

EVERYTHING YOU NEED TO KNOW ABOUT PROPELLERS.

FIFTH EDITION



PREFACE

When it comes to boat performance, propellers are second in importance only to the power available from the engine itself. Without the propeller's thrust, nothing would happen. Propellers affect every phase of boating performance—handling, riding comfort, speed, acceleration, engine life, fuel economy and safety. Much like tires on a car, the propeller conducts the power from the engine to the “road”. Your propeller is the primary connection between your engine and the water, making the propeller you select critical to achieving optimum boat performance.

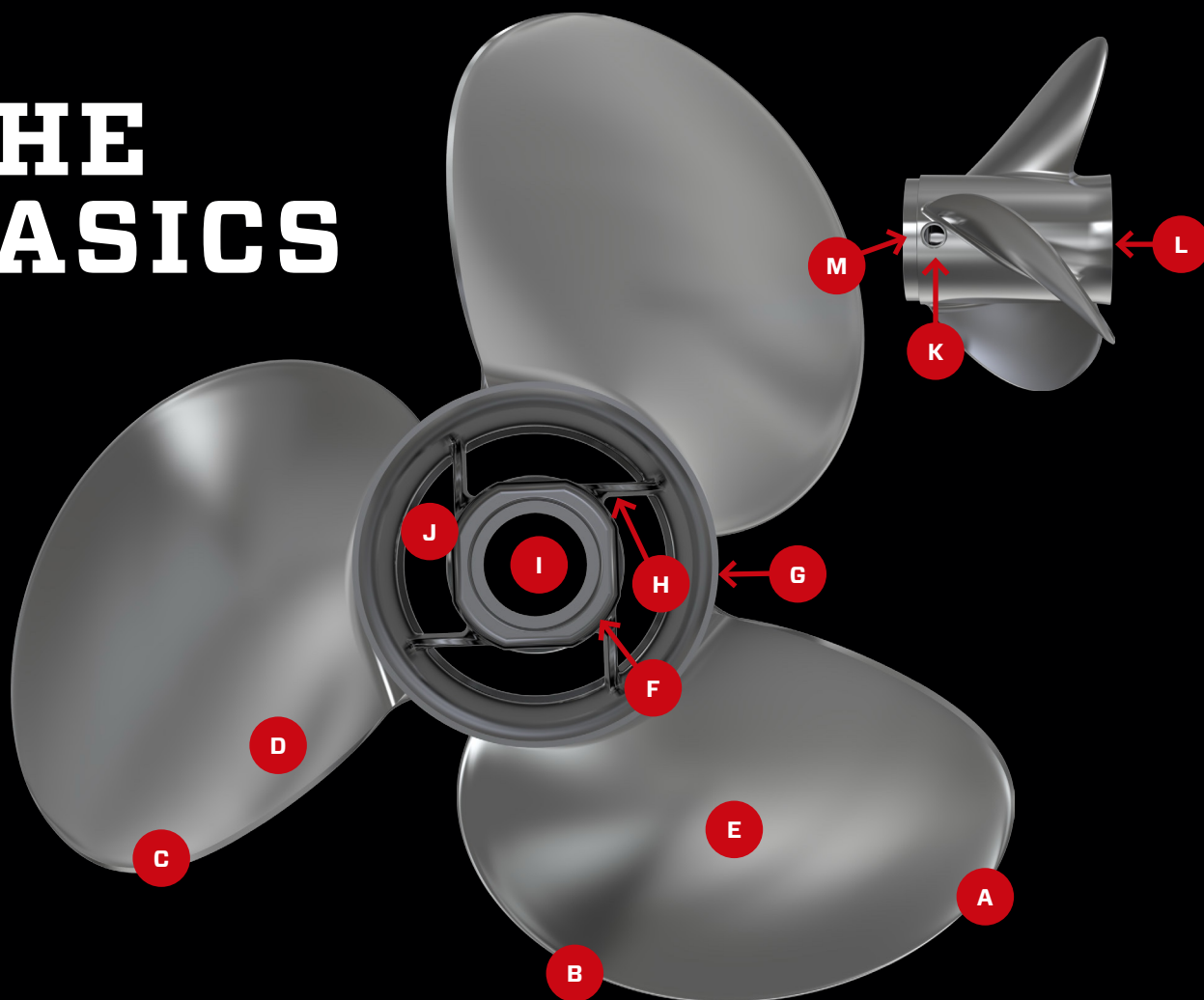
We wrote this book to help you make that choice wisely. We will teach you how a marine propeller works, and how engine and boat performance are directly related to it.

Mercury Marine manufactures over 400 different and distinct propellers for Mercury® and Mariner® outboards and MerCruiser® stern drives. These range from the simplest of plastic propellers for electric trolling motors to the blueprinted, custom-vented stainless-steel propellers in Mercury's line-up. Each propeller is designed to maximize the performance return available from a specific engine or group of engines. We can assure this only through designing, engineering and manufacturing our own propellers at dedicated facilities.

As a result of decades of research, our engineering staff has acquired extensive experience and knowledge of propeller design and innovation. If you find that claim hard to believe, consider that one of the engineers featured in the 1992 version of this book, Roger Koepsel, still works at our propeller plant and has been a dedicated and hard-working engineer with Mercury Propellers since 1970.

This book, which is now in its fifth edition, has been compiled from engineering data and factual engine and boat test results obtained from our on-the-water test sites. At the time of printing, this information represents the latest technology for marine pleasure boat propellers. Although written to provide even the most novice of boaters a solid understanding of propellers, some information is a bit more technical.

THE BASICS



A Blade tip: The blade tip is the farthest point on a propeller blade from the center of the propeller hub (parts F & G).

B Leading edge: The leading edge is the part of the blade that first cuts through the water. It extends from the hub to the tip.

C Trailing edge: Unlike the leading edge, the trailing edge is the part of the propeller that last interacts with the water. But, like the leading edge, the trailing edge goes from hub to tip.

D Cup: The cup is the small curve adding pitch to the trailing edge of the blade. This cupping allows a propeller to hold water better. (See page 7 for definition of *pitch*.)

E Blade face, blade back, & blade root: The blade face is the side of the blade facing away from the boat and the blade back is the side facing the boat. The blade root is where the blade meets the outer hub (part G).

F Inner hub: The inner hub houses the hub system discussed on the next page.

G Outer hub: The exterior surface of the outer hub is the portion that is in contact with the water, while the interior surface is in contact with the exhaust passage.

H Ribs: The ribs are the connections between the inner and outer hub. Propellers have from two to five ribs, which are either parallel to the prop shaft or parallel to the blades.

I Flo-Torq hub: The Flo-Torq hubs are there to transfer thrust from the shaft into the propeller.

J Exhaust passage: The exhaust passage is the hollow area between the inner and outer hub. This open area lets exhaust gases discharge into the water.

K PVS holes: The Performance Vent System allows exhaust to enter the blades at low rpms, resulting in better acceleration.

L Diffuser Ring: This aids in reducing exhaust pressure and in preventing exhaust gas from feeding back into propeller blades.

M Labyrinth Seal: This reduces the escape of exhaust gases between an outboard and a propeller.

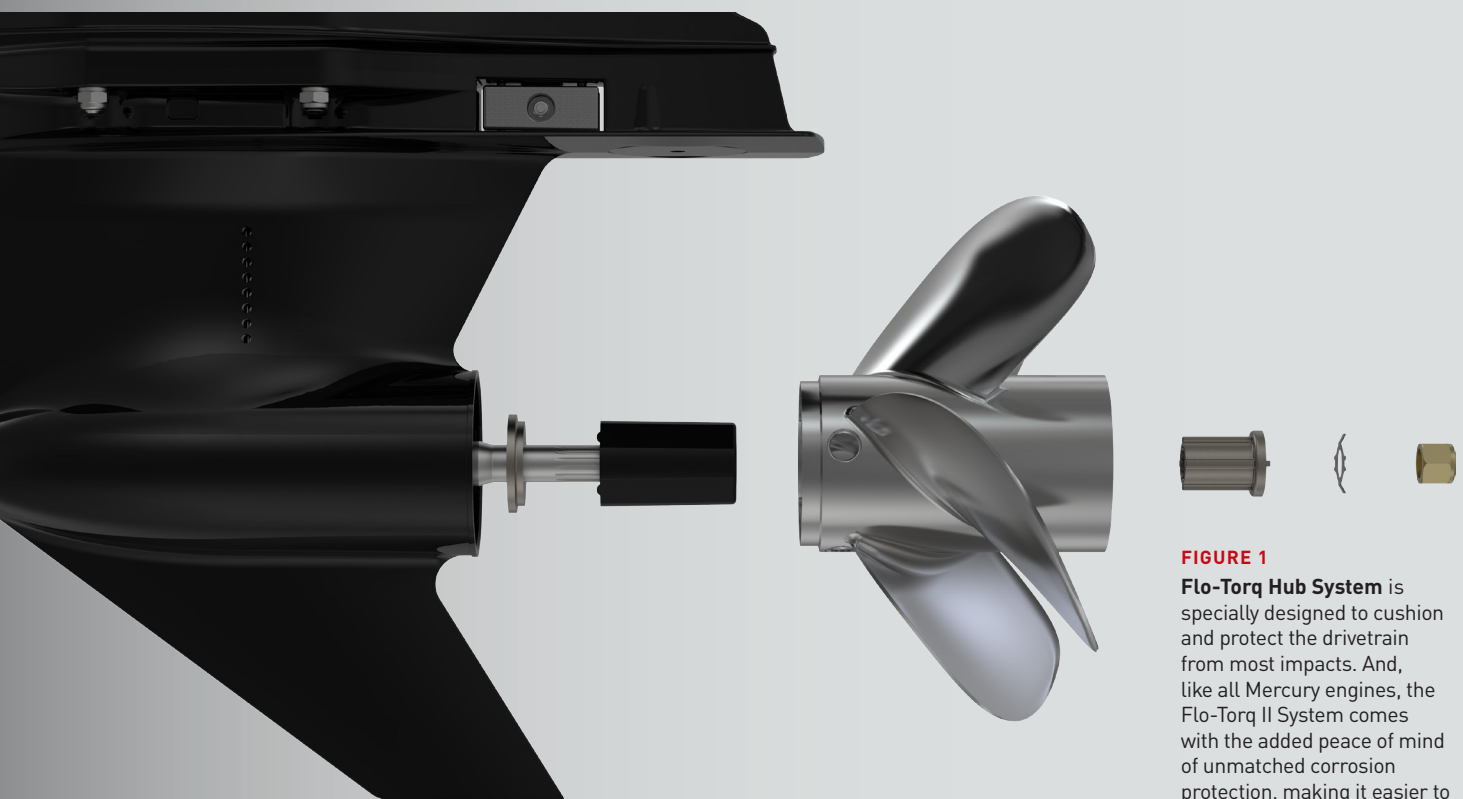


FIGURE 1

Flo-Torq Hub System is specially designed to cushion and protect the drivetrain from most impacts. And, like all Mercury engines, the Flo-Torq II System comes with the added peace of mind of unmatched corrosion protection, making it easier to go farther and get the most out of your time on the water.

HUB CONFIGURATIONS

At the center of the propeller is the hub. Fortunately, the types of hubs are easy to remember. If exhaust gases are discharged into the water through the hub, the propeller is called a through-hub exhaust (or Jet-Prop exhaust) propeller.

If exhaust gases are not discharged into the water through a passage in the hub, but rather over the hub, the propeller is predictably called an over-the-hub exhaust (or non-Jet-Prop exhaust) propeller.

While over-the-hub propellers tend to be mounted to the prop shaft with broached splines, Mercury through-hub exhaust propellers are mounted to the propeller's shaft through the use of Flo-Torq modular hub systems. Modular hub systems, as seen in Figures 1 & 3, allow for easy end consumer maintenance and replacement.

The bonded rubber portion of the Flo-Torq SSR HD reduces noise and vibration during shifting events.

The stainless steel portion of the hub provides durability for the high horsepower outboard applications up to 400 HP.

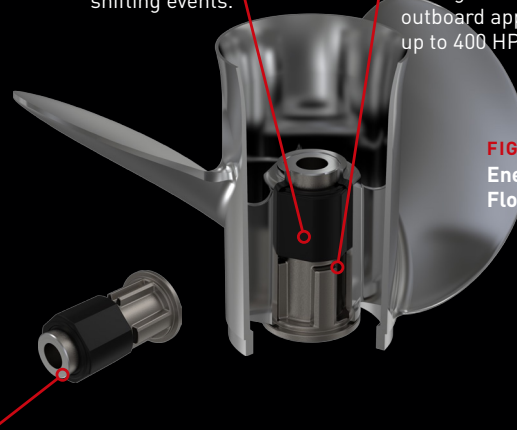


FIGURE 3
Enertia with Flo-Torq SSR HD

FIGURE 2

Flo-Torq SSR HD is the quietest and smoothest shifting propeller hub system in the market for high horse-powered outboards. It delivers a 10-19% shift clunk improvement vs. other noise reducing rubber hub systems and a 25%+ improvement vs. solid hub designs. The Flo-Torq SSR HD rotates both port and starboard—eliminating shift clunk and vibration, giving it its trademark smooth, quiet shifting.

HOW PROPS WORK



FIGURE 4
Thrust
Development

THE “PUSH / PULL” CONCEPT

To understand the “push/pull” concept, we froze a propeller at the point where one of the blades is projecting directly out of the page (Figure 6). This is a right-hand propeller, meaning it turns clockwise. The blades are moving from top to bottom. As the blade moves downward, it pushes water down with it, like we do when we swim. At the same time, water rushes to fill the space that was just created, leaving a difference in pressure between the two sides of the blade. The pushing effect, or positive pressure, is on the underside of the blade and the pulling effect, or negative pressure, is on the top side. Because of this, we can say that the propeller is both pushing and being pulled through the water.

These pressures cause water to be drawn into the propeller from the front and accelerated out the back, just like a typical fan pulls air from behind and pushes it forward (Figure 5).

Marine propellers draw or pull water in from the front end through an imaginary cylinder that is a little larger than the propeller’s diameter (Figure 4). As the propeller spins, water accelerates through it, creating a stream of water behind the propeller, which is smaller than the actual diameter of the propeller.

This action of pulling water in and pushing it out again at a high velocity adds momentum to the water. This change in momentum results in a force which called “thrust.”

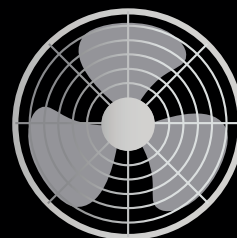


FIGURE 5
Airflow through a fan is similar to water flow through a propeller.

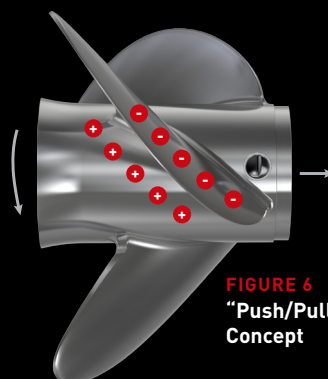


FIGURE 6
“Push/Pull”
Concept



FIGURE 7
VIBRATION LEVEL As blades are added, efficiency and vibration level decrease.

HIGH

LOW

PROP TERMS

ROTATION (“HAND”)

As you may have already noticed, there are two main types of propellers, right-hand rotating (RH) and left-hand rotating (LH). Most single-outboard and sterndrive propellers are right-hand rotation.

The easiest way to determine if a propeller is right-hand or left-hand is to watch it spin on a boat. A right-hand propeller will spin clockwise when pushing the boat forward, while a left-hand propeller will turn counter-clockwise.

Another method is to watch the propeller from a position as shown

in Figure 8. Note that with the right-hand propeller, the blades slant from lower left to upper right when looking at the blade face. A left-hand propeller, however, has the opposite slant: from lower right to upper left.

NUMBER OF BLADES

Technically speaking, single-blade propellers are the most efficient propellers. However, this efficiency comes at the cost of high levels of vibration that most of us would not want to deal with. That’s why most propellers have three blades—a compromise between efficiency and vibration levels. As blades are

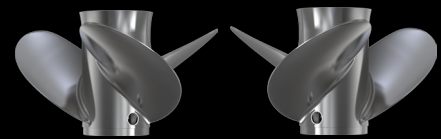


FIGURE 8 Left & Right Hand Rotations

added to a propeller, efficiency is decreased, but the vibration levels also become more tolerable (Figure 7). Interestingly, the efficiency difference between a two-bladed prop and a three-bladed prop is less significant than the vibrational difference.

Recently, four-blade propellers have become more popular because four-blade props suppress the higher level of vibrations and improve acceleration by putting more blade area in the water. They also help make the rake more effective in lifting the bow of a boat, thus reducing hull drag on heavy boats for improved speed.

DIAMETER

You might remember diameter from your high school math classes. When talking about propellers, the idea is similar. Diameter is the distance across the circle made by the blade tips as the propeller rotates (Figure 9).

Diameter is an integral part to the propeller design and must be appropriately matched with the pitch, rake and cup of the propeller to provide maximum thrust and mid-range fuel economy. Mercury's engineering team uses proprietary methods to combine these propeller features, which allows Mercury to offer the perfect propeller for any boating application.

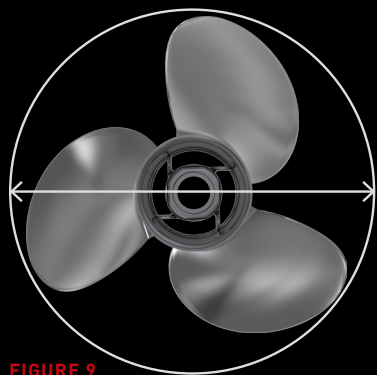


FIGURE 9
Propeller
Diameter

PITCH

Pitch is the distance that a propeller would move in one revolution if it were moving through a soft solid, like a screw in wood (Figure 10).

When a propeller is identified as 13 $\frac{3}{4}$ x 21, it has a 13 $\frac{3}{4}$ inches [35 cm] diameter with 21 inches [53 cm] of pitch. Theoretically, this propeller would move forward 21 inches in one revolution.

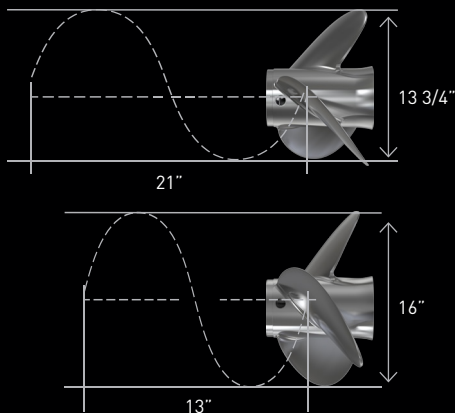


FIGURE 10
Propeller Pitch

Pitch is measured on the face of the blade. Keep in mind, a number of factors can cause the actual pitch of a propeller to vary from the advertised pitch stamped on it.

There are two common types of pitch: constant (also called "true" or "flat") pitch and progressive pitch. Constant pitch means the pitch is the same at all points from the leading edge to the trailing edge. Progressive pitch (also called blade "camber") starts low at the leading edge and progressively increases to the trailing edge. The pitch number assigned is the average pitch over the entire blade.

Progressive pitch improves performance when forward and rotational speed are high and/or the propeller is operating high enough to break the water surface. It is commonly used on mid- to high-horsepower propellers.

RAKE

If the face of the blade is perpendicular to the propeller hub, the propeller has 0 degrees of rake.

As the blade slants back toward the aft end of the propeller, blade rake increases (Figure 11). With standard propellers, the rake angle varies from -5 to 20 degrees. Basic propellers for outboard engines and stern drives commonly have approximately 15 degrees of rake. Higher-raked (high-performance) propellers often have progressive rake, which may surpass 30 degrees at the blade tip.

Rake is either flat (straight) or curved (progressive) as shown in Figure 11.

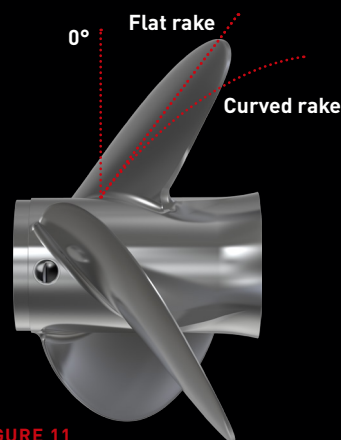


FIGURE 11

A higher rake angle generally improves the ability of the propeller to operate in a cavitating or ventilating situation, such as when the blades break the water's surface. With such surfacing operation, higher blade rake can better hold the water as it is being thrown off into the air by centrifugal force and, in doing so, create more thrust than a similar but lower-raked propeller. On lighter, faster boats, with a higher engine or drive transom height, higher rake often will increase performance by holding the bow of the boat higher, resulting in higher boat speed due to less hull drag.

CUPPING

When the trailing edge of the blade is formed or cast with an edge curl (away from the boat), it is said to have a cup (Figure 14). Originally, cupping was done to gain the same benefits as progressive pitch and curved or higher rake. However, cupping benefits are so desirable that nearly all modern recreational, high-performance or racing propellers contain some degree of cup. Cupping usually will reduce full-throttle engine speed about 150 to 300 rpm below the same pitch propeller with no cup. A propeller repair shop can increase or decrease cup to change the engine rpm to meet specific operating requirements on most propellers.

IMPORTANCE OF CUP LOCATION

Using a round-bladed propeller as an example, if the cupped area is perpendicular to pitch lines, as in Figure 13, it will increase blade pitch. Cupping in this area will reduce rpm by adding pitch. It will also protect somewhat against propeller "blowout."

If the cup is placed perpendicular to rake lines (Figure 12) it then has the effect of increasing rake (see Rake, page 7).

There is clearly some overlap where cup affects both pitch and rake.

In some cases, adding a normal cup has reduced engine rpm by an unusually high number, as much as 1000 rpm. This can happen if an uncupped propeller is running partially "blown out," a common situation that often goes undetected. A partially blown-out propeller has a mushy, somewhat unresponsive feel, and may produce excessive propeller spray. An accurate slip calculation (see Slip, page 9) can be beneficial here. Slip will generally jump from its normal 10% to 15% to more than 20% for a partially blown-out propeller (on average- to-lightweight boat).

FIGURE 12

Cupping along rake lines changes rake.

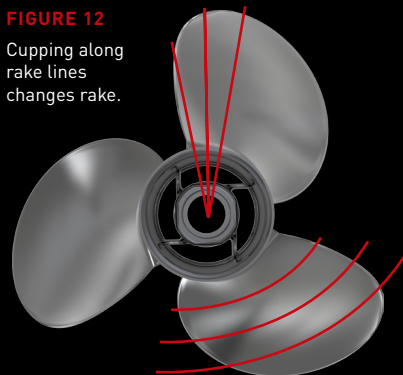
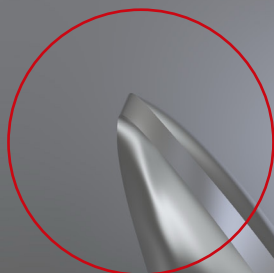


FIGURE 13

Cupping along pitch lines changes pitch.

FIGURE 14
Cupping

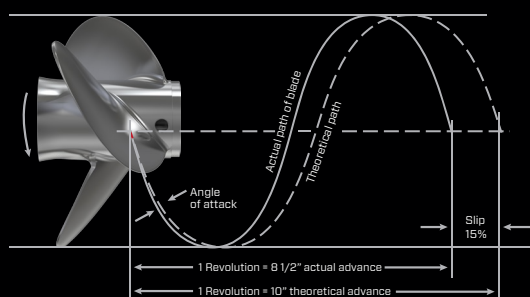


SLIP

Slip is the most misunderstood of all propeller terms, probably because it sounds like something you do not want. Slip is not a measure of propeller efficiency. Rather, slip is the difference between actual and theoretical travel resulting from a necessary propeller blade angle of attack. For example, in Figure 15, a 10" propeller actually advances only 8 1/2 inches in one revolution. Eight and one-half inches is 85% of 10", leaving a slip 15%. If the blade had no angle of attack, there would be no slip; but, of course, there would be no positive and negative pressure created on the blades and, therefore, there would be no thrust.

To create thrust there must be some angle of attack or slip. The objective of propeller design is to achieve the right amount of slip or angle of attack, which is approximately 4, give or take a degree. This is accomplished by matching the right amount of blade diameter and blade area to the existing engine horsepower and propeller shaft rpm. Too much diameter and/or blade area will lower slip but will also lower propeller efficiency, resulting in reduced performance. Figure 4-29 illustrates this point.

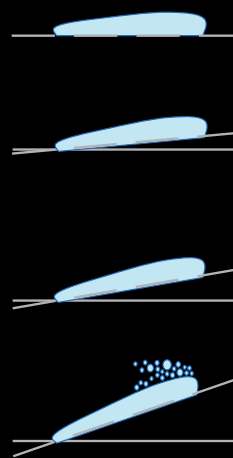
FIGURE 15



SETBACK

Outboard setback is becoming very common in boating. Setback works by moving the outboard engine away from the boat, which changes a boat's center of gravity, allowing it to adjust to any type of water conditions. As the center of gravity is moved aft, higher engine heights tend to be used.

FIGURE 16



No slip can only occur when the propeller is windmilling (boat is coasting to a slower speed or being towed).

Too little slip. Too much diameter for the engine. A wasteful amount of power is used up in blade friction rather than in producing thrust.

Slip is correct. This is the most efficient use of power at the propeller shaft.

Too much slip occurs when the propeller diameter is too small for the power and load. It can also occur when there is too much cavitation or ventilation.

COMMON SLIP BY BOAT TYPES

Fiberglass Fishing	10.3%
Bass	10.5%
Aluminum Fishing	12.5%
Fish & Ski	9.5%
Offshore Fishing	9.5%
Tritoon	12%
Pontoon	20%
Runabout	9.6%
Cuddy Cabin	11%
SD Performance	7.0%
Cruiser	13.8%
Flats	10.1%
Utility	16.1%
Deck	10.7%
Rib	10.3%

MERCURY PROP SELECTOR

Find the perfect prop. Boat performance is equal parts power and propeller. In just four simple steps, our propeller finder will help you narrow down your search to only the best propellers for you. mercurymarine.com/propellers

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