2006 Evinrude E-TEC Outboards

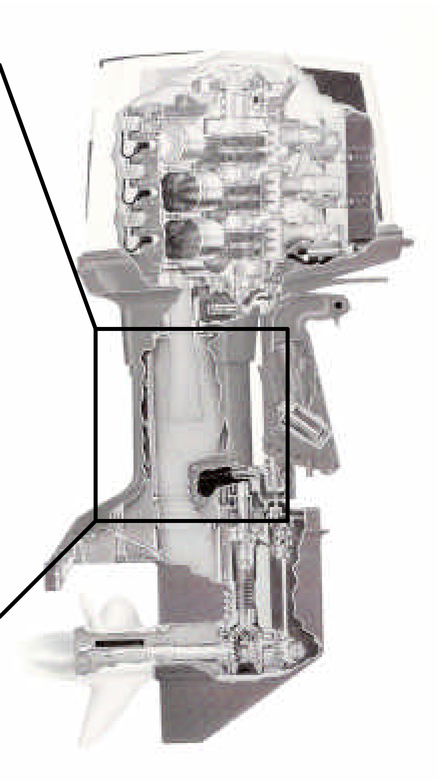
Two years ago Evinrude announced the release of the first E-TEC engines, ranging from 40 to 90 HP. These were revolutionary 2-stroke engines with lower emissions, better economy and less maintenance than 4-strokes. Last year the 3.3 Litre V6 E-TEC engines of 200 to 250 HP appeared to rave reviews of their performance, economy and quiet operation. Now for 2006 the 60 degree V4 and V6 engines between 115 and 200 HP will arrive. The 2006 E-TECs not only continue the E-TEC philosophy, but add some new features – the industry's first electronically controlled tuned exhaust systems.

1966 Johnson 100 HP with early tuned exhaust system

Tuned exhaust systems on 2-stroke engines have been around since the early 1960's on motorcycles and go-karts where they were also very visible. The first tuned exhaust systems on production outboards happened in 1966, but these were well hidden inside the engine casings. It consisted of a short megaphone suspended inside a rectangular box and made some use of the pressure wave energy available in the exhaust gasses to increase the charge in the cylinder.

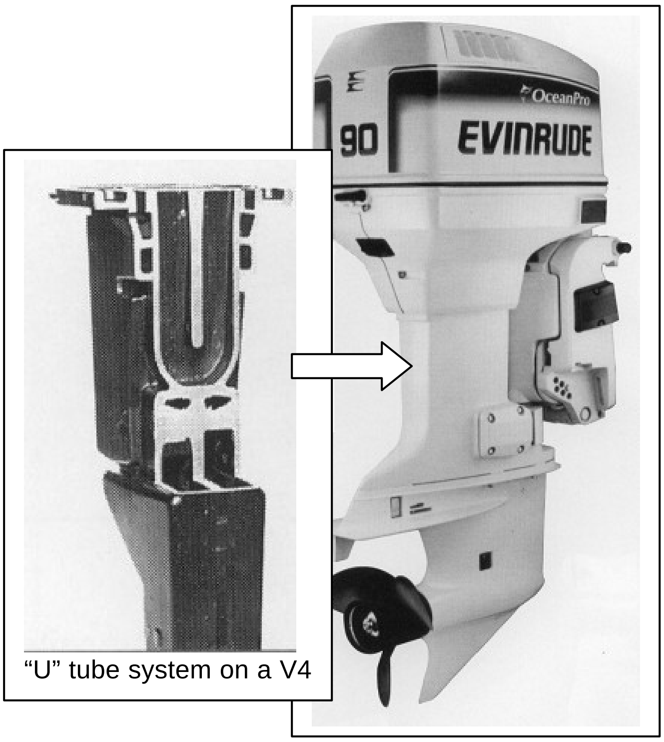
3 Cylinder outboard engines also started to appear in the 1960's for the very good reason that having 120 degrees between cylinder firings just happens to provide nearly ideal spacing for a tuned exhaust system. That is the pressure wave created in the exhaust system when an exhaust port opens just happens to be at the same time as another exhaust port is closing, raising the pressure in that cylinder by pushing back some of the over scavenged fuel and air. Having higher pressure in the cylinder just after the exhaust port closes is like a little free supercharging, providing a power boost and better economy through less wastage of fuel out the exhaust.

One of 2 tuned 3-cylinder systems in a V6 mid-section



In the mid 1970's V6 outboard engines arrived and immediately power jumped by over 50HP. Although it was not very obvious at the time, one of the main reasons was exhaust tuning. V6 engines easily lend themselves to having two 3-cylinder exhaust systems neatly hidden away in the V of the engine.

However not all engine sizes can be 3 or 6 cylinders. Engines around the 100 to 130 HP range are too big for 3 cylinders and too expensive with 6 cylinders, so 4 cylinders is much more common. 4 cylinder 2-stroke engines fire every 90 degrees which makes for a nice smooth, low vibration engine, but the exhaust pressure waves travel across the exhaust system a little too early to be useful as a “plugging” pulse for another cylinder. By arranging the firing order to alternate between port and starboard sides on a V4, and keeping the port and starboard exhaust systems separate, the pressure waves then need to travel to the base of the engine then up the other side. This lengthens the wave travel path and helps to get it to arrive at the right time, but it was still not quite as good as a 3 cylinder system.



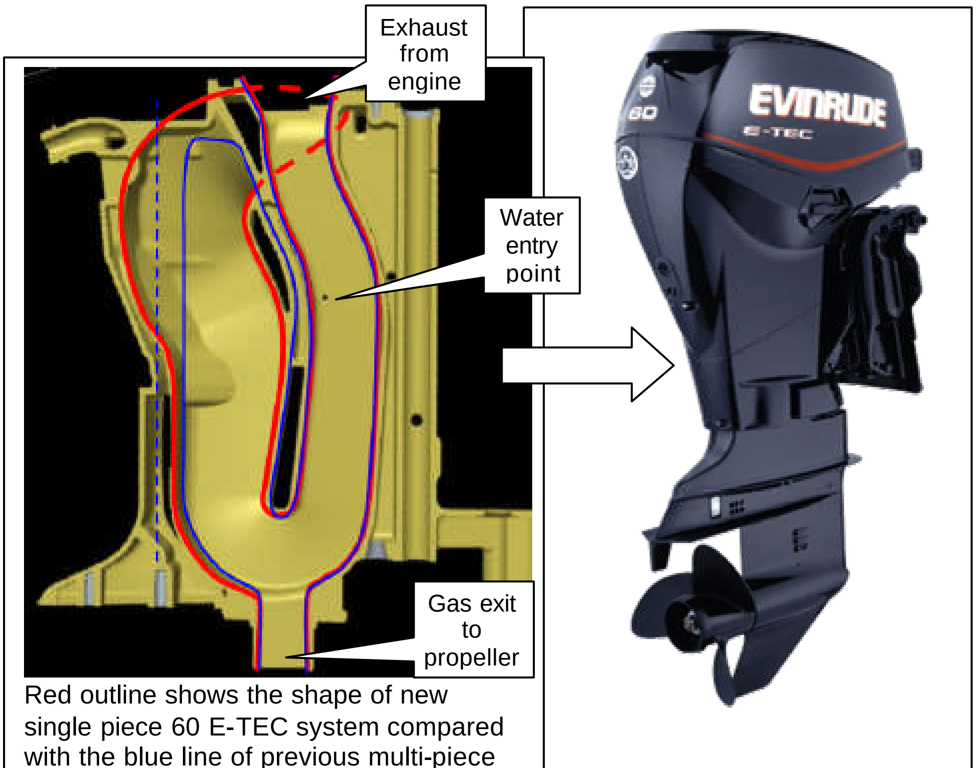
“U” tube system on a V4

Then in the mid-1990’s the “U tube” exhaust system arrived. The join between port and starboard exhaust systems now extended well down into the mid-section of the engine, increasing the exhaust pressure wave travel distance and improving the tuning.

The 2006 Evinrude E-TEC 2 and 4 cylinder engines now add electronic control to vary the tuning at different engines speeds to provide a very broad flat torque curve.

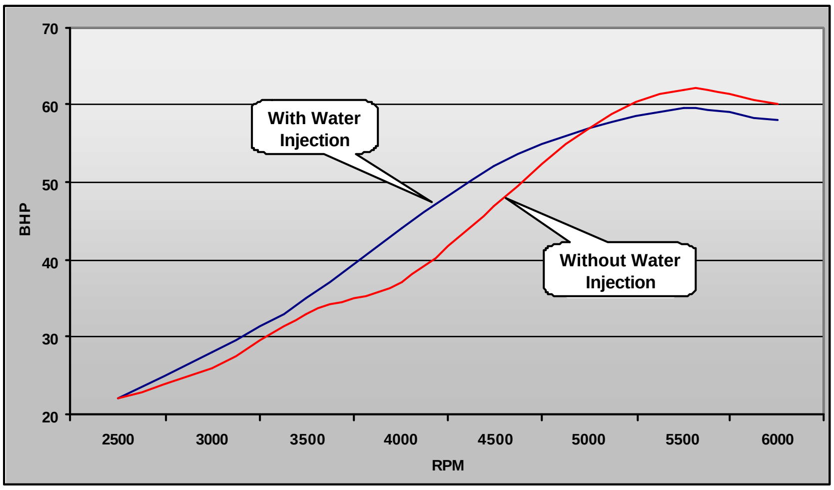
The new 60HP E-TEC is an 860cc twin cylinder engine. Two cylinders fire too far apart to allow the pressure wave from one cylinder to be used as a “plugging” pulse for the other cylinder, so the exhaust system utilizes a reflection of the pressure wave from the same cylinder. The tuned exhaust system in the engine’s mid-section resembles an “expansion chamber” system, but folded up to fit into the available space.

A completely new, single piece lost-foam casting is required in order to fit the new larger system into the engine while still retaining room for the cooling system water pump, engine mounts and the driveshaft.



Red outline shows the shape of new single piece 60 E-TEC system compared with the blue line of previous multi-piece systems

Exhaust gasses enter the system at top right. The exhaust gas outlet is at bottom centre. Pressure waves travel around the U shaped loop and are reflected from the far end (upper centre on picture). The timing of the reflected wave is crucial to tuning and is determined by the distance it needs to travel and its speed. The new single-piece system has a large volume for a stronger reflection and greater length for best tuning effect at a lower RPM. In addition, water is injected into the system by the Engine Management Module (EMM) switching on a solenoid valve when it senses high throttle opening. Cool water on its way into the engine is injected by the solenoid valve, lowering the gas temperature inside the tuned section and slowing down the wave speed. Pressure waves in the exhaust gas travel at the speed of sound, about 1100 kph in the atmosphere at room temperature, but in the exhaust gas where temperatures get to 500C+ it can be 1500 kph, so cooling the gas temperature has a large effect on the timing of the pressure waves and therefore the engine speed where the exhaust tuning works best.



Power output curves for the 60 HP E-TEC, with and without water injection into the exhaust system.

The EMM monitors throttle opening and RPM, and when the throttle opening is above 80% water is injected between 2500 and 4500 rpm. The result? Between 3500 and 4500 RPM, at full throttle, power is increased by around 5 HP or more than 10%. Above 4500 rpm the system is dry to get the fastest pressure wave travel for best power at high RPM.

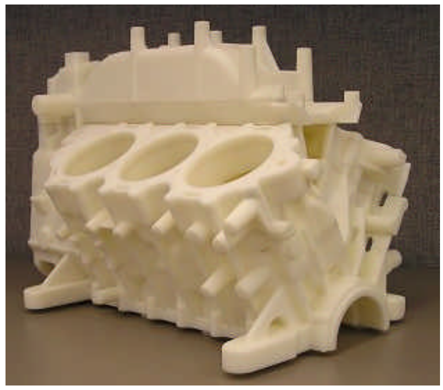
New V4 and V6 "Small Block" E-TECs

2006 also sees the long awaited release of the 1.7 Litre V4 and 2.6 litre V6 E-TEC models, with outputs between 115 and 200 HP. These new engines now fill the gaps in the E-TEC range so there's now a full range from 40 to 250 HP. To enhance quality and durability, E-TEC models use many common components across the model range. The 40 to 200 HP range utilizes 2, 3, V4 and V6 cylinder engine all with identical bore and stroke. These models use the same –

- Piston rings
- Crankshaft bearings
- Con Rods
- Cylinder heads (starboard head on V engines same as 2 or 3 cyl inline engine)
- Electronic sensors for engine management
- Linkages and external hardware.

In addition the mid-sections, gearcases and crankshafts are shared over several models.

The new V4 and V6 models from 115 to 200 HP all share a 60 degree V angle and the same bore and stroke as previous Evinrude 60 degree V angle engines, but that's where the similarity ends. The E-TEC models have a newly designed lost foam cast cylinder block with larger air intakes and reed valves, more cooling system area and a larger, more free-flowing exhaust system.



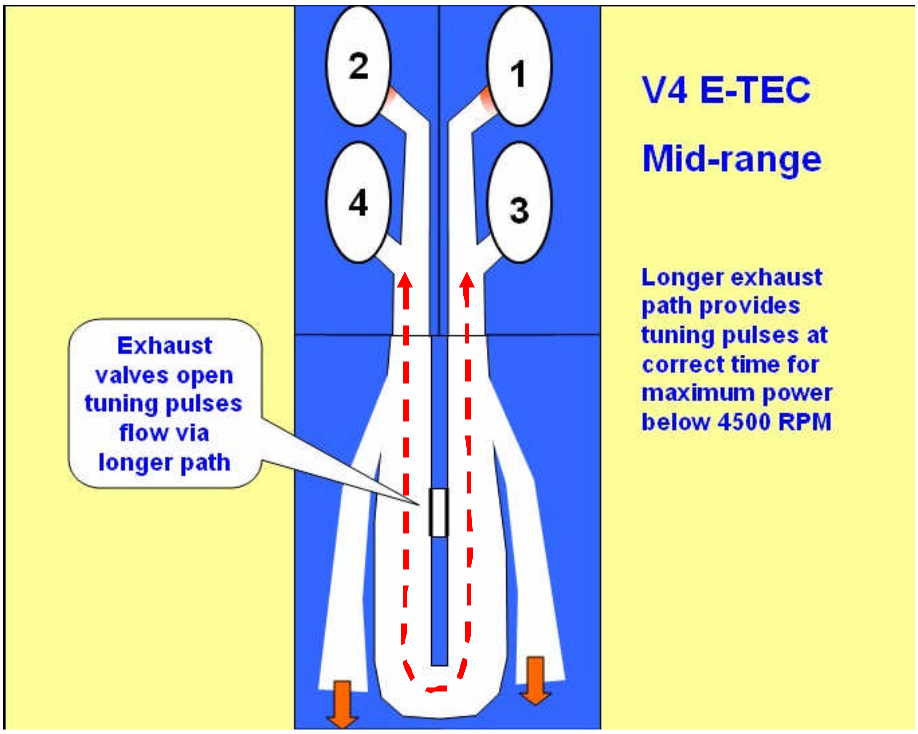
Lost foam castings allow very complex shapes to be cast in a single piece allowing freedom from the need for many fasteners to hold several pieces together and all the room they need along with gaskets to seal the joints. The process is simple, make a cylinder block out of many small pieces of polystyrene foam glued together to get the desired shape. Coat the resulting assembly in a hard ceramic shell by dipping in a slurry solution then baking in an oven. Now support foam block and its ceramic shell in a sand box to hold its shape while you pour in the molten metal.

The molten metal vapourises the foam and takes its exact shape. After it's cooled, you vibrate the new casting to break away any remaining ceramic shell (it also cracks a lot during the cooling), then it's ready for machining and surface coatings.

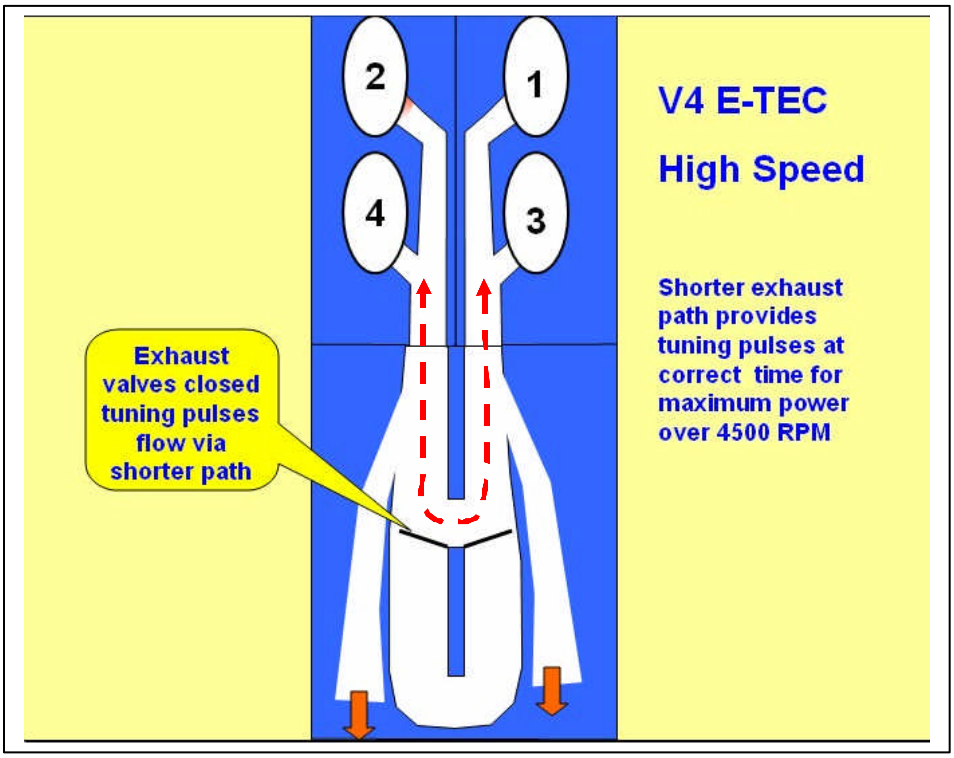
The new 115 and 130 HP V4 E-TEC models also introduce an electronically controlled tuned exhaust system, but being a 4 cylinder engine it requires a different method than that describe above for the 60 HP. For best mid-range power and acceleration, the "U" tube that joins the port and starboard exhaust systems needs to be quite long, but that then detracts from peak power. So the V4 E-TEC utilises a system where the pressure wave travel path can be switched from long to short.

For best power below 4500 RPM, the "plugging" pulse travel needs to be long, in the order of about 80 cm. A "U" shaped passage is provided inside the engine's mid-section to get the required length. A pair of mechanical valves in the exhaust are moved by an electric motor controlled by the engine's EMM. With the valves in the open position, waves travelling from one side of the engine to the other must travel the longest distance, arriving at the right tune for best tuning effect between 3500 and 4500 rpm. This improves mid-range torque and economy at cruising speeds.

For maximum power a shorter wave path travel is better, so above 4500 rpm the valves are moved to the closed position, opening a crossover port in the exhaust system.



Now the pressure waves are forced to travel a much shorter distance, about 60 cm, so they arrive at the correct time for best tuning effect in the 4500 to 5500 rpm range.

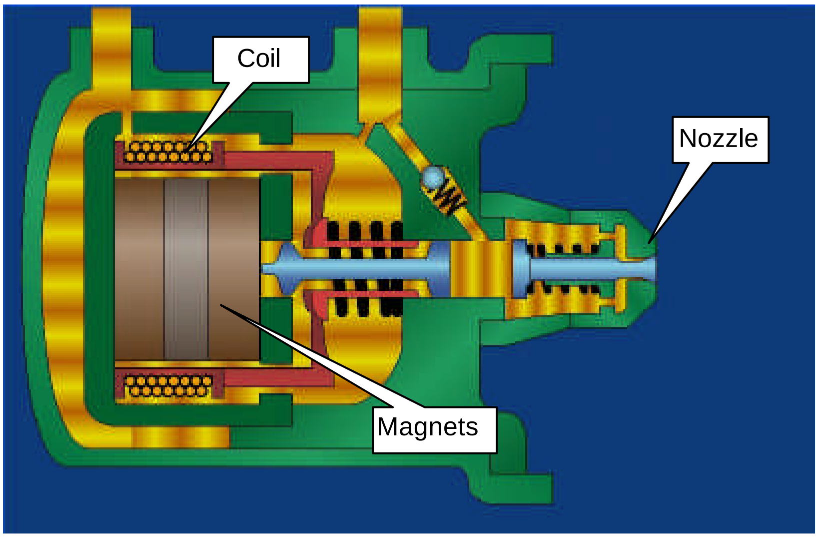


These new E-TEC models also share the very low emissions, excellent performance and fuel economy for which Evinrude E-TEC engines are now well known. Features brought about by the use of 2-stroke engine technology combined with the revolutionary E-TEC direct injection system. Two stroke engines have twice as many power strokes for any given RPM, so making the desired power level is much easier. They also have far fewer engine components making for a smaller and lighter package which is very noticeable in boat performance. The cylinder heads is where the really big difference is obvious.

On a typical V6, 4 valve, 4 stroke outboard engine there can be as many as 195 individual components parts in the cylinder heads, not including the fuel and electrical system parts. On the E-TEC V6 the comparable parts count is just two.

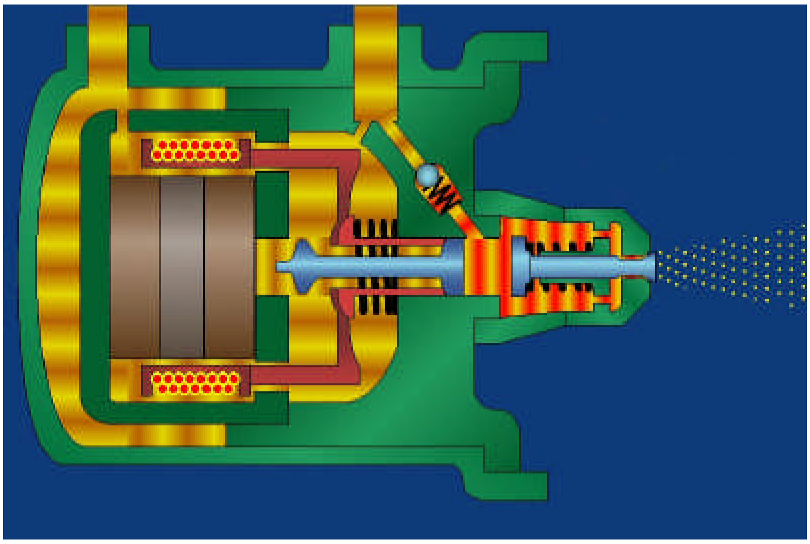
Of course, this relative simplicity of the 2-stroke engine was, for most of the last 100 years, offset by their sometimes erratic running and heavy appetite for fuel, but not any more. Direct fuel injection provides a way to inject fuel after the ports are closed so all that is lost during scavenging of the cylinder is fresh air and exhaust gas. Immediately 2-stroke engines became much cleaner and more economical, and because of their simplicity they retained their great power to weight ratio. These early direct injection systems sometimes utilised an electric solenoid type of injector to create the rapid fuel pressure pulses required to inject the fuel in the short time available. Here an electromagnet moved an iron armature to create the fuel pressure, and they were effective. They had great power, excellent economy and low emissions on a par with most 4-stroke outboards. To get better they needed a way to inject the fuel faster, although being able to inject enough fuel for each 40HP cylinder in about 5 thousandths of second probably sounds very fast indeed. However at 5000 rpm, that time represents nearly 180 degrees of crank rotation, which is about the time limit before we start to lose fuel out the exhaust again.

The Evinrude E-TEC injector can inject all the fuel we need in less than 90 degrees of crankshaft rotation, or 2.5 thousandths of a second. It can do this because rather than a "solenoid" design, the E-TEC injector is a "voice coil" design. Like a loud speaker, the electromagnet coil is moveable (not the armature) and it reacts against a powerful stationary permanent magnets.



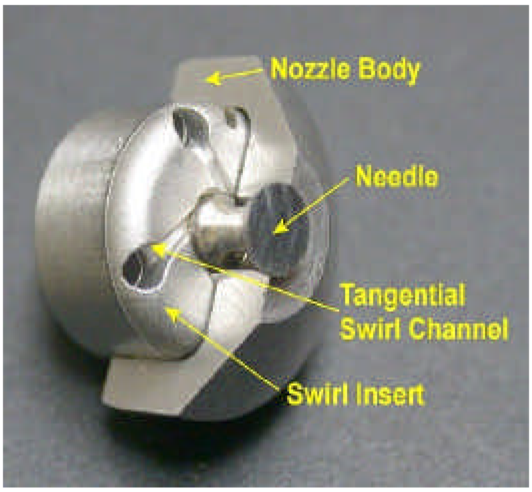
E-TEC injector at rest

In addition E-TEC engines operate the injectors at 55 volts. The end result is faster and much more powerful injectors, with peak fuel pressures reaching over 600 psi. Being a Voice Coil design, the injector can be driven in both directions. An electrical pulse starts it moving and an opposite polarity pulse can stop it, much faster than a spring can, so now you have much greater control over how much fuel is injected and exactly when.


E-TEC injector during fuel injection

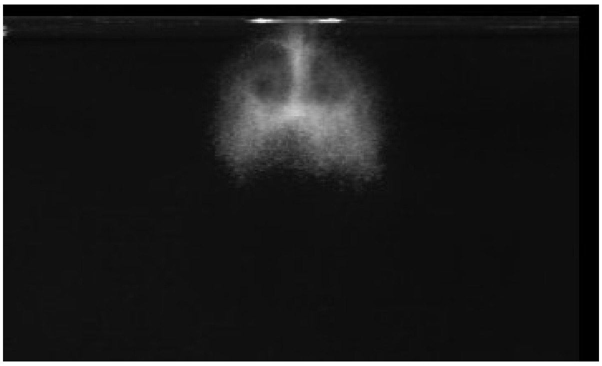
So much control that now you can easily operate an engine in either stratified or homogeneous modes, which ever is best for the rpm and load. Stratified mode uses only a small portion of the combustion chamber, so when only a little power is required, the engine runs like it has much smaller cylinders.

A small cone of fuel is sprayed into the combustion chamber, close to the spark plug. The E-TEC nozzle shape and tangential flow channels allow very fine atomisation of the fuel while retaining the fuel plume in close proximity to the spark plug. The rest of the combustion chamber and cylinder contain only air and some exhaust from previous cycles.

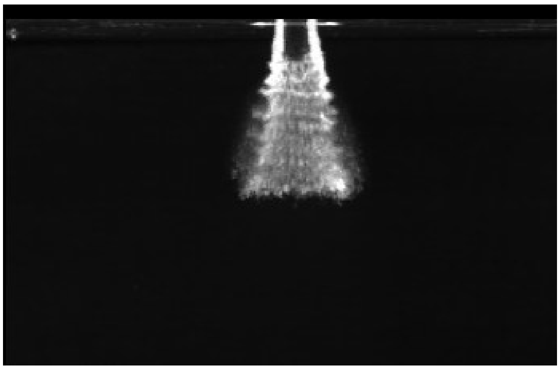


Close up cut-away of the E-TEC injector nozzle

When higher power is required, homogeneous mode is used where the whole cylinder is utilised. More fuel is injected, earlier and with more force. The fuel spray is bounced off the piston crown to help spread it across the cylinder mixing it with the all the available air, and providing the maximum power available.

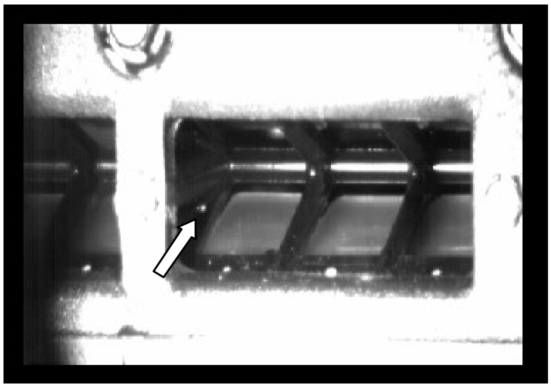


High speed photograph of a stratified injection spray plume.

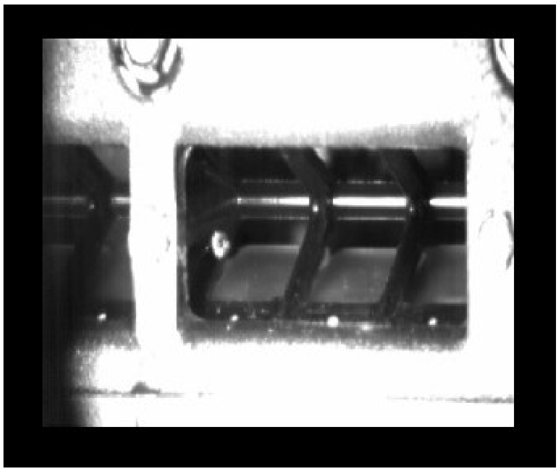


The beginning of a homogeneous injection spray plume

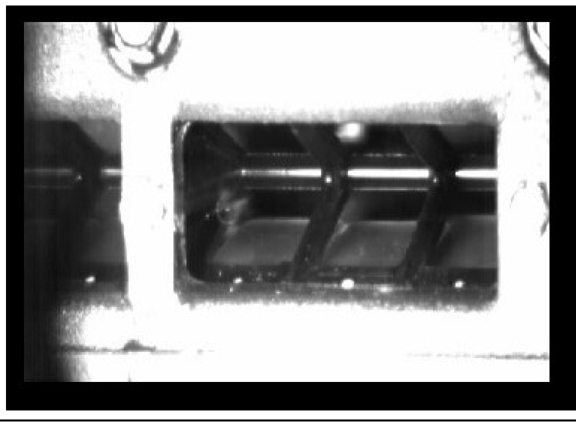
Now that the fuel is injected directly into the cylinder, the engine's lubricating oil can no longer be carried into the crankcase by the fuel, the old traditional 2-stroke method. E-TEC engines use a modified version of the fuel injector to inject oil into the air stream entering the crankcase where it is distributed throughout the bearing surfaces and cylinder walls. It's easy to think the oil droplets might not mix very well with air and just cling to the walls. This series of high speed photo's will show just how well the oil droplets are broken up into a fine mist.



The arrow points to a small drop oil that is on the side wall of a reed box. This is a drop of oil that has been recirculated from the crankcase back into the intake manifold. The reed valves are starting to open, and the engine is running at 5000 rpm. The next picture shows the oil droplet pulled off the wall and starting to "explode" by the air speed. The camera's bright light shows the exploding droplet as a little white cloud. The last picture shows the oil droplet now converted to a mist so fine that is hardly reflects any light.



Because there is no fuel in the air traveling into the crankcase with direct injection engines, the oil is not washed away and can remain on the bearing surfaces for many hours of engine operation. E-TEC engines have a warning mode where if oil pressure is lost for any reason, the rpm is brought back to 1200, where the engine is capable of running up to 5 hours without damage.



The warning system is called SAFE (Speed Adjusting Failsafe Electronics) and monitors all engine management sensors. Any engine "life-threatening" problem, such as no oil or no cooling water, will bring the engine back to 1200 rpm and signal the operator via a 30 second horn and visible indication on the dash instruments. A minor intermittent problem will be recorded in EMM memory to aid the service technician, but the operator is not bothered with warning signals.

All Evinrude E-TEC engines 115 HP and larger are also compatible with NMEA 2000 (National Marine Electronics Association) standard for CAN Bus instruments. CAN Bus (Controller Area Network) enables the various pieces of modern electronics on board your boat, like the engine management computer, your dash instruments, your GPS and your Fishfinder to all network together and share information, and even displays.

Several types of CAN Bus instruments are already available and more will follow. Evinrude's own I-Command system combines analogue and digital displays on the same dials. The digital displays are changeable so you can display one, or more, of several possible combinations, at the press of a button. Figuring out how much fuel you have left, or how many miles you can travel on the remaining fuel is now easy.

Lowrance have a different approach in their new LowranceNET LMF 400 series. Here the entire instrument face is an LCD display and which feature or type of dial you have showing, or how many dials, is very flexible and easy to use. A simple push of a button can offer you up to 8 screen layouts, with the data of your choice.

CAN Bus adds more features to the electronics available onboard, but surprisingly the wiring actually gets simpler. Gone is the power and ground to every gauge, plus signal wires and wires for lights. CAN Bus instruments have a single, multi-cored cable that is just "daisy chained" from one instrument to another. All instruments share the same power and signal wires, the difference is the data is sent around the networks as small "packets", each with its own identity. For example, a packet of data about fuel flow is ignored by gauges not involved in fuel flow or economy. The NMEA 2000 standard lays down how packets of data are constructed and what "language" is used so all NMEA 2000 compatible gauges can communicate.