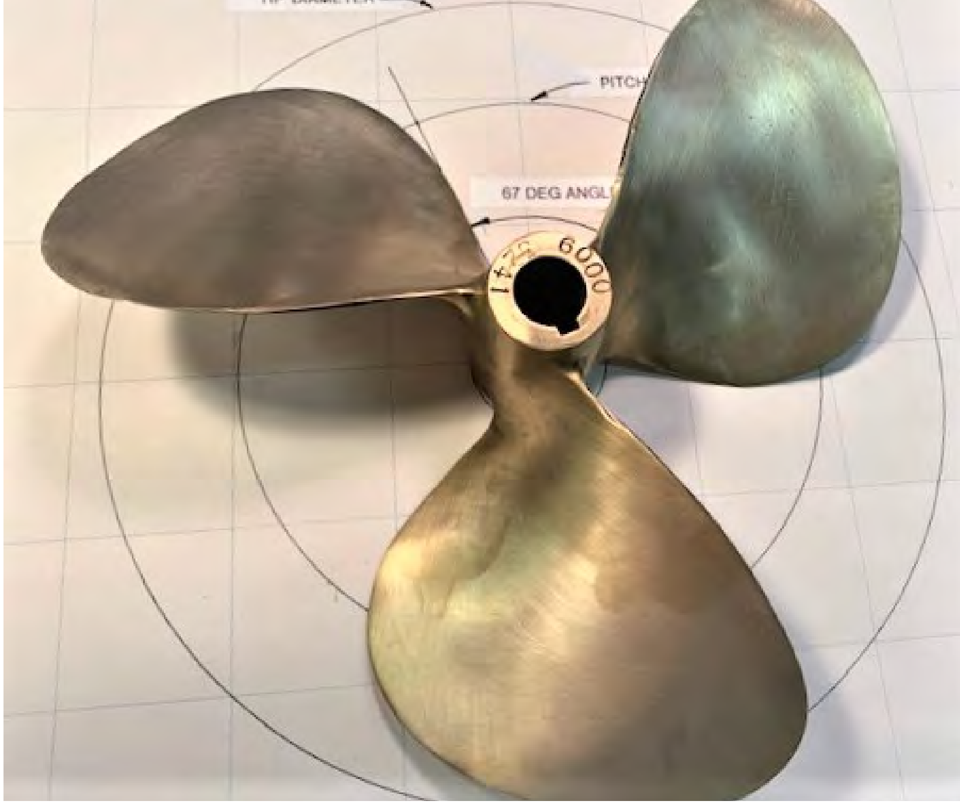

PROPELLERS

By Bill Hancock
Assistant Editor

Editor's Note: As many Sunnyland members know, Bill Hancock is a retired engineer with extensive experience in auto racing, engine design and problem solving. As you read this article keep in mind that you will not be called upon to design a propeller for your boat. Read it to gain an appreciation for what it takes to propel your boat and for you to make an intelligent choice between the various sizes and types available.

Most of our boats have been restored and typically during the process, the power has been increased. Unfortunately, in many cases, the original prop has simply been polished and remounted which means there may be additional performance left lurking under your boat! Therefore, it is important to understand how a prop works as well as how to measure and evaluate it.

At first glance a propeller may be somewhat mystifying, however if you view it as a screw that rotates in the water as it propels the boat, it is really quite simple. The Egyptians started using the inclined plane to build the pyramids back in 2500BC. A spiral staircase, which is simply a circular version of an inclined plane, was found in the Temple of Solomon, built around 1000BC. So based on that concept, a propeller is simply a spiral inclined plane which rotates. Instead of climbing the plane, the plane rotates thus forcing the load up the spiral much like a post hole auger. However, it took until the early 19th century before a Czech-Austrian named Joseph Ressel invented the propeller that we use today.

Let's look at one of our typical propellers to unlock some of the mystery. Propellers have between two to as many as seven or more blades depending on the vessel. Most of our antique boats typically have a common three bladed prop. Optimum boat performance depends on correctly matching the prop to the boat which takes some thought and a little experimentation. The hull design, whether it is a displacement type hull found on a launch or a planning hull found on our runabouts, coupled with the available engine power and the desired speed of the boat, determine the primary requirements for a prop.

Because of the number of variables and the nature of the device, there are no hard and fast rules for overall propeller selection. Once you understand propeller theory, you will be able to make some educated guesses. However, at the end of the day, the experts all agree that the good old-fashioned cut and try method yields the best result. Specialists at the various propeller manufacturers are very good at getting you close if you have a readily recognizable hull and powerplant. Unfortunately, many of our boats as well as their engines, fall outside of the typical envelope.

When determining the operating profile, acceleration, top speed, and fuel economy should be considered. Some users such as water skiers, need a boat which will accelerate quickly and have pulling power while others may be willing to sacrifice some acceleration to gain more top speed. Others may want fuel economy while cruising. When all these factors are considered, it becomes readily apparent that unless you are a

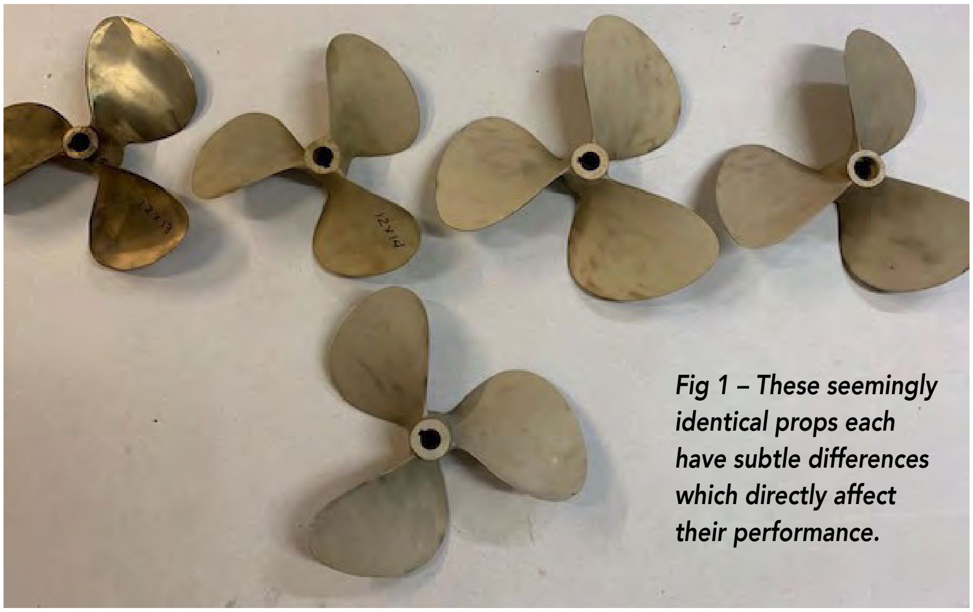

Fig 1 – These seemingly identical props each have subtle differences which directly affect their performance.

prop specialist we will be relegated to trying a bunch of props to find the one which best suits your needs. There is nothing wrong with this time-honored iterative process, and if you are careful and take good notes, you will be able to find the best prop for your boat thus unlocking its true potential.

Since most of us are not starting from scratch but merely trying to optimize our boat's performance, the outside diameter of the prop is typically the first thing one must consider. Due to space considerations, the dimensions of the prop are often defined by the envelope or space available. The vertical distance from the bottom of the boat to the tip of the propeller shaft, as well as the distance from the bottom of the boat to the trailer frame typically determine the potential outside diameter of the prop.

The shaft size is next, and unless we have upgraded the shaft diameter, we are stuck with the original diameter. The diameter of the shaft is determined by the amount of torque produced by the engine. More powerful engines require a larger diameter shaft. Pitch is the second attribute that determines a propeller's performance. Let's look at pitch and learn what it does and how it is measured. Remember that the propeller is in effect a screw, which when turned, moves the boat a defined distance. Pitch is merely a measurement of how far the propeller would move in one complete revolution, assuming there was no slip.

Water is a fluid with a low sheer

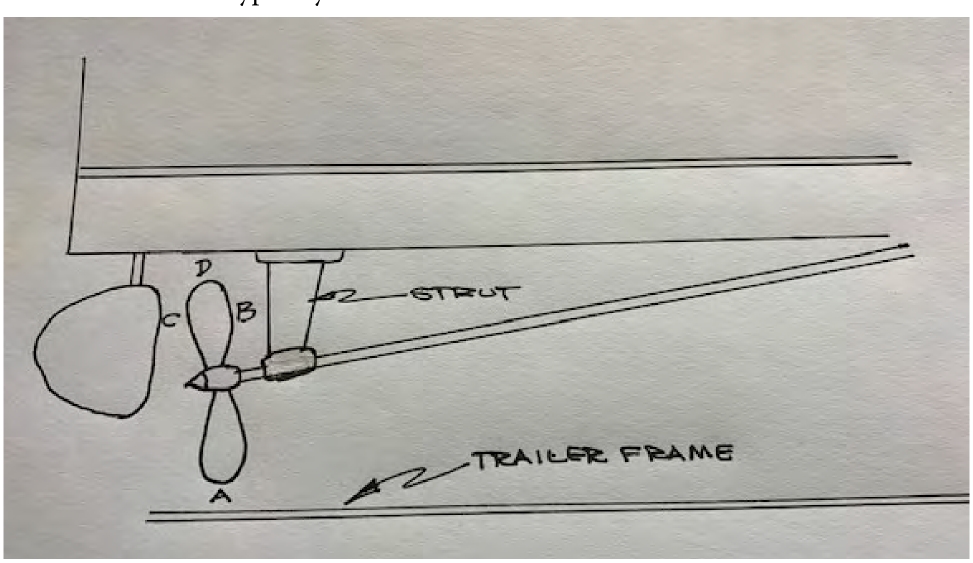

Fig 2 – The propeller size is determined by the space available

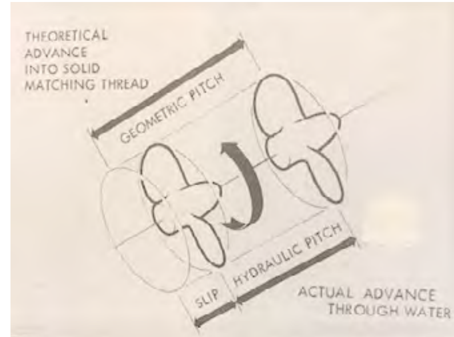

Fig 3 – The hydraulic pitch of the propeller is the theoretical pitch minus the slip.

strength so as the propeller turns, it drives the water past the blades, and in so doing moves the boat forward. If the propeller ran in a sticky viscous substance like molasses, it would have less slip, but since it runs in water, the prop designers typically use between 20-30% slip depending on the blade shape.

The final detail is rotation. Our engines, turn the propeller either clockwise or counterclockwise as viewed from the stern. The easy way to determine your prop rotation is to have somebody watch the propeller while the boat is on the trailer and the transmission is in forward gear. Simply bump the key and watch the rotation from the stern. Do not start the engine! If your propeller turns clockwise as viewed from the stern it is classified as a right-hand rotation propeller. Conversely if it rotates counterclockwise it is said to be a left-handed prop.

Twin engine boats often have one of each rotation, called counter-rotating props, in order to cancel out the effects of torque steer. When shopping for a prop you will need to know five things: rotation, shaft size, diameter, pitch, and blade count. Spending some time matching a prop to your boat can be a

Fig. – 4 The left-hand LH rotation prop is on the left while the right-hand rotation prop is on the right.

TORQUE STEER

Torque is the force associated with twisting. Your engine twists your propeller. And because the engine is attached to the stringers or frame, the boat will move when the propeller spins. Since the engine is firmly attached to the boat, the boat must take the reaction torque which causes it to lift one side and dip the other. You may notice boats running in front of you which lean slightly to one side when underway. When this happens, the boat tends to steer in the direction of the bank angle, hench the term "torque steer". When this happens, the driver gently corrects by applying some rudder to counter the direction of turn, and the boat now assumes a straight-line course. However, this results in an inefficient solution since the boat is running with a slight amount of rudder drag. The better solution is to trim the boat by either moving passengers around to level the boat, or by moving ballast. Most of our runabouts locate the driver to one side or the other. In theory, when running alone, the driver's weight balances the torque forces, and the boat runs level when it is at speed. Idling around the dock, the boat will list slightly due to offset ballasting, since the torque forces are virtually greatly reduced at low speed.

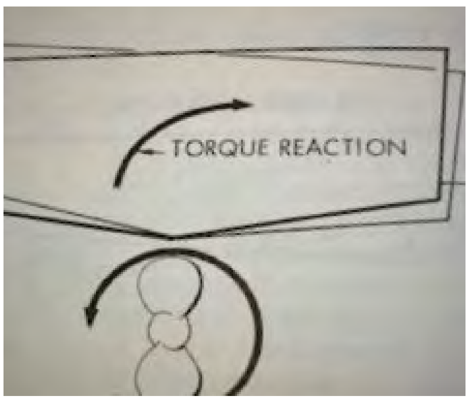

Fig. 5 – Torque reaction

fun exercise for a Sunday afternoon at the lake. In the long run, matching your prop to your boat's requirements will pay some nice dividends.

Fig. 5-Torque reaction

So, where do we start? If your boat has an upgraded engine, it will presumably make more power. When running wide open, if the engine exceeds the recommended rpm limit, consider replacing your prop with one which has more pitch. This will increase the speed of the boat while lowering the rpm and hence reduce the chances of damaging your engine due to over revving. Let's begin by finding out what prop you currently have. If you are lucky, your prop info will typically be stamped on the hub with the diameter and pitch and in some cases even the rotation. Once you have that information, do some research, and find out what prop the boat was equipped with when it was delivered from the factory. Chris-Craft numbered their props with their own internal somewhat generic part number while others simply designated their props with an alpha numeric designation, thus 12x14 LH would designate a 12 " diameter 14" pitch Left Hand rotation prop. Specifications for each Chris-Craft part number are available online. Once you determine the diameter and pitch, call around and see who may be able to loan their spare prop in your rotation, diameter, and shaft size but with a different pitch than yours.

If you don't know the specifications of your prop, follow along as we explain how to measure a prop. Start by getting a large piece of paper. Measure the outside diameter of the hub at the forward end. The forward end will have a larger hole because the shaft is tapered. Make an "X" in the middle of the paper and using the X as the center, use a compass to draw a circle the same diameter as the hub diameter. Place the hub inside the circle so that it is perfectly centered within the circle.

Next, stand up a carpenter's square on the paper and slide it toward the outer tip of one of the blades until it just touches at the largest diameter. Make a mark on the paper at the base of the square. Move the prop and measure the radius "R" of your propeller. (The radius is the distance from the center X to your mark at the tip of the blade.) The diameter is simply twice the radius.

Most of our propellers have progressive pitch which means that the pitch changes as we move outward from the hub out to the tip of the blade. To standardize the pitch measurement on a variety of propellers manufacturers typically measure the pitch of a propeller along a pitch radius circle "r" which is 70 % of the full radius "R".

r = .7 x R where r is the pitch radius and R is the prop radius.

Example: For our example, we are using a propeller marked "12x13" indicating a 12inch diameter with a 13inch pitch. Our careful measurements

Fig. 6 – Place a square next to the blade and make a mark at the base of the square where it meets the pitch circle to locate a line.

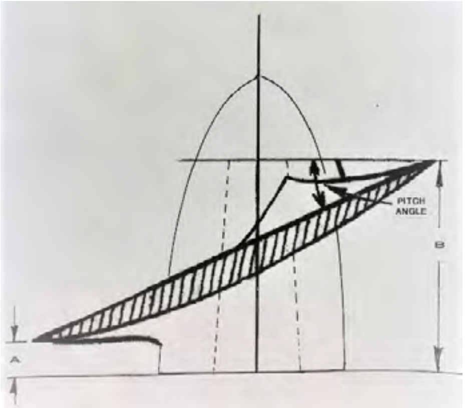

Fig. 7 – The two height dimensions shown, plus the cross section airfoil shape of the blade at the pitch circle

revealed that the true radius is actually 5.625 inches which would make the diameter 11.25 inches. To find our pitch radius, we multiply 5.625 times .7 resulting in 3.938 inches.

Using the compass set for 3.938 inches, draw the pitch circle using the original center at X then place your propeller centered on the X again.

Using a square lined up on the pitch circle, carefully slide it toward a blade until is just touches the lower edge and make a mark on the pitch circle. Repeat this on the opposite or higher side of the same blade and make another mark. Next, using an accurate ruler or machinists scale, measure the vertical distance from the paper to the edge of the blade at each of the two marks. Subtract the smaller number from the

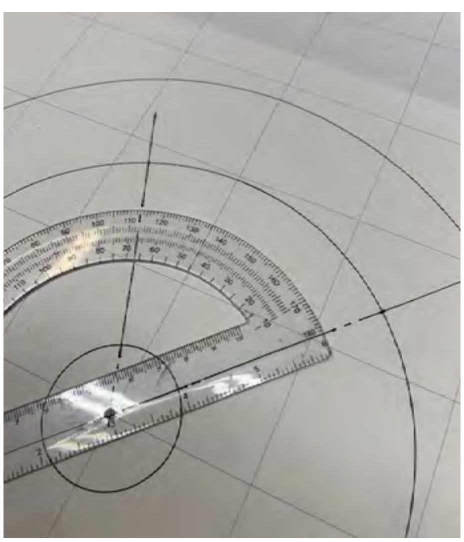

Fig. 8 – Measuring the 67 deg. angle between the two lines formed by the upper and lower parts of the blade

larger number and write it down. Our measurements were .400 inches and 2.550 inches. The resulting number is 2.15 inches.

Remove the propeller and draw a line "A" from the center X to the first mark on the pitch circle, then repeat with line "B" from the second mark. These two lines will form an angle intersecting at the center X. Using a protractor, measure that angle. Our angle is 67 degrees. So now we know that our blade rises 2.15 inches in 67 degrees of rotation. To find out how much it rises in a full rotation of 360 degrees, simply divide 360 deg by 67 resulting in 5.373.

To get the pitch we simply multiply 5.373 times 2.15 inches resulting in 11.55 inches. This means that in one complete revolution, our propeller would theoretically advance 11.55 inches, assuming there was no slip. So, what we have learned is that our 12x13 prop is actually an 11.25 diameter x 11.55 pitch prop! Obviously, it pays to measure your props before drawing any conclusions regarding their performance. So, using the same procedure, carefully measure each of your props and plan a test.

Propeller pitch is often misunderstood. As we said earlier, the pitch of a propeller is the distance in inches a propeller would theoretically move forward in one complete rotation assuming no slip. A typical well matched boat propeller has between 20-30% slip. When you closely examine a propeller, you will notice that it has more pitch in its blades at the hub than it does at the tip. This decreasing pitch is designed to coincide with the increasing radius thus creating what's called a geometrically perfect propeller. If you were to slice through a prop blade along the pitch circle, you would find that it had the shape of an airfoil. The airfoil shape creates lift by creating a vacuum on the top or long side of the shape. Good design practice has determined that the ratio of pitch to diameter should stay between .8-1.5 and optimally be 1.2-1.3, so the aforementioned prop would be 11.55/11.25 = 1.02 which is close to the optimum recommendation, while

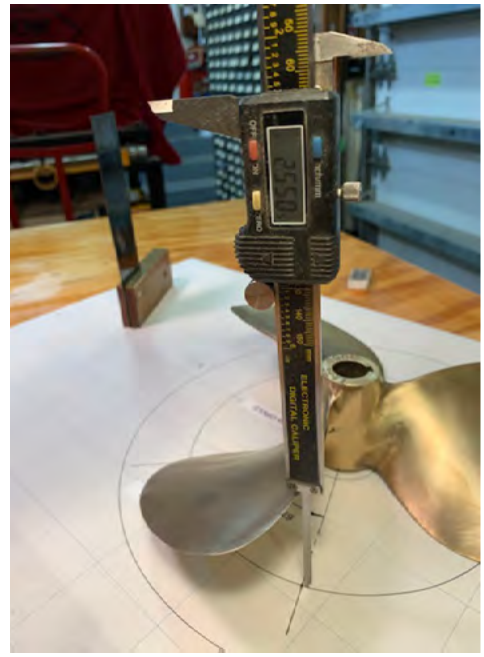

Fig. 9 – Measuring the upper blade height on the pitch circle.

Fig.10 – A three fingered prop puller

Fig. 11 – Be sure to bring a spare square key as well as a few cotter pins.

a 12 x 16 prop would have a 1.33 ratio. Using these guidelines will narrow your selection, however, because there are so many variables, the best prop will always be the one that provides the best performance for your individual boat.

To change your propeller, you will need a prop puller see figs. 2 & 3, and the necessary wrenches. Don't forget the large wrench to remove the prop nut prior to using the puller and have some spare cotter keys and a spare square shaft key of the correct size. I always recommend doing a dry run in your own backyard to familiarize yourself with the process and confirm the necessary tools needed to do the job, before you drive all the way to the lake and try to change props.

Fig. 5-make a mark on the prop pitch line where the edge of the leading and trailing edges of the prop are directly above the theoretical pitch line

Make sure your tachometer is working and take a GPS unit which will give you true ground speed since boat speedometers are notoriously inaccurate. Find a location which has a long uninterrupted straightaway with an easily accessed ramp. Note: Having tried both methods; I can assure you that changing the prop while the boat is on the trailer is much easier than changing it while the boat is in the water.

Find a long calm, straight stretch of water where you can repeat a series of runs at different rpms typically 200 rpm apart in the speed range where your engine likes to run. Note the boat GPS speed for each rpm. Be sure to run each test in the opposite direction and repeat the rpm ranges, then average the two readings to cancel out wind and current effects. Once you have done the speed profile, do some acceleration runs. Start each run from the same speed (5-10 mph), and using a stopwatch, time how long it takes to accelerate from 5mph to 25 mph or higher at wide open throttle. Do these same tests for each propeller you test. It is recommended to make each acceleration run at least three times and average the data to eliminate the lag factor in GPS updates.

It is always fun to calculate the slip rate of your prop for your cruising speed. For our example, assume you are turning 2500 rpm and your two mph readings average out to 21 mph. If we use our 11.55" pitch prop that says that at 2500 rpm we should theoretically travel 2500 x 11.55 inches or 28875 inches in one minute with no slip. To convert 28875 inches per minute into miles per hour, simply divide by the inches by1056, which yields a speed of 27.34 mph, but we know that we only travelled 21 mph, so:

Divide 21/27.34 which equals .768, or 77%

so our prop is 77 % efficient or put another way:

It has a 23% slip factor.

Knowing this, you can compare slip factors for the various props to find the most efficient one. If the rpm is too high and you want to run at a lower RPM, simply install a prop with a larger pitch.

After testing three or four props you will begin to have a much better idea of where your performance lies and how props perform.

If you see little to no improvement, at least you will have become proficient at changing propellers and will have had a good day on the lake. Once you settle on a favorite prop, completely fill your gas tank, and run a known distance of twenty to thirty miles at your typical

Fig. 12 – A mandrel style prop puller that is less likely to damage the hub.

cruising rpm, then return to fill your tank at the same place, then divide the miles traveled by the gallons used to calculate your cruising fuel economy. This will be helpful in the future to determine fuel stops when planning a cruise.

Above all, have fun while improving your boat's performance.