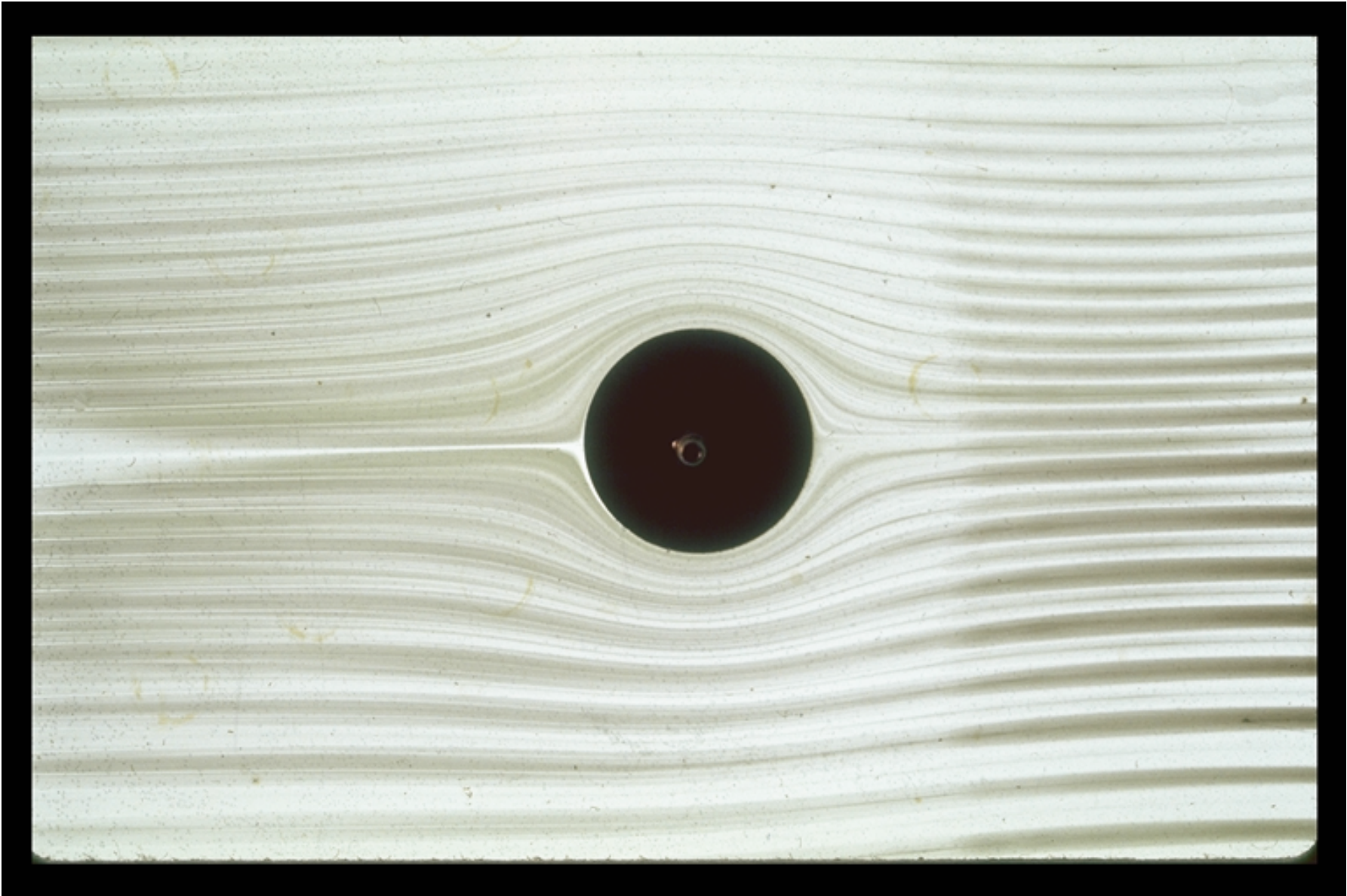
Hydrogen bubbles and Laser Sheet flow visualization. in a water tunnel. Co-rotating vortices and saddle points upstream of a bluff protuberance mounted on a flat plate (flow from right).



Colored water flow visualization : fluidic bistable amplifier in a free-surface water table.



Colored water flow visualization: fluidic oscillator (jet-edge-cavity resonator) in a free-surface water table.



Hele-Shaw flow visualization of potential flow around a cylinder.