
A Beginner's Manual for Outboard Hydroplane Racing
by John M Adams

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Introduction

I wrote this manual for you, if you are new to outboard boat racing. It is intended to give you a head start in understanding your boat, motor and prop. For a new racer, there is probably too much information here to absorb in one reading. However, it is intended more as a resource that can be referred to when a question arises. It is far from a complete book of outboard racing but I hope it covers the basics in such a way that the new racer will find it useful and helpful in the enjoyment of outboard racing.

Unlike just about every other type of motor racing, you cannot go to an “Outboard Boat Racer Shop” and buy everything you need to race a boat. There are several people who sell some of what you need and many are listed in APBA’s (American Power Boat Association) resources on the Internet.

Boat racers tend to be people who like to make or fix things with their own hands and it shows with the tremendous diversity in boats that you see at a race. The best thing a beginner can do is go to some races and ask a lot of questions. You will find outboard boat racers very friendly and willing to answer questions.

Your first boat will likely be a used boat and that is perfectly fine as long as it is sound. The boat does not make a lot of difference speed-wise, if it is sized right for your engine. Differences in boats show up more in their ability to handle the corners than in their speed in the straightaway.

There are two basic types of boats involved in outboard racing, hydroplanes and runabouts. Runabouts have flat bottoms while hydroplanes have sponsons out front and airtraps along the sides. Generally hydroplanes are faster because they float partially on a cushion of air when moving fast. Many drivers race both types of boats and much of what follows applies to both, but the emphasis is on the hydroplane.

Motors and props are the most important performance items. There are some beginner classes where the motors are sealed and they all are the same (300SS class) and some classes all use the same propeller. These are perfect places for new racers to start. They allow you to learn about racing in an environment where the boats are more closely matched in performance. In the Northwest we have a local class called “Novice C” which is also designed as a starting place for new racers.

Perhaps most important of all are the Junior Classes for kids nine years old and up. These run 15 hp motors with restrictors that lower the power to about 7-8 hp. It is common to find racing families with three generations of racers all participating.

I would like thank Bob Wartinger, Steve Vincent and Janet Adams for their valuable suggestions and skillful editing.

Chapter 1

Hydroplane basics

Hydroplanes are race boats designed to float partially on a cushion of air that is trapped under the hull as it moves swiftly over the water. A typical side view of an outboard hydroplane is shown in Figure 1.

You will see outboard hydros in all sizes and shapes, but underneath they all have a basically flat center section with airtraps on either side starting at the back of the sponson and going to the transom. Sometimes the airtraps disappear at the transom, sometimes they terminate before, and sometimes they still have some depth at the transom.

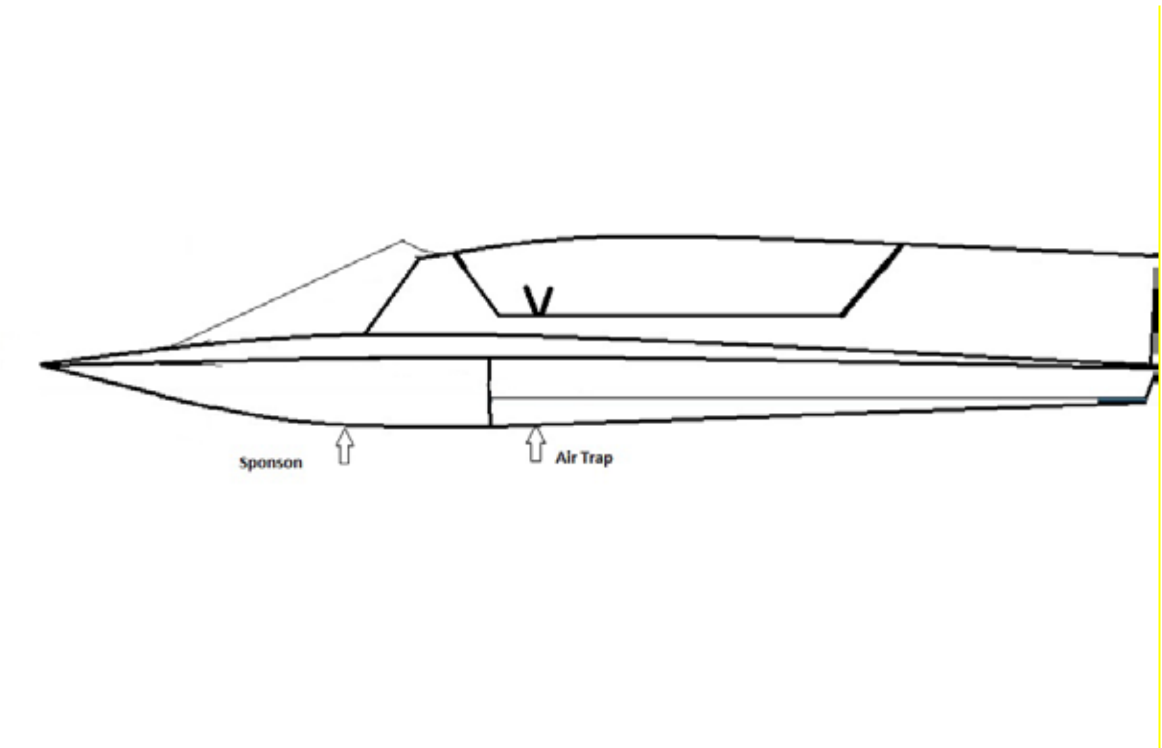

Figure 1. Profile view of typical Outboard Hydro

These variations will be discussed later but for now let's talk about the version where they disappear at the transom. Figure 2 shows this bottom configuration with the rest of the hydro removed. Notice the front where air enters the space under the bottom and is confined by the airtraps. They are called airtraps because as the hydro moves forward, air goes into this space and gets trapped there, causing a lift on the boat. We will talk about how this works and what happens to the air trapped next.

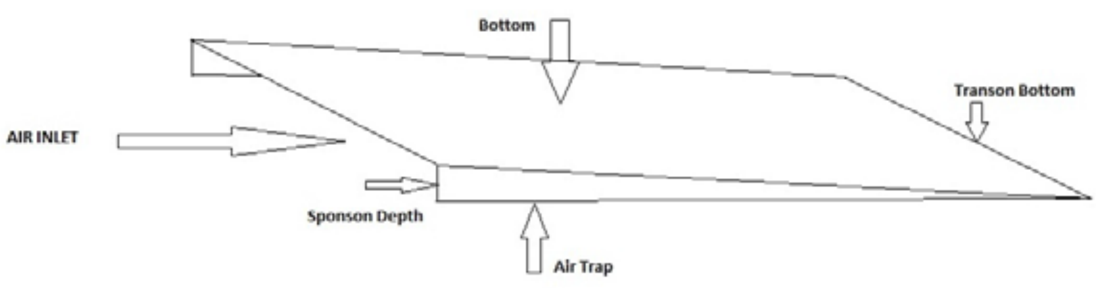

Figure 2. Airtrap section common to all hydroplanes.

When a hydro moves fast enough the sponsons lift off the water. How high will they lift and why? This is a question every boat designer and hydro racer wants to know. If it lifts too high, it is easy to understand that it may not be too good. In the best case the boat will just be acting as a sail, pushing too much air around and in the worst case it may act as a wing… unfortunately an unstable wing. The result is the familiar “blow over” and the driver goes for a swim (Figure 3).

Figure 3. A good example of running a little TOO high. This driver was real wet shortly after the photo was taken.

We can get some insight on how the hydro lifts with Figure 4. Note the air intake section and the air outlet sections. The air comes into the trap area between the sponsons and spills out under the airtraps to the sides. If the sponsons were flat on the water, the airtraps as shown here would not allow a way for the air to exit. At some speed the air pressure trapped in this space lifts the boat, causing the sponsons and airtraps to rise off the water to a height “H” shown in figure 4. As the boat rises the exit area for the air increases until the inlet area and the exit area are the same size. The boat will then ride at this stable point, “H” inches off the water. What follows is a discussion which includes some of the mathematics involved. You may choose to skip the rest of this chapter now and refer to it later as a resource when designing a new boat or fixing a problem with an existing boat.

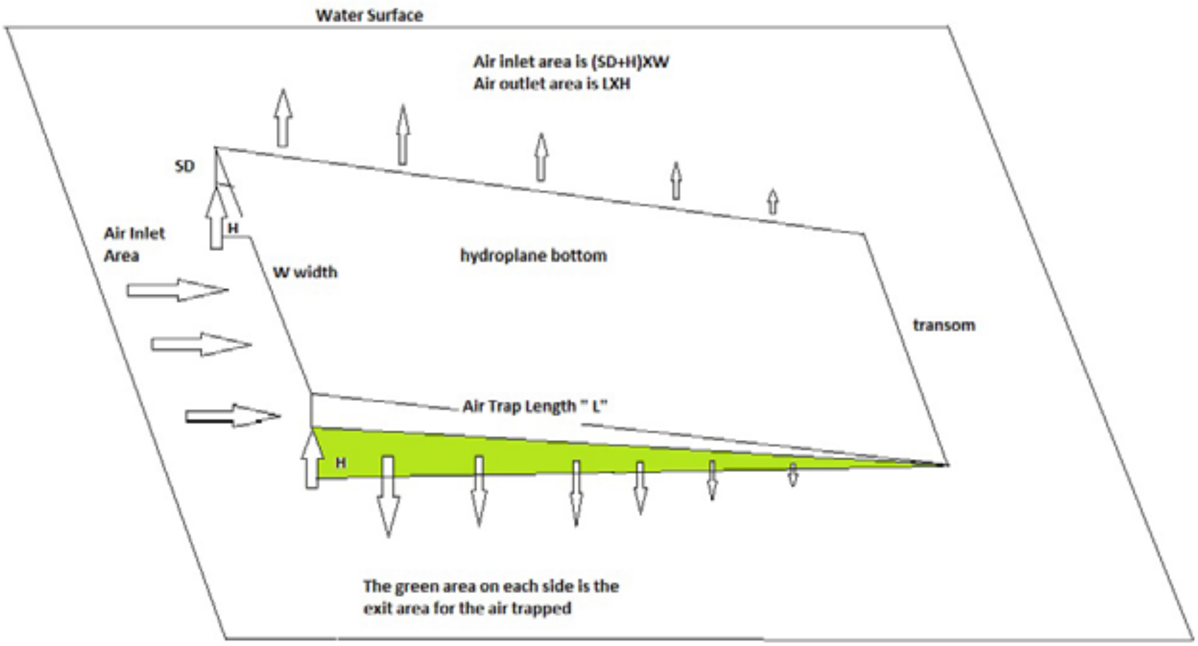

Figure 4. Intake area and exit area for air trapped in the airtrap.

Referring to Figure 4, the air inlet size is the Width X (S.D. + H) so for a 35 inch wide bottom with 2 inch deep sponsons (S.D.), riding 1 inch high(H), the total intake area will be 105 square inches. The exit area will be the length of the afterplane (or airtrap length) times H. Say the afterplane is 65 inches, then the total exit area is 65 square inches when H is 1 inch (the exit area is ½ of 65 square inches on each side).

Since in this example, the exit area is smaller than the intake area, the hydro will continue to rise, in fact to a height of 2.33 inches. Below 2.33 inches the intake area is bigger than the exit area, so the boat rises. Above 2.33 inches the exit area is bigger than the intake area, so the boat comes down. In this example, then, the hydro rides at the stable spot with 2.33 inches of air under the sponson. At this height the intake area is equal to the exit area. Here's the equation you can play with to determine the height "H".

"H"= SDxWidth/(L-Width)

Try the calculation on your boat and see if you are happy with the size of "H". If you are building a hydro, the sponson depth SD, Width W, and afterplane L are all within your control as a designer/builder. If you have a boat already, about the only thing you can do is cut the depth of the airtraps (SD) down to lower the hydro or build them up if it rides too low. Playing with the equation for “H” will give you a rough idea of how much to add or cut. Of course there is more to it than this but this is a good starting point for understanding the hydro.

How high should “H” be? Every racer will have an opinion and it will be based on how the boat handles in the straights and in the corners and how it accelerates out of the corners. All this is a matter of personal choice. However, the drag force of a boat moving through the water is lowest at 3-4 degrees angle of attack. So given our 65 inch afterplane boat in this example, an “H” of 1.4 to 2.5 inches is ideal. Our calculated “H” above at 2.33 inches is in the correct range.

How much lifting force is created by the air trapped? Not as much as you would guess, but still a real force is generated lifting the boat. The pressure under the boat will be variable but we can estimate the maximum pressure. And by applying that number to the size of the bottom, we can get an approximate number for the lifting force of the air trapped. The maximum pressure will depend on the speed. See the table below for air pressure at different speeds. Because the actual air pressure created depends on air density, it will vary somewhat from this table with altitude and temperature. But this chart gives some good general numbers for air pressure at various speeds.

Speed	**Air pressure**
50 mph	**0.044 psi**
60 mph	**0.063 psi**
70 mph	**0.086 psi**
80 mph	**0.112 psi**

So with this information, let us get some order of magnitude of the lifting force on the airtrap area of our theoretical boat with a 35-inch wide bottom and 65-inch afterplane. This boat has 2,275 square inches of area under this airtrap section (36x65). This is a surprisingly large area, so you can see that a tiny increase in air pressure (psi= pounds per square inch) will create a real lifting force and that is what happens.

At 60 mph there could be as much as 143 lbs. of lift on that area of the boat (0.063 psi X 2275 sq inches)! The same boat going 70 mph could have 195 lbs. of lift force from this area. You can see from the chart that the faster the boat goes the more lifting force we get from the air in the airtrap space. The actual lift will be less because air is spilling out under the airtraps, but there is enough lift to at least raise the front of the boat.

Such a race boat would have a required weight of about 350 lbs, so the air under the boat is not doing all the lifting! Something else is providing about 200 lbs. of lift to keep this boat on a plane (skimming on the water surface). Some lift comes from the top of the hydro as well because it has a wing shape, but it is generally accepted to be a small number at these speeds.

The rest of the lift comes from the wetted planing surface of the boat. We all enjoy those photos of our hydro completely aired out with only the prop in the water and the boat flying like an airplane (Figure 5). However, let’s get real. They do not do that except when they launch off a wave and fly long enough for a fast camera shutter to get the “money shot”.

Look closely at most hydro photos and you will see the last 12-18 inches firmly planted in the water. This part of the hull is planing and thus lifting the remaining weight of the boat up so it rides on top of the water. The speed and water at the wetted surface is providing between 1/3 to ½ psi of lift on the rear of the boat in our example. The wet area 630 sq. inches (18x35) at 1/3 psi water pressure can generate 207 lbs. of lift. So the forces lifting the hydro are shared by the air and the water. Hydros will find a balance point depending on their size, weight and speed. The higher it rides (bigger "H") more lift will be from air and less from the water. As a racer, you want to find the optimum where you can go as fast as you can with the power you have available.

Figure 5. We all like photos like this but hydros really do run with the rear in the water most of the time.

If you ran the calculation of "H" for your boat, you may have noticed that it actually flies higher than the calculated "H." This is generally true because that last 12-18 inches of the hull are actually in the water and the length of the afterplane (for the purpose of calculating the size of the area for air to spill out) is shorter by 12-18 inches. If we shorten the length of the real afterplane by the amount touching the water, the new calculated "H" will be 3.9 to 5.8 inches for our example boat! This may seem more realistic based on photos of you in your boat.

Figure 6 shows the effect of the wetted area of the boat and how the effective afterplane L is shorter than the afterplane. One way to tell how high you are riding in your boat is to watch the spray off your turn fin in the straightaway run. You can measure how deep your turn fin is and if there is no spray, you know you are riding at least that high or higher.

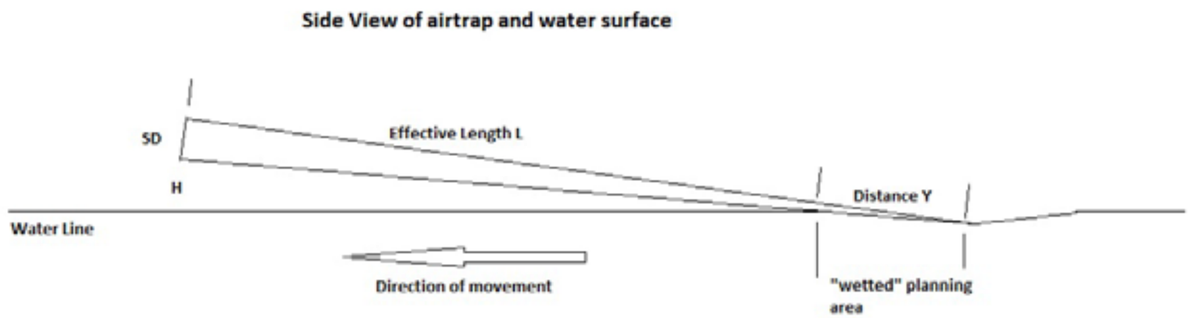

Figure 6. Wetted area changes effective "L".

Another way to lower "H" is to kick the engine in. A kicked-in engine lifts the rear, reducing the wetted area and increasing effective length of the airtrap, thus lowering H. There is probably a trade-off between engine angle and speed and handling. Is power better used to lift the rear or motivate forward? Questions like this can only be answered on each boat and by each driver's personal preference.

In the next chapter we talk about drag force and angle of attack, which helps to understand why "H" is such an important parameter for a hydro racer.

What about the term "Lift"? Lift is a measurement from an imaginary straight line from the bottom at the transom to the front of the boat center. Figure 7 shows the lift measurement is between the imaginary line (blue line) and the bow of the boat, usually a couple inches. High-powered fast boats have very low lift while slower, lower-powered boats may have 1-3 inches. High lift tends to raise the bow sooner as the speed increases. A boat with too much lift will fly high in the front and be difficult to lower by moving your weight forward. Cutting out airtrap area usually helps this problem. Many boats have an S shape in the bottom, usually starting near the rear of the sponson. As the S shape is moved further back, a hydro will be more sensitive to driver position—and some say, more like balancing on a "teeter totter".

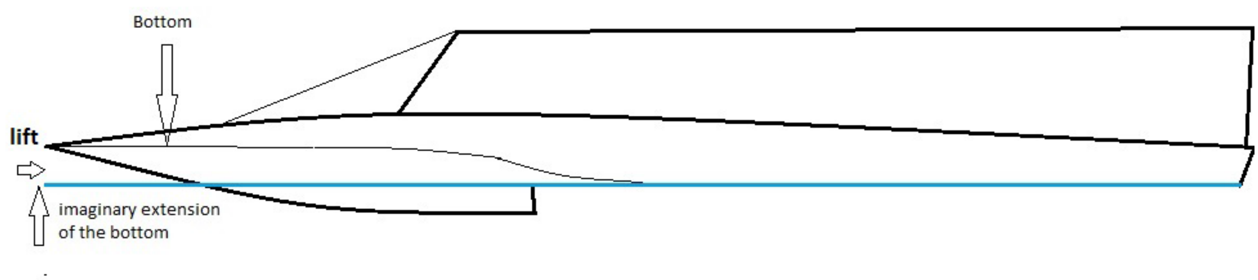

Figure 7. Lift.

Overall boat size is related to the power used and subsequent speed. As the power increases, so does the boat size. Figure 8 shows three typical hydros. The bottom boat is an 11 ft C Mod Hydro, the Middle is a 10 ft 25XS hydro and the top boat is an 8 ½ ft A/J hydro. The speed range is 75mph to 50mph (35mph in J).

Figure 8. Various hydro sizes: J/A on top to C Mod on the bottom.

Chapter 2

Angle of Attack and Drag

Angle of attack is the angle the flat part of your boat makes with the flat water surface. There is an optimum angle where the drag is the lowest.

Drag is a measure of the force it takes to move through the water. The motor generates a force to move you forward and drag generates the resistance to that force. If the drag is low, that is good and your motor will make you go faster. For example, the worst case drag is a flat surface at 90 degrees with the water. This is like pushing a flat board or paddle through the water and we all know that is not easy.

Surprising is the fact that a flat surface at 0 degrees (level or even with the water) sliding over it is not the lowest drag! This is probably due to the large surface area dragging in the water. It turns out that the lowest drag is at 3-4 degrees angle of attack. You can search the Internet on marine design and will find this angle repeated many places.

So when you see a hydro with the bow real high, packing 12-18 inches of air, you know it is not going as fast as it could. Actually, for two reasons—the angle of attack against the water is greater than 4 degrees so the drag with the water is high, and it is pushing a huge amount of air out of its path as well. So a large portion of the force generated by the motor is spent pushing air and water aside instead of making you go faster. Ideally, you want the amount of air being displaced to be as small as possible and to have your angle of attack with the water to be at 3-4 degrees.

Drag has another interesting aspect for boats and airplanes. It goes up dramatically with speed; the drag force increases with speed squared. This means the drag will increase 4 times if you double the speed. So a 7 hp J motor can make a boat go about 30 mph, but in order to go 60 mph it takes a lot more than double the power. So, as a racer, you want to keep drag as low as possible. That means “H” or your angle of attack is very important. Another interesting point is the water drag force is several hundred times more than the air drag force.

Next we will discuss more things that affect angle of attack. The depth of the airtraps at the rear of the boat will affect the angle of attack. Deep airtraps in the rear tend to trap the water there, making it more difficult for the water to be displaced as you go by. Figure 9 shows a rear view of an airtrap. The depth here lifts the rear and changes your angle of attack.

Figure 9. The rear view of a typical left airtrap.
This one is about ¼ inch deep at the transom.

Figure 6 showed the wetted surface Y; and deep airtraps can shorten Y and cause less depth of penetration into the water surface. I think they tend to act similar to the effect you would see if you had denser water. The APBA has a specification on the maximum depth allowed. Deep airtraps can have a stabilizing effect, kind of like an extra rudder, and the size effects how your boat handles in the turn and the straights. Since deep airtraps at the rear have more surface area there will be an additional drag element associated with them as well.

What is best is, again, an individual preference. Look around the beach and you will see every possible combination of airtraps or traction rails at the rear of the bottom. If you are having handling problems with your boat, the airtraps are a good place with which to experiment.

Earlier I said the weight of the boat was only partially lifted by air pressure within the airtraps. The rest of the weight—actually most of it—is lifted by displacing the water at the wetted surface. You will hear that deep airtraps allow the air to lift the rear; this is not so. The air pressure is just not high enough to lift the rear but the water pressure is. Deep airtraps do make the rear sink less deep at speed and they change the angle of attack, but they do not lift it out of the water on a layer of air as is commonly believed.

Each class has a weight requirement where the driver, boat and motor must weigh a minimum amount at the end of the race. After the race you may be called to inspection where you and your boat will be weighed. Most drivers need lead to meet the weight requirement. You want to have enough lead added to your boat to meet the minimum weight plus a pound or two for good measure.

Your lead must be fastened to the boat. I recommend that it be bolted down. One time at the Nationals we were running in 2nd place in the finals and our lead was screwed down with wood screws. This seemed good enough but it was not. The lead came loose and, while bouncing in the back of the boat, it punched a hole through the hull on the last lap and we did not finish! Now we always use bolts!

Another time while I was an inspector, a racer came in and weighed one pound light. I DQ'ed the racer who was very upset at me because "What difference could one pound make?" I responded, "None, so add two pounds to your boat and be legal." It is a lot more fun for you and the inspectors to be legal on weight. Since race officials use different scales from one race to the next, always weigh your setup before the race.

When adding lead, where should you put it? You want the boat to be balanced about the center position of the driver in race attitude. For a very new driver, I would advise evenly spacing the lead on the floorboard under the driver area. Drivers will learn to move around the boat to control its attitude as they gain experience. Once that experience has been gained, many drivers like the lead at or near the transom so their body weight gives them maximum control of the boat attitude (angle of attack). Many believe the sponsons will lift off the water coming out of the turns faster with the lead rearward. Having the lead forward and evenly distributed for a new driver will dampen the response of the boat and tend to keep the front or bow lower.

Chapter 3.
Props, Pitch, Gear ratio, RPM

Most experienced racers will tell you the most important thing in successful racing is your propeller. They are correct. I cannot tell you what to look for in a good propeller—only you can determine what works best on your boat and motor. People usually talk about how fast their prop is (they usually are stretching the truth as well) but the fastest prop oftentimes will not be the one that will win you races. A fast prop is like driving your car in high gear. In a long straight line it can work pretty well, but on a short course with tight turns it can be a poor choice and load the engine down! Oftentimes a prop that may not be the fastest can win races for you if it accelerates well and gets you through the corners well. You have to test and write down what you learn and then apply that information to racing.

As you look around the beach you will see props of all blade shapes, but in general there are two kinds; cleavers with straight backs to the blades, and round blades. Neither one is definitely better than the other. The best one comes down to personal choice.

Some cleavers when set high will make the back of the boat walk in toward the center of the race course. This can be a big surprise the first time it happens to you.

Also, props come with 2, 3, 4 or more blades. Certain classes will limit how many blades you can have, so check your rule book. The blades of the props also come in low rake and high rake. This means they are either perpendicular to the prop shaft (90-80 degrees) or they are laid back further in the high rake versions (80-75 degrees) from the prop shaft. High rake props will tend to lift the bow of the boat more than low rake props. Again, this becomes another personal choice item, and what works best may depend on the boat design. For example, if your boat rides high in the front with a low rake prop, you probably will not have much luck putting on a high rake prop; but vice versa, the high rake prop may help a low riding boat. The funny thing about props is that there is almost nothing that we can say about them that is certain (maybe you already detected that ☺).

I can teach you some propeller basics that you can use to help gather information about your prop. With this basic information you may be able to explain to yourself differences in performance that you see while testing different props.

Propellers are measured in "Pitch" inches. The pitch of a blade is equal to the distance that blade will move forward when turned 1 revolution in a solid material. So let's say for example we have a 10-inch pitch prop and we turned it one revolution in something like Jello where there is no slip like you can easily imagine happens in water. A 10-inch pitch prop will move forward 10 inches with that single turn. OK, now you are going to ask, "How fast will that 10-inch pitch prop go?" To answer this we need some additional information and we need to make one big, yet reasonable, assumption. That assumption is that there is no slip. It turns out that in hydroplanes there is not much slip, so to get a first order answer we are going to assume it is zero slip.

How fast we go will depend on how fast we are spinning that prop. To know this, we need to know how fast your engine is running, or the RPMs (revolutions per minute). Let's assume we have a Yamato that runs 6900 RPM at the end of the chute and we want to guess how fast this 10-inch pitch prop will go. We need to know the gear ratio, because the prop turns slower than the engine. In most Yamatos, the prop speed is 93.3% (14/15 gear ratio) of the engine RPM. So the prop is turning 6438 RPM when the engine is at 6900 RPM. Therefore, each minute it moves 64,380 inches forward (6438x10). In an hour it moves 60 times that or 3,862,800 inches.

A mile has 5,280ft X12 inches = 63,360 inches. So in an hour this engine and prop will go 3,862,800 inches/63,360 inches/mile or 60.966 miles or more simply 61 miles/hour. This calculation can be simplified to speed in **MPH = RPM X Pitch X Gear ratio X 0.000947**.

If we want to go faster, there are only two things we can change in this example. We can make the engine run at a higher RPM by getting more power some way and/or we can increase the pitch. In this example, if the pitch were 10 ½ inches and the RPM stayed the same, we would be going 64.1 mph! You can quickly appreciate now how important pitch is! However, often when you increase the pitch, the maximum RPM will drop because it takes more hp to spin it. To get a good understanding of racing propellers, you need speed and RPM data when testing. The gear ratios for some common motors are listed below. You can find this information in APBA's spec sheets for your particular engines. In the old days more than one gear ratio was legal on some motors.

Yamato102/302   14/15 = 0.933

OMC   14/19 = 0.737

Merc Bs and 25xs   16/21 = 0.762

This is all nice and simple except props don't come in a nice 10-inch pitch like my example. Real props have a generally low pitch at their leading edge, and get higher in pitch as you move from leading to trailing edge, 9 inches to 13 inches for example. So now we are getting into the "mystery" of propellers. What pitch props do you have? They are never marked this way. Sometimes they have a stamp on the hub that may say "11" or "12," for example. But if you measure it you will find it is all over the place like my example, 9-13 inches; and worse yet, each blade can be slightly different.

How do you know the pitch of what you have in your prop box? Some guys just test them on the water and keep good records. For me, I want to measure the prop's pitch and I keep performance data on each. To do this you need a pitch gauge that measures pitch anyplace on the blade and tells you in inches what the pitch is at that spot. In order to do this the pitch scale or reading scale must be set at a specific radius out on the prop. If your pitch gauge is not set to read at specific radii, it is not accurate and the numbers cannot be used in the calculations I have made here.

Adams Racing (me) sells a pitch gauge that is accurate at 1, 2, and 3 inch radius (Figure 10). Once you know the pitch of the blades you can begin to understand why some props work better than others. High pitch numbers are like "high" gear in your car and low pitch numbers are like "low" gear. One is faster; the other accelerates harder. Once you have mastered reading pitches and can always pick the best prop, you will be able to write a book and make a lot of money. The number of blades, blade area and blade diameter also affect performance. Testing and recording speeds and RPM are very important to developing a good understanding of your props. Understanding props is a life-long challenge for racers ☺.

Remember, the single most important thing in boat racing (besides having fun and staying safe) is the propeller. It is also the least understood ☹.

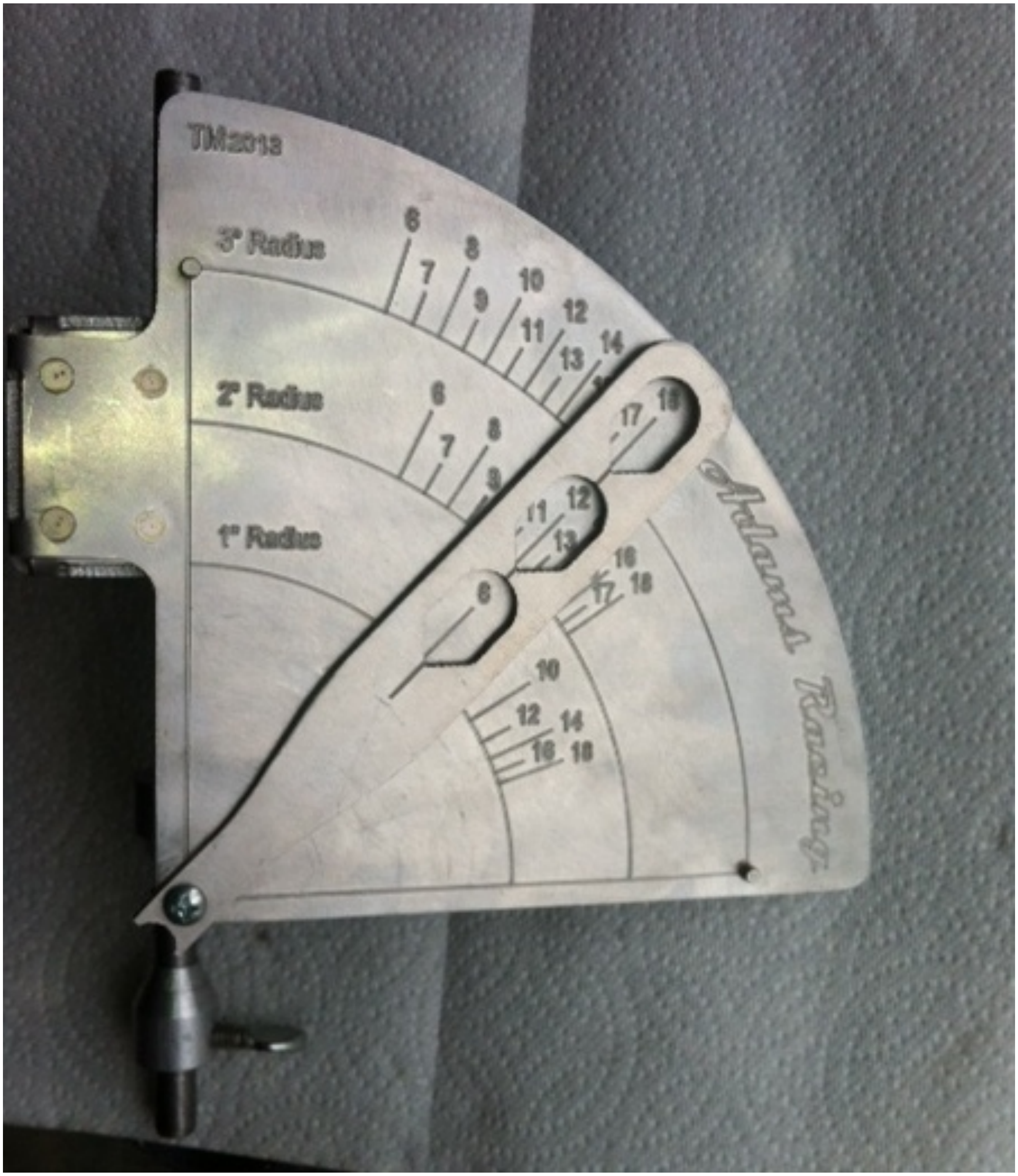

Figure 10. Adams Racing Pitch Gauge. Notice that the pointer angle shows pitches of 6, 12 and 18 inches depending on the radius being measured.

What is the most important part of the propeller? This is another question where you will get every answer under the sun. But let me give you some information about area of work being done by a propeller. The propeller pushes you forward by pushing an area of water backward. The outer part of a prop blade covers a bigger area or pushes more water than the inner part of the blade. Look at Figure 11 for an example. A prop 7 inches in diameter is divided into 1-inch rings. You can see that the area of water pushed by the outer 1 inch of the prop is 49% of the total area while the 1.5 to 2.5 inch area is only 33%. So, most of the work is being done at the outer radius of the prop.

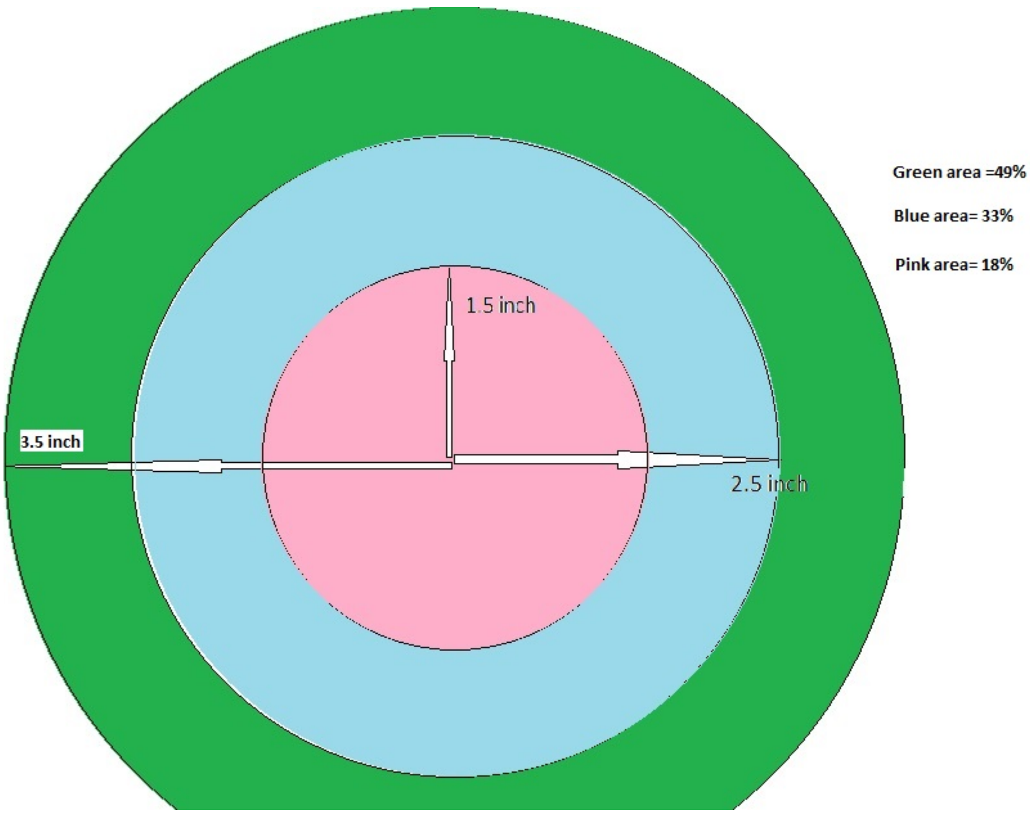

Figure 11. A 7 inch diameter propeller area chart.

How do I make a “quick change” to a prop? It is not uncommon to see an old guy at a race take a brass or dead blow hammer to a prop placed on his trailer ball! All kinds of stories are told about the prop that set a record or won a race after an owner made a few whacks on a trailer ball. Be careful if you do this and make small changes rather than big ones. Remember, you could make the prop better or worse doing this ☺

Chapter 4.

Engines, Gas and Oil, Restrictors, Tuning

As of this writing, all racing engines are two-cycle. This likely will change in time, much as it did in motocross racing. Four-cycle motors are generally heavier and develop less power for the same displacement.

Stock Outboard racing is supposed to be “stock” but that is virtually impossible to control unless engines are sealed. By “stock” we mean as originally produced without modification. APBA also has a sealed engine class called 300SS where the engine has a seal that cannot be tampered with without showing evidence.

You will notice in racing that some motors are faster than most others. There are many reasons for this, but it may be as simple as the owner just got lucky and got a fast engine from the factory (not the usual case, but it does happen). More realistic is the motor has been “blueprinted” by an engine builder to be the best possible in each area specified. New racers will be frustrated by this, but in time they will learn the tricks of the trade and will know the good builders to take their motors for a tune-up. There are so many different motors that it is beyond this book to even attempt to tell how to “soup up” a motor. The term “blueprinting” goes back to the days when specifications were printed with blue ink. It basically means that an engine is modified to the maximum limits allowed in the specification sheets (which no longer use blue ink). There are classes where modifications are encouraged but still limited in scope. This is called the Mod Division. There are also PRO classes, where about the only rule is bore and stroke in an engine.

There are some generic engine things to know, however. The simplest thing a racer can do is to make sure your engine is tuned properly. This involves things like spark timing, spark plugs, carb setting or jet sizes, gas/ oil mixture, etc. If you take a stock engine and tune it perfectly for a day of racing, you probably will have an advantage over half the boats on the water which are running in less than perfect tune. If you have a 0.2% speed advantage in a typical 3-mile long race among 60 mph boats, you could win by four boat lengths! So a very tiny advantage can make a big difference in racing.

Tuning can get very technical but there are basic things you can do if you do not have access to weather stations, computers and Dynos or load cells. Probably the easiest thing to do is to “read” your spark plugs. The color of the plug will tell you a lot about your carb jet setting (gas to air mixture). A perfect setting will yield a nice tan-colored spark plug after it has been raced. It takes a new plug a couple of races to color properly. Too rich will be dark, or black and oily; while too lean will be dry and white. By too rich, I mean the jet size is too big and your ratio of gas to air is too large, so you are putting too much gas in the engine. Rich settings tend to start well and seem to run pretty good so you can be fooled into thinking it is OK. An engine running too rich will not develop as much power as a properly jetted engine. Too lean means there is not enough gas; i.e. the fuel jet is too small.

Some engines like the Yamato have an adjustable jet with a needle valve. Turning it in (clockwise) causes it to lean and turning it out (counterclockwise) causes it to richen. When an engine runs lean it also runs hot—and often too hot. They generally start hard but run faster lean, and then better leaner, and then they “stick”. I have heard it said many times, “It was <u>really</u> running good just before it stuck.” When an engine sticks it can be bad. The piston and rings get so hot they stick in the cylinder and the engine stops suddenly! The rings are usually shot afterward; the piston is often shot as well. Sometimes the cylinder is hurt as well, but less often than the rings and piston. This situation can be avoided by always checking your plugs for proper color.

You may ask, “Why do I need to check the plugs after I get it jetted properly?” The reason is that the proper jetting can change at every race for reasons beyond your control. The proper jetting depends on the amount of oxygen in the air, and the air changes. The biggest change is something called air density. If the air is dense, there is more oxygen to make power and you need more gas to have the correct ratio of fuel to air. Cold air is denser than hot air. Humid air is less dense than dry air (counterintuitive, I know).

Air density is very dependent on the altitude of the race site. Low altitude sites have denser air. So on a hot, humid day at 2000 ft. altitude you need a smaller jet than a 50-degree dry day at sea level. The cool air at low altitude will have more oxygen in the air to burn; so the engine will be more powerful and, if tuned properly, will make you go faster. This is why so many records are set at places like Lawrence Lake at about 400 ft. elevation in the Fall or Spring when it is cool. Below is a chart showing basically how air density can change from the most to least dense situations. For simplicity I did not include humidity, which has a smaller effect than temperature and altitude. 100% air density is dry air at 59 degrees at sea level.

Temperature	**Altitude**			
Fahrenheit	**Sea Level**	**1000ft**	**2000ft**	**3000ft**
50	**101.5**	**97.9**	**94.4**	**91.0**
60	**99.6**	**96**	**92.6**	**89.2**
70	**97.7**	**94.2**	**90.8**	**87.5**
80	**95.9**	**92.5**	**88.2**	**85.9**
90	**94.1**	**90.8**	**87.5**	**84.3**
100	**92.5**	**89.1**	**86**	**82.8**

Table 1. Air density % as a function of temperature and altitude above sea level (0ft)

So you can see you get a lot less air (14% less) on a 100 degree F day at 2000 ft altitude than a cool day at sea level. Therefore you need to jet properly. But even with that, you will be way down on power on the hot day, as will all your competitors.

Besides proper jetting you can also adjust your oil ratio. Your engine does not burn the oil mixed in the gas, but the oil displaces the gas, so decreasing the oil increases the gas amount and raising the oil lowers the gas. This is an easy way to fine-tune between jet sizes if needed. Be careful to not go too low on oil or you may stick your engine. Speaking of gas, I always used low-test gas or low-octane gas. The reason is there is no more energy in high octane and it costs more. Many believe high octane gas burns slower than low octane but experts say it burns at the same speed, just that high octane does not knock in high compression engines. In a 2 cycle engine the compression ratio is low and high-octane gas is made for 4 cycle engines with high compression ratios.

Of course your gas must be alcohol free per the rules. Alcohol has less energy than gas, so you do not want it anyway. The farm stores usually have alcohol free gas or ask around, you will find a local source or check here:

http://pure-gas.org/index.jsp

Also, airports sell alcohol free gas but it is usually 100 octane and expensive.

Figure 12 shows the location of the main jet in an OMC A engine. This is typical of carburetors with fixed jets. They are usually brass and can be purchased in a large variety of sizes (openings). They are removed with a flat screwdriver. Figure 13 shows a typical Yamato carb with adjustable main jet being the large knob below the carb.

Figure 12. OMC A carb with float bowl removed. The brass jet is located on the top and another jet is shown on the workbench.

Figure13. A typical Yamato carburetor. Main jet adjustment is performed with the large knob. IN is leaner, OUT is richer.

Another tuning item to check is spark timing. This is a little more difficult to do properly, so you may want to seek the help of an old-timer. Generally, once you set the timing you will not have to fool with it from race to race. Timing is an adjustment of when the spark plug fires as the piston is compressing the fuel air mixture. The spark plug preferably fires before the piston reaches top dead center (TDC) since it takes a certain amount of time for the fuel to ignite and heat up the air in the cylinder. You want maximum pressure to occur just as the piston moves from compression to the expansion stroke. The exact best timing for your engine is probably best determined by the manufacturer, but each racer will have a strong opinion as well. I have found it does not seem to be a critical adjustment unless it is way too early or way too late. If it is way too early, it will fight against you when starting and can pull the rope right out of your hand! When this happens, it usually means the key on the flywheel has been sheared off and it has slipped. Normally this only happens after the motor went into the water while running—not good for many reasons ☺.

Can you win with a stock engine? Absolutely you can if it is tuned properly. Like I said earlier, if your engine is properly tuned for the conditions of the race day, you will have an advantage over a good number of your competitors whose engines are not. I no longer race; but when I did I was very competitive and set several records at Lawrence Lake, and every one of those records was set with a box stock engine! However, sadly, today it may be more difficult to set records with a box stock engine.

Not cooling your engine properly is another way to ruin your day by "sticking" it (getting so hot it stops suddenly). For most engines with water pumps, this is not an issue. But with a Yamato, one must always be concerned if it will cool adequately. Props, engine height, kick-out angle and water conditions all can affect cooling. If you stick your engine due to lack of cooling, change something or it will keep happening. Usually, you will see lower compression after sticking your engine and that is not so good. Many race with a CHT (cylinder head temperature) gage to help them avoid overheating.

Restrictors are plates that go between the carburetor and the intake to "restrict" the amount of air an engine can get. This is an easy and cheap way to lower the power and slow down an engine to make it fit into a slower class. Generally, adding a restrictor can change the optimum setting for the jet, so one must experiment to achieve the best performance with a restricted engine.

How do you experiment with an engine? The easiest way is with a test wheel. A test wheel is a plate of some sort that you put on the prop shaft instead of a prop in order to load your engine. If the load is well matched to the engine you can run the engine wide open in the water and watch the RPM while you tune the engine for best performance. Talk to your fellow racers to get the right test wheel for your engine. Fluted test wheels are the most common, but sometimes they cavitate, making it difficult to get steady readings. I personally have much better luck with flat disc test wheels (see Figure 14). Find out by asking friends what the RPM is for best power is for your engine. Generally it will be between 6000 and 7500 RPM. The Yamato spec says 6600 RPM for a 302. When testing on the beach with a test wheel load, you find the best jet by looking for the one that gives the highest RPM and accelerates well. Test wheels generally do not work well in a test tank unless the tank is very large; they want to cavitate and/or blow all the water out of the tank.

Figure 14. Flat disc test wheel.

Dyno (dynamometer) testing is another option. Dynos are expensive and most are not suited for small engines. If you have access to a dyno, it is by far the best way to test engines, in my opinion. Horsepower is measured by this equation HP=RPM x torque/5252. RPM is easy to measure, and if you have a test load of some sort you can tune for max RPM and infer from that that you are close to maximum power. However, to know for sure, you need torque data—and for that you need a dynamometer.

Chapter 5

Testing, RPM, Speed, GPS, Data Loggers

You will always hear racers talking about testing or bragging about their test results. In general you will be happier if you ignore any claims made about their speed. You can accept the information they are sharing, but don't take it too seriously. If you suddenly found an extra 2 mph, would you go tell all your competitors how you did it? Not likely. The best way to show your competitors how fast you are is on the racecourse.

Testing is important and very useful. If you can find a friendly lake on a wind-free day you can learn a lot about your boat, motor(s) and props. (Finding a test-friendly lake on a hot summer day is nearly impossible; you are competing with water skiers and jet skis, and they do not care that you need calm water. Also, you may need a permit from the local authority.) You must write your results down in a notebook. After a day of testing, without written notes you will not remember properly what happened. And a few days later, it will be even more difficult to remember the best prop at the best setup with the best turn fin, etc. Besides a notebook, you need all your safety equipment, at least one helper and a kicker boat to pull you in when you run out of gas or have some other unfortunate event. If you think you will not need a kicker boat and a helper, Murphy's Law will teach you a lesson.

Be aware that the wind will affect your speed while testing. I have seen on our data logger 1-2 mph changes between going with the wind and against the wind, even when I thought it was a pretty calm day. Also, since we test when other people are not on the lake, that means it is usually a cool day. Cool air generally makes more power, so the testing speeds are affected positively ☺.

The instruments you <u>need</u> are a good GPS speedometer and a tachometer as a minimum. Instruments with big digits are best because at speed it is hard to see tiny displays—actually it is almost impossible. Dads, be patient with young drivers. They often forget to look at the speed and RPM when testing or forget the numbers when they come to the beach. There is a lot going on in a young kid's mind when driving a hydro, and remembering data is not easy for them. Instruments with maximum memory are a big help when you have very young drivers.

Be careful about max RPM readings because often they occur while getting on a plane! Stopwatches, buoys, CHT (cylinder head temp) gages are an added big help; and finally, a data logger and computer will fill the bill for top quality testing. Things to test are top speed and RPM for all your props, corner speeds (that is what the buoys are for) and acceleration. Use the stopwatch to measure time between two buoys for acceleration. A good quality data logger can record all this information and it can be downloaded into your computer for later analysis. With one, you will have more data than you can handle initially; but eventually it will start to make sense. This sounds like a lot of work, but the guys that win, the "fast guys," do it all.

The CHT will be useful to evaluate your cooling and engine setup if you have cooling problems with your Yamato.

If you don't have access to that friendly lake, you will have to test at the races. This can be done and will still provide useful information. Most racers only test at the races, so you are not alone if that is your only option. The best data-gathering tool is a data logger. (It is the most expensive, too.) Mine stores speed, RPM, latitude and longitude position, temperatures, even lake altitude. You can even plot your speed around the course. In general, you will be shocked to see that you may spend only a few seconds each lap at top speed.

Chapter 6

Safety, Helmets, Kevlar, Lifejackets, Socks, Gloves, Shoes, Kill Switches.

No one wants to get hurt racing. The best safety device is your brain; don't do stupid things. Anticipate what may happen while milling and racing, and avoid situations that may end badly. There are things that can help reduce the chances of an injury, and most are required.

The most important and most often used is the "kill switch." This switch is attached to the driver and the boat with a tether. When the tether is pulled, the engine stops. Be sure it is connected to the engine and make sure it works. The tether should be as short as possible while still allowing the driver to move as normal while driving without accidentally being pulled. An accidental pull, and sudden stop can surprise the driver. On the other hand, if you go out of the boat, you want it to stop the engine ASAP. The tether is also a common way to stop the engine when approaching the beach.

Other driver protection equipment is required by APBA; and you need to read the rule book to know the requirements. Kevlar life jackets, arm and leg protection are generally required; but consider also Kevlar gloves, socks and boots as additional safety devices. Helmets and eye protection are required, of course. There are specific rules on these that you need to be familiar with.

Chapter 7

Steering, Off-center Cockpits, Windshields, Tunnels, Steps, Wood, Honeycomb, Height and Kickout.

As you get into racing you begin to notice other things such as variations in steering, off-center cockpits, windshields, tunnels, steps on the sponsons, wood, honeycomb, etc. Just ask your racing friends about the differences. Many will be happy to explain the benefits of one thing over another. Usually the claimed benefit is much greater than the real benefit. However, the diversity of ideas and opinions makes boat racing fun. Only in outboard boat racing can you go in your garage and modify your racing machine easily yourself. You can even build your own new boat. Many racers do this.

You will notice that some boats have off-center cockpits. That is, the cockpit is moved toward the left side of the boat. This is intended to make it easier to turn left. Some like it; some don't. Another thing that is claimed to make a boat turn better is to build it with a twist. The boat is twisted so the left sponson is lower than the right one. It is very difficult to detect this visually on the beach. Also, the bottom surface of the sponsons is built with every imaginable step and angle. Hopefully you are going fast enough that you get through the turn with your sponsons not touching the water.

Steering arrangements typically are "direct" or "indirect." In a direct setup the cables go to the engine turnbar and terminate there. This gives you the most turning movement of the engine with the steering wheel. The indirect system runs the cable through a pulley attached to the turnbar and back to a hard attachment point on the hull. With indirect steering you get a mechanical advantage at the steering wheel, making it easier to turn the wheel. At the same time you have to turn the wheel further to get the same change in engine angle. Some high torque engines like Yamato give a constant torque to the steering wheel, which is much easier to control with indirect steering. Simply, it is easier to hold the boat in a straight line.

There is a flip side to this, however. When you make a tight turn you have to move the wheel through a longer arc, maybe even greater than 180 degrees. Your right hand can make a 180 degree transition but that is about it. So going into the turn you have to place your hand on the wheel in such a way that you can turn the wheel the necessary distance. Usually this starting position is near the bottom of the steering wheel and it is a little awkward there. Because of the high torque of the engine you do not want to release your grip and move your hand in the middle of the turn.

The big difference between direct steering and indirect can be softened by using different-sized hubs for the cable wrap on the steering wheel. If indirect steering requires too much wheel movement for your driving style, a slightly larger hub on the steering wheel will allow less steering movement. Be careful, however, because as the hub gets bigger you require more steering force and can effectively be back to the equivalent of direct steering condition. Direct steering is the preferred method in the classes with smaller engines where the torque is lower.

One item you need to become familiar with is engine height—or, more accurately, propshaft height. In most stock classes there is a requirement that the center of the rear of the propshaft has to be at least a specific distance below the planing surface of the boat. This is both a safety rule and an attempt to equalize performance. From a safety point of view, if the propshaft is too high, the boat can become difficult to handle. So by specifying a maximum "height" there is improved stability. In the old days this was not specified and as racers raised the height of the propshaft, two things happened: first, they went faster (due to less drag) and second, they became harder to control. There is a tool known as a "height checker" (Figure 15). You may as well buy one now, because you will need it every time you put your motor on your boat. Several accessory makers sell these.

Another important setup feature for your motor is the "kickout". Kickout is basically the angle between your prop shaft and the bottom (see Figure 17). Hydro outboard engines are set with a level angle, or "kicked in." Kicked in is where the motor's thrust angle is such that it lifts the rear of the boat. Some boats go faster kicked in. You will have to test to determine your best setting. Again, there is another tool, a "Kickout Checker" (Figure 16) which you may as well buy because you need it as well. The same vendors sell both tools. There is a spec for the maximum allowed kick-in on some classes. No one races kicked out. The boats get too difficult to handle and have a hard time getting on a plane when set up kicked out.

Figure 15. Brown Tool & Machine height checker

Figure 16. Brown Tool & Machine Kickout checker

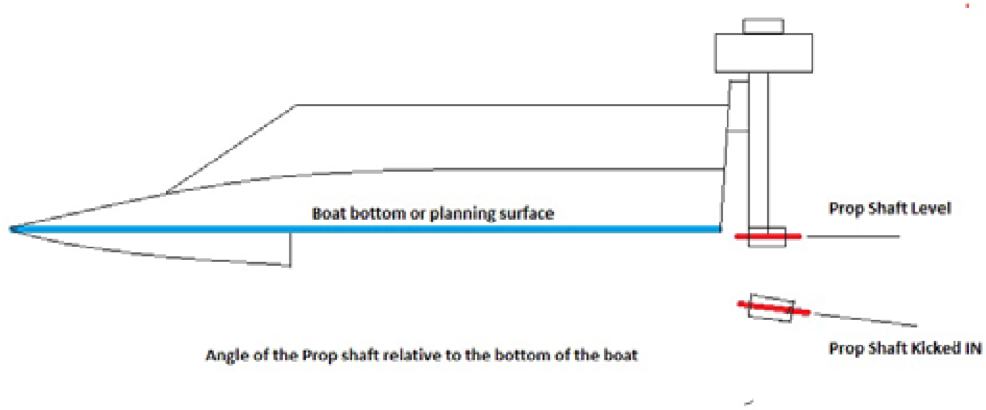

Figure 17. Kick IN

Chapter 8.

Driving, Racing

What do you need to win races? Simply, you need a good boat, a good prop, a good engine, a good setup, a good start, a good driver, and also a bit of good luck. Many old-time racers will tell you that winning is not easy; and winning often is even harder.

The most important skill in racing is “nailing” the start. You want to cross the starting line with a wide-open throttle at full speed and be the first one to do it without jumping the gun. It is hard to do this consistently, but in time you will get pretty good at it. The best advice I can give a new driver is to determine during the 3-minute warmup gun the number of seconds it takes you to travel from the exit buoy in the turn to the start/finish line. Use that time to judge where you need to be positioned at the starting run.

My next advice is to watch the clock and the flags on the course and DO NOT JUST FOLLOW THE OTHER RACERS. You will never win if you are following them to the starting line.

Now, let’s say for example you have been working on the start and you finally get a good start; maybe you even are the first legal boat over the line. This is a great feeling and if you can keep the lead into the first turn you have a good chance of winning or at least being on the podium (in the top three). However, reality will likely set in on the way to the first turn. The fast guys are likely on either side of you and pulling past you by the time you get to the first turn. They will leave you a lane as wide as your boat and you need to try to stay there where you are not getting wet.

You do not want to slip directly in behind either boat on the right or the left. If you do you will get real wet and possibly be blown over by the water coming off the other boats. Getting directly behind a Yamato is like being in front of a fire hose, a 4-5 inch diameter jet of water coming at you 60 mph from a 30 hp motor. If it gets under your bow it can blow you over, if it hits your face you cannot see until you are out of the jet.

As you approach that first turn, you need to determine “Can I lead the pack through the turn?” This is the best case. Or “Am I going to get real wet from boats that are nearby and faster?”

Sometimes if this is the case, you are better off slowing enough to safely cross the path of the inside boat. If the path is clear there, you can often come out of the turn in 3rd or 4th place. This is because the faster boats will typically slide out as they exit the turn and take most of the pack with them. The safest option, if you cannot keep the lead, is to slow enough to avoid being washed out (maybe this term originated with boat racing) and enjoy the rest of the race thinking about the great start you finally made!

After the start and the first turn, the rest of the race is pretty relaxed and fun!! A slower racer who gets a good start and can be the first one into the first turn can win a race. A faster boat running on the outside has a real hard time passing a slower boat inside. Let’s look at a typical 1-mile long racecourse where half the race is straight and half is turning. The guy on your outside running through the corner 10 ft. out will have to cover three boat lengths further in each corner just to keep up! You cannot let that faster boat get on your inside—once there, he will pass you easily. I have written this paragraph for the beginner; the fast guys know all this and they will probably not read it anyway… because they are the “fast guys.” Just remember: at one time they were beginners too.

One thing that can be done legally is to get a one boat length or space between you and a boat on your inside, and then move in front of that boat. This is known as “cutting him off” but be aware a turn judge may disqualify the driver doing the cutting if they think it was less than a boat length of free space between boats. A boat length is very hard to judge and is barely enough space to safely pull this move. There is a chance the guy behind will tip over due to your roostertail. This is dangerous, of course, and the other guy probably will be not happy about it. The race also will likely be black-flagged (stopped) and whatever advantage you thought you gained by the maneuver will be lost. The reality is that by keeping your arc and staying in your lane, you probably would have gotten through the corner faster anyway. The guy behind you probably will thank you for the “lane” and leave one for you next time. I always say you go faster looking forward, not behind!

Chapter 9.

"Dad, my boat sucks!"

Chances are that your boat doesn't suck. It is always nice to get a new boat and new hopes for the coming race season. I think half the fun of racing is having an excuse to build a new boat and try new things. However, to give dads some support here, most boats don't suck. In a straight line, the speed one can achieve will be mostly determined by the engine and prop, and not the boat (assuming we are using the right size boat in such an imaginary test). Boats can be bad, but rarely are they real bad.

Some turn better than others but even the turning quality of a boat can be changed by adjustments to the prop height, prop angle, the prop itself and, to a large extent, the turn fin. Adjustments to the turn fin are probably the first place to experiment if you want to change the turning characteristics of your boat. Different area fins, depth, the angle of the leading edge, and the angle of the fin relative to the bottom of the boat are all areas to explore in fine-tuning your turn. So give your boat a chance unless you want an excuse to build a new one, not that there is anything wrong with that! Many dads and their grown children will happily tell you about the time they and their dad built a boat together. These stories are usually fondly told and are part of those memories you never forget!

One time I had a boat that did suck! It wanted to roll/spin out when you least expected it. Every driver who drove it eventually ended up going for a swim, including myself and several drivers whose names you would recognize. It was just a bad boat, and ended up in a fire at Newburg, Oregon many years ago—an appropriate ending for this particular boat. The boat had too much lift too far rearward, and was like driving on a teeter-totter. It went fast, faster, then too fast… crash. When you buy a boat, watch it race and ask a lot of questions. Boats earn a reputation and it is quick and easy to learn what that reputation is. An old boat isn't necessarily a bad boat. Recently we entered a 35-year-old hydro in A Stock and won both heats with it.

I hope this information is helpful to new racers. Good luck in your racing careers and remember we are out there to have fun and be safe. Winning is more fun, but outboard racing is still fun even if you are not the winner! You and your family will have a common bond that can be shared forever.

About the author

John M. Adams is a retired electrical engineer. He received his BSEE from the University of Minnesota in 1968. John's professional career has involved the design and development of medical devices. These range from implantable pacemakers and defibrillators to insulin pumps and special angioplasty devices. John has over 135 issued and pending US patents.

John built his first outboard hydroplane at age 16 and actively raced for over 20 years in Region 10 with the Seattle Outboard Association. He is currently a retired driver and helps as a crew member of Adams Racing. He is also a private pilot who built his own airplane, an RV7. John can be reached at Johnrv7@gmail.com.