SURFBOARD HYDRODYNAMICS, PART I: **DRAG**

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Pipeline, thick and glassy, machine perfect, peeling out to the left like a zipper sliding shut. You take off at the apex of the peak, falling two-thirds of the way down oily perfection, and crank it over and into trim, moving forward for speed, tucking fetal-like over the front third of your board. The thick arch of the wave heaves muscle over your shoulder, now onto your shoulder, daylight a foot away. Then, impact, suck, throw; wrapped in a watery explosion, caught a foot from freedom when you could have made it. How? By scraping off those scabs of wax on the bottom of your board, that's how. Don't believe it? Read on.

The hydrodynamics of a surfboard on a wave is a complicated system to analyze. Even in the case of a ship's motion on smooth water, it is often necessary to make model tests to verify assumptions made in the mathematical calculations. A similar test system for surfboards, including waves, would be prohibitively expensive, so surfboard manufacturers rely on the combination of designer-shaper-tester to evaluate new designs. Such a process tends to blur the effects of individual changes, because usually more than one variable, such as plan form, rail shape, rocker and kick is simultaneously changed. This series of articles will cover some of the fundamental hydrodynamic aspects of a surfboard and will attempt to analyze the individual effects of various design factors. The proper choice of variables in building a board will depend on its usage and the skill, style and personality of the surfer, and hence, remains the realm of the traditional designer-shaper.

Almost all board designs compromise speed potential in return for flotation or maneuverability; however, many of the latest boards are designed with speed on a wave as a major consideration.

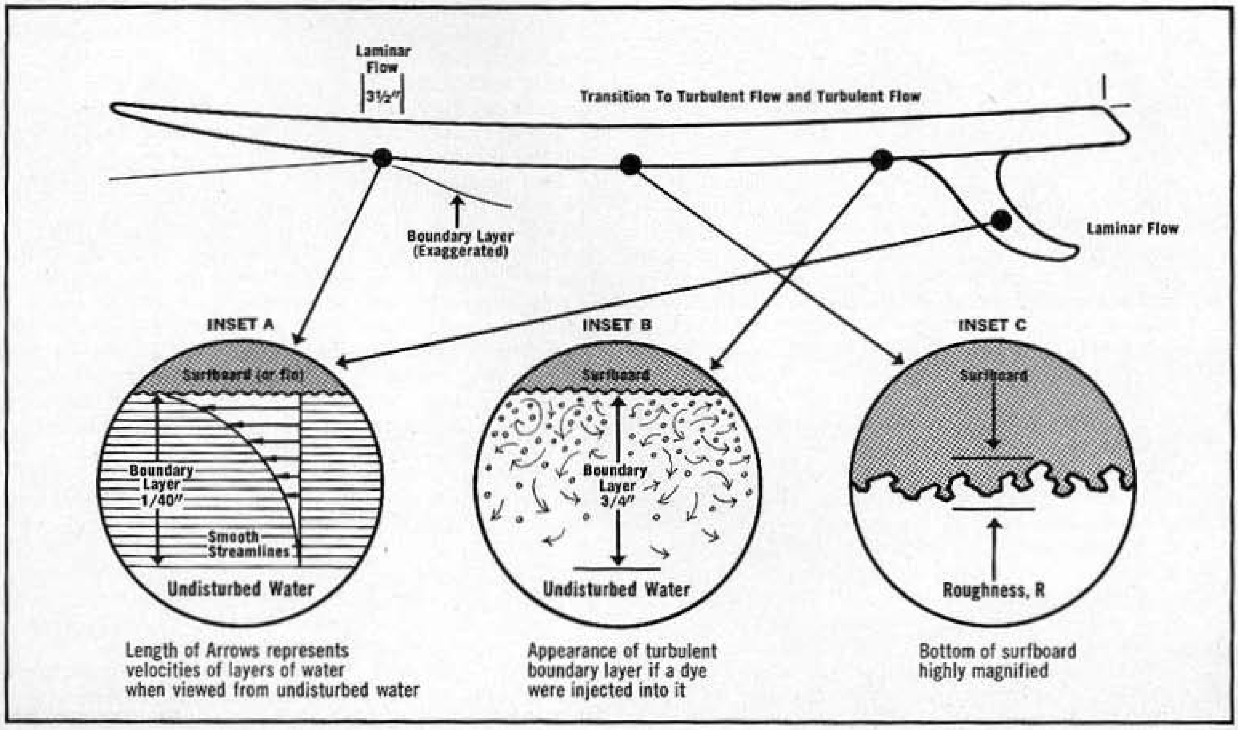
A surfboard attains its maximum speed when the drag of the board through the water is equal to the propulsive force of the wave. Drag is defined to be the force that acts opposite to the direction of motion. Forces that act perpendicular to the direction of motion are called "lift" forces and are related to turning, noseriding, etc. Drag, in general, may be related to the following four effects:

1. Skin Friction Drag—Primarily dependent on the velocity of the board and its wetted area.
2. Form (or Pressure) Drag—Closely related to shape factors such as rocker, kick, rail shape, etc.
3. Wave-making Drag—Generated by any object moving on, or near, the surface of a liquid.
4. Spray-making Drag—Important at planing speeds.

Skin friction drag is a result of water being a viscous liquid (although its viscosity is much less than that of oil or resin). All solid objects, such as a surfboard, exhibit an interesting property when moving through a viscous liquid. It is found that water immediately adjacent to the object moves along with the object. A region, or layer, also exists, extending outward from the surface of the board, in which the velocity of the water decreases from the boards velocity until it eventually is indistinguishable from the undisturbed water. This layer is commonly referred to as the boundary layer. Its thickness depends primarily on the wetted length of the board, the board's velocity and the nature of the flow (as well as the viscosity of the water).

The nature of the flow falls into two general categories — laminar and turbulent. Near the front of a smooth object, the flow is laminar; that is to say, the motion of each layer of water (see Insert A, Figure 1) is along a line essentially parallel to the surface of the board. If the board is moving rapidly, or is sufficiently long, there will be some point on the board where the character of the flow will change to turbulent flow. A simple means of visualizing the difference between laminar and turbulent flow is to observe the motion of the smoke rising from a cigarette (in a still room). At first, the smoke rises in a smooth, regular column, until a point is reached where the column still moves upward, but the smooth

Figure 1—Flow in a Surfboard's Boundary Layer (6 Ft. Wetted Length—14 mph)



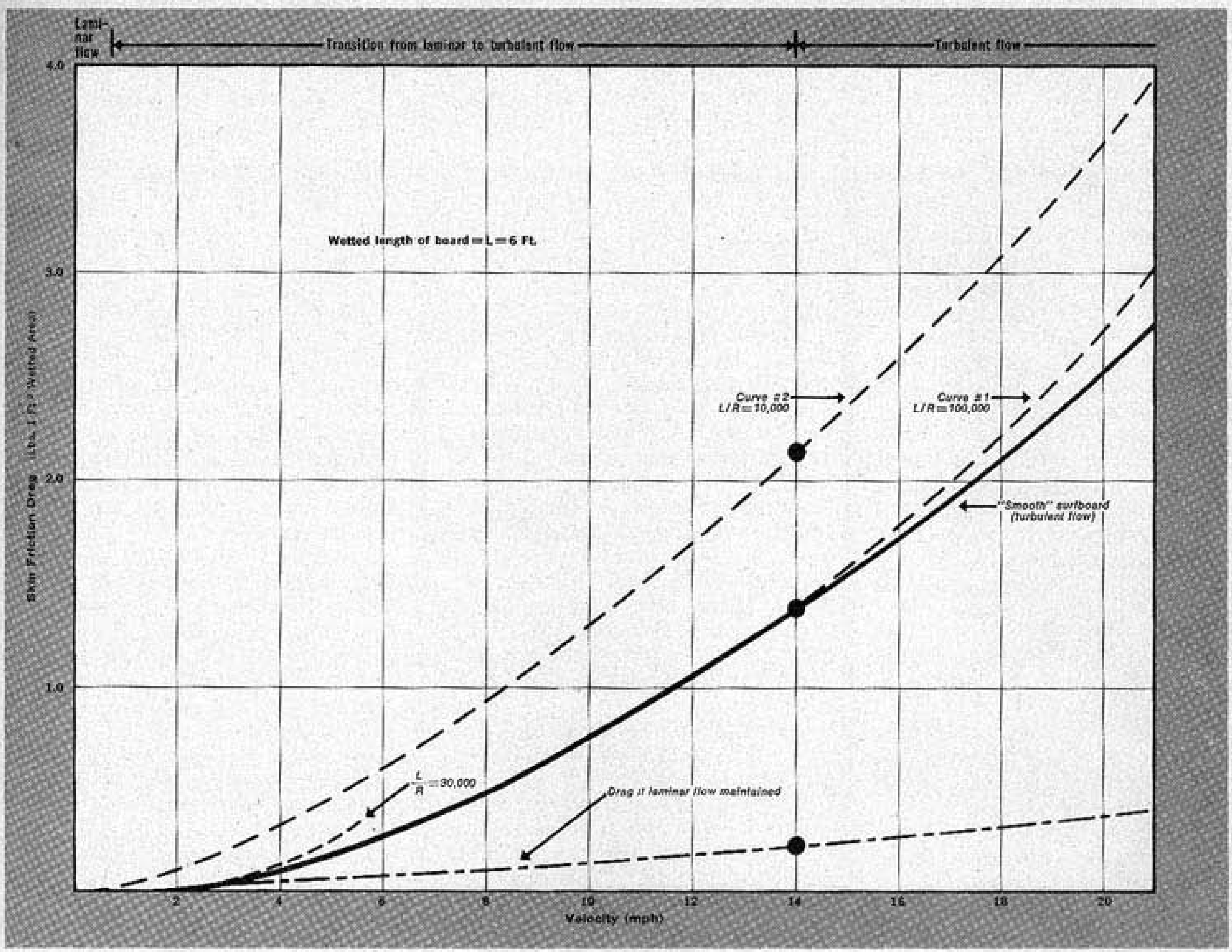


Figure 2—Skin friction drag of 6 ft. wetted length for various velocities and degrees of roughness

column is replaced by large eddys in which the smoke mixes with the surrounding air. The same general mixing occurs in the turbulent flow near a surfboard (see Insert B, Figure 1).

Since the skin friction drag is dependent on the nature of the flow (being greater for turbulent flow than for laminar), it is interesting to determine where the transition in the flow takes place.

It can be shown that for water at 60° F, this point is approximately given by the relation:

$$L = 4/V$$

where V is the board's velocity in mph, and L is the distance in feet from the (wetted) front of the board. If we assume a velocity of 14 mph for a board, only the first 3½ inches are laminar flow, and most of the flow is turbulent. It should be noted, however, that since modern fins are only 3-4 inches wide, the flow over them (except near the board) is laminar. The effect of this will be discussed in a following article.

The penalty one pays for having turbulent flow over the board can be seen from Figure 2. The solid curve gives the approximate skin friction drag per square foot of wetted area for a wetted length of 6 feet and for various velocities. For our case of a board traveling 14 mph, the drag can be seen to be 1.375 lbs/ft.^{2} instead of the 0.225 lbs/ft.^{2} it would be if laminar flow (dot-dash curve) could be maintained over the whole surface.

Although it is impossible to prolong laminar flow (at least for conventional surfboard construction) beyond the point given by the earlier equation, turbulence may start at an earlier point if the surface is not hydrodynamically smooth. The dashed lines give the drag for two ratios of the roughness, R (see Insert C, Figure 1), to the wetted length.

Curve #1 corresponds to "peaks" of 1/1000 of an inch in height for our board with a wetted length of 6 feet. These peaks represent the maximum roughness that is allowable without increasing the drag of our board when traveling 14 mph. For comparison, a typical human hair is 2/1000 of an inch thick, so any bump greater than half a hair thickness would cause an increase in the drag (and even bumps 1/1000 of an inch high would cause an increase in the drag if the velocity is increased).

Now suppose several boards have been stacked on top of each other and the bottom of one has picked up pieces of wax (like the board on our Pipeline wave). Assume that the thicknesses of the chunks of wax are on the order of 1/140 of an inch. The drag for this case is given by Curve #2 (L/R = 10,000) of Figure 2. For our hypothetical case, the drag at 14 mph is 2.25 lbs/ft.^{2} instead of the 1.375 lbs/ft.^{2} for a smooth surface, or an increase of 63%! In actual practice, the situation would not be this bad, since it is unlikely that the whole wetted surface would be covered with wax. Moreover, skin friction drag is only one of the four causes of drag. However, skin friction is an important source of drag, and it is clear that roughness caused by poor glassing, rough sanding, wax, or pin-stripes will never cause a decrease in skin friction drag, and even small imperfections may increase it, possibly making the difference between making a wave and getting eaten.

It can be shown that the skin friction drag is proportional to the wetted area of the board, hence, builders have already discovered the simplest way to reduce this drag—reduce the wetted area by making smaller boards. Although the small wetted surface of small, fast boards, such as mini-guns, certainly contributes to their speed, there are many other factors, such as flat planing surfaces and turn-down rails, which may also have a large effect. The relation of these factors to drag will be included in the next article.