The Twin Propeller W-Drive.

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

Part II: Chasing The Center of Gravity Demon, and Dispelling The Myths Of TheV-Drive Push-Point and Location. ***By: James Faulkerson of Aqua Systems Engineering***

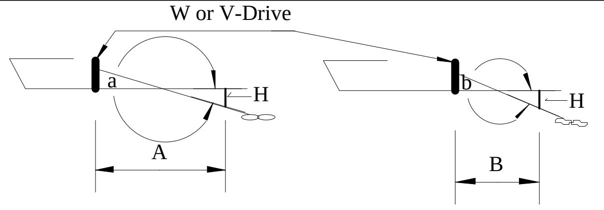
It has always amazed me to hear the scuttlebutt in the pits at the races regarding the placement of the V-Drive for a particular model or manufactured boat. You hear such things as; “Yah man, you need to put the V-Drive at one hundred and two inches from the transom for the best push point on the boat”.

Other typical comments that you hear are; “the farther forward you locate the V-Drive the better the boat will handle”, or “be careful not to get the V-Drive too far forward or it will push the bow of the boat into the water off the starting line”. So, you observe individuals putting their boat V-drives in various locations with the idea the V-Drive location, and its so-called “push-point”, is the basis for their boat handling behavior.

The truth of the matter is, the forward and aft location of the V-Drive “push-point” has very little to do with the handing characteristics of a watercraft.

The V-Drive location does establishes one end of the propellers shaft thrust angle in relation to the boats center of gravity (c.g.) and the water surface. Consequently, changing the V-Drive location forward and aft, (assuming you hold the propeller strut at the same height) does influence the handling of the watercraft because of the change in propeller shaft angle and not because the point, or location of the so-called “push-point” has changed.

The principal to understand here is the location of the point at which the propeller thrust is taken by the watercraft (the V-Drive thrust bearing) has very little to do with the resulting behavior of the watercraft. It is the angle or change in the angle of the propeller shaft relative to the watercraft c.g. and water surface that is the principal to grasp here. See figure 1.



Given; Angle "a" is less than "b"
Distance A is greater than B
H = H, propeller strut height and location
Conclusion; Reduce distance A holding H the same and angle "b" will always be greater than angle "a"

Figure 1.

The myth of the so-called “push-point” location and its effect on the handling characteristics of a watercraft has been propagated for years amongst racers and boat builders alike. I have heard these stories for the last eighteen years that I have been involved with high performance boating.

Lets apply a basic test to the notion of “push-point” and its alleged effect on watercraft handling along with a simple application of Sir Isaac Newton first law of motion. Incidentally, Newton first presented his first law of motion to the world in the year 1686. His first law of motion stated in his own words is: *“Every body persist in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by forces impressed on it”*. With regard to a watercraft under power; the watercraft will remain in motion and in a straight line unless acted upon by other forces such as a rudder, propeller dynamics, aerodynamic, hydrodynamic, etc.

Now we need to define some initial conditions for our test. Figure 2 depicts a boat with a conventional

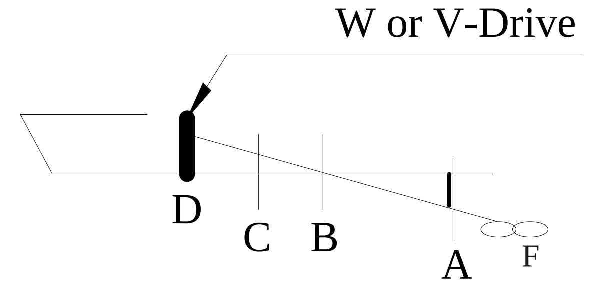


Figure 2

V-Drive. This could also be a twin propeller W-Drive drive. In figure 2, the drive location that takes the propeller force F, the so-called “push-point” is denoted by point D. Other locations in space are denoted by letters A, B, and C and at this initial time of our test do nothing but represent positions in space. We will also assume that our test drag boat handles perfectly with the drive transmission and propeller thrust taken at location D.

Now our test of the notion of “push point” location using Newton’s first law of motion will be accomplished by placing the “push-point” of the watercraft at different locations A, B, and C and observe if any new forces will be generated to change the watercraft motion. It will be assumed that our test drag boat is at a position away from the starting line where the propeller is just “hooking-up” and the propeller force F is at its maximum.

Now, at this point in our test we will freeze the boat in time. Lets now put a thrust bearing at location C and remove the thrust bearing at the drive at location D. Now the drive transmission does nothing but rotate the propeller as it did before, however, the propeller force F is now taken at point C. Remember, according to Newton there must be an additional (key word) force or forces somehow generated to “compel” our test boat to change its motion either accelerate, decelerate, turn left, or turn right, go up or go down.

Now we start our boat in time once again. Examining the forces, we see that no new forces have been introduced. The propeller is producing the same thrust, and all other forces acting on the boat that were there before we move the thrust point from location D, to location C, remain unchanged. Simply changing the location of the point at which the propeller thrust is taken by the watercraft introduces no new forces.

Now, lets apply Newton’s first law of motion. If no new forces have been introduced to our test boat, then our test boat will not change its motion.
If you think there should be changes in the test boat motion, then ask yourself where does the force to cause a change in motion come from? Out of thin air? Of course not.

It becomes apparent that there is no additional forces generated that can act on the boats motion by simply moving the thrust point to location C, or for that matter to point B, or A. Consequently, according to Newton and his first law of motion, it can be seen that the notion of “push-point” and its location having an effect on the handling of a watercraft is really a myth rather than physical fact.

The important principal presented here is the propeller shaft angle relative to the water surface is what influences the handling of the watercraft not the location of the famed mythological “push-point”.

This principal has been put into practice on all three of my Nitro Bullet Top Fuel Hydroplane boats. The actual point of propeller thrust was, and is now taken on the Nitro Bullet III just in front of the propeller strut, about sixty inches rear of the W-Drive. The disciples of the push-point cult would shutter in their boots knowing this information.

Another important performance and handling related principal to propeller shaft thrust angle is the concept of center of gravity or c.g.. The c.g. of a watercraft is equally as important as the c.g. of an Indy car, top fuel dragster or unlimited hydroplane.

The c.g. of a rigid body is a three-dimensional point in space that can be located on, or about a body, where the weight of the body is equally distributed in all three dimensions about this point.

The c.g. of a watercraft is not to be confused with its balance point. The balance point is the intersection of two lines at a point where the weight of the watercraft is equally distributed forward and aft of this point and equally distributed across the beam of the watercraft at this point. The balance point makes up two of the three points necessary for establishing the c.g..

The third point of the c.g. of a water craft can be found by turning the boat on its side and finding on a line extending orthogonally (at right angles) from the balance point plane to a location of a third point that balances the boat on its side. See figure 3.

The c.g. of a body does not represent the point of application of the body’s weight; all that can be said is that the line of action of the weight always passes through this point.

The key to understanding the behavior of any rapid accelerating vehicle lies in the concept of; “the line of action (rapid acceleration in the case of drag boats) of the weight (of the boat) always passes through this point (the c.g.)”

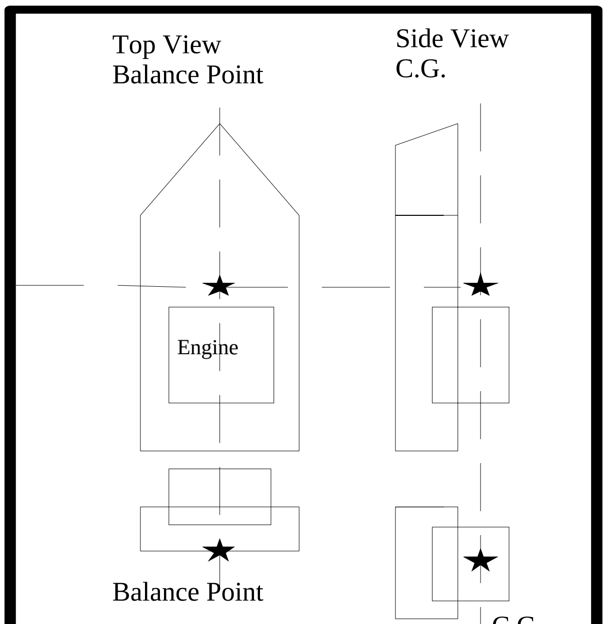


Figure 3

The Author Locating The C.G. of His Nitro Bullet 1

With this basic definition of the c.g. we can now in part explain with relative ease the basic behavior of why a boat under rapid acceleration can behave as it does.

However, we need one more concept defined to explain the action of the c.g. for a body under rapid acceleration. That is the notion of moments of inertia or moment arm producing a torque. Sounds like an exotic dish from an Italian restaurant. Well not quite.

A moment arm acting on a rigid body can be explained in terms of a marching bandleaders baton. See figure 4. If we hold the baton exactly in the center (at its

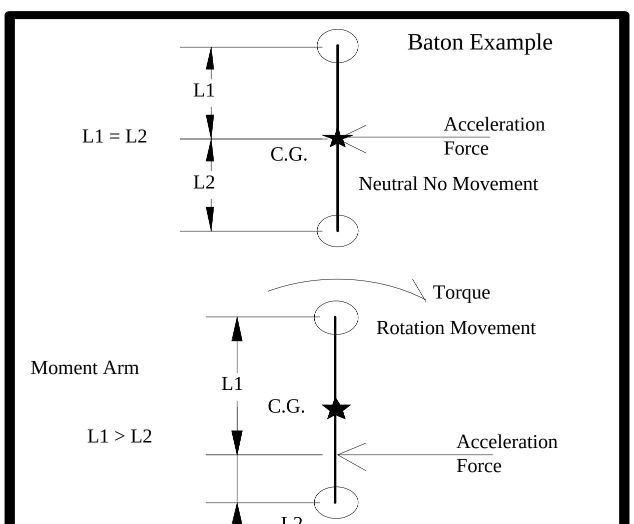


Figure 4

c.g.) and rapidly accelerate or move the baton away from our body we find that the baton relative to our hand stays still and the entire body of the baton is accelerated uniformly.

However, if we hold the baton some place other that in the exact center (c.g.) and rapidly move the baton away from our body we find the baton will rotate. This rotation is due to a torque (a force through a distance, a moment arm) resulting from the acceleration of an amount of weight distributed over a longer distance above the point that we are holding the baton as compared to the distance below this holding point. Essentially there is a longer lever above the holding point as compared to below the holding point..

The greater the distance of the holding point from the c.g. (the greater the differences in the lever lengths) the more rapid the baton will rotate given a constant source of acceleration. In other words, the force acting through a distance (torque) on the baton is directly proportional to the distance from the c.g..

Now with this brief definition of c.g., moment arm, and torque, we are now ready to apply these notions to the behavior of a watercraft under rapid acceleration.

I believe one can see from the baton example; if we want to accelerate a watercraft with the minimum of torque effects (driving the bow in the water or pulling the bow up in the air) on a watercraft then one would ideally want to apply the accelerating force (propeller thrust) to accelerate the watercraft at its c.g..

Applying the propeller thrust through the c.g. would in effect produce a boat launch that is neutral in behavior. However, this can only be achieved in practice with a twin propeller W-Drive. A single propeller drive produces to many adverse propeller and rudder forces to achieve true neutrality in behavior, especially in a top fuel hydro.

If we apply the acceleration force below the c.g. of the watercraft (shallower strut angle) then the watercraft would pick the bow up in the air. Like the baton example, the further we apply the propeller thrust below the watercraft c.g. the more the torque will be applied to the watercraft that would result in a greater

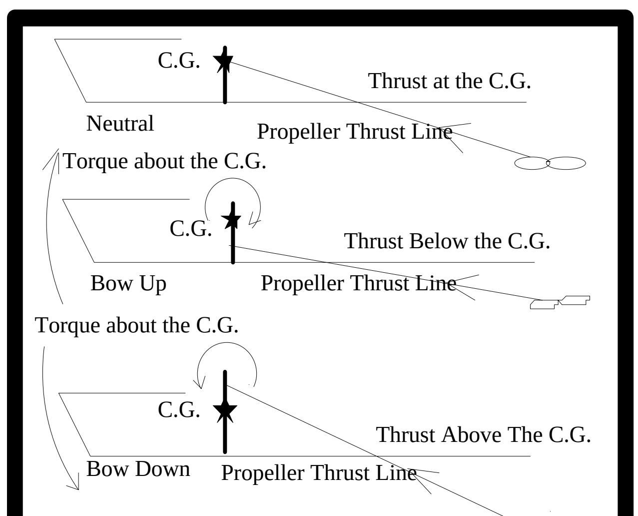


Figure 5

degree of torque, thus pulling the bow of the watercraft out of the water to a greater degree.

If we apply the propeller thrust force above the c.g it will push the bow of the watercraft into the water. See Figure 5.

Some racers like to carry the sponsons of a hydroplane off the water over the first part of the track. This can be accomplished by applying the propeller thrust just below the c.g.. However, be careful with this idea. There is a reciprocal behavior associated with the biasing of the thrust force from one side or the other of the c.g.

If you chose to carry the bow of the boat during the first part of the track, then when you get off the throttle, and the propellers become dragging devices instead of thrusting devices, the bow will be pushed into the water at the top end of the track because of the opposite direction of force applied about the c.g. by the dragging propellers.

In this example, the behavior at the top end of the track, when the throttle is released, is less intense in nature than its reciprocal behavior when you step on the throttle at the beginning of the track, because the amount of propeller drag force applied to the boat when you get off the throttle is less than the propeller thrust force created with you step on the throttle. None-the-less, proceed with caution when applying propeller thrust below the c.g. to carry the bow. The boats reciprocal response at the top end of the track could create a devastating effect.

There is an interesting phenomenon that can take place with a drag boat that has its propeller thrust line to c.g. ill placed. Usually this ill placed propeller thrust line to c.g. situation is a consequence of a light boat to heavy engine ratio. What we are about to examine I call “chasing the c.g. demon”. It goes something like this.

Lets take a condition of a drag boat that exhibits a behavior of its bow severely coming out of the water as it leaves the starting due to the propeller thrust being applied below the boats c.g.. The boat mechanic, being a smart person and knowledgeable about such things as c.g. and propeller thrust angles, knows that he has to increase the propeller strut angle to get the propeller thrust line closer to the c.g. of the boat to make it handle better. He remounts the engine, V or W drive transmission, propeller strut(s), shaft log(s), whip strut(s), etc. to increase the strut angle closer to passing through the existing c.g. of the boat.

However, by relocating higher, the two heaviest items of the boat, namely the engine, and drive transmission, to mechanically facilitate the increase in propeller shaft angle causes the c.g. to change, also. Now, you can again remount the components to attempt to realign the propeller shaft angle to the new established c.g., and once again the c.g. would have moved because of relocating the heavy internal parts of the boat. You will find that you will continue to chase the center of gravity demon to no avail!

In practice, especially in the top fuel class, many boats are made heavy (typically 3000 pound plus) to achieve a low c.g. (more weight below the engine) allowing the boat to obtain a relative good alignment of the propeller thrust to c.g.. However you pay a big performance price for dragging this excess weight down the racetrack.

However, for a lightweight (2000 pounds or less) drag boat, it is near impossible to find that “sweet spot” of propeller thrust angle and c.g. alignment because most of the boats weight is concentrated in the engine which is located, by in large, above the boat creating a high c.g..

What is needed is a way to keep the center of gravity of the boat as low as possible, allowing the engine and related parts to be mounted low into the boat to provide good stability, hold all components fixed inside the boat, and adjust the propeller shaft angle independent of the components in the boat. Ideally, this device should allow adjustments to be made easily between passes at the racetrack without the physical remounting of any parts. The Aqua Systems Engineering Constant Velocity Joint (CVJ) does just that.

Aqua Systems Engineering CVJ

Since the introduction of my top fuel hydro drag boat, the Nitro Bullet I, in 1997, this constant velocity joint has been a part of all my top fuel drag boats (Nitro Bullet 1-3) and has permitted near perfect alignment of the propeller thrust to c.g. It took only two passes, with adjustments in between each pass, to get the new Nitro Bullet 3 “dialed in”. I must admit that the first pass was a bit exciting. I had a real good look at the sky, demonstrating what happens when the thrust angle is below the c.g..

The Authors Nitro Bullet 2. Propeller Thrust Applied below the C.G.

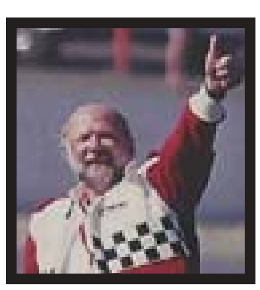
Over a year and half of testing and development went into this CVJ resulting in having to design and manufacture a custom (no off the shelf parts would handle the stress) CVJ from exotic aircraft steels that could take the punishment of twenty thousand RPM of shaft rotation while transmitting a thousand foot pounds of torque.

The above concepts and ideas should provide the reader with some basic concepts and ideas to help adjust or tune their drag boat to achieve better performance. I hope the above will clear up some of the mysteries and dispel some myths behind the art and science of tuning the rapid accelerating watercraft.

All that has been discussed above applies primarily to hydroplane boat hull designs with, or without twin propellers. However, in principal, this material may be applied to most watercraft hull designs.

No attempt is made to explain in totality, the forces that act on rapid accelerating watercraft. This would be more a subject for a book than a journal article. Please be aware that many other factors beside what has been stated above influence the behavior of a rapid accelerating watercraft. Please be careful, and good luck!

About the author:
James Faulkerson is founder of Aqua Systems Engineering that currently designs and manufactures the only commercially available unit construction W-Drive.



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

He holds degrees in Mechanical, and Electrical Engineering.

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

You can contact Jim by e-mail at: fms4racing@aol.com. Read more about his Nitro Bullet and the W-Drive at www.faulkerson-motorsports.com. Contact Aqua Systems Engineering for more information about the W-Drive and related drive line components at: 702-396-7068.