The Twin Propeller W-Drive.

A series of articles on the application and theory of the twin propeller drive systems.

Part III: <u>The Shape of Things That Drag In The Water</u> ***By: James Faulkerson***

The shape of things that drag in the water significantly influence the behavior and performance of a drag boat.

Often, the designer and builder of a drag boat will overlook the shape of underwater components such as sponson skags, rudder, propeller strut(s), etc. without realizing that the drag force of these components represent hundreds of pounds of force working against the drag boat intent of rapid acceleration. And for the Top Fuel Hydroplane, tons of force that rob many hundreds of horsepower can be attributed to the underwater component drag force demon.

Fluid dynamics is a complex and mathematically laden science. However, there are a couple of relatively simple and useful concepts that can be applied to the design of underwater components that will reduce the amount of drag force acting on the quarter mile performance watercraft.

We need to now define the basic concept of drag force and its relation to shape.

The Drag force D_F, as you might expect, is directly proportional to the density of the fluid p in which our shaped object is immersed, the speed or velocity squared V^2 of the object in the fluid medium, the frontal area "A" that is orthogonal, or at right angles to the direction of fluid flow about the object, and the coefficient of drag C_D of the object shape, that is usually determined experimentally.

Mathematically stated, $D_F = C_D A\ pV^2/2$. This equation states the drag force D_F equals the coefficient of drag C_D of the shaped object, times the frontal area of the object, times the density of the fluid medium that our object is immersed in, times the velocity of the shaped object squared divided by two.

Now let's examine some of the variables in the drag force equation. The density of water "p" is equal to 62.428 pound per cubic foot. Generally, this number is for fresh water at 20 degrees centigrade. This number will increase when you operate a boat in salt water or cold water. This means all drag forces will increase for salt water, and or cold water.

For the drag boat application, V is the speed or velocity of our boat in feet per second. The reason this value is in feet per second instead of mile per hour is that we must keep the units consistent. You know, apples with apples, oranges with oranges. You can convert miles per hour to feet per second by multiplying miles per hour by 1.467.

"A" is the frontal area of our underwater object. You can envision the frontal area by placing a white piece of paper in front of the object and shine a flashlight behind the object or in the direction of intended motion. The shadow cast on the white paper is the frontal area of the shaped body.

The coefficient of drag C_D for various shaped objects in cylindrical form are presented in Table 5.1 and have been experimentally determined.

The Table 5.1 illustrations are of cross sections of body shapes that are immersed into a fluid medium with a portion of the body shape object out of the fluid. Since the object body shape is not entirely immersed in the water it is therefore considered two dimensional flow about the body.

An example of a body shape relative to a drag boat would be a transom mounted rudder on a hydroplane. For example, imagine looking down on the top of the boat rudder and taking a saw and cutting through the rudder horizontally and parallel with the water surface. Still looking from above, the cut portion of the rudder would represent the two dimensional (length and width) cross sectional body shape of the rudder.

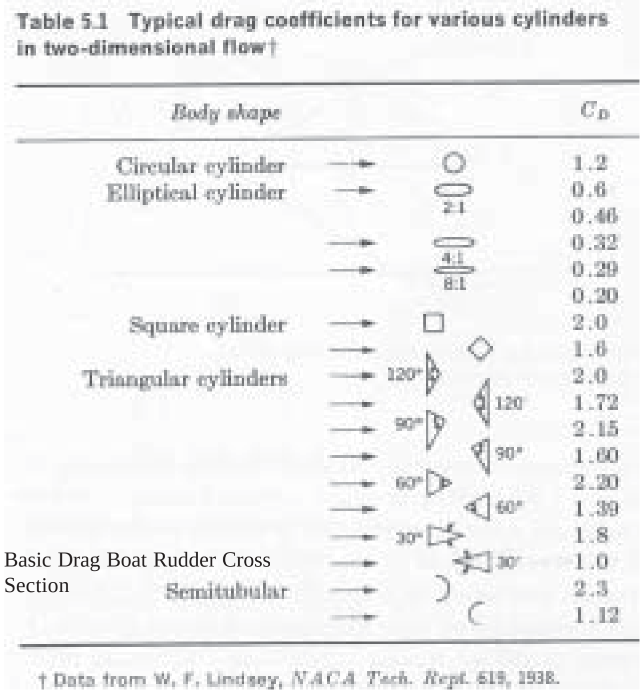


Table 5.1 Typical drag coefficients for various cylinders in two-dimensional flow†

Body shape		C_D
Circular cylinder		1.2
Elliptical cylinder	2:1	0.6
		0.46
	4:1	0.32
	8:1	0.29
		0.20
Square cylinder		2.0
		1.6
Triangular cylinders	120°	2.0
	120°	1.72
	90°	2.15
	90°	1.60
	60°	2.20
	60°	1.39
	30°	1.8
Basic Drag Boat Rudder Cross Section	30°	1.0
Semitubular		2.3
		1.12

† Data from W. F. Lindsey, *NACA Tech. Rept.* 619, 1938.

In Table 5.1, the heading C_D contains the coefficient of drag for the various body shapes. It should be recognized, the drag force D_F for a given body shape will increase as the value of C_D increases, and decreases with a decrease of C_D.

Also note, the arrows in the table represent the direction of fluid flow. Reverse these arrows' direction for the direction of motion of the body shape.

Now let's examine some of the body shapes found on a drag boat's underwater hardware. The most common shape is the basic 30-degree wedge body shape of a rudder. It has a C_D of 1.0. Not the best shape for a rudder. We can do much better by having an elliptical body shape. See Table 5.1. ***<u>Is it possible that after all these years that drag boat rudders have been incorrectly shaped?</u>***

The numbers under the elliptical body shapes (2:1, 4:1, and 8:1) represent the aspect ratio of the body shape design. That is, for a 4:1 aspect ratio the long-wise portion of the ellipse is 4 time larger than the narrow portion of the body shape.

The elliptical body shape with a C_D of 0.29 can have up to 71% less drag than a wedge shape rudder. ***<u>That is a significant reduction in drag force!</u>***

Let's calculate the difference in rudder drag force between a wedge body shape and an 8:1 aspect ratio elliptical body shape for a **T**op **F**uel **H**ydro traveling at 235 M.P.H..

Figure 1 calculates the drag force for two different body shape rudders with the same cross sectional area. The cross sectional area was calculated using a three quarter inch thick steel rudder that is immersed eight inches into the water. It is assumed the transom is well out of the water at 235 M.P.H. and only eight inches of rudder is in the water.

The results of the calculation in Figure 1 are quite extraordinary and would not be, for most people, intuitive given that you would reduce the drag force acting on a Top Fuel Hydro traveling at 235 M.P.H. by 1.7 tons just by changing the body shape of the rudder from a wedge to an ellipse!

However, there is one catch to the effective implementation of this extraordinary savings in power and therefore increase in performance. You must have a W-Drive twin propeller propulsion system with the rudder center mounted.

A single propeller drive system on a drag boat (especially a TAH and TFH) will produce dramatic and unwanted "paddle wheel" forces that tend to walk the back of the watercraft in a clockwise direction (see my article "Why Two Propellers" Jan., 2002 DBR). Rudder angle needs to be applied to counteract this "paddle wheel" force. Having the rudder turned just a few degrees to counter the undesirable "paddle wheel" forces of the single propeller will lead to a disruption of the water flow around the body shape of the rudder. Any gain that you would obtain from an elliptical rudder body shape would now, to a large degree, be lost.

<u>Figure 1</u>

$V := 235\ \frac{mi}{hr}$ $\quad V = 344.7\ \frac{ft}{sec}$ Boat Velocity

$A := \frac{3}{4}\cdot in \cdot 8 \cdot in$ $\quad A = 0.042\ ft^2$ Rudder Cross Sectional Area 3/4" wide X 8" into the water

$\rho = 62.245\ \frac{lb}{ft^3}$ Density of Fresh Water 25 °C @ 14.7psi

$C_D := 1$ Coefficient of Drag; Wedge Body Shape

$D_{FW} := C_D \cdot A \cdot \rho \cdot \frac{V^2}{2}$ $\quad D_{FW} = 4788\ lbf$ ***<u>Drag Force Wedge</u>***

$C_D := 0.29$ Coefficient of Drag 8:1 Ellipse Body Shape

$D_{FE} := C_D \cdot A \cdot \rho \cdot \frac{V^2}{2}$ $\quad D_{FE} = 1389\ lbf$ ***<u>Drag Force Ellipse</u>***

$D_{FW} - D_{FE} = 3399\ lbf$ ***<u>1.7 Tons Less Drag Force</u>***

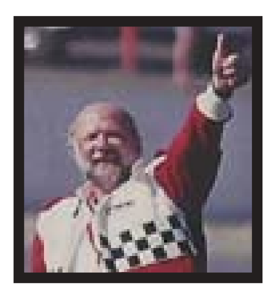
I have demonstrated in my Nitro Bullet III Top Fuel Drag Boat that virtually zero rudder angle is required for a W-Drive twin propeller equipped boat, thereby allowing the advantage of an elliptical shaped rudder to be exploited. During a race, the NB III rudder broke its mounting at over 230 M.P.H. with little or no effect on the direction of motion of the boat. If the NB III would have been a single propeller drive boat it would have crashed without a doubt. The crash would have been a result of the large amount of rudder angle missing that would have been needed to keep the boat going in a straight line.

Given figure 1 above, you can imagine the drag forces of a single propeller TFH or TAH with 5 to 10 degrees of rudder angle resulting in an increase in the rudder cross sectional area that will produce drag forces in the multiple tons!

The rudder drag force on a single propeller drag boat is one of the major reasons that the elapsed times between the Nitro and Alcohol classes were so small until I reintroduced the twin propeller drive system a few years ago. The undesirable propeller "paddle wheel" forces on a single propeller TFH require so much rudder angle that it cancelled, to a large degree, the TFH two-times increase in engine power over a TAH boat. A W-Drive allows much of this lost power from rudder drag to be recovered as has been demonstrated by lower ET's for the TFH with twin propellers.

The above principal of body shape and drag force apply to all underwater hardware for all classes of boats from River Racer to Top Fuel. ***<u>The Flatbottom drag boat with its hardware underwater for the full quarter mile run can really benefit from correct body shaped hardware.</u>***

There is much more that remains in fluid dynamics than I have discussed here. However, the application of the above should move you closer to the winners circle. Good Luck!



<u>James Faulkerson</u> is founder of Aqua Systems Engineering that currently designs and manufactures the only commercially available unit construction W-Drive.

Jim has been a practicing engineer and a machinist for over thirty years and has been granted five US patents.

He holds degrees in Mechanical, and Electrical Engineering.

Jim is the owner, driver, and builder of the Nitro Bullet series of Top Fuel drag boats.

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