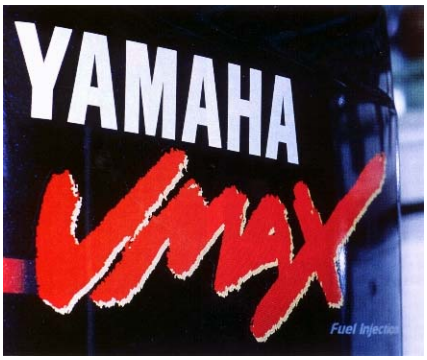
Servicing Yamaha's Super 'Sniffer'

When a Yamaha EFI engine is ailing, servicing the oxygen-density sensor may make it run more efficiently

Story and photos by Bill Grannis - Bass & Walleye Boats

Yamaha didn't lead the way with electronic fuel injection (EFI), but in 1997 it was the first to install an oxygen-density sensor in its 0X66 EFI system to fine-tune the fuel-to-air mixture. Similar to those used in late-model cars, the O2 "sniffer" helps lower emissions through better combustion and increases miles per gallon by "telling" the engine's computer when the exhaust gases are too "rich" or too"lean" according to oxygen content.



Yamaha's OX66 outboard is the only two-stroke to use an oxygen-density sensor in its fuel4njection system. The VMax model is in the high-performance model line.

The engine's Electronic Control Unit (ECU) adjusts the fuel injectors "on time" to compensate for any changes in the exhaust mixture. If the sensor becomes disabled, the engine exhibits a noticeable surging, along with poor acceleration and a lack of power. Excessive smoking, poor idle quality, and increased fuel consumption may also be obvious symptoms.

Other problems can cause similar symptoms, so systematic troubleshooting is recommended. If you decide to tackle the problem, be sure to have the recommended tools, a clean place to work, and the proper service manual.

FUEL INJECTION 101

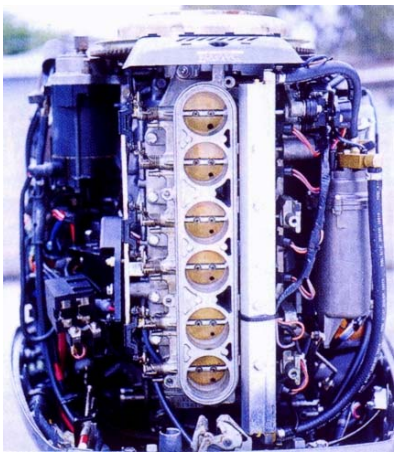
Think of fuel injection as an electric carburetor. EFI is simply one or more electrical on-off valves (fuel injectors) that are operated by a control box. The ECU is nothing but a decision maker that is fed information from external sensors reporting air temperature, coolant temperature, throttle position, engine speed and so forth. When the control box receives the information, it consults a chart (called a map) that tells it what to do, when to do it, and for how long. The ECU then sends voltage to the appropriate fuel injector (on-off valve) for a certain length of time.

By using your finger or other object to cover the No. I cylinder throttle-plate hole, the voltage reading should change if the O2sensor is operational.

Because the fuel pressure in the system is regulated to a constant amount (about 35 psi), opening the injector (on-off valve) for a short period of time (measured in thousandths of a second) allows a specific volume of gasoline to flow out of it. If the injector is held open for twice as long, it will deliver exactly twice as much fuel.

Use caution when removing and handling the oxygen sensor assembly. The internal ceramic element is easily broken and using the wrong type of cleaning solvent could cause it to malfunction.

The opposite occurs (half the fuel) if the injector is held open only half as long. With that correlation in mind, the ECU can decide to send a longer voltage pulse to the injector to increase (richen) the fuel flow or a shorter pulse to reduce (lean out) the fuel flow, according to its map. At 6000 rpm all this happens 100 times per second, times the number of injectors. A Yamaha EFI V-6 generates 600 injector pulses per second at that speed.



The O2 sensor determines if the engine is running too rich or too lean by sampling the amount of unburned oxygen in the exhaust gas and sends that information to the ECU.

Remove the front air box to gain access to the throttle bodies. A thorough visual inspection of the engine is an important first step when trying to solve an engine problem.

This is called a closed-loop system because the ECU receives instant feedback for any changes that it makes to the fuel/air mixture, and is forced to adjust for those changes according to the information received.

SENSOR OPERATION

The oxygen sensor is mounted behind the black plastic cover on the upper starboard side of the engine block at the No.1 cylinder. A drilled hole through the cylinder wall makes a passageway for exhaust gases to migrate to the sniffer without becoming contaminated by the exhaust from the other cylinders. The sensing element consists of a zirconium-oxide ceramic bulb, covered with a thin coat of platinum on the inside and outside surfaces.

A perforated metal tube encases the fragile ceramic bulb to protect it from damage and to minimize carbon deposits on its surface. The element acts as a voltage generator

When tightening the O2 sensor; the torque wrench should be mounted at a 90-degree angle to the special socket to obtain an accurate reading.

whose output varies according to the differential between the oxygen level of the outside air and the oxygen level of the exhaust gas. We breathe air that contains about 21 percent oxygen. A rich mixture has less oxygen - a large distinction between exhaust and ambient air -and thus produces a higher output voltage.

Leaner exhaust mixtures contain more oxygen - more similar to the outside oxygen level - so the sensor develops lower output voltage. Normal generated voltage is in the neighborhood of between 0.1 and 0.9 volts DC. The ECU senses the changing voltage (from more or less oxygen) and compensates the fuel injector delivery time in reaction to it. That way the closed-loop system is constantly trying to obtain the optimum fuel/air ratios for best drivability and economy according to the conditions encountered.

After removing the black plastic insulated cove,; the sensor and its housing are visible. Loosen the sensor before removing the housing bolts.

For an oxygen sensor to function correctly, it needs to be kept at or above 600 degrees. A heating element in the sensor tip keeps things operational when the exhaust temperature is low, such as when idling or slow trolling for extended periods of time.

The oxygen sensor cannot work with either a deposit buildup on the sensing bulb or if contaminated with lead, phosphorous, or silicon. The metallic tube shields the bulb, but the vent holes in the tube can become plugged with carbon if there is a problem with the engine condition or from the use of poor-quality fuels and oils.

Before starting a do-it-yourself project, be sure to have the required tools, parts, and the correct service manual on hand. A torque wrench is mandatory for almost every repair procedure.

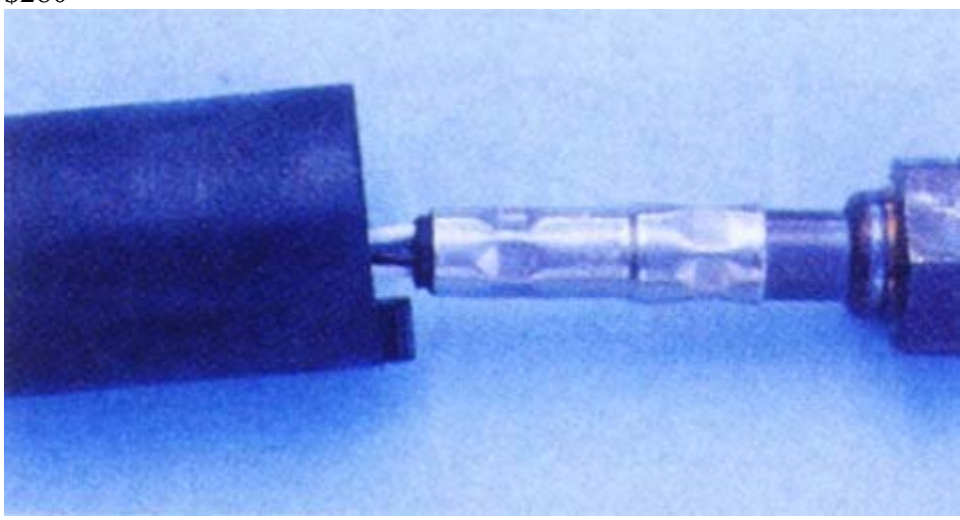
TROUBLESHOOTING

Drivability issues can be the result of a number of engine- or boat-related problems that have to be resolved before condemning the oxygen sensor. An EFI outboard, as with all outboards, still needs the basic trinity: the correct fuel-to-air mixture, adequate compression, and ignition at the appropriate time. Do not forget the basics of good troubleshooting: a thorough visual inspection, a fuel sample, a compression or leak-down test and an ignition output test

For surging problems, check both the regular fuel pump output and the electric-fuel-rail pump pressure as explained in the service manual, and then test the boat's fuel system for restrictions or air in the lines. A vacuum gauge into the fuel-pump inlet and a length of clear fuel hose make the job easy (refer to B&WB March 2001). Replace any questionable fuel filters, check for loose clamps or kinked lines, and test for any gas tank pickup or anti-siphon valve problems.

Linkage adjustments and timing (called sync and link) must be performed in accordance with the service manual, and throttle-position sensor adjustment is critical for good running quality. If the engine has not been de-carbonized within the last 100 hours, that should be performed using the factory-recommended products and procedures. With the sensitivity of the oxygen sensor, it is false economy to use aftermarket additives and cleaners without knowing if the ingredients could make things worse, especially with the cost of a new

element being approximately
$280



The 02 sensor tip consists of a perforated tube that protects the sensing element and the heater assembly.

Use a test light (Part No. YB-06444) to learn if any error codes are stored in the ECU. Follow the instructions in the service manual and repair any problem codes that show up.

TESTING THE SENSOR

Without disassembling the cover, sensor, and housing, a quick test can be performed that tells if the element is sensing a change from rich to lean and vice-versa. Trace the gray and black wires from the sensor and install the Yamaha test harness (Part No. YB-06767) between the connectors, or fashion an adapter to allow the meter to measure the voltage across the sensor wiring. Use a quality digital meter with the test probes inserted into the adapter harness and set the scale to read in the 1-volt DC range. The other wires from the sensor are for the heating element and should be checked for proper resistance and volt-age input.

Remove the front air-silencer cover and run the engine until it comes up to temperature, at least 120 degrees, before conducting the test.

Yamaha's VMax 0X66 calls for maintenance every 100 hours, or once a year, whichever comes first.

The voltage shown on the meter screen will read between 0.3 and 0.6 volts DC with a good sensor and will vary continuously as the computer (ECU) adjusts the mixture. A lower voltage reading indicates a leaner mix and a richer mixture raises the voltage output from the sensor. If the voltage remains near 0.9 volts, the oxygen probe is showing signs of becoming fouled.

While the engine is idling, carefully use your finger to cover the air-bleed hole in the top of the cylinder throttle plate and watch for a significant change in voltage readings. By blocking the air-bleed hole, that cylinder becomes very rich briefly as a result of the reduced air flow, and the ECU should respond immediately to "lean out" the fuel-to-air mixture. The voltage should first increase because of the initial richer mix, then become lower as the ECU "leans out" the fuel mixture to compensate. As you remove your finger from the hole in the throttle plate, the increased air causes a momentary lean condition and the sensor's voltage output decreases in response.

You should then observe an increased volt reading as the ECU "richens" the fuel to stabilize the engine. If any of the changes in voltage are very sluggish or nonexistent, the oxygen sensor may be fouled and in need of cleaning or replacement.

SENSOR REMOVAL

Follow the service manual explicitly when removing and installing the 02 sensor to avoid an expensive replacement. Have the required special tools, torque wrench, sensor wrench or crows-foot socket and gasket kit on hand before attempting removal.

Make note of the orientation of the rubber sleeve, wire routing, and tie-strap positioning before taking things apart. Disconnect the two wiring plugs, and then gingerly "roll up" the rubber sleeve, taking care not to pull the wires out of the sensor assembly. Remove the black protective cover held in place by two bolts. Make sure the inside of the cover is clean and that the foam is not oil soaked. Replace any wet insulation that could foul the sensor upon installation.

Loosen the 22 mm nut before taking out the housing bolts to facilitate the sensor removal. After detaching the housing from the engine, gently unscrew the sensor and inspect the probe for any damage or carbon encrustation. Extract the small exhaust tube from the cylinder block and check for blockage. Yamaha changed the design on some of the early (1997-99) 3.1L engine tubes to minimize carbon buildup. Take the tube with your model and serial number to a dealer to see if your engine could benefit from the improved part. Pictures and details of the old and new styles of tubes can be found in Technical Bulletin No.099-024, dated December 3,1999. Carefully clean out the carbon from the tube, cylinder passage-way and sensor mount, and clean the gasket surfaces.

A clean sensor probe has clear perforations, is a medium brown color, and is free of any oil or carbon formations. Heavy deposit buildups or metal flakes indicate internal engine problems that should be addressed. Only use Yamaha's Ring Free (No. ACC-RNGFR-EE-12) or Combustion Chamber Cleaner (No. ACC--CMBSN-CL-NR) to soak the tip, immersing it no deeper than the start of the threads. Chemicals in other types of solvents or soaking the sensor up to its "neck" could ruin it and require the purchase of a new one. Spray the probe clean with Contact Cleaner after soaking and wait until it is thoroughly dry before re-testing it

SENSOR RE-TESTING

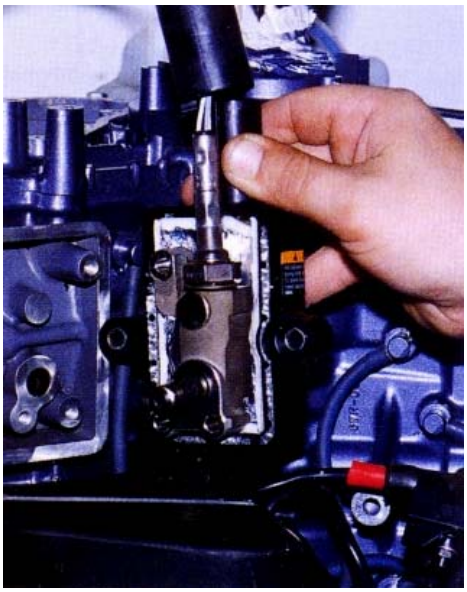
Bench testing the oxygen sensor will indicate if it is clean and good enough to be reused. Hook up the digital meter to the black and gray sensor wires and set it again to read 1-volt DC. Use a propane torch, never an oxy-acetylene torch, and pass the probe through the flame for about 15 seconds. Do not allow the sensor to be heated above 1400 degrees or hold it in the torch flame for more than one minute. You can also use a butane lighter, but it will take about two minutes for the probe to come up to temperature. Use caution around an open flame and work in a ventilated area away from flammable and combustibles.

To see if the sensor is operational, pass it through a propane flame and watch for a change in voltage readings.

The meter reading should be close to 0.6 volts and should change as it passes in and out of the blue flame. Blow on the probe to cool it quickly and see if the reading drops below 0.3 volts within five seconds. If the sensor does not respond correctly, re-clean it and try again. Excessive contamination ruins the sensor and no amount of cleaning will bring it back to life.

INSTALLATION

Insert the small exhaust tube into the engine first so that it is not forgotten. Thread the sensor into its housing and, with a new gasket, attach the housing to the cylinder block. Hand tighten the screws first, then torque them in two steps: 5 ft/lbs, 10 ft/lbs. Use the special sensor wrench tool, or a correctly sized crows-foot wrench, with a torque wrench fastened at a 90-degree angle to tighten the sensor nut to 35 ft/lbs. Carefully install the cover, making sure to route the wiring correctly and slide the rubber boot on completely before fastening the tie-strap.



A hole is drilled through the cylinder wall in the cylinder block behind the sensor housing. This allows the oxygen sensor to sample the exhaust of only the No.1 cylinder without the mix of gases from the other cylinders and eliminates the chance of cooling-water ingestion.

Double check your work, and then perform an on-water test to see if your efforts have paid off. If the 02 sensor was the culprit, and is now properly cleaned, your EFI Yamaha will run better than before.

CONTAMINATION PREVENTION

Because of the engine's complexity; more care and attention to maintenance is needed to keep your Yamaha 0X66 EFI outboard running well. To minimize carbon buildup, stuck rings, and fouled oxygen sensors, the factory recommends the continual use of Ring Free additive to be mixed by adding one ounce to each 15 gallons of gasoline at every fill-up. The engine's state of tune makes a big difference in the performance and longevity of an outboard. Be sure to perform routine maintenance at 100-hour intervals, per the owner's and service manuals, or once a year, whichever comes first.

Refer to the B&WB 'S June 2000 issue for illustrated outboard maintenance procedures to supplement the factory recommendations. Stale or contaminated fuel and oil that only meet minimum TC-W3 specifications (refer to August 2000B&WB) contribute to sensor problems, as do the use of un-approved additives, sprays, and cleaners. Reformulated (oxygenated) gasoline sold in some areas of the country fool the sensor into thinking the mixture is lean (more oxygen is sensed), and the ECU erroneously richens the mixture and performance suffers. Try to use an alcohol-free regular grade of fuel (not premium) for best results.

Malfunctioning thermostats may cause the engine to run too cool causing a quicker creation of carbon (refer to July/August 2001 issue of B&WB); and worn or the wrong style of plugs can cause misfiring, affecting the 02 sensor if it occurs on the No.1 cylinder.

Avoid extended periods of idle or slow-speed trolling to prevent excessive carbon formation. Make sure the oil-pump link is adjusted exactly as the service manual illustrates to keep from over oiling the engine and forming more carbon deposits. The factory recommended volume of oil is sufficient, but more is not necessarily better and could cost you in the long run.