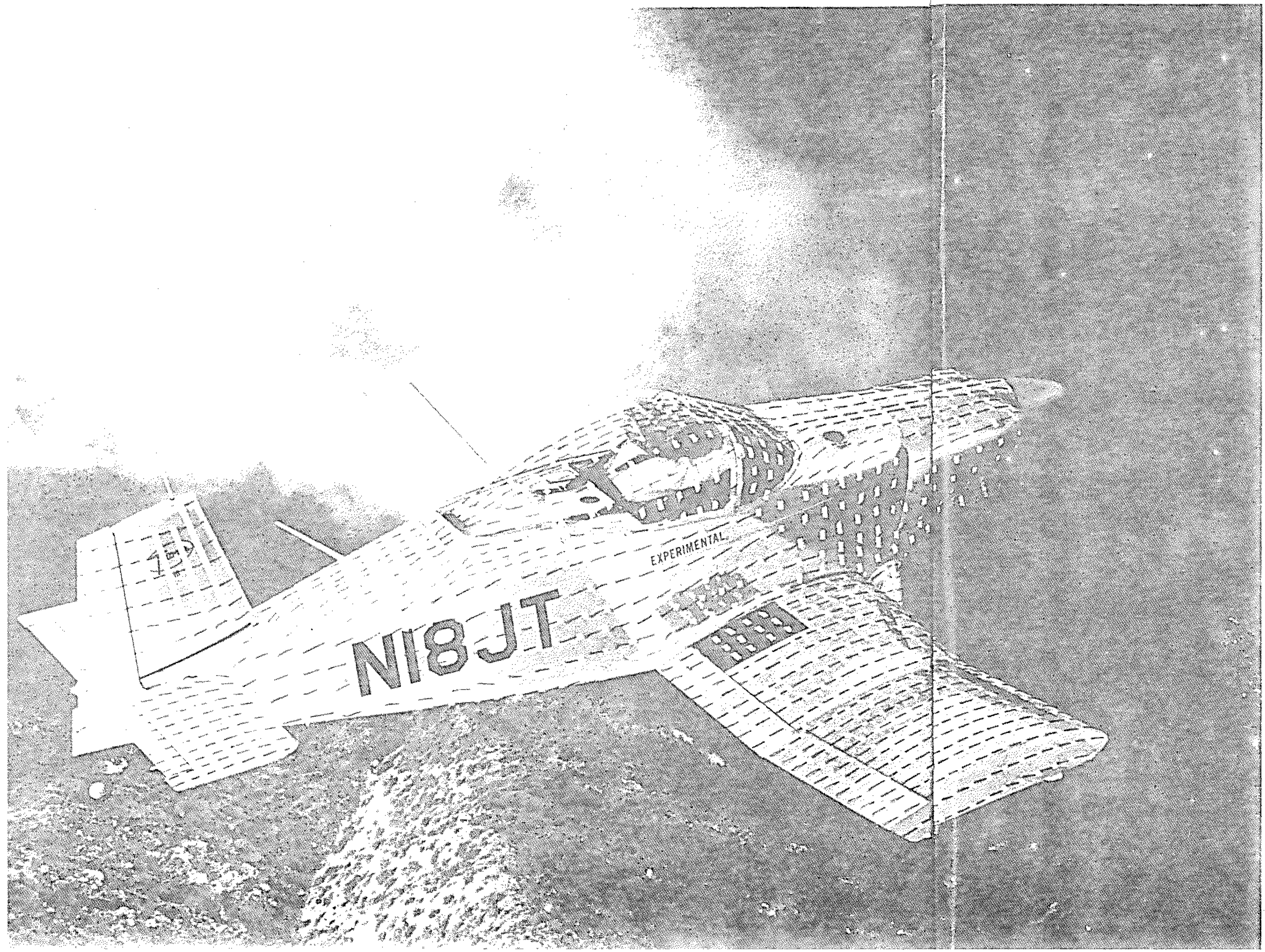
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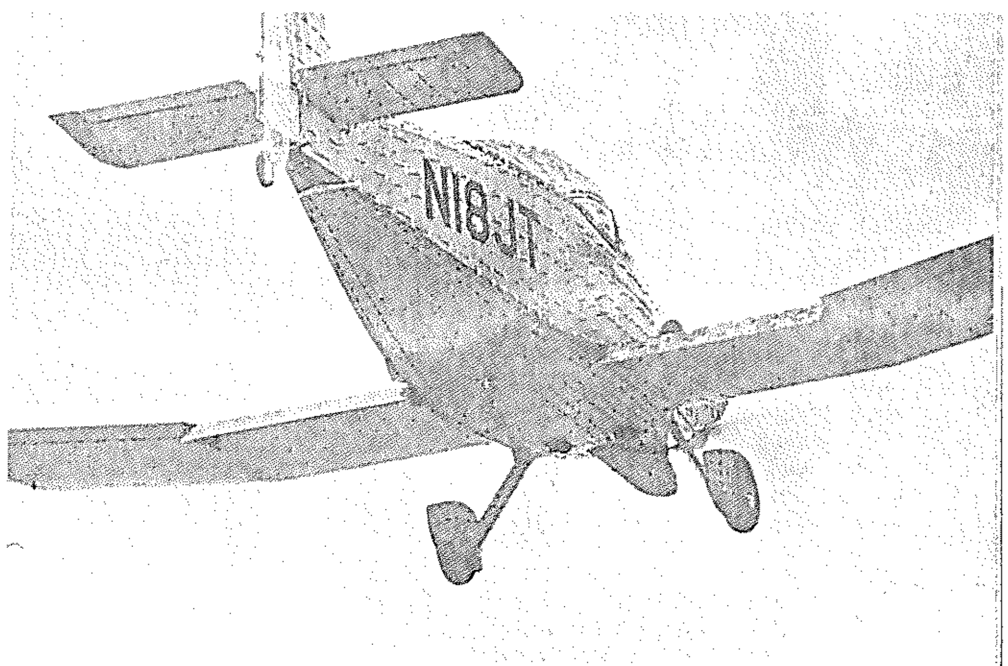
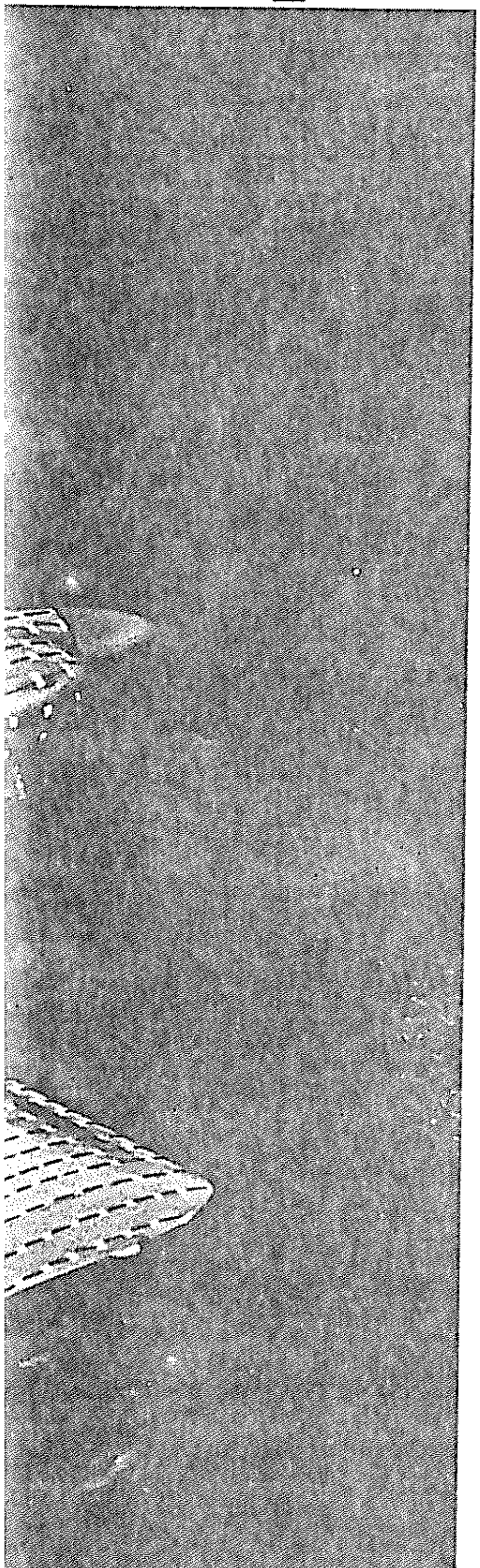


Figure two

Mad dogs and airplane designers fly around in fuzzy abandon. It may look weird, but tuft-testing is easy—and anyone can do it.
by Peter Garrison



Top of page: With full flaps, airflow around the horizontal stabilizer begins to break up.

A STREAMLINE is an idealized line followed by an idealized air molecule past a body. You have probably seen drawings of wing sections with parallel lines flowing to meet the leading edge, parting at the stagnation point and meeting again behind the trailing edge; those lines were streamlines. They were idealized because the movement of air is usually much more complicated than those neatly combed lines would suggest, and involves local turbulences, little eddies and whirlpools, reversals of flow and trapped dead areas. A shape as simple as an airfoil's may not give rise to all these irregularities of flow, but one as complicated as an entire airplane's inevitably does. It is the strenuous job of the aerodynamicist to coax as many air molecules as possible into following smooth, parallel and undisturbed courses around the airplane.

If the designer is inspired, lucky and clean-living, he may be rewarded with large areas of what is called *laminar flow*. Laminar flow is flow in parallel streamlines; a laminar-flow airfoil is one that is shaped in a way that keeps the air flowing smoothly over it for as long as possible. Contrary to common belief, a laminar-flow airfoil is *not* simply one with a curved, rather than a flat, bottom surface.

The next step after laminar flow is turbulent flow; the difference may be clearly seen in the column of smoke rising in still air from a parked cigarette, which begins in smooth, parallel, laminar streamlines and then suddenly transitions into a billowing, turbulent flow. When this phenomenon occurs in the air flowing over an airplane wing, it is called *separation*; aft of the separation point, there is a thin turbulent layer between the skin and the parallel streamlines farther out. This layer, called a *boundary layer*, has a higher drag than a laminar flow. It is, therefore, desirable to delay its onset and keep it as small in extent as possible.

When the turbulent boundary layer gets thick enough—and once it has established itself, it gets thicker and thicker as it moves aft along the airplane—it becomes liable to flow reversal: Air starts moving from back to front along some parts of the airplane. If this seems counter-intuitive, think of the flow downstream from rocks in a rapid river; some of it is often moving the opposite way from the bulk of the current.

The analogy of moving water is helpful because we are used to seeing how water behaves when flowing past an object, whereas the usual image used in aeronautical discussion—that of air flowing past a stationary airplane—is remote from everyday experience. Also, water is heavy, while air seems ephemeral to the point of insignificance; and so when we are talking about using hundreds of horsepower to overcome some eddies in the air, it is easier to comprehend if you think of the air as water.

Any air that comes to rest or moves forward on the airplane is air that has been picked up and carried along by surface friction and turbulence. The more easily an airplane can shed the air going past it, the less drag it has; if, on the other hand, it picks up a lot of air as it goes along, its drag will be high and its performance poor. The essential thing, therefore, is to get air past the airplane as expeditiously as possible, and to change its velocity as little as possible on the way.

Various means are available for making visible the passing air; it can be dyed in a smoke tunnel, or its pressure patterns can be studied by Schlieren photography—you may