FUEL-EFFICIENT CRUISING

Special formulas and charts make it possible for you to develop a personalized performance plot detailing fuel consumption of your engine be it gas, diesel, inboard, outboard, single or twins.

BY MIKE CARLSON

With today's high prices, good fuel economy demands good engine performance. But without a lab-grade fuel meter aboard every boat, how do conscientious skippers know they are getting good performance?

A while back, this question prompted ne to take a systematic look at engine performance data. This probe for answers lead to some interesting conclusions. First, I found that fuel consumption graphs presented by engine manufactur-ers reflect only the pure, theoretical ipplications. However, I did find that nagazines such as *Motor Boating & Sailing* were gathering real-world data ising lab-grade fuel meters. Exhaustive-y, I collected 150 such boat reports and inalyzed the data to develop performance verages for a variety of boat and engine ombinations.

Using these performance charts, it's ossible to get a handle on what engines ive what performance at what rpm. Sur-risingly, a spread of only a few hundred pms can mean the difference between ood fuel economy and exorbitant usage.

By studying the specific charts shown ere, you can derive average fuel con-imption figures for your own boat and ngine combination. By using the formu-s, you can develop a chart for more etailed analysis of your particular situa-on. With your own chart, you can see at hat rpms performance peaks. Thus the est fuel economy can be realized at the ost realistic cruising speeds.

Fuel Consumption at Wide-Open Throttle

The simplest measure of fuel consump-on is at wide-open throttle (WOT). This is frequently reported as gallons-per-hour required to deliver one horsepower. It is calculated by dividing the number of gallons-per-hour consumed at WOT by the engine's rated horsepower.

As shown in Figure 1, fuel consumption data tends to separate engines into three clusters: diesel; gasoline inboards, and outboards. Regardless of cluster, though, nearly all the engines examined fell within a band plus-or-minus 15 percent from the average (center) line—a surprisingly narrow and linear band.

For those boat owners with naturally aspirated engines, a quick check of Figure 1 will provide average fuel figures for comparable engines at WOT.

For specific fuel consumption figures use the following formula:

$$G_N \text{ (gal/hr)} = \frac{\text{(Engine Horsepower) (RPM at WOT)}}{50{,}000}$$

For example, if your boat has a single 165-hp gas engine turning at 4350 rpm at WOT:

$$G_N = \frac{(165)\,(4350)}{50{,}000} = 14.36 \text{ GPH}$$

This formula holds whether the boat is a displacement trawler, a high-speed planing boat or anything in between. It holds true, also, for inboards, outboards and stern drives. At WOT, no other factors, such as weight or hull design, were found to affect fuel consumption. (Obviously, speed is the variable factor.)

For turbocharged engines, a slightly modified formula is used. Turbos require about 10 percent more fuel-per-horsepower than naturally aspirated engines. Remember, turbos produce more horsepower-per-pound-of-engine. This translates into more miles-per-gallons, even though the gph figure is higher. So for fuel consumption in turbocharge engines operating at WOT use:

$$G_T \text{ (gal/hr)} = \frac{\text{(Engine Horsepower) (RPM at WOT)}}{45{,}000}$$

Even using this modified formula, the fuel-consumption spread of turbocharged engines is greater than other engine types in Figure 1. There's a reason. On the market today, there are a number of different turbocharge designs. The older designs require about 40 percent more fuel than similar engines with newly engineered turbochargers designed to match fuel use of naturally aspirated engines.

Thus, for prospective turbo buyers, a look at fuel consumption charts can help you spot the more fuel efficient engines.

Fuel Consumption for Displacement Boats

Throttling-back makes sense. Fuel consumption for intermediate throttle performance, as expected, broke into two categories. Displacement boats and planing boats showed distinctly different fuel consumption characteristics.

Figure 2 shows fuel consumption data for 90 percent of the displacement boats

Computers can draw boats, and headlines, as well as fuel-use formulas.

THREE TELL-TALE CHARTS NEEDED TO TRACK FUEL-USE OF YOUR ENGINE.

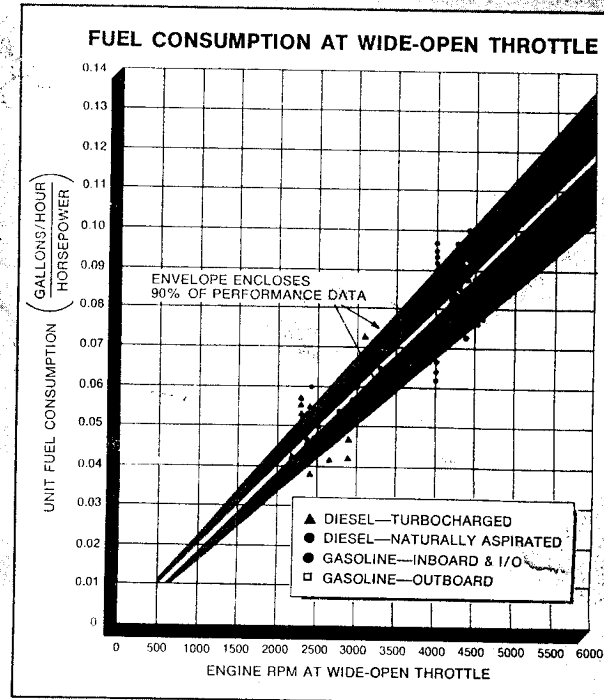


Figure 1. Against the norm, compare fuel-use of your engine regardless of type.

examined. Most of the few falling outside the band were tagged with such author's comments as "black smoke at highest rpm . . .", engine in need of tune-up . . .", ". . . improper propeller . . ." Obviously, attention to these details would help considerably the fuel efficiency of anyone's yacht.

Referring to Figure 2, the economies of throttling back is clear. For instance, a 20 percent reduction in engine speed from WOT reduces average fuel consumption to 48.5 percent—less than half the full-throttle figure. That's a healthy reduction in your fuel cost. There's another important benefit to cutting back as well. Not driving the engine at top rpm increases, significantly, the life of your engine.

For your own engine, you can easily estimate average fuel consumption at any rpm. The equation for displacement boat fuel consumption uses the fuel-consumption-factor (FCF) found in Figure 2. The formula is:

$$G_T \text{ (gal/hr)} = \frac{\text{(Horsepower) (RPM at WOT) (FCF)}}{50{,}000}$$

For example:

Your boat is a twin 225 hp diesel with WOT rpm of 2400.

When running at 1200 rpm, your fuel consumption is

$$\text{RPM Ratio} = \frac{1200 \text{ rpm}}{2400 \text{ rpm}} = 0.50$$

From Figure 2, the average fuel consumption factor is 0.155.

Thus, estimated average fuel consumption at 1200 rpm

$$= \frac{(2)(225)(2400)(0.155)}{50{,}000}$$

= 3.3 gallons per hour total for both engines combined

The calculation can be repeated for other rpm. A plot of average-fuel-consumption vs rpm can be constructed for comparison with fuel consumption measurements made for your own boat at different points. If your engine's fuel-use is within 20 percent of that calculated for the average boat, you're within the normal range. If consumption exceeds that figure, check for problems.

These include damaged or incorrect propeller; engine in need of repair or in need of a tune-up; bottom fouling, or a combination of all three.

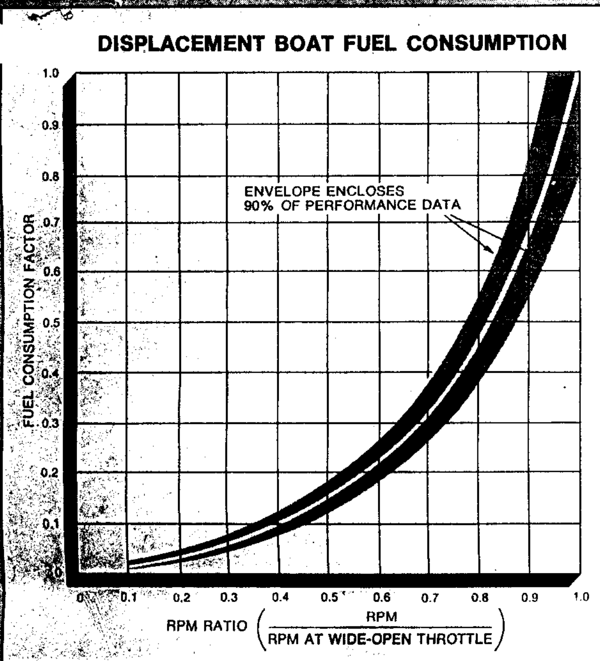
Interestingly, variations in engine efficiency outweigh the effects of boat weight. In general, the boat-weight-per-horsepower ratio was not significant, although higher ratios tended to lie in the upper portion of the fuel consumption envelope.

Fuel Consumption for Planing Boat

As expected, the chart for planing boat fuel use differs from the displacement chart. The surprise comes when you compare the displacement sections. In displacement operation, the planing hull uses more fuel. This results from design differences between a planing hull and a true displacement configuration. Figure 3 shows that fuel consumption rises more rapidly with rpm in planing boats operating in displacement mode, than with true displacement hull operating in the same range. The transition from high consumption displacement to low fuel-use planing is quite obvious. Once on plane, the area of contact between hull and water is considerably smaller—thus fuel consumption rises more slowly with rpm than in the displacement region. Note, however, that for WOT of Figure 1 in both displacement and planing boats, fuel consumption is the same in boats of equivalent horsepower.

The Figure 3 envelope for planing boats is almost twice as wide (plus-or-minus 35 percent) at mid-engine rpm due to the greater sensitivity of planing boat fuel consumption to weight distribution; bottom design, and the like. Fuel consumption is particularly sensitive to weight distribution since excessive weight in the stern, without trim tab or outdrive corrections, causes delay in transition from the high-fuel-consumption Region 1 to planing Region 2. Increases in fuel consumption of up to 30 percent have been observed at engine rpm near the transition when poor weight distribution prevented the boat from achieving plane, when compared to the same boat in which the weight was redistributed to achieve plane at lower rpm.

If your boat is showing an extremely bow-high attitude before plane, you should be looking at either weight redistribution or trim tabs to improve fuel economy. Even after achieving plane, poorly balanced boats fell higher on the



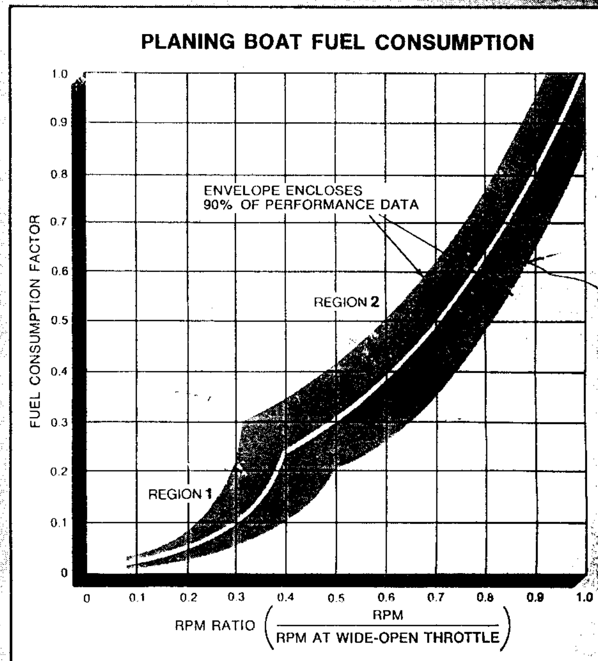


Figure 3. The FCF for planing hulls is plotted here. Note displ/plane dip as boat goes on step.

fuel consumption curve than the same boat with trim tabs or weight redistribution. Fuel consumption varied even more widely below planing due to significant variation in bottom design and the impact of boat weight distribution.

As with displacement boats, those having fuel consumption curves falling above the envelope were generally noted in the boat tests as having improper or damaged propellers; engines in need of repair or replacement; fouled bottoms, or some combination of these. Clearly significant fuel savings can be achieved for high fuel consumption planing boats, as with displacement boat, by corrective action.

Average fuel consumption for planing boats at mid-rpms is calculated the same as for displacement boats, except you use chart 2 instead of chart 3.

For example:

Twin 235 horsepower gas engines with wide open throttle at 5000 RPM when run at 4500 RPM in a planing boat.

$$\text{RPM Ratio} = \frac{4500}{5000} = 0.90$$

From Figure 3, the average Fuel Consumption Factor (FCF) is 0.79.

Average fuel consumption

$$= \frac{(\text{Horsepower})(\text{RPM}_{\text{WOT}})(\text{FCF})}{50{,}000}$$

$$= \frac{(2)\ (235)\ (5000)\ (0.79)}{50{,}000} = 37.1 \text{ gal/hr.}$$

The economic value of throttling back on planing boats is evident. Dropping to 90 percent of wide-open-throttle rpm gives an average fuel savings of 21 percent. In this case, it amounts to about 9.9 gallons per hour. That 10 percent reduction in rpm will result in a speed reduction of only 5 percent, but results in a significant cost and fuel savings. Note that another 10 percent reduction, to 80 percent of wide open throttle rpm cuts fuel consumption to 62 percent savings of 17.9 gallons per hour (about $22 per hour savings at today's fuel prices). In this case speed will be reduced to about 90 percent of the wide open throttle case.

As with the displacement boats, the effects of boat weight and bottom design, plus propeller size and type, were masked by other more significant factors. This made it impossible to determine from the test data their effect on gas consumption.

The data for planing boats covered over 100 boats, driven by engines including naturally aspirated and turbocharged diesels, plus gas inboards, outboards, I/O's. The data for all of these types of engines showed about even distributions above and below the average, thus, no engine type showed superior fuel consumption factors. The diesel engines, with their lower wide-open-throttle rpms, of course, showed lower overall fuel consumption in gallons (or dollars) per hour.

If you decide to determine your fuel consumption and want to do so from engine operating hours and gallons added at the fuel pump, be careful to keep track of the actual time run at each rpm level. Running even 15 or 20 minutes at very low rpms such as during departure or return to your slip will signficantly lower your calculated fuel consumption rate. A fair, although slightly high, fuel consumption rate can be calculated using only the time spent at cruising speed and the full amount of fuel consumed if the amount of time spent at harbor speeds is one tenth of the cruising time or less.

While the above data won't help you design a boat or fix an engine, you can easily compare your fuel consumption with the averages reported for a large number of typical boats. Where your fuel consumption is unusually high, significant savings in fuel and dollars can often be achieved with engine repair. ⚓