The New Evinrude E-TEC Outboards

In 2001 when Bombardier purchased many of the assets of the Outboard Marine Corporation, parent company to the Evinrude and Johnson outboard brands, one of the jewels was the FICHT direct injection technology. A very simple direct fuel injection system based on an electric solenoid injector, it had been developed over 4 years of production onto a range of reliable, economical and very low emission engines. However, they were all engines of 90 HP or more and for the future, Bombardier knew they'd need to expand DI to smaller engines and also be able to meet ever more stringent emission requirements. Smaller engines also meant incorporating DI onto manually or rope starting engines. The new Evinrude E-TEC engines, first announced to Australian dealers in July 2003, can do all that and more.

Outboard consumer surveys, conducted around the world in 2001, were commissioned to gauge if the typical outboard owner's requirements had changed. The results were a little surprising to many of the older marine engineers. In order of preference, the modern outboard owner wanted –

1. DQR - Dependability, Quality and Reliability
2. Ease of Maintenance
3. Easy starting
4. Performance
5. Economy
6. Style/appearance

Bombardier engineers have designed the E-TEC to incorporate these customer requirements by focusing on 4 main design criteria –

1. **Easy to own and operate** – E-TEC engines are instant starting, lightweight high performance engines that can go 3 years or 300 hours between scheduled dealer servicing.
2. **DQR** – By utilising larger engine capacities and many parts from the proven V4 and V6 models, E-TEC engines have lower stress levels than many previous designs in this power range.
3. **Clean and Quiet** – E-TEC engines feature new and very effective sound proofing for very low noise levels and the E-TEC direct injection system can already meet the toughest impending emission regulations anywhere in the world.
4. **Style and appearance** – E-TEC engines feature unique styling that will "stand out from the crowd" and enhance their long-term value to the owner. They also feature innovative coloured plastic alloy outer covers that can be buffed or polished to remove scratches and bring back that original showroom shine.

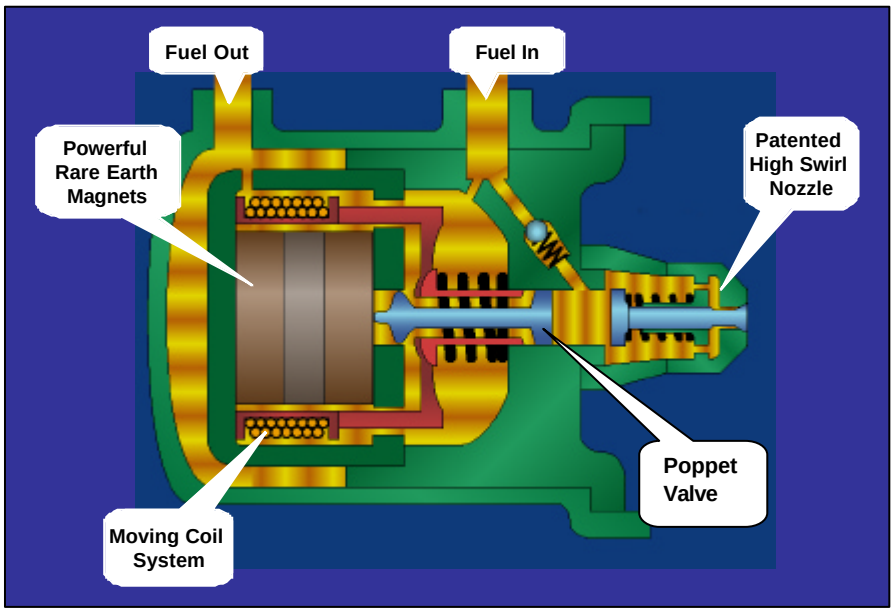
The new 2 cylinder E-TEC is available in 40, 50 and 60 HP versions

3 Cylinder E-TEC models come in 75 and 90 HP sizes

E-TEC Injector

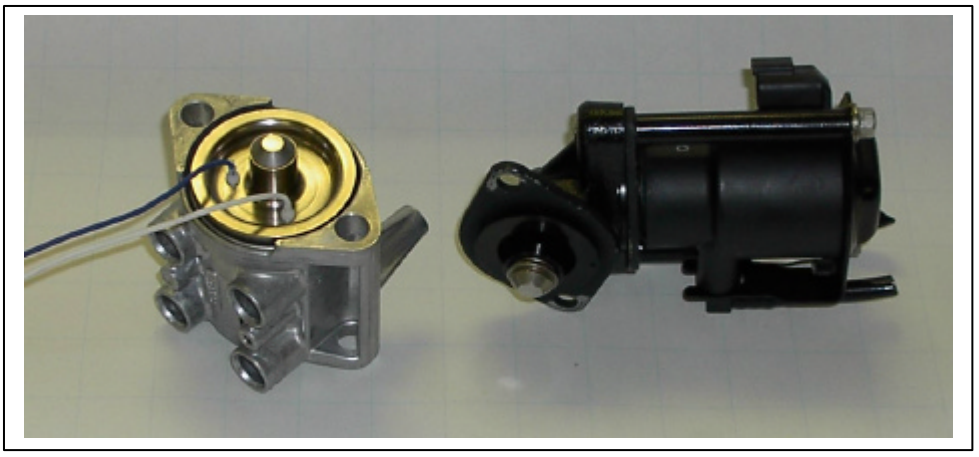
At the heart of the engine is the E-TEC injector. If you recall similar graphics in previous stories of the FICHT injectors, you'll see some similarities. Fuel is recirculated through the injectors continuously to cool the injectors and ensure any air or vapour is removed. This is because all injection systems can only accurately meter liquid fuel and any air or vapour must be removed. The E-TEC injector also uses an electro-magnet, but instead of a fixed electrical coil and a moving heavy steel armature, the E-TEC uses a lightweight moving coil bobbin. Inside the coil are two fixed, powerful rare earth permanent magnets. When current in the coil is switched on the electro-magnetic field reacts with the permanent magnets, causing the coil bobbin to move with great force. The coil bobbin pushes the plunger, and for the first ½ a mm or so it moves freely through the fuel, until it contacts the poppet valve. Now the plunger and poppet valve form a piston and any further movement pressurises the fuel behind the nozzle forcing it open and spraying fuel into the cylinder as very fine droplets.

When sufficient fuel has been injected, the current is turned off in the coil and a very brief reverse polarity pulse is sent. This immediately stops the bobbin and plunger, and starts it returning in time for the next injection event. A second very brief reverse polarity pulse is also sent when the coil is almost fully back to stabilise it (prevent bounce). The use of a lightweight moving coil system and electrical pulses to control movement in both directions is how the E-TEC injector can be both more powerful and faster than previous designs.



Injector Size

The new E-TEC injector is on the left. Compared to previous designs (shown at right), it is smaller, lighter, has 25% less total parts and 50% fewer parts with critical tolerances. It also has a die-cast alloy outer casing.



Injector comparison

A comparison of the basic specifications showing the new E-TEC injector with the existing DI injector, serves to highlight why this new design is so superior. The existing DI injector is capable of about 45 HP per cylinder. More than we need for all current outboards, but not by very much. The existing DI injector is capable of 7500 rpm, again more than we currently need, but not by much. The E-TEC injectors can beat these figures easily and inject all the fuel required in half the time. 0.0025 seconds is about one quarter of a revolution (90 degrees) at 5000 rpm. The E-TEC injector can also exceed 600 psi ensuring very good atomisation of the fuel.

	DI	E-TEC
Maximum HP per cylinder	***45***	***80***
Maximum RPM	***7500***	***10000***
Injection time	***0.005s***	***0.0025s***
Maximum injection pressure	***450psi***	***>600psi***

Fuel pump and vapour separator

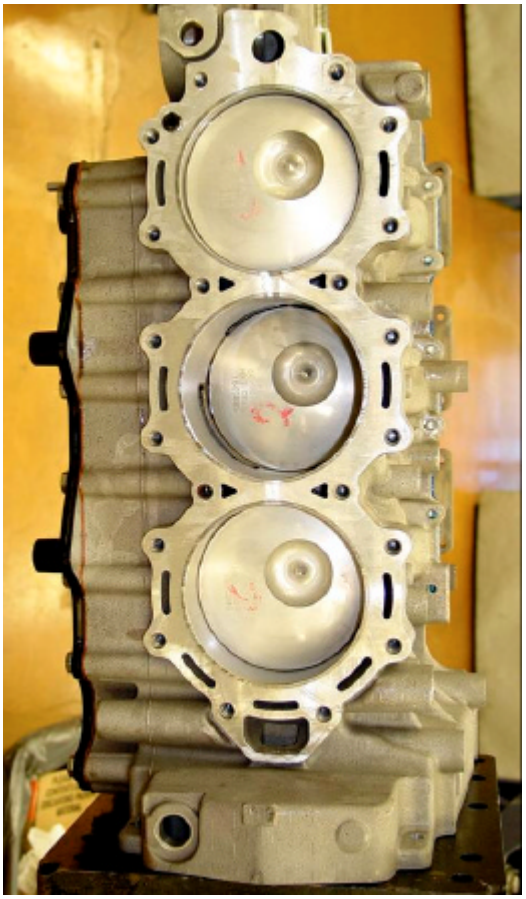
The remainder of the fuel system uses proven existing components. The fuel lift pump on the left will be familiar to many marine technicians, its most recent use was on the 55 HP commercial models. The vapour separator (right) is the same well proven water cooled unit, with integral electric fuel pump, as that used on current V4 and V6 DI models.

The vapour separator is a fully pressurised design that captures and separates any vapour present in the fuel, then releases the vapour only when the internal liquid fuel level drops. This ensures there are no vapour emissions until the engine is running when any trapped vapour is then vented into the intake manifold where it is consumed during combustion. The vapour separator is also water cooled to remove excess heat from the fuel, especially at low speeds when very little fuel is consumed and most of the fuel is being re-circulated between the injectors and the vapour separator.

All New Powerheads

These are the largest capacity 2 and 3 cylinder engines ever to wear the Evinrude Logo, at 864 cc and 1295 cc respectively. They share the same bore and stroke dimensions, and many internal components, with the current V4 and V6 engines of 90 to 175 HP.

All E-TEC engines feature cylinder blocks manufactured using the Lost-Foam casting process that allows very complex shape aluminium castings, with a minimum of joint lines and gasket surfaces. These are multi-cylinder, loop charged engines with all cylinders and the exhaust manifold, in a mono-block casting, including a closed deck design for better cylinder bore support. The cylinder head surface is sealed with O rings, and conventional gaskets are only used in low temperature and low stress areas like outer water jacket covers and the intake manifold.

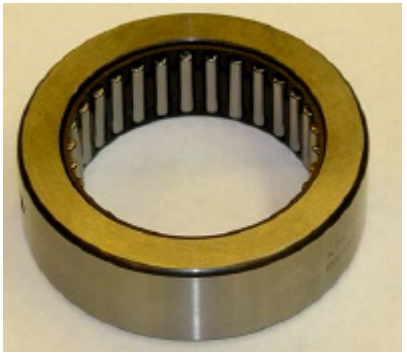


Large bore, lost-foam casting features a closed deck design for rigidity.

The pistons feature a new alloy developed from the NASA Space Program that is twice as strong as conventional pistons alloys, at normal operating temperature. The new pistons also feature a long, full skirt design, without ports, for a close fit in the cylinder and very low noise in operation.

CNC machined ports and Boron-Nitride honed cylinders mean extremely accurate bores that do not require the operator to follow any break-in procedure. The only concession required for break-in is a little extra oil that is provided by the EMM controlled oil injection system, during the first 3 hours of operation above 2000 rpm.

E-TEC piston shows the “Re-entrant Splash Port” that concentrates the fuel air mix in the centre of the combustion chamber.



Large diameter roller bearings are used throughout the engine and gearcase

Full Magneto Electronics

And here's the other side of the E-TEC equation. In order to get DI onto smaller engines a whole new approach to the electronics was necessary, both to fit the smaller engines and to allow easy rope start capability. Special rare earth powerful permanent magnets are used in the flywheel, so that all electronics are powered entirely by rotating the flywheel. The battery is only used for the starter motor on all E-TEC models. The compact 5 inch (125 mm) stator has a single voltage output (55V) from three windings that are switched between series and parallel to vary the output with engine speed.

Total output is 1100 watts, which if it all could be used for battery charging at 13.5 volts, would equal 75 amps. We don't need anywhere near that, so the EMM (Engine Management Module) converts the stator output to a regulated 55V for Injectors and Ignition, 14 V for dash instruments, power trim and battery charging, and 5 V for sensors and EMM internal circuits.

Battery charging is controlled by the EMM at 3-5 amps at idle, 10 amps at 1000 rpm and 25 amps max.

Flywheel

Magneto Stator

Battery-Less Fuel Injection

One of the biggest accomplishments of the E-TEC engineers is getting the EMM (Engine Management Module) to wake up and be ready to run the engine in less than one crank revolution. Everyone knows how long it takes most computers to boot up ready for work. Usually you can go and make a cup of coffee while your PC is booting up. This sort of delay could not tolerated on any engine management computer, however even today most modern ECU's require at least 2 revolutions of the crank before they are ready to run the motor. That's no problem with electric start engines, but on rope or manual start versions that's too long. The E-TEC EMM wakes up and is ready to go in one quarter of a crank revolution. No external power is required nor is there any battery power drain when the motor is switched off.

By one half of a turn, there is about 20 volts available, the EMM is awake, the electric fuel pump is turned on, just briefly to ensure fuel to the injectors, and the piston position has been determined. By three-quarters of a turn, we have about 30 volts available, fuel is injected and then the spark plug is ignited, and the engine starts.

EMM

The E-TEC EMM (Engine Management Module) still has to perform all the functions we expect from a modern engine management system, - operate the injectors and ignition, provide the tacho signal, monitor all sensors for faults, control battery charging and provide a stable smooth idle speed. S.A.F.E. (Speed Adjusting Failsafe Electronics) is also incorporated to ensure that if an engine life-threatening fault should develop (like overheating or no oil pressure) the rpm is reduced to 1200 maximum, an audible alarm is sounded and a warning light is displayed on the dash. At this speed the engine requires almost no cooling or lubrication system functions. Tests have shown an engine can be run all day at 1200 rpm with only the oil inside the crankcase when it was started.

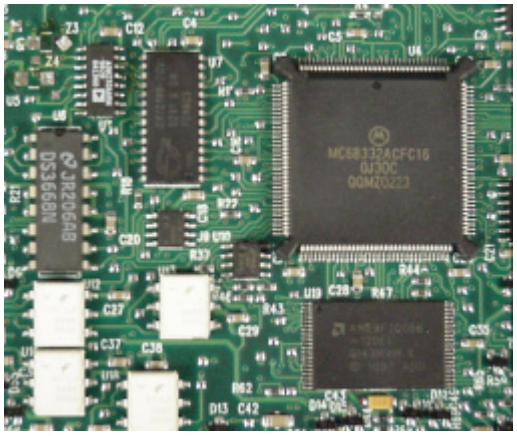
New shutdown modes are also incorporated. If the engine cooling system or EMM temperatures continue to rise, even after activating S.A.F.E, the EMM will shut down the engine before permanent damage is done. Once temperatures have reduced the engine can be restarted. Should engine speed suddenly rise, without the throttle

being opened, indicating a fuel leak, the engine will also be shut-down but cannot be restarted until the code stored in the EMM is cleared by a dealer. This removes the risk of a fire, in the event of a fuel leak.

The E-TEC EMM also features the 0.093" thick PCB pioneered by Bombardier when it first became the owner of Evinrude. This feature greatly improved existing DI engine EMM quality and endurance over previous designs.

EMM size reduction

On the left is a portion of the EMM printed circuit in the current state of the art DI EMM showing the main processor and peripheral integrated circuits required for engine control. The new E-TEC EMM combines all of these into just one small chip (on the right). Something that was not possible just a couple of years ago. Now the size of the wires and plugs can be a limiting factor in getting the size of the electronics down. E-TEC engine EMMs use new more compact AMP electrical plugs. These alone are responsible for removing about 40 mm from the EMM length.



- **Microprocessor**
- **FLASH memory**
- **EEPROM**
- **RAM**
- **Analog to Digital converter**

- **E-TEC All-in-one**

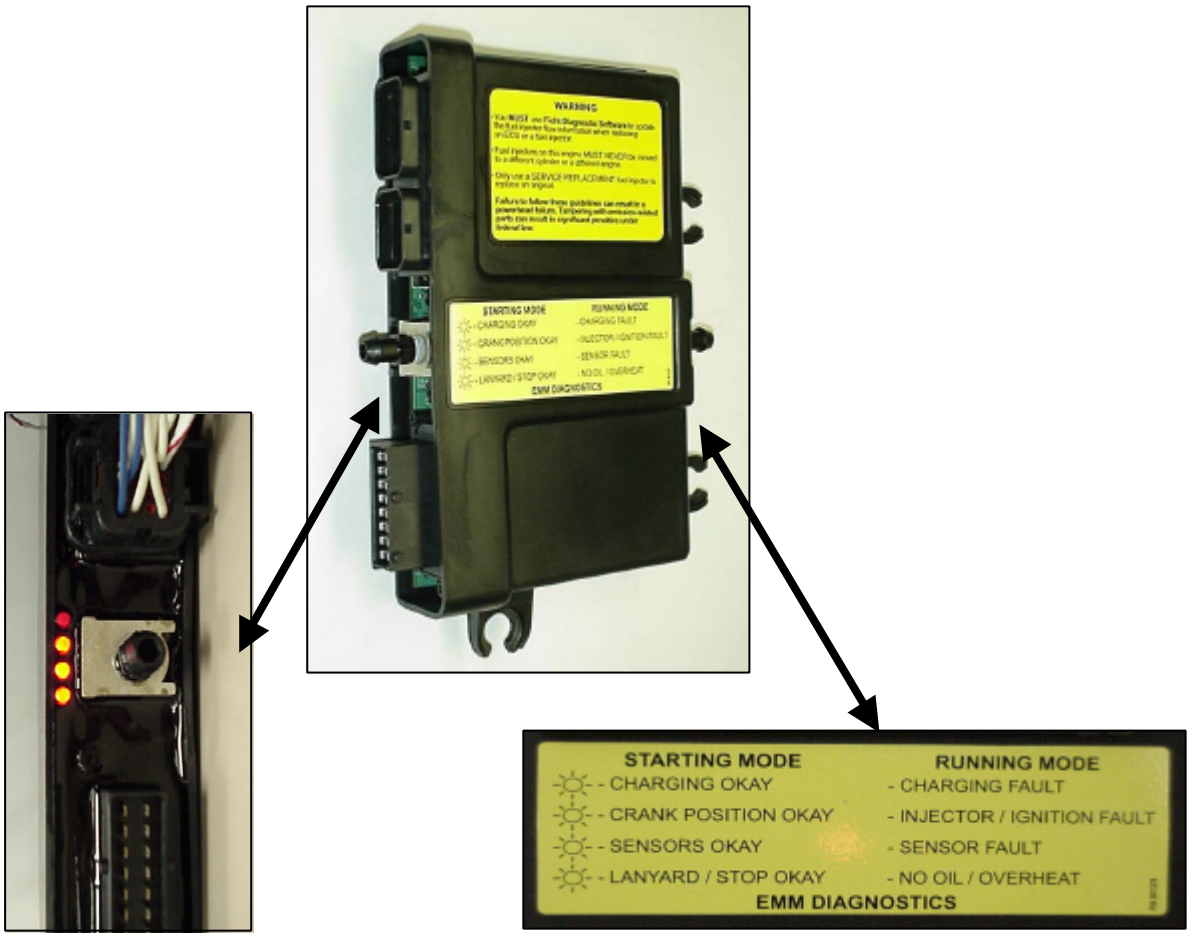
The EMM also operates the ignition system, regulates all voltages, contains two of the sensors and retains the same diagnostic cable and connection point as previous DI models. The communication program will be new to match the new programming, however there will now be several choices available to dealers for diagnostics, including some on-board LEDs.

3 Levels of Diagnostics

All E-TEC EMM's will come equipped with 4 onboard LEDs that light up to indicate if circuits are OK,. These provide low level diagnostics that the technician can do without any tools at all. For example, if an engine won't start, the LEDs will give a quick indication if it is an electrical problem and which main circuit is the culprit.

There will also be PDA diagnostic program. These Palm based PDA devices are becoming more common for engine diagnostics in many industries. Primarily because they are easy to read in full sunlight, run on small easy to replace or recharge batteries, will easily fit into your pocket and cost about only half that of a modern laptop PC. They are great for boat testing.

There will also be a Windows compatible PC program, because for some operations there's no substitute for a larger screen that can show more data at once, and the immediate print-out ability that your workshop PC can provide.



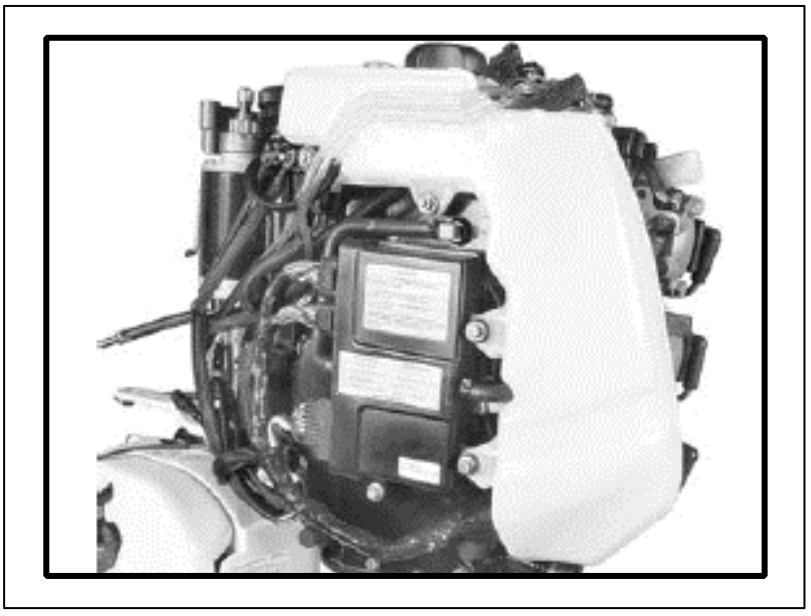
LED Diagnostics

Here's what the 4 LED's on the EMM can do. The EMM has two modes of operation for the LEDs. When the engine is being cranked the EMM sees the rpm is below idle speed, it switches to the starting mode where each LED is turned on as the EMM sees that circuit is complete. In this way a problem circuit preventing the engine from starting is easily seen because that LED does not light up. When the rpm is at idle or above, the EMM switches over to running mode where the LEDs normally stay off and are only turned on to indicate a problem in that circuit. Simple easy to use low level diagnostics.

Oil Reservoir

E-TEC engines use an all new, on-board automatic oiling system. 2 cylinder engines get a 1.8L reservoir, 3 cylinder models get a 2.8L tank. Enough for about 40 hours of typical recreational use with TC-W3, or 60 hours with E-TEC oil.

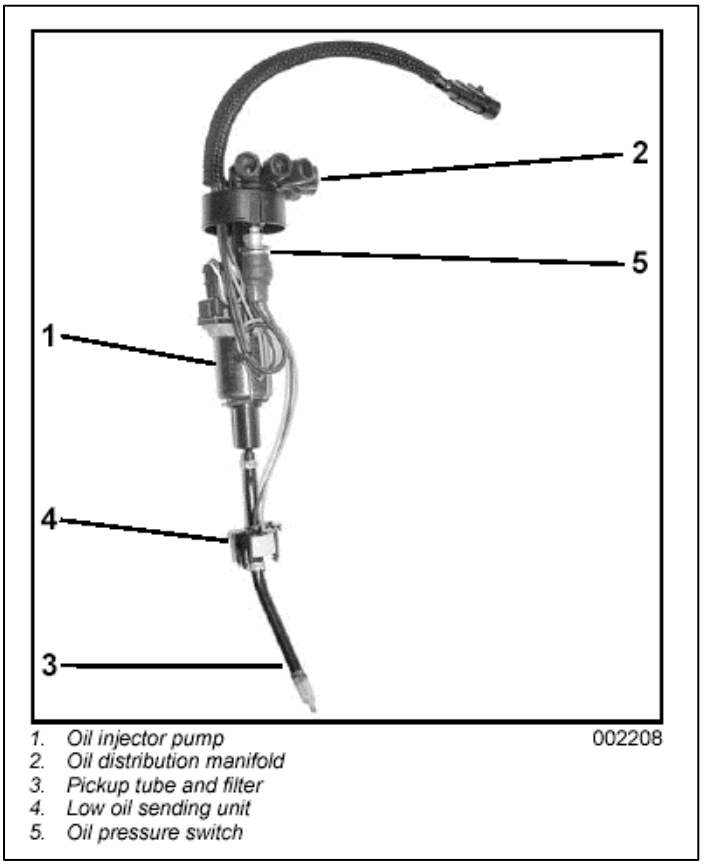
E-TEC models will be the first to allow the dealer to select which oil the customer wishes to use. Now there is a real benefit to being able to use a high-tech synthetic, higher cost oil because the engine can be programmed to use less of it.



Oil Injector

The new oil injector, no oil sensor and low oil sensor are all contained inside the oil tank, on the powerhead. The Oil injector is a solenoid type pump operated by the EMM. The No Oil sensor is a pressure switch that is pulsed each time oil pressure is created in the outlet manifold. The EMM looks for a return pulse after each activation of the oil injector. If the EMM does not get a return pulse, it assumes there is air in the lines, so it rapidly cycles the injector about 100 times to prime the system. If there still no oil pressure signal, then the EMM says "we are not pumping oil into the engine", turns on SAFE, the No Oil System Check warning light on the dash and sounds the warning horn. This is a true "No Oil" warning system.

The Low Oil level switch is also inside the oil tank. It will activate the Low Oil SystemCheck dash light when there is about ¼ of the tank remaining. This is easily enough for a full days boating, about 8-10 hours, so there is no need to rush off looking for a dealer to get some oil, you can do it on the way home later.



1. *Oil injector pump* 002208
2. *Oil distribution manifold*
3. *Pickup tube and filter*
4. *Low oil sending unit*
5. *Oil pressure switch*

Service Items

Most modern outboard owners have a car that they use every day and it gets serviced maybe once per year. Gone are the days of frequent servicing on just about all consumer equipment, and customers now expect modern outboards should be low maintenance as well. E-TEC engines in normal recreational use do not require any scheduled dealer servicing for 3 Years or 300 hours (whichever comes first). Even then it will be relatively simple. You'll replace the fuel filter, install a fresh set of spark plugs, change the gear oil, look at the water pump, lubricate grease points and not much else. E-TEC engines have no adjustable items like the valve clearances or the carburettor adjustments used on older technology engines, nor do they have any belts to replace.

Will there be any servicing needed before 3 years/300 hours? Yes, there will be some operator maintenance, such as cleaning the engine, flushing the cooling system, initiating off season storage and lubrication of grease points. Things that many owners may still wish their dealer to perform.

Emissions

Engine emissions are mentioned a lot today and even though none of the Australian/New Zealand marine engine markets is yet directly affected by emissions legislation, they are driving the technology of most modern engines. About 70% of the worlds outboard markets are now, or will be by 2006, directly controlled by emission regulations. There are three main emission regulating bodies, the USA Federal EPA, The California Air Resources Board (CARB) and the more recently formulated EU (European Union) Recreational Craft Directive.

US EPA

The US Federal EPA affects all of the United States. It started in 1998 and is being phased in each year until full compliance is required by 2006. Hydrocarbons (HC), Oxides of nitrogen (NOx) and Carbon Monoxide (CO) are all measured and reported, but only HC and NOx are currently regulated. Corporate averaging is allowed, so that each "clean" engine produced provide credits that allow some "dirty" engines to be made. The legislation even allows for buying a selling of credits should an engine maker want to. To give you an idea of how the rules get stricter with time, back in 1998 we could make about 20 old technology "dirty" engines with the credits we got for making just one "clean" model. However by 2006 it will be completely reversed, with about 20 clean engines required for every old technology "dirty" model sold. The US EPA 2006 regulations represent a 75% drop in emissions over older technology carburettor engines.

CARB

The California Air Resources Board took the Federal EPA rules and said "we'll go tougher than that", the US federal 2006 rules are in force by 2001, then another 20% lower emissions by 2004 and another big drop for 2008. These rules were given star ratings to make it easy identify the engines that comply. One star for 2001 models, 2 stars for those complying with 2004 rules and 3 stars for 2008. Engines sold in California must have Star ratings shown on a label. The same pollutants are measured as for Federal EPA. Only applies in California, but with 25 million people, good boating weather and lots of places to go boating, it's a big market.

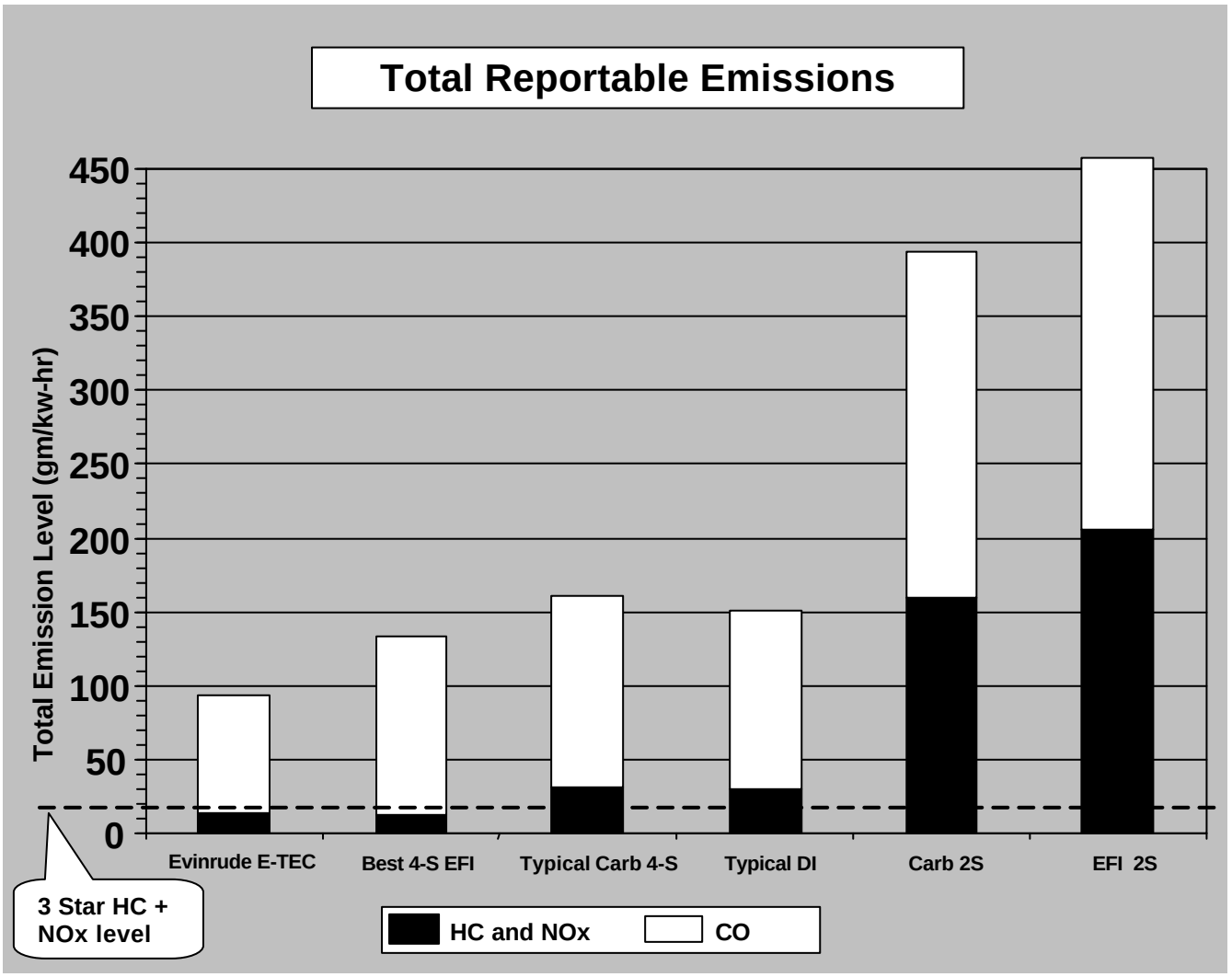
EU

Applies to all countries in the European Union. Applies different rules to 2-stroke and 4-stroke engines, and separate requirements for all three main pollutants (HC, NOx and CO). The levels allowed are similar to the US EPA, but no corporate averaging is allowed, and independent engine testing is required. The need for outside independent testing and regulations for CO levels, mean the EU rules will be quite a challenge for some engine technologies.

Total Reportable Emissions

To give you an idea of how E-TEC easily complies with emission regulations, here is a chart of how the various outboard technologies compare. The dark (lower) bars are the HC and NOx emissions levels. Most modern low emission designs are a marked improvement over the older technologies shown in the two right-side bars (Carburettor 2-S and EFI 2-S). However only the very best of modern designs can achieve the California 3 Star rating (below the dashed line). E-TEC is equal to or better then all current designs for HC and NOx, and is lower than any for CO. All E-TEC models will be 3 Star rated.

The simultaneous opening of both intake and exhaust ports in 2-stroke engines, for nearly one half of the cycle, was once their Achilles heel. It allowed the easy escape of unburnt fuel that caused high emissions. However, with DI it becomes an advantage, as scavenging the cylinder with a new fresh charge of air is relatively easy, compared with 4-stroke engines where the inlet is only open for one out of 4 strokes. This means that DI and E-TEC engines have much lower pumping losses (effort required to scavenge the cylinders) and that leads to lower emissions and better fuel economy, especially at low speeds.



EVINRUDE E-TEC