Chapter 2

ASPECT RATIO

The lift and the drag, or the carrying power and the resistance, of a simple plane are combined functions of the effective planing angle, together with those characteristics inherent in the particular plane's beam-length proportion, or aspect ratio.

For bodies which are submerged, such as the hulls of displacement craft, proportions are determined by experience with lines of flow. According to Newton's Second Law of Motion, the resistance encountered is equal to the time rate at which the body changes the momentum of the fluid. That is, the rate at which the driving force does work is equal to the rate at which kinetic energy is imparted to the fluid.

However, in ship forms moving at relatively high speeds, momentum can be imparted to the fluid not only by the forward onrush of one bulk displacing another, but also by the resulting turbulence and suction according to the density of the medium. Such a resistance, demonstrated by dragging a flat plate crosswise to the stream, is expressed by Newton's equation:

$$R = KApv^2$$

where:

K = A constant for plates having similar shape
A = Area of plate
p = Density $(\text{lb./ft.}^3/\text{g})(\text{lb. sec.}^2\ \text{ft.}^4)$
v = Speed in feet per second

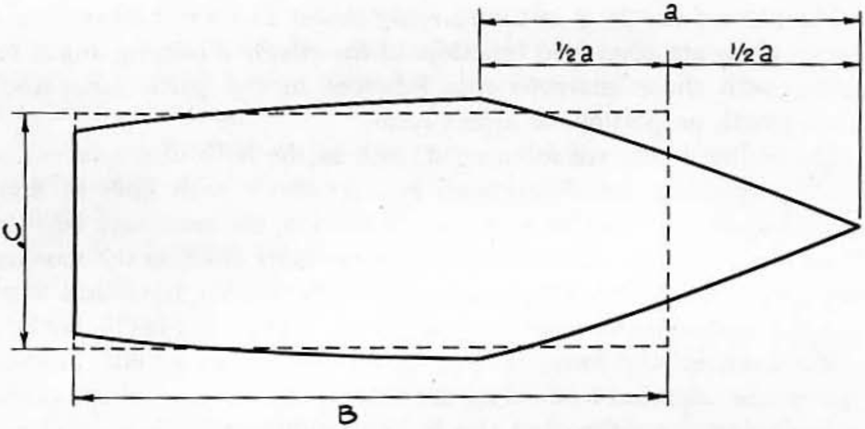
In the case of plates being moved in their own planes, the resistance rises less rapidly than the square of the speed, and the constant also has to be diminished as the physical size of the plate is increased. This situation is closely approximated by Froude's equation:

$$R = f'Apv^n$$

where symbols are the same as before, except that n is a little less than 2 and f' decreases as the length dimension of area increases.

This difference in behavior is fundamental in the differing performance between displacement hulls and planing hulls when both are being driven at high speeds. Obviously, the submerged body, moving with sufficient rapidity, increases the turbulence and the resulting suction drag, soon reaching a speed at which the viscosity of the liquid prevents further increase of speed regardless of practical increases in power.

With the plate moving in its own plane, this type of suction drag due to viscosity of the liquid is not a factor in the performance. Rather, the resistance, aside from skin friction, is largely due to the simple transfer of kinetic energy at the leading edge. Thus it becomes apparent that the leading edge of the plane at once accounts for a major portion of both drag and lift. But since lift rises as the square of the speed, and drag increases at less than the square of the speed, every proportionate increase in leading edge increment becomes successively more and more worth while.



ASPECT RATIO = $\frac{C}{B}$

WATER PLANE SHAPE AT REST

FIGURE 4

In other words, while increasing speeds require the displacement hull to become progressively narrower, the planing hull moving at high speed requires the widest possible beam. To simplify still further, the displacement hull can improve its speed only with added length; the planing hull requires added beam.

The effect of beam-length relationships on displacement hulls has been well standardized by generations of trial and error. A similar standard for optimum performance of the planing hull is needed. The first step toward such standardization of beam-length relationship must, of course, be an acceptable method of measurement which can be applied to all planing hulls with equal success. Such a measurement of the beam-length ratio is shown in Figure 4. Here is the waterplane shape of a typical planing hull. The dotted rectangle is presumed to have the same area as the waterplane. For hulls of ordinary shape, the width of the rectangle, *C*, is the median beam of the hull between midships and the transom. The length, *B*, is the distance from the transom to a point midway between the entrance of the stem and the entrance of the chine. Dividing the width *C* by the length *B* gives a percentage, or aspect ratio, suitable as a standard relationship in the comparison of planes.

The beam-length proportion is fundamental as a controlling factor in hull performance. This relationship, as indicated by the aspect ratio, is basic in the estimate of potential lifting power, resistance, stability and other qualities of sea-keeping ability. However, for convenience and for accurate standardization, the aspect ratio is always considered as of the waterplane shape while the hull is at rest.

In Figures 5 and 6 are shown a series of true aspect ratio floats, or bottoms, identical in area and weight but varying in aspect ratio from .2 as the narrowest one, to .6 as the widest of the series. The resistance characteristics of these bottoms, towed at planing speed, are shown in Figure 7.

Each bottom is a theoretically perfect plane of straight and parallel running lines with a slightly cambered cross section to assure a reasonable degree of directional stability when being towed. The necessity for parallelism in the longitudinal running lines is obvious in any plane which is expected to deliver similar and calculable lift across an entire cross section. Neither can there be any suggestion of a downward hook. The reasons for straight running lines will be developed and clarified in subsequent chapters.

The photograph at the top of Figure 5 shows the .2 aspect ratio bottom planing at an angle of .75 degree, its normal position for the entire range of planing speeds. Compared with the wider bottoms, it is in-

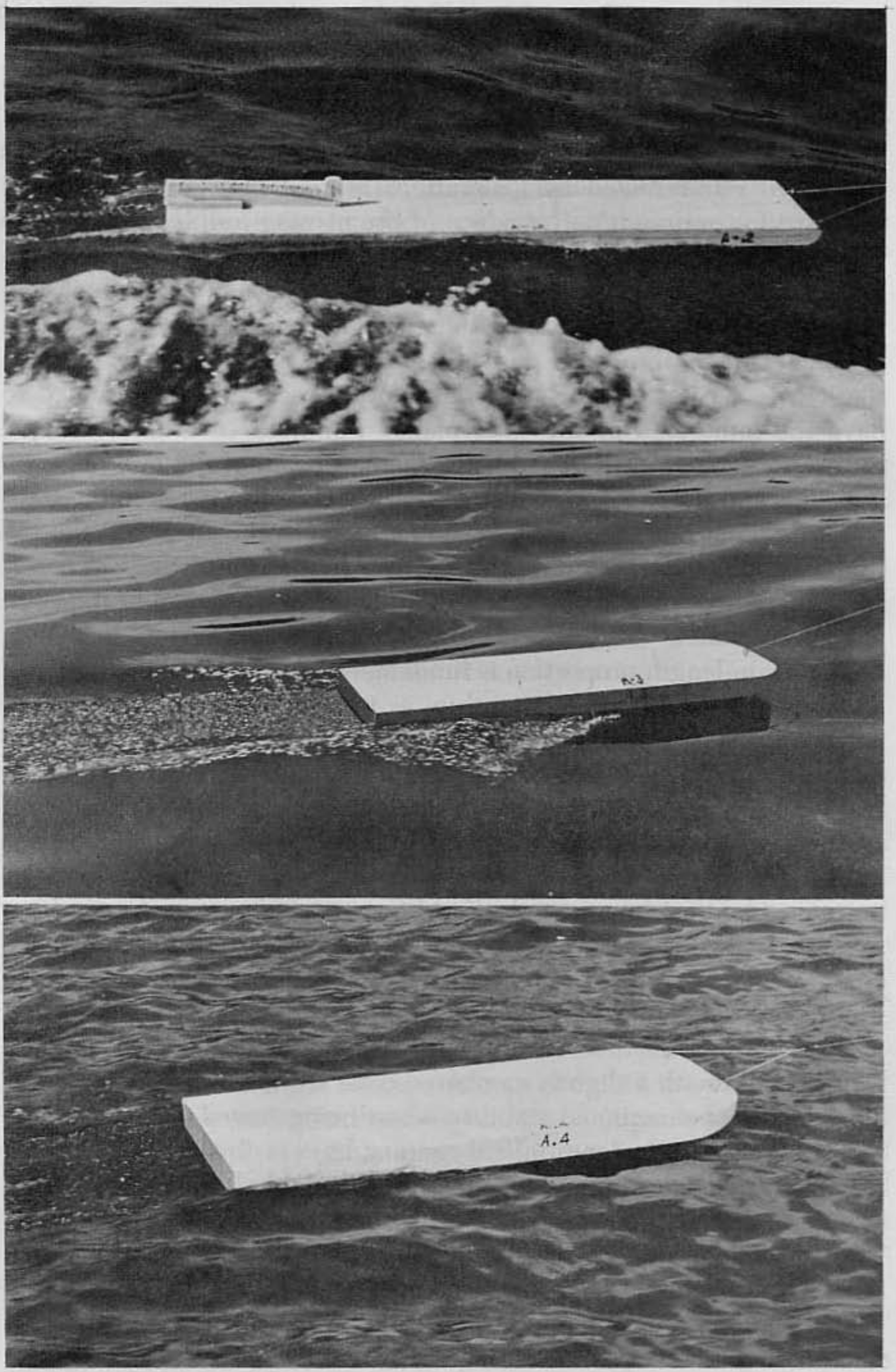


FIGURE 5

ferior on every count. The resistance is higher at all speeds, the lift is low, the stability poor, the longitudinal moment excessive and the wetted surface reduction almost zero. Even the wake is not "ironed out" as it should be.

All of these characteristics show proportionate improvement in successively wider bottoms up to aspect ratio .4, at which point wave-making resistance in rough water ceases to decline with the higher aspect ratio and begins to show an increase. While this fact rules out aspect ratios .5 and .6 as suitable shapes for seagoing bottoms, it is significant to note their continued decrease in total resistance for smooth-water operation. The beautiful wake of the wider bottoms, shown in Figure 6, is also worthy of attention.

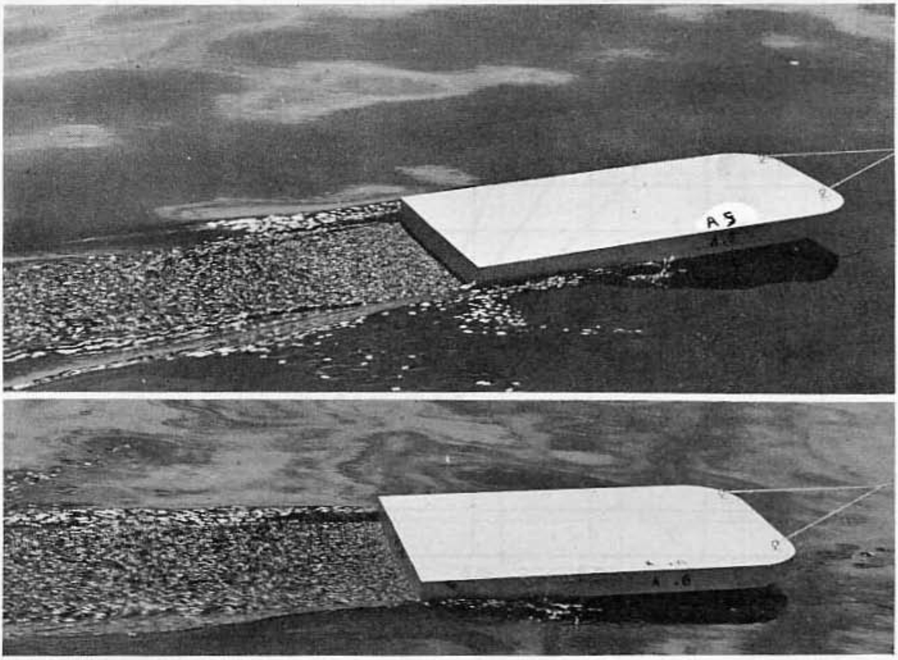


FIGURE 6

Other characteristics of varying aspect ratios are summarized in the following table of aspect ratio effects. In this table the resistance is the average for a standard total weight, or displacement, of 20 pounds. Planing angle is the normal one assumed with evenly distributed weight and a center of gravity amidships. Wetted surface reduction is shown as a percentage of still-water wetted surface. Maximum load is that total weight at which clean planing ceases in the range of normal seagoing speeds.

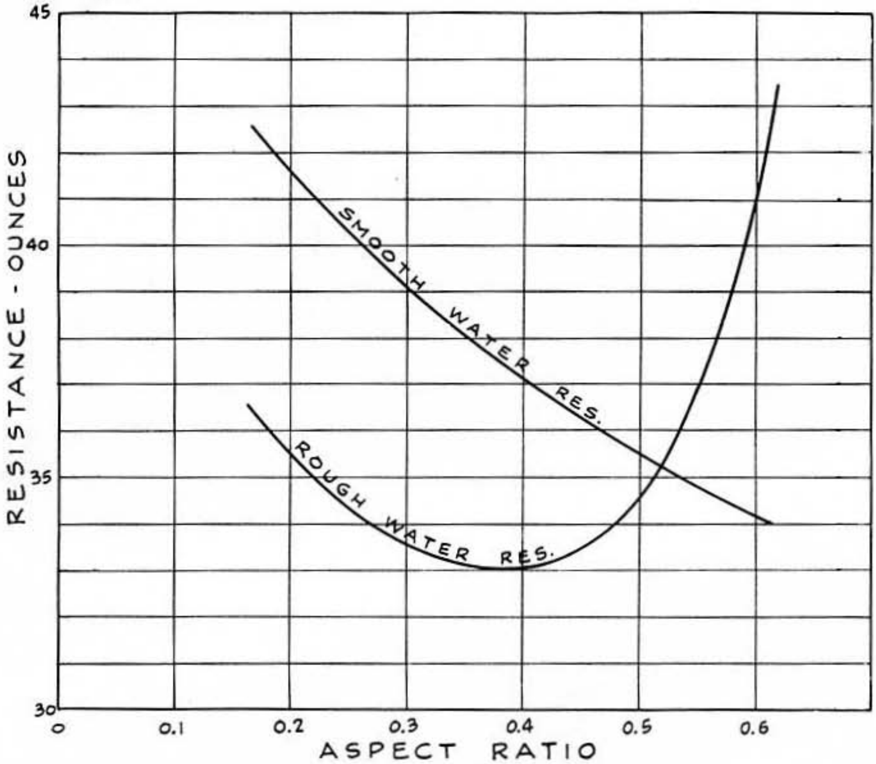


FIGURE 7

ASPECT RATIO EFFECTS

Aspect Ratio	*Resistance @ 20 lbs.*	*Planing Angle*	*BML*	*W.S. %*	*Max. Load*
.2	50 oz.	.75°	8′ 3″	90%	21 lbs.
.3	42 oz.	2.00°	5′ 2″	70%	27 lbs.
.4	37 oz.	3.00°	4′ 0″	62%	33 lbs.
.5	40 oz.	3.75°	3′ 8″	58%	38 lbs.
.6	42 oz.	4.25°	3′ 4″	56%	42 lbs.

Figure 8 shows in graphic form the load-carrying power of these varying aspect ratios and the effect of load upon resistance.

The conclusions to be drawn from these tests have been borne out repeatedly in actual boats and there can no longer be doubt as to the very real advantage of generous beam for best planing. Most high-