Troubleshooter BY STEVE ZIMMERMAN

The Fuel Burn

Jonathan Cooper

If you cruise on a powerboat, you pay attention to fuel consumption. Despite the importance of this topic, confusion and false assumptions abound. Many assume that an engine of moderate power runs more economically than a high-output version, but is that always true? Should you prefer a single-engine trawler over a twin-screw, semidisplacement boat because of fuel economy? If you have a twin-engine boat, can you run on one engine to reduce fuel burn?

Let's begin by agreeing on the standard. While many boaters focus solely on gallons per hour (GPH), this is a meaningless number on its own. For example, here's a question: Which is more efficient, Boat A burning 11 GPH or Boat B burning 22 GPH? Without calculating miles per gallon (MPG) it is impossible to say. Gallons per hour can be helpful when calculating range and determining whether you have enough fuel to get to your destination. If you are consuming 20 GPH and you will be running for five more hours, then you know you will burn 100 gallons of fuel before arriving. But that does not speak to fuel economy. When we compare cars, we all agree that MPG is our standard. So we will adopt the same standard for this article.

Let's return to the question of which boat is more efficient, Boat A burning 11 GPH, or Boat B burning 22 GPH. Let's include the speed and look at the math.:

Boat A: **10 knots (nautical miles per hour) / 11 GPH = 0.9 miles per gallon**

Boat B: **22 knots (nautical miles per hour) / 22 GPH = 1.0 miles per gallon**

In this particular example, we see that although the difference is minor, the boat burning more gallons per hour achieves better mileage. For the purposes of this discussion, we will concentrate on nautical miles per gallon, which we will abbreviate to nMPG.

FUEL BURN BASICS

A given hull will require a certain amount of energy to move it through the water. The fuel contains the stored energy and we can describe that in terms of horsepower (hp), kilowatts (kW), or British thermal units (BTU). One gallon of diesel fuel stores about

38 kilowatt hours of energy, or 130,000 BTU. The engine converts that energy into the power needed to overcome resistance and move the boat through the water.

As for the boat, the more easily it moves through the water, the less energy is required. The primary factors that influence how easily the hull can be moved include hull shape, length, total weight, and drag.

Hull shapes can be sorted into three basic categories: full displacement, semi-displacement, and planing. Which offers the best fuel economy? To answer that question we have to introduce the most important variable of all: speed.

These hull forms respond in very different ways to the demand for speed. As speed increases, boats move through the water in three basic ways. At slow speeds (for the technically inclined, speeds below 1.3 times the square root of the waterline length), the boat sits fully in the water, riding between a wave at the bow and a wave at the stern. Full displacement boats live in this zone. As soon as speed increases above this number, fuel burn rises sharply. At speeds above 1.3 times the square root of the waterline, the burn starts to climb dramatically.

Semi-displacement and planing hulls can apply more horsepower and begin to climb up onto the bow wave. We refer to this condition as transition, or "climbing out of the hole." In this phase the bow rides awkwardly high and fuel economy plummets.

By applying even more power, these hulls ride more on top of the water. The bow comes down, speed increases, and fuel burn levels off. All boats maximize fuel economy at the slower speeds, but the penalty for higher speeds varies substantially between hull types.

FUEL BURN COMPARISONS


Krogen 48

Courtesy Kadey-Krogen Yachts

FULL DISPLACEMENT

Let's look at some actual numbers from a full-displacement trawler in the 40- to 50-foot range:

7.5 knots @ 3 GPH = 2.5 nMPG

If we push for a little more speed the fuel burn changes:

9 knots @ 11 GPH = 0.8 nMPG

Notice that by slowing down 1.5 knots, this boat increases its fuel economy almost 300%.


Krogen Express

Images courtesy Krogen Express and MJM

SEMI-DISPLACEMENT

Now let's look at a semi-displacement boat of similar size:

8.5 knots @ 3.4 GPH = 2.2 nMPG
10.5 knots @ 14.2 GPH = 0.74 nMPG

Once again, at displacement speed, a 2-knot decrease in speed increases fuel economy 300%. If we push this boat into higher speeds, though, the fuel burn differs significantly:

15 knots @ 23.5 GPH = 0.64 nMPG
20 knots @ 35.0 GPH = 0.57 nMPG

Once this boat gets "out of the hole" (more on top of the water than in it) the penalty for increases in speed diminishes dramatically and economy levels off. As speed increases, fuel economy will gradually decline in small increments.


MJM 50z

PLANING

Finally, let's look at a boat designed for speed, a lightweight planing hull:

7.5 knots @ 2.6 GPH = 2.9 nMPG
9.0 knots @ 5.4 GPH = 1.7 nMPG
11.0 knots @ 9.2 GPH = 1.2 nMPG
15.0 knots @ 14 GPH = 1.1 nMPG
25.0 knots @ 27.5 GPH = 0.9 nMPG

Notice that at displacement speeds, an increase of 1.5 knots causes a 41% decrease in fuel economy (from 2.9 MPG to 1.7 MPG), but at planing speeds an increase of 10 knots only causes an 18% drop (from 1.1 MPG to 0.9).

It should also be pointed out that weight matters, but it matters considerably less at displacement speeds. A full-displacement trawler can pack on the cruising weight without much of a penalty. The other hull types won't pay a penalty at lower speeds, but at higher speeds the additional weight will take its toll.

FRICTION AND DRAG

Friction and drag also matter. Friction can be created by engine misalignment or by a worn bearing binding on the shaft. Drag can be caused by a fouled propeller or growth on the hull. Assuming no current or wind, friction or drag can be detected when you need more throttle to achieve the same RPM. This data point illustrates the value of keeping a log, or at the very least noting your baseline when all conditions are good. The wide-open throttle (WOT) test described in the previous issue provides the most reliable reference point.

Let's assume that over a period of a year or two you've noticed a gradual increase in the RPM needed to achieve the same speed. You can confirm your suspicion by running at WOT and checking your records. Two years ago you attained the rated 3,000 RPM and now you max out at 2,850 RPM. If this reduction is due to increased drag, we can estimate the impact on fuel burn. Let's look at the numbers at your usual cruising RPM:

Normal conditions: **2,600 RPM produces 14 knots and burns 12 GPH = 1.2 nMPG**

New conditions: **2,750 RPM produces 14 knots and burns 14 GPH = 1.0 nMPG**

The extra friction has reduced fuel economy by 17%. Engine misalignment or a binding Cutless bearing would impact fuel economy in this range. A fouled bottom or fouled propeller can cost you even more efficiency. This effect becomes far greater at planing speeds.

SINGLE VS. TWIN

It seems intuitive that running one engine must be more fuel-efficient than running twins. Let's look at some numbers at semidisplacement speeds. In order to move this hull through the water at 15 knots we need 300 hp. If we power the boat with a single 370 hp engine we must run at 2,800 RPM to reach 300 hp. Let's look at the numbers for this scenario:

15 knots requires 300 hp
300 hp requires 2,800 RPM
2,800 RPM burns 15.8 GPH
15 knots / 15.8 MPG = 0.95 nMPG

If we put two smaller engines–say, 220 hp each–in the same boat we still need roughly the same horsepower to reach 15 knots. So now we need less horsepower from each engine, in this case 150 hp each. Looking at the data for these engines we see that they will now have to run at 2,350 RPM to achieve 150 hp:

15 knots requires 300 hp (or 150 hp per engine)
150 hp requires 2,350 RPM
2,350 RPM burns 8.8 GPH per engine
15 knots / 17.6 GPH = 0.85 MPG

If we want to get more scientific we would have to factor in the weight of the second engine and some increased inefficiency caused by two propellers. We can see, however, that any differences will be relatively minor (in most cases, +/- 10%). And in some cases the twin engines will burn less fuel than a single, depending on horsepower and propeller configurations.

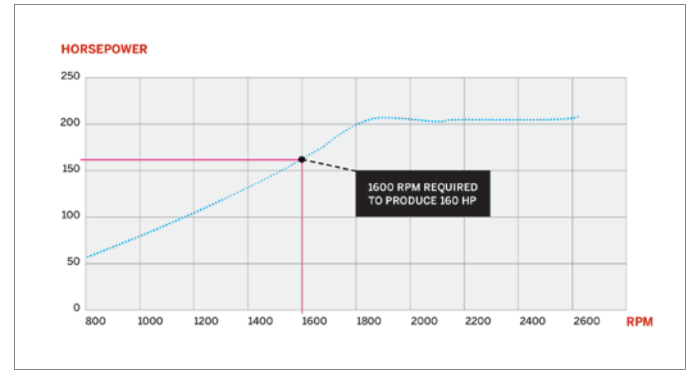
Note that we are avoiding a host of other thorny considerations, including boat handling, maintenance costs, engine access, and propeller inefficiencies, to name a few. If you want to start an argument with a roomful of cruisers, taking a stand on singles versus twins would be a great way to start.

This same data answers a similar question: "What happens if I run my twin-engine boat on one engine?" At displacement speeds you can read the math above in reverse order and you have the answer: changes in fuel consumption will be minor again, probably within 10%. This scenario becomes impractical at planing speeds, however, as the load on one engine will likely be a problem.

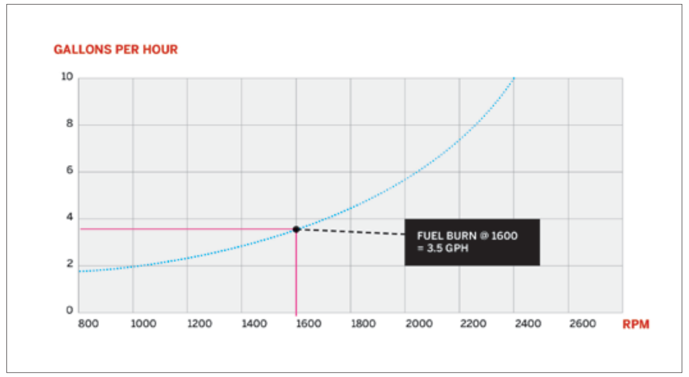
Once again, we are leaving out another set of considerations, such as what to do with the shaft on the dead engine. If it is allowed to freewheel, we have to be concerned about the spinning transmission and the shaft seal. However, a fixed prop moving through the water behaves like a propeller running in reverse. If the prop cannot spin, it dramatically increases drag and fuel economy plummets.

HORSEPOWER

When comparing two similar boats, fuel-conscious buyers often favor the boat with the smaller engine, assuming it has better fuel economy. But remember our initial premise that it takes a given amount of energy to move a given hull form through the water at a given speed. Let's assume that we need 160 hp to achieve our optimum cruising speed of 7 knots. If we look at the specs for a 210 hp engine, we see that we need to run at 1,600 RPM to attain 160 hp.

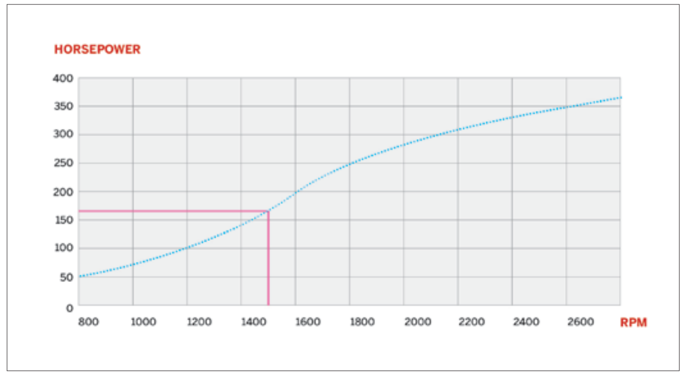


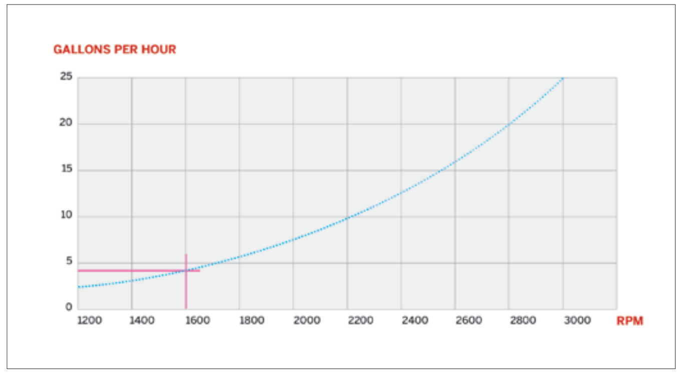
Now we can look at the same specs to estimate fuel consumption:



At 7 knots we will burn 3.5 GPH, resulting in a fuel economy of 2 nMPG. We can compare this performance to a larger engine, increasing from 210 hp to 370 hp. In the following engine performance specs *(graph, top-right)* we see that this engine will need 1,450 RPM to produce the same 160 hp.

And now the last piece of the puzzle *(graph, right)*: How much fuel will the larger engine burn when generating the same horsepower (and therefore the same speed)?





At 1450 RPM the higher horsepower engine will burn 2.7 GPH. Given the running speed of 7 knots at 160 HP, we arrive at a fuel burn of 2.6 nMPG–a 30% improvement over the smaller engine.

CONCLUSIONS

For all cruising powerboats, when it comes to fuel economy, speed trumps all other factors–but only at slow speeds. At full-displacement speeds going a knot or two slower can double or triple your fuel economy. Almost all other factors, such as twin engines versus single, high horsepower versus low horsepower, and engine misalignment or binding bearings might individually account for differences of only 5 to 15%.

Let's put this information in perspective. If you have 75 miles to cover in a day, at 7.5 knots it will require 10 hours of running time and will consume 30 gallons. If you increase your speed to 9.0 knots you might arrive about 90 minutes sooner and will consume roughly 90 gallons. Assuming diesel costs $4/gallon, the difference comes to about $255. If 90 minutes makes the difference between arriving at an unfamiliar entrance in daylight or after dark,

Among the things that influence fuel economy on this planing hull are the condition and cleanliness of the props and rudders, alignment of shafts and health of bearings, fouled bottom.

or avoiding a forecasted increase in wave heights, it is probably worth the additional cost. But if you are running offshore and covering hundreds of miles, these differences accumulate in meaningful ways.

If you have a boat that will plane, once you get the boat on plane, increases in speed cause much smaller increases in fuel consumption. In the example given earlier, at 15 knots the boat achieved 0.64 nMPG, and at 25 knots the number was 0.57 nMPG. At 15 knots the 75-mile trip will take 5 hours and will consume 117 gallons, while at 25 knots the time falls to only 3 hours and 132 gallons. The fuel cost for an extra 10 knots is only $60.

No matter which hull form you cruise, whether you run twins or a single or have high horsepower or low, nothing will affect your fuel economy more than cruising at full-displacement speeds. (Typically less than 1.2 times the square root of the waterline length will be a sweet spot.) Once you are on plane, increases in speed matter far less, but the importance of a clean underbody and running gear matters far more. Don't be misled by GPH, and keep in mind that it all comes down to a cost-benefit calculation. Otherwise we would all be cruising around at 4 knots. ■

(Special thanks to naval architects Lou Codega and Doug Zurn for their input on this column.)