The Diesel Engine

HOW IT ALL STARTED

Rudolf Diesel was granted the first patent for a diesel engine in 1892, when petrol engines were in their infancy. Whereas petrol engines could be built small enough to be put in a motor car, the diesel engine was on a different scale completely. Early examples were 3 metres tall!

Although diesels were used in German flying boats and even Zeppelins in the 1930s, they were really too big and heavy and were not considered a success.

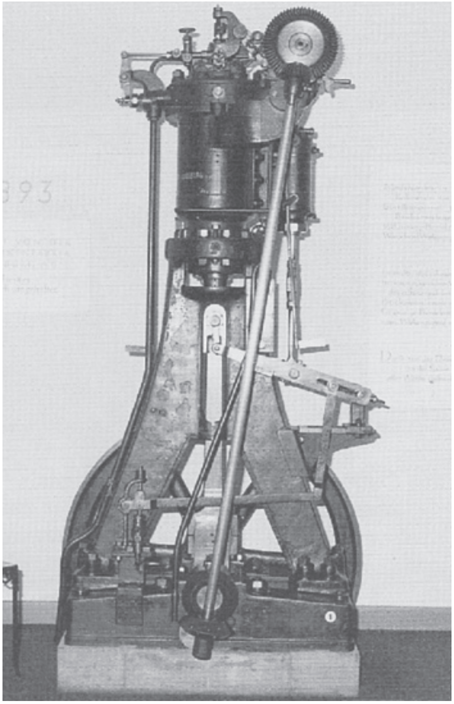
It was not until the late 1950s that any real success was achieved in building small, relatively lightweight diesels for use in small leisure craft. These were one-, two- and three-cylinder engines revving at around 2300 rpm and developing from 7 to 35 hp. They were quite heavy and bulky, but the smallest could be fitted into a 20-foot boat.

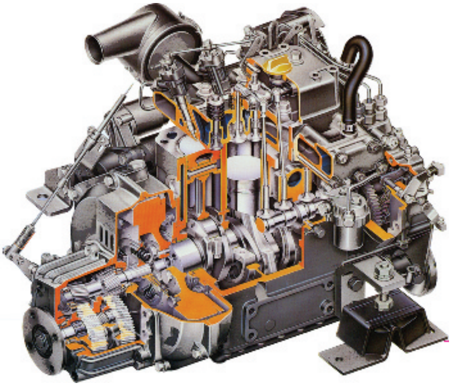
In 1970 Petter produced a 6 hp single-cylinder engine built mainly from aluminium and derived from one of their small industrial units. This was very compact, light in weight and revved at 1500 rpm. This was quickly followed by a two-cylinder 12 hp version.

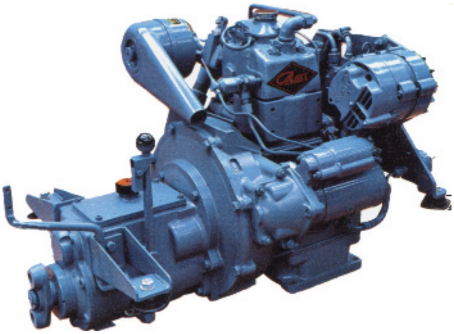
Larger boats needed more power, and by this time there were a number of smaller diesel-powered cars on the market, some of which were marinised by independent companies to give engines producing 35 to 45 hp. Larger motor and work boats used marinised truck engines.

Planing motor cruisers need lots of power and relatively light weight, and it's here that the modern turbo-charged truck engine plays its part.

All modern marine diesels destined for the leisure market are marinised versions of automotive or industrial engines. This marinisation may be carried out by the original engine builder or by an independent marinising company.







THE MODERN DIESEL ENGINE

Compared with its forbears, the modern diesel is light in weight and relatively high revving. It is in all ways comparable to the modern petrol engine but more economical to run and a little more expensive to buy.

Modern diesels range from around 10 horsepower right upto 1000 or so in the leisure engine ranges. Low-powered engines up to around 40 hp are simple in operation, with no electronic 'goodies'. Above 100 horsepower, leisure engines rely much more on electronic engine control and methods of augmenting their power. Between 40 and 100 hp it's an either/or situation.

The type of engine we use should be dictated by the use to which it will be put.

Displacement hulls

Where the boat's speed is limited by its waterline length, relatively low power is required. The old rule of thumb was 2 hp per tonne displacement. Much more realistic in these days of needing to get home to go to work would be 4 hp per tonne. Many builders seem to be offering as much as 6 hp per tonne or even more, but this brings with it problems of high fuel consumption and engines that are run at far too low a power for normal cruising. Diesels need to be worked hard, so it's no good saying that I won't use all that extra power that I've installed 'just in case'. If you don't work them hard you are storing up problems for later, and sometimes sooner, in their life.

Displacement motor boats are normally cruised at a constant speed and the engine is in use all the time. The engine gets warmed up properly and as long as it doesn't have too many hp per tonne, it gets a reasonably easy life.

A sailing boat's engine has a much harder time, as often it doesn't reach normal running temperature before it's stopped. It's also often used at relatively low power when 'motor sailing'. These conditions are not good for a diesel, and even less good if it's turbo-charged. Unless there's just no suitable non-turbo engine of the power required, I'd suggest avoiding a turbo-charged engine in a sailing yacht.

A modern 36-foot yacht weighing 6 tonnes needs 24 hp by the 4 hp per tonne rule. This would give a cruising speed of 6.6 knots with a fuel consumption of 11.5 mpg. Install a 40 hp engine, as many builders do, and you get a 7.3 knot cruising speed and 7.3 mpg. Cruise that 40 hp engine at 6.6 knots and you are using only 12.5 hp, under a third of its rated power rather than the minimum recommended 50% (that's power, not rpm). The argument about having extra power for heavy weather has a serious hole in it. If you bear away about 20 to 30 degrees from the direction of the waves, you'll go faster, use less fuel and have a much more comfortable ride!

Semi-displacement and planing hulls

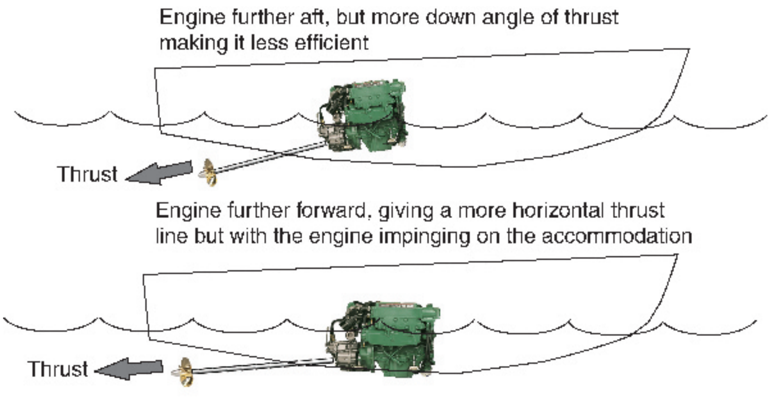
These hulls need much more power than a displacement hull. Because of the demands that the engine should be as light and as compact as possible, these engines are normally turbo-charged and have electronic engine management. To save carrying redundant weight, these engines are normally cruised at about 300 rpm below maximum continuous rpm. Heavy weather will require a reduction of speed, so you don't need any extra power.

Hull design and desired cruising speed affects the power requirement and it's not easy to use any rule of thumb, as it is for a displacement hull. Once the hull gets beyond 'displacement speed' you'll almost certainly be using enough power to avoid problems caused by running a diesel at too low a power. If you are forced to slow to displacement speed and you've got two engines, shut one down if safe to do so.

GETTING THE POWER TO THE PROP

Shaft drive

Traditionally, the propeller, or screw, is mounted directly on a shaft extending aft from the engine's



Conventional shaftdrive

'gearbox' and exiting through a waterproof gland towards the rear of the hull. Traditional hulls were relatively deep and the shaft could exit more or less horizontally. Modern hulls are relatively shallow, so if the downwards angle of the shaft is not to be too great, the engine needs to be mounted fairly well forward in the hull, but this may then intrude on the accommodation space.

Advantages:

- simple design;
- relatively cheap to make;
- easy maintenance;
- thrust bearings can be used so that no thrust load goes into the gearbox or through the engine mounts.

Reproduced by permission of John Bass

Disadvantages:

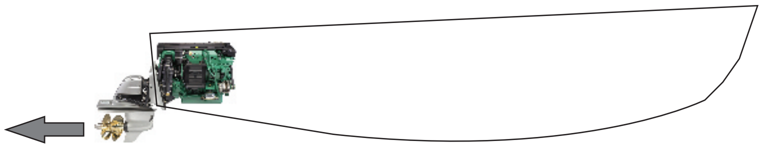
- engine and shaft need proper alignment if wear and vibration are to be reduced;
- the thrust line may be angled downwards.

An alternative solution is to use several shafts and angled gearboxes, either in the form of a 'Z' drive or a 'V' drive, to keep the engine further aft. This solution may help the weight distribution on some planing boats. 'Z' and 'V' drives are heavier and more costly than simple shaft drives.

Stern drive

Many planing motor cruisers have 'stern drives'. The engine is mounted right at the rear of the boat and drives the propeller through a stern drive leg and gearbox mounted to the rear of the boat's transom. The leg tilts to adjust the planing trim, and swivels to achieve steering. The boat has no rudder. If you like, it's a bit like an outboard engine but with the engine unit inside the boat. Driving a boat with a stern drive needs a different technique than that for a shaft drive.

Engine right aft, giving good accommodation, but suitable only for planing boats as engine weight is right aft

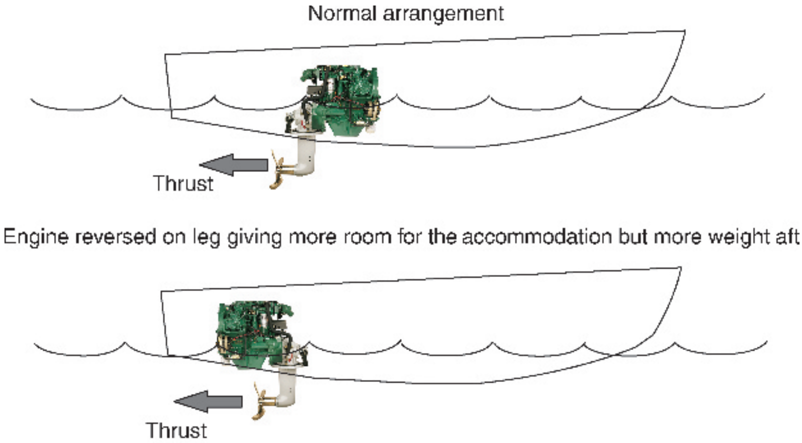


Advantages:
- engine weight can be kept far aft, an advantage in planing boats;
- installation costs are reduced with no engine alignment costs;
- with aft cockpit boats, engine accessibility is good;
- with aft cockpit boats, engines do not intrude into the accommodation;
- thrust angle can be 'trimmed' from a basic horizontal thrust line;
- speed is potentially greater than with a shaft drive.

Disadvantages:
- more expensive to build;
- externally mounted leg and drive unit needs frequent and expensive maintenance;
- electrolytic corrosion of 'out-drive' unit in salt water;
- boat has to be out of the water to service the gearbox/leg unit;
- with a deep 'V' hull configuration and twin engines, the engines have to be mounted so close together that servicing can be almost impossible.

Sail drives

A sail drive engine has its gearbox, leg and propeller all mounted as one unit, with the leg exiting through a hole in the bottom of the boat. This allows the engine to be mounted where it won't interfere with the



Sail drive

accommodation, but keeps the propeller's driving axis horizontal.

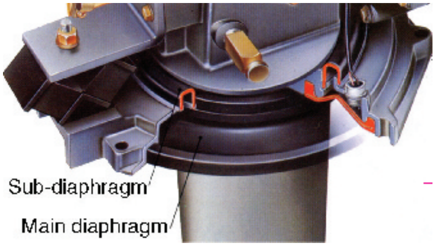
Advantages:

- installation costs are minimal;
- no engine alignment required;
- more choice of engine position, so its intrusion on the accommodation can be minimised;
- often less vibration (no shaft vibration as there would be in a poorly aligned shaft drive).

Disadvantages:

- large rubber diaphragm sealing hole in hull requires expensive replacement (every seven years for Volvo Penta, but not for Yanmar, which has a double diaphragm and a moisture detector);
- oil changes require the boat to be out of the water (except for the very latest Volvo and Yanmar models);
- possible corrosion of aluminium leg components in seawater;
- electrolytic corrosion of larger propellers as the leg anode is relatively small and often electrically isolated from the propeller;

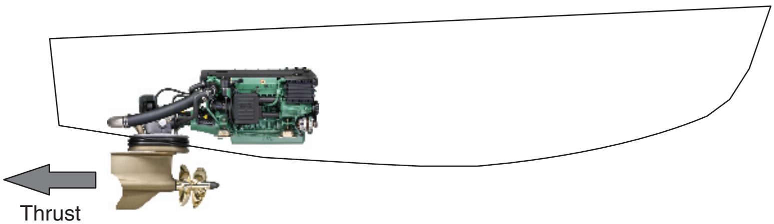
- propeller mounted much further from the rudder, requiring more anticipation in close quarters manoeuvring;
- external water temperature may dictate non-optimal gearbox/leg lubricant;
- external water temperature may require non-standard battery charging until leg oil temperature has risen sufficiently to reduce friction drag;
- cannot use a thrust bearing, so all thrust is taken by the engine mounts and gearbox.



Volvo IPS

Introduced in 2004, Volvo's revolutionary IPS combines most of the advantages of the shaft and stern drives in one unit. It's a bit like a forward-facing sail drive with a steerable leg protruding from under the hull. The engine and drive are supplied complete and installed in pairs in fast motor cruisers.

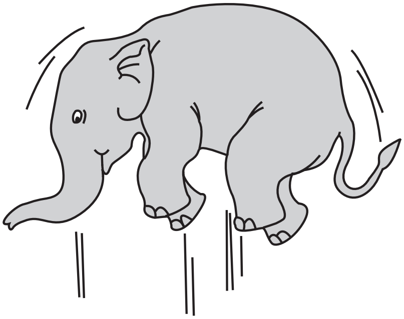
IPS allows a horizontal thrust angle maximum efficiency and the engine far enough aft give good accommodation

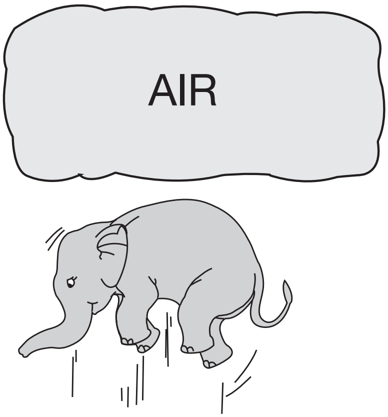


Volvo Penta IPS

Advantages:

- horizontal thrust line for higher speed potential;
- propeller in front of 'leg' in clear water;
- exhaust about 80 cm below the waterline to give very quiet running;
- steerable legs, giving good manoeuvrability;
- cast bronze under-water unit, giving good corrosion resistance;
- lower installation cost.





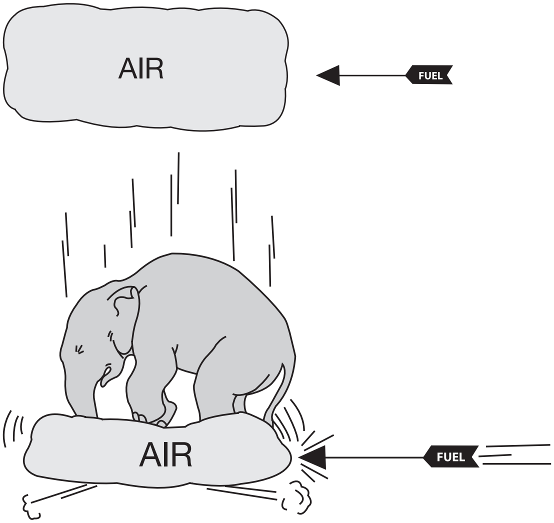
Disadvantages:

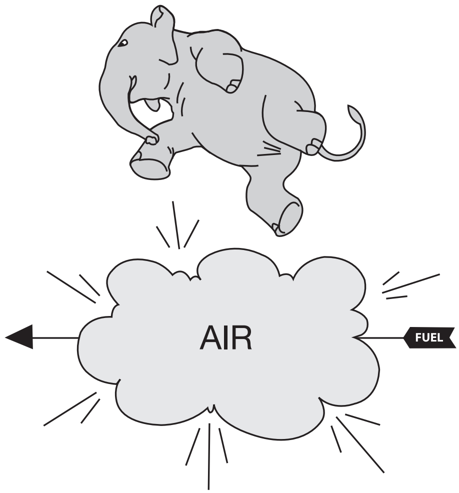
- high unit cost;
- available only with a couple of 4–500 hp Volvo Penta engines.

COMPRESSION IGNITION

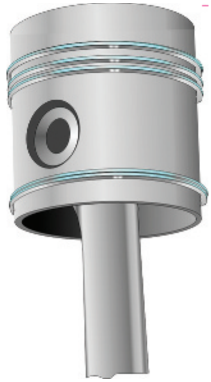
A diesel engine has no ignition system or sparking plugs. Diesel fuel ignites at a temperature of around 320 Celsius, so what ignites the fuel and allows the engine to run? (*some writers give the ignition point as 900°C. This arises from one document which translated °C to °F but then labelled the result in °C–most other writers followed suit!)* When air is compressed, work is done on the air, increasing its energy and thus its temperature. Provided that the air is compressed rapidly enough so that the heat has little time to escape to its surroundings, the air in a diesel engine cylinder can be made to rise to above the ignition temperature of the fuel by compression alone. If diesel fuel is then injected into the hot air, the mixture will ignite, releasing energy. This is known as *compression ignition*, unlike a petrol engine which uses *spark ignition* to ignite the fuel/air mixture.

Let's imagine an elephant jumping from a height onto a bag of cool air! And let's imagine that at the

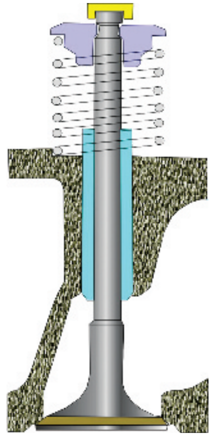




same time, an archer shoots an arrow full of diesel fuel aimed to arrive at the bag of air at exactly the same time as the elephant. As the bag of air is *very* rapidly compressed by the arrival of the elephant, the arrow with exactly the correct amount of fuel arrives and penetrates the bag of now very hot air. There's only one inevitable outcome: the elephant gets a free ride!



Very simplistic, I know, but the basic diesel engine is as simple as that. If the air is heated to above the combustion temperature of the fuel very rapidly AND if the correct amount of fuel is injected into this hot air at the correct time, the engine will run. No electricity is required, except to turn the engine over fast enough to start the engine.



Compression of the air takes place in the engine cylinder by reducing the volume of the air by around 20 times. In other words, there is a compression ratio of 20:1. The compression ratio by itself is of no use unless the air cannot leak out of the cylinder as the volume is reduced. Air is prevented from leaking past the piston as it moves in the cylinder by means of one or more piston rings, which press outwards against the cylinder wall to form a seal.

The inlet and exhaust valves must also seal properly on their seats. Valves must be seated properly to prevent gases escaping between the valve seat and the valve face.

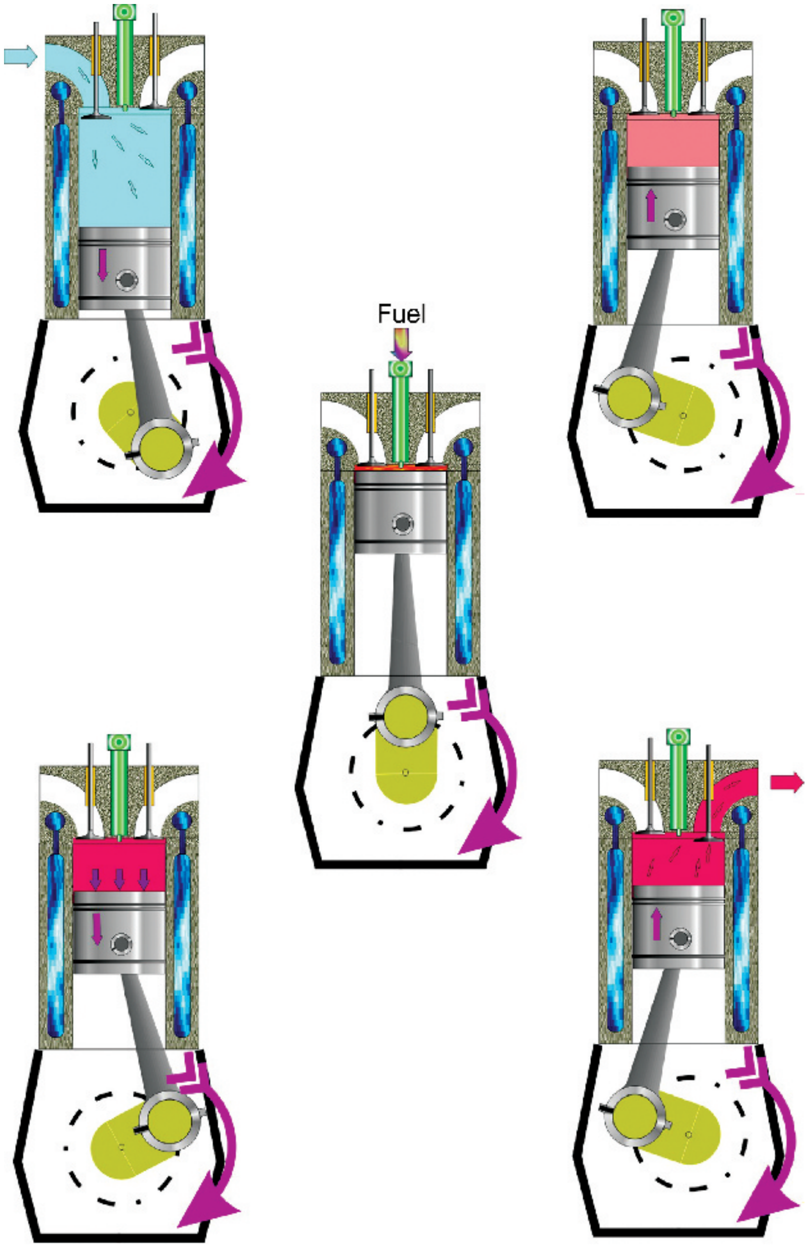
THE FOUR STROKE CYCLE

Most diesels use the four-stroke cycle:

- Air is 'sucked' into the cylinder as the piston moves down with the inlet valve open – *the induction stroke*.
- Air is compressed and heated as the piston rises in the cylinder – *the compression stroke*.
- Fuel is injected into the hot air as the piston nears the top of its: compression stroke – ignition.

- Work is done on the piston by the rapid spontaneous combustion of the air and fuel mixture pushing the piston down – *the power stroke* .

- The piston rises, pushing the burned air/fuel mixture out of the cylinder with the exhaust valve open – *the exhaust stroke.*



The four - stroke cycle

Note that the piston moves up and down twice for each 'bang' or power stroke. The valves operate only once for each two revolutions of the engine crankshaft. You get only one bang for each two revolutions in a single-cylinder, four-stroke engine.

The essential requirements for a diesel engine to start are:

- Adequate compression, supplied by the cylinder bore, piston rings and valve seats all being in excellent condition so that the temperature of the air is raised to the ignition temperature of the fuel.
- Rotating the engine quickly enough to obtain rapid compression to minimise the escape of heat from the cylinder – this requires a well-charged battery of sufficient power if electric starting is used.
- The correct quantity of fuel injected at the correct time.

It can be seen that a diesel engine in good mechanical condition *will* start if it is turned over rapidly enough to raise the air temperature to ignition point *and* the correct quantity of fuel is injected at the right time. It should be noted that other than powering the starter motor, the basic diesel engine requires no electricity for its operation.

MULTI-CYLINDER ENGINES

Four-stroke multi-cylinder engines have the crankshaft and valve timing arranged so that the 'bangs' don't all occur at the same time. The 'firing order' for the cylinders is designed to give the smoothest running. Some engines use gear-driven counterbalance weights in the crankcase to give even smoother running.

TURBO-CHARGING

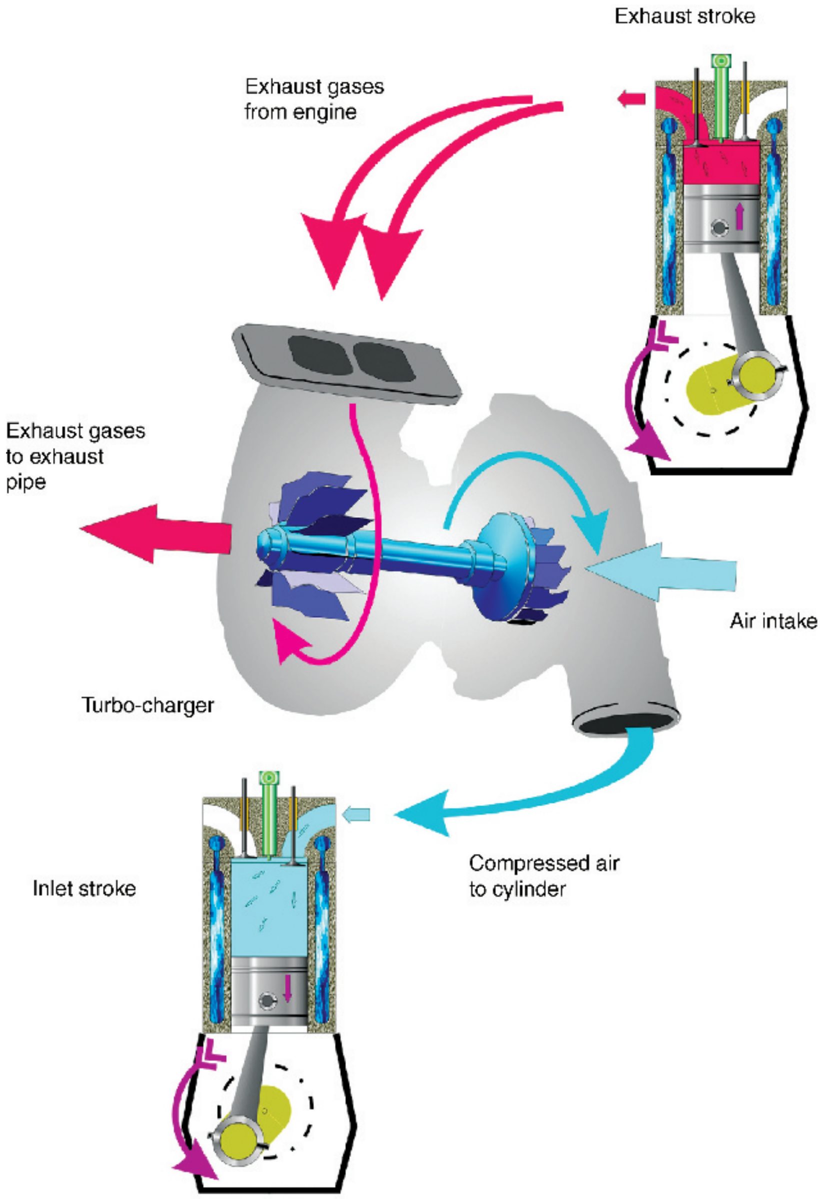
There is a point at which adding more fuel to the air in the cylinder of a diesel engine will produce no extra power. The extra fuel will be wasted because there is insufficient air to burn it.

There are several ways to provide more air: make the engine physically bigger by having bigger cylinders or more cylinders of the same size, or feed the engine with heavier air. Making the engine bigger increases its weight as well as its size, and where we need lots of power from an engine, such as in a planing motor cruiser, this method will be impracticable. We need more power per kilogram of engine and more power per 'litre' of engine than this method can provide. However, we can 'feed' the engine with compressed air, and then add more fuel to this heavier air to produce more power. The normal method of achieving this is by adding a turbocharger to the engine.

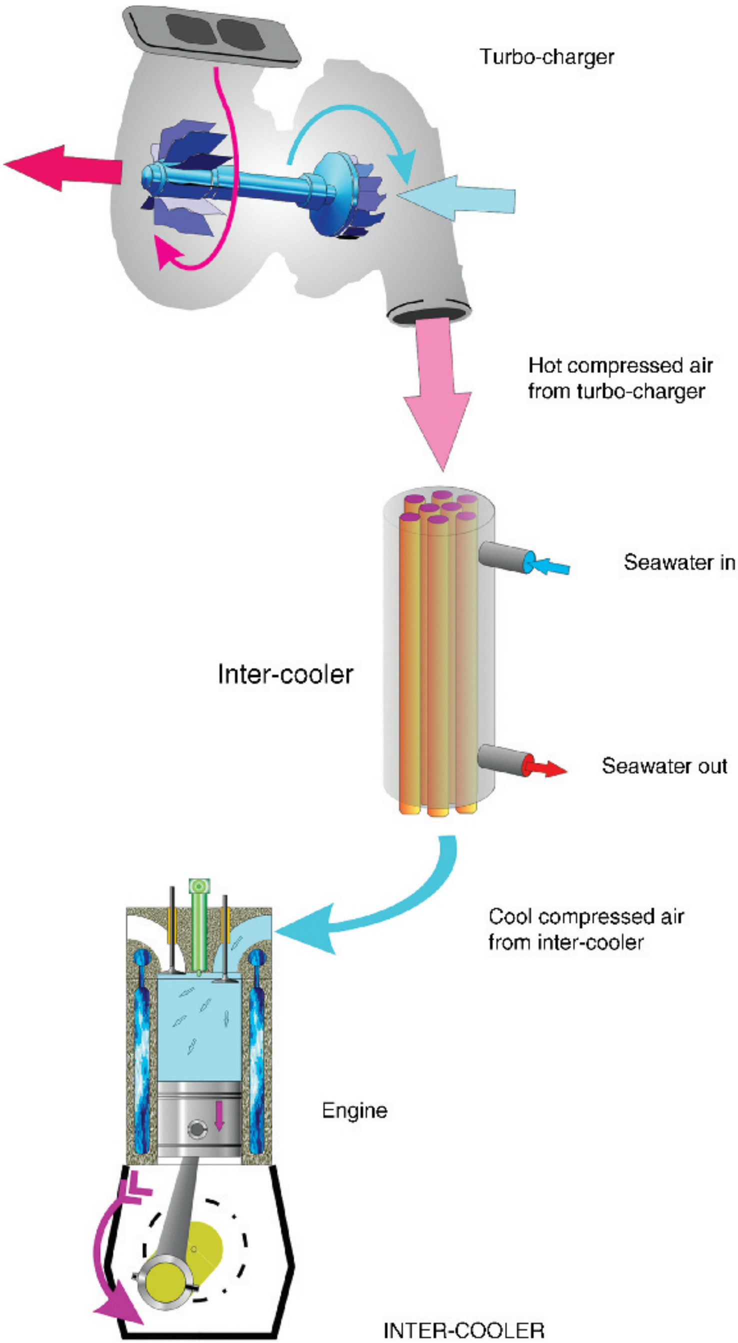
There is still plenty of energy remaining in the exhaust gases that are ejected from the engine's cylinder after combustion. Putting a 'fan' in the exhaust gases can harness this energy. The fan drives a compressor, which then supplies the cylinder with 'heavy air' rather than air at atmospheric pressure. If you double the mass of air you supply, you can add twice the mass of fuel and theoretically produce twice the horsepower than you would get from a 'naturally aspirated' engine. Producing more power increases the load on the engine's components. Double the fuel and you double the 'bang' hitting the top of the piston. In order to retain reasonable reliability, the increase in power provided by turbocharging is usually limited to an increase of 50% of the normally aspirated engine. The diagram shows how its done.

Compressing the air, as we know, raises its temperature. Raising its temperature lowers its density. Thus, the increase in mass of the compressed air will not be as much as we thought, due to this increase in temperature. We will, therefore, need a bigger turbocharger to make up for this shortfall, and this will cost more money.

We could cool the air after it's been compressed to increase its density and allow us to use a smaller turbo-charger. This would give us a smaller and cheaper



TURBO-CHARGING



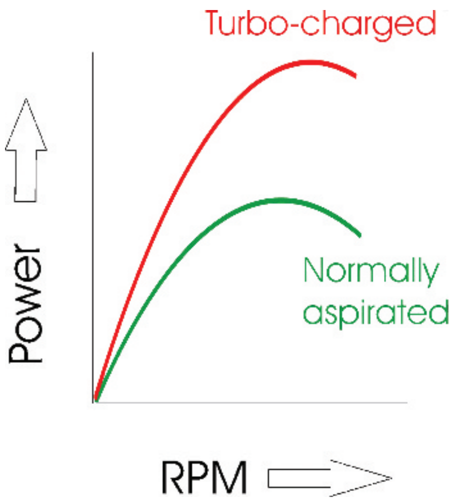
INTER-COOLER

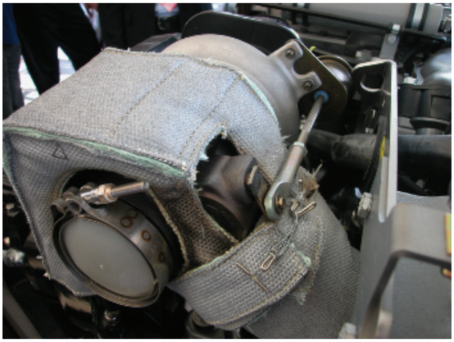
turbo-charger, but we would now have to buy a cooler. The balance in cost occurs around 80 to 130 hp, so that smaller engines have no cooler and bigger ones do. It's all a matter of economics.

The cooler is fitted between the turbo-charger outlet and the engine air intake, and is usually called an *inter-cooler*. However, this same inter-cooler also goes by the name of *pre-cooler* or *after-cooler*.

Road vehicles use air to cool the engine and turbo-charger heat exchangers. Marine engines use 'raw' water to cool the heat exchangers because there is insufficient air flow to give effective cooling in most cases. Raw water is the water the boat is floating in, normally seawater.

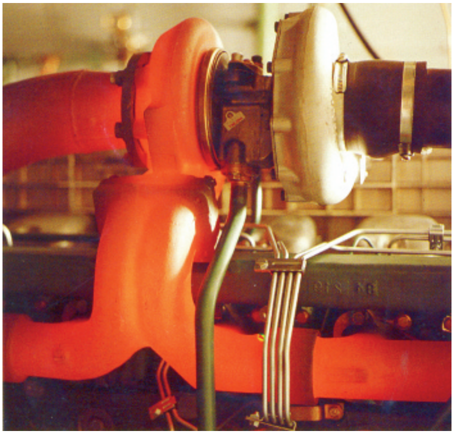
A turbo-charger adds power at higher rpm, rather than all across the rev range.





In order to add power all across the rev range, a bigger turbo-charger is needed, and this will give too much 'boost' at high rpm. To overcome this, an automatic *waste gate* is fitted, which allows excess pressure to be bled off to 'waste' at high rpm.

The life of a turbo-charger is a hard one. The turbine will have blade temperatures in excess of 900 °C, while just a few inches away, the compressor is running at around 100 °C. The whole rotor of compressor and turbine may be running at up to 120 000 rpm at maximum output.



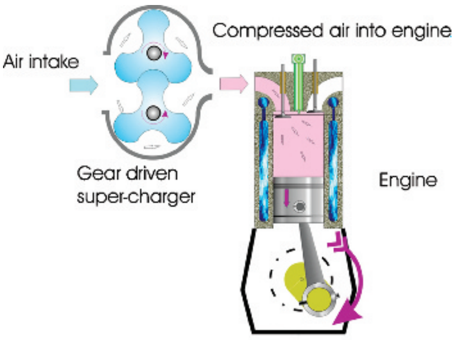
There are certain things the boat owner can do to increase the longevity of a turbo-charger:

- make sure that the engine is idled for two minutes after running at high speed before stopping it;
- use only the recommended engine oil and change the oil at least as often as specified;
- make sure that the engine is not run at low power for any lengthy period of time to avoid carbon build up on the turbine blades.

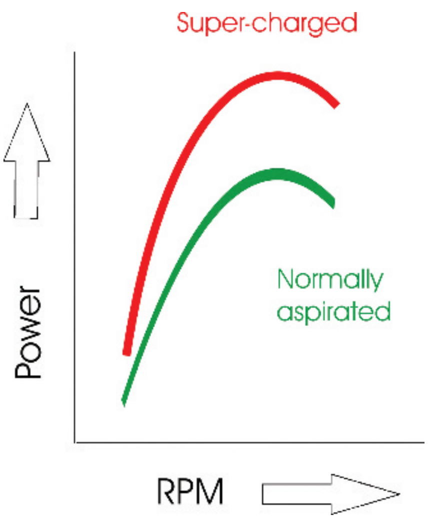
This last requirement makes a turbo-charged engine a questionable choice for a sailing boat, which often is run at low power and then shut down before it is fully warmed up, or indeed an inland waterways boat, which is never run at much more than idle power at any time.

SUPER-CHARGING

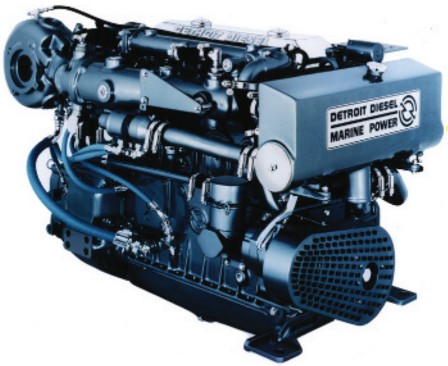
A super-charger is a gear-driven compressor used to compress the air prior to delivery to the engine



Super-charger



to increase the power of the basic engine in the same way as a turbo-charger. It can be geared to produce extra power at low rpm. It is not usually used on marine diesels. Volvo Penta does, however, use a combination of both super-charger *and* turbo-charger to increase the power over the whole rev range. This produces a relatively compact, high-power engine, at the expense of extra complexity.

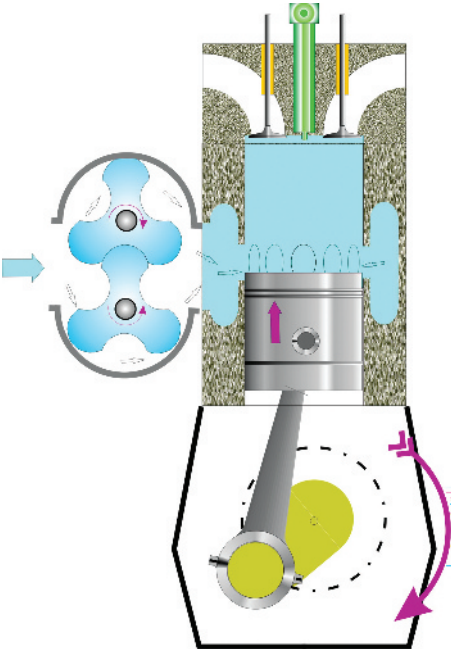


THE TWO-STROKE DIESEL ENGINE

This is a very different beast from the four-stroke engine and also bears little resemblance to a two-stroke petrol engine, and there is only one player in the field – Detroit Diesels.

Because the four parts of the induction–compression–power–exhaust cycle are compressed into only one up and one down stroke in the two-stroke engine, it cannot compress the air enough to raise its temperature to the ignition point of diesel fuel unless there is some form of additional compression. The additional compression is provided by a gear-driven super-charger that compresses the air before it passes into the cylinder. Thus, the cylinder is supplied with pre-heated compressed air.

The smallest engine in the Detroit marine engine range is 400 hp.

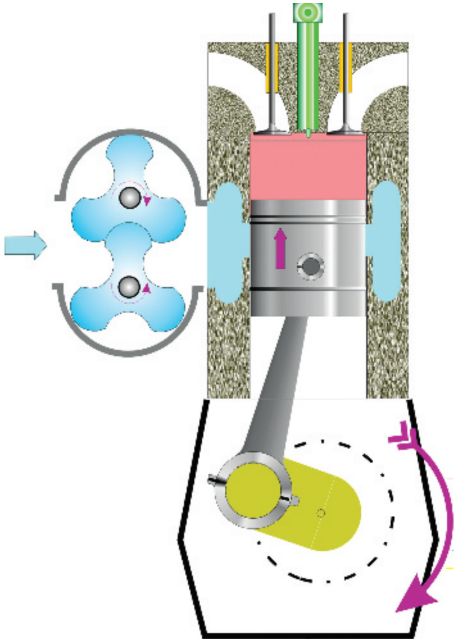


Inlet phase

At the lower portion of the piston's stroke, inlet ports in the side of the cylinder wall are uncovered, allowing compressed (and heated) air from the super-charger to enter the cylinder.

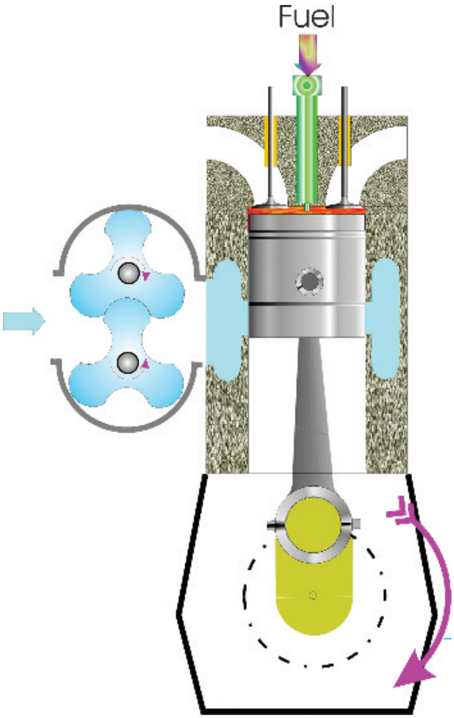
Compression phase

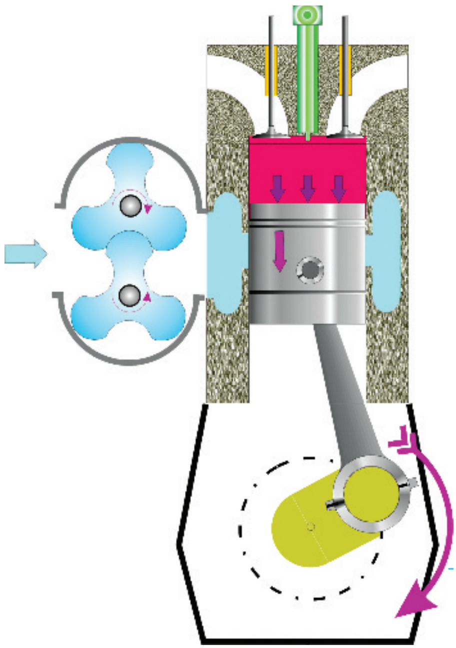
Once the inlet ports are covered by the upward moving piston, the air is compressed in the cylinder. Because the air has been compressed in the super-charger, by the time the piston reaches the top of its stroke, the air is above the ignition point of the fuel.



Ignition phase

With the piston approaching the top of its stroke, fuel is injected into the very hot air, where it ignites and burns very rapidly.



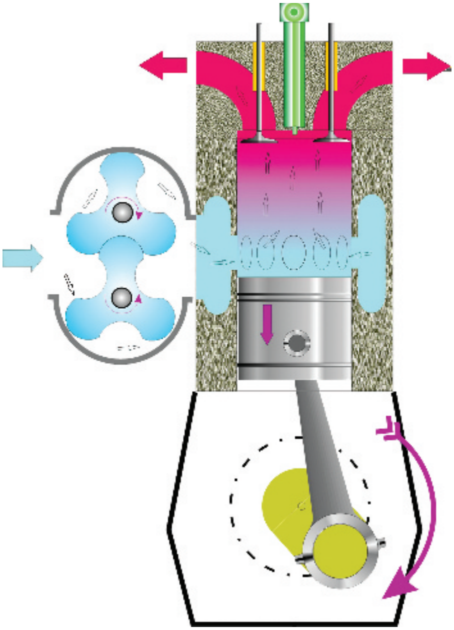


Power phase

The force created by the rapidly burning mixture pushes the piston downwards.

Exhaust phase

As the piston approaches the bottom of its stroke, the two exhaust valves open, allowing the exhaust gases to escape. At the same time, the inlet ports are uncovered, allowing compressed air into the cylinder. This



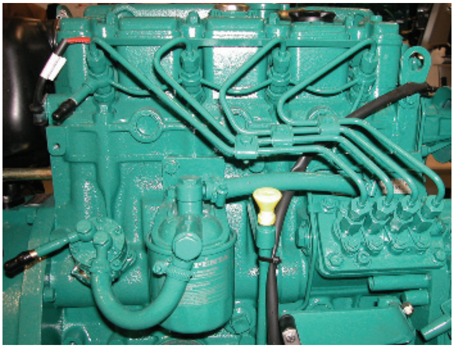
incoming air helps scavenge the exhaust gases from the cylinder.

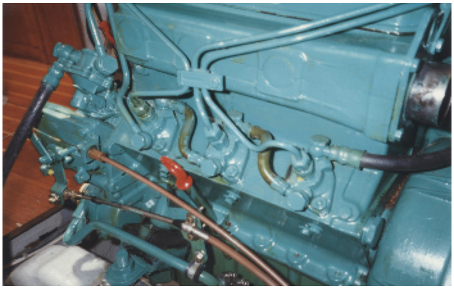
The two-stroke diesel has a power 'stroke' once every revolution and so has twice as many 'bangs' as a four-stroke engine at the same rpm, so should give twice as much power as a similar sized four-stroke engine. However, its 'breathing' is not as efficient as a four-stroke, so, in reality, their power outputs are similar. Detroit Diesels claim very good fuel efficiency, but they now use them only for 'off-road' engines.

INJECTING THE FUEL

The fuel injection pump

The fuel system delivers fuel at low pressure to the fuel injection pump, which raises the pressure of the fuel to 2000 to 3000 psi (130 to 200 atmospheres) and meters out the fuel, as required, to the individual fuel injectors (atomisers). Mechanical injection pumps use individual pumps for each cylinder, although these pumps are usually part of a single injection pump unit mounted externally and gear driven. These have their governor (see p. 37) mounted inside the pump unit's body.

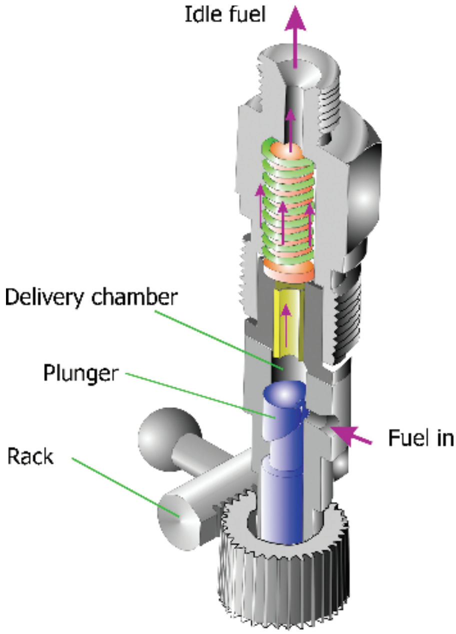




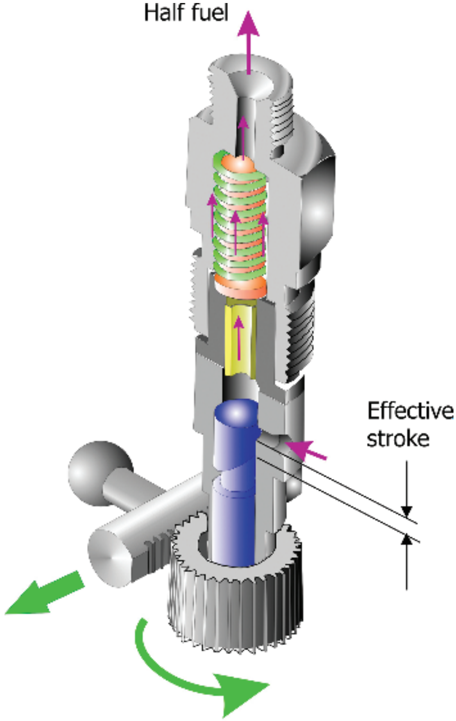
Smaller engines often have a set of pumps, mounted either collectively or individually, and operated directly by the engine's camshaft. In this case, the governor is part of the engine itself.

The amount of fuel delivered to each fuel injector is controlled by adjusting the effective stroke of the individual pumps by means of a fuel *rack*, whose position is controlled by the governor. Although the actual stroke of the pump plunger (piston) is constant and actuated by a cam, the position of the tapered groove in the plunger allows the volume of fuel delivered to be varied.

With the ‘throttle’ at idle, the rack is at its idle position and idle fuel is delivered to the fuel injector(s).



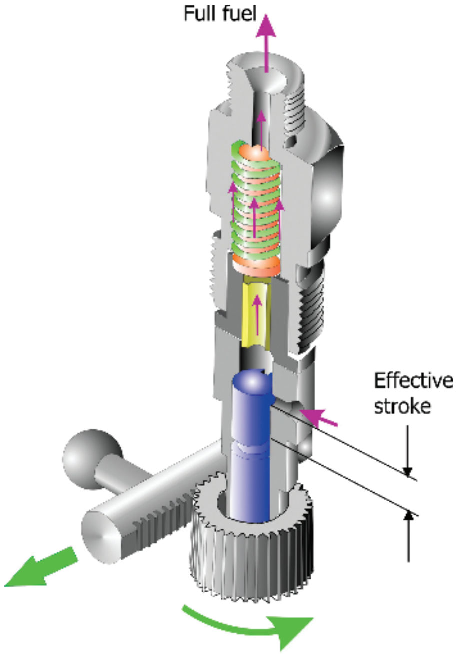
Idle Speed



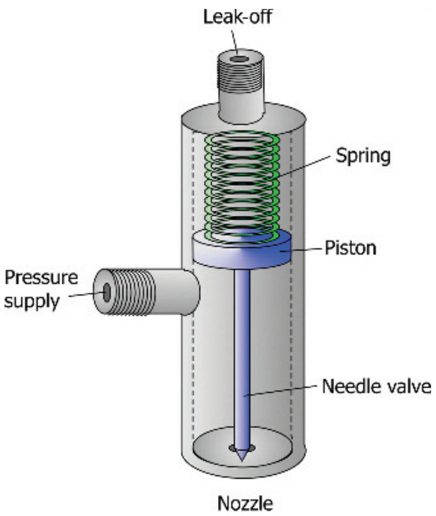
Half injection

The fuel rack is moved to its half fuel position under the influence of the governor and rotates the gear and plunger so that the tapered groove gives more ‘effective stroke’ before it cuts off the fuel supply.

With the rack at full travel, the tapered groove allows ‘full stroke’ and delivers maximum fuel.



Full injection



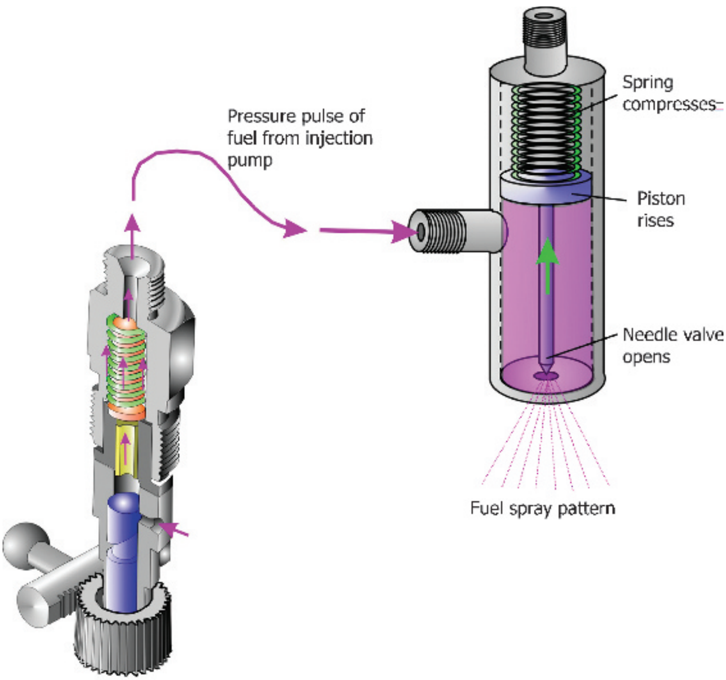
Fuel Injector

Some engines use a slightly different type of injection pump and have a hydraulic governor. Essentially, all fuel injection pumps are precision-made and cannot be serviced by the user.

The injector

The pressurised pulse of fuel from the injection pumps doesn't reach full pressure instantaneously. If the injector consisted of one simple orifice, fuel would dribble from it into the combustion chamber until the pressure rose sufficiently to form a spray. The dribbled fuel wouldn't burn, so would be wasted and would produce smoke. This is undesirable, so the injector has a valve mechanism within.

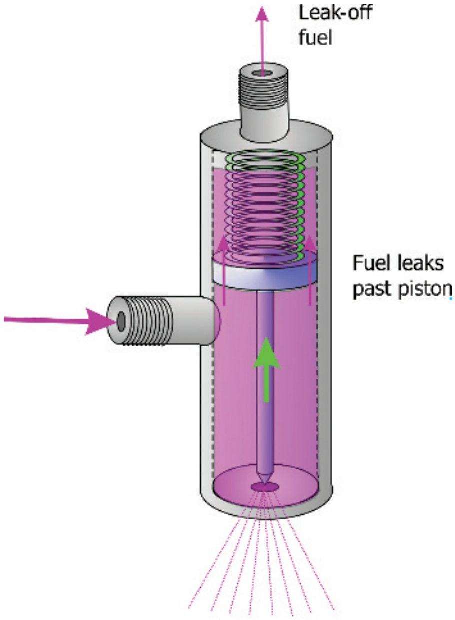
1. A spring, bearing against a piston, holds a needle valve closed against the orifice.
2. As the fuel pressure rises, the piston moves upwards, lifting the needle valve and opening the



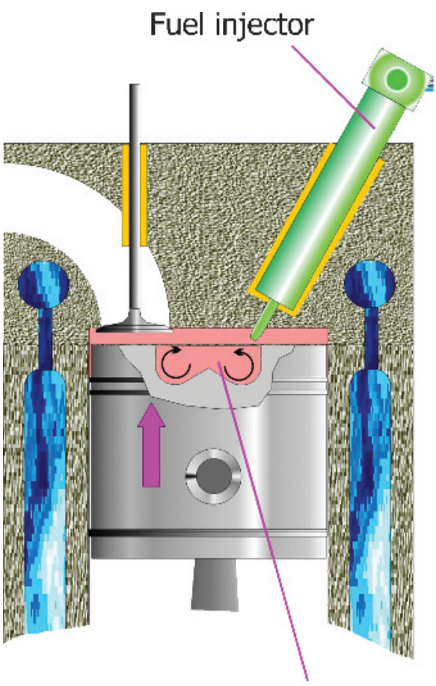
Injector valve open

orifice, allowing a controlled spray pattern to emerge.

3. The piston has a simple seal inside the injector and high pressure fuel will leak past it. This fuel would fill the cavity above the piston, preventing the piston from rising on the next pulse. To prevent this, a leak-off pipe ensures that only very low pressure exists above the piston. The leak-off fuel is returned to the fuel tank or to the fuel filter inlet.



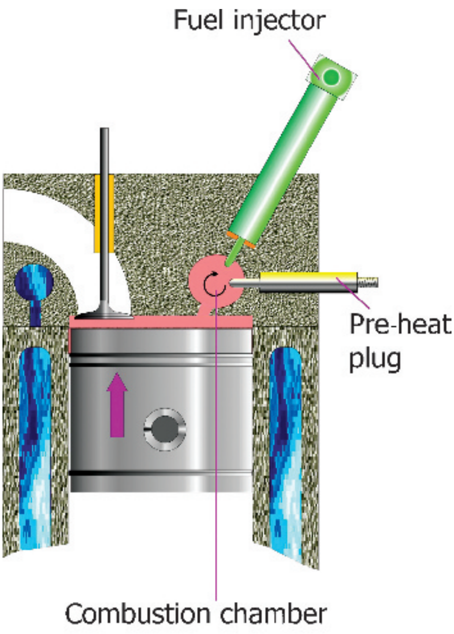
Injector leak-off



Direct injection

Direct injection

For many years, fuel was injected directly into the cylinder. The top of the piston is not flat, but contains a large depression that acts as the combustion chamber. The shape of the depression is such that it tends to induce a swirling motion to the air as the piston rises



Indirect injection

on the compression stroke. The injector directs the fuel spray, at an angle, towards the depression, so that the fuel is mixed with the swirling air in as homogenous a way as possible.

Indirect injection

In order to give better mixing of fuel and air to achieve more efficient combustion and less emissions, a move to indirect injection was made. A further gain was smoother running. In this set-up, the combustion chamber is situated outside the cylinder and the fuel is injected into this external combustion chamber.

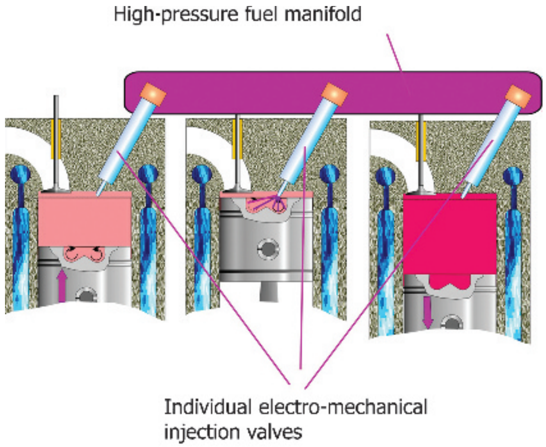
The combustion chamber can be designed to give much better mixing of the fuel and air and is sometimes known as a *swirl* chamber. The very small cross-sectional area of the passage linking the cylinder and the combustion chamber reduces the shock of the combustion 'bang' hitting the piston and increases the time that the 'bang' pushes down on the piston. This makes for smoother running. Despite the better combustion efficiency and reduced emissions, the restriction reduces overall power and so an overall increase in fuel consumption occurs.

Indirect combustion engines will not start from cold at low temperatures. Not all the potential increase in temperature occurring during compression is available, as the extra metal surrounding the combustion chamber 'robs' the heat from the hot air. Indirectly injected engines need some form of *pre-heat* to achieve cold starting.

Many modern designs of diesel engine are returning to direct injection because electronic fuel injection can reduce emissions without recourse to indirect injection with its attendant power loss.

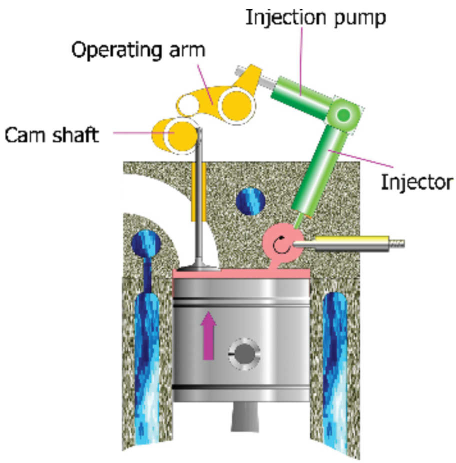
Common rail injection

Modern car engines often have common rail injection. The high-pressure fuel pump doesn't measure the fuel, but supplies the fuel at injection pressure to a storage manifold running along the top of the engine. The fuel injectors, which are controlled electronically and fed directly from the manifold, open as required to allow a measured quantity of fuel into the cylinder. This system achieves improved efficiency and emission control, and is beginning to find its way into marine engines.



Common rail injection

Some engines, such as Lombardini, use individual combined fuel injection pumps and fuel injectors operated directly by the overhead valve camshaft. They are supplied from a low-pressure fuel supply and again have no central fuel injection pump.



Combined injection pump and injector

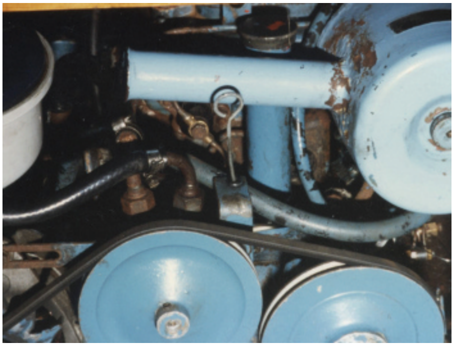
COLD STARTING

When it comes to cold starting, there's just no substitute for reading the handbook! You would be amazed at how many people who have owned their boat for some time have no idea how to start the engine from cold.

Extra fuel for starting

Many direct injection engines use extra fuel for cold starting. On some, like the small Yanmars, this extra

fuel is supplied automatically, and the owner need do nothing except set the 'throttle' correctly. On others, however, special actions have to be taken prior to starting from cold. For instance, on the old Volvo Penta MDI, 2 and 3 and their derivatives, there's a cold start button at the back of the engine that must be pressed down for each cold start attempt. This action allows the fuel control rack to run to a 'cold start' position by removing a rack normal stop. This is often situated under the cockpit sole and many owners are unaware of its existence. In some cases, an enterprising owner has rigged up a cable-operated remote control for it.



The Volvo Penta MD 2000 series engines require that the 'throttle' should be opened about two-thirds (the book says less, but in my experience you need more) and *then*, afterwards, pull the STOP handle and return it to run before starting. If the engine fires but doesn't run, you must do this again. The rack stop is temporarily removed as for the case above.

On the Petter mini 6 and mini twin, a wire loop will be found on the front of the engine. This is pushed down and released after the 'throttle' has been set and before starting.

Raising the compression ratio

The engine's compression ratio can be increased for cold starting on some engines by the addition of lubricating oil to the cylinder above the piston. In particular, this is done on the Petter mini 6 and the mini twin and the Sabb, as illustrated.

Pre-heating

Engines having indirect injection are fitted with pre-heating as an aid to cold starting, and some direct engines may be fitted with some form of pre-heating as an option for use in low-temperature situations.

Pre-heater plugs

Electric pre-heater plugs (glow plugs) are fitted permanently in the combustion chamber and powered prior to start from the engine's electrical system. The heater pre-heats the whole combustion chamber. Its tip, which extends into the combustion chamber, is still hot when the fuel is injected, aiding ignition.

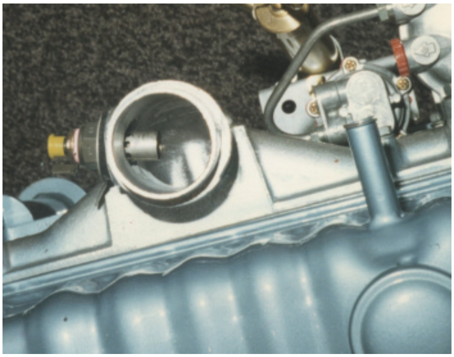
Where used on cars, an orange light on the instrument panel is illuminated when pre-heat is selected and goes out when the required temperature is reached, indicating the starter motor may now be engaged. On most marine engines, this indication is not given, so the operator needs to be aware how long pre-heat should be applied for. If the battery is so low that engine starting may be impaired, correct use of pre-heating is essential – read the manual.

Other forms of pre-heat

There are other forms of pre-heat on some engines.

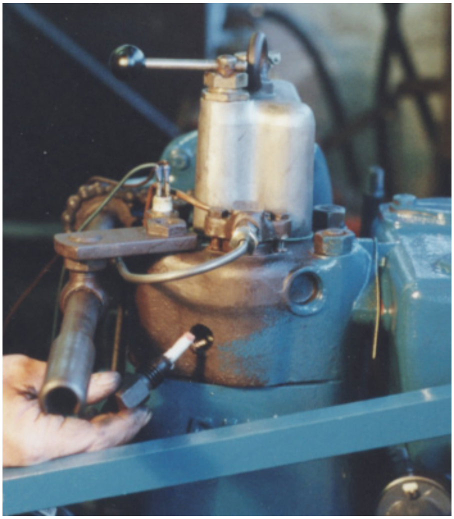
Thermostart

A fuel reservoir supplies a burner in the air intake manifold. This burner is ignited during a cold start to pre-heat the air and was standard on Perkins 4-107, 4-108 and 4-109 engines.



Chemical igniters

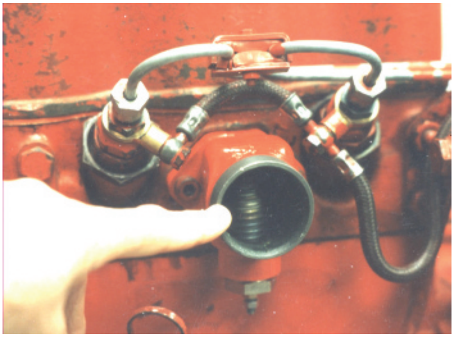
Sabb engines use a chemical 'cigarette' inserted into a special holder, which is ignited by the elevated compression pressure during starting. This raises the

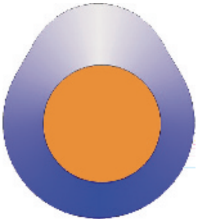


temperature further to achieve combustion temperature. These are used only for very low-temperature starting, not as a matter of course.

Electric heater in the air intake

An electrical coil, mounted in the air intake manifold, is supplied with electric power during cold starting to pre-heat the air as it passes to the cylinder.

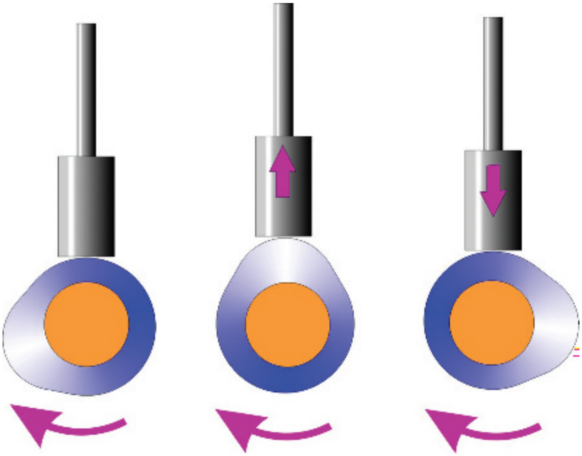


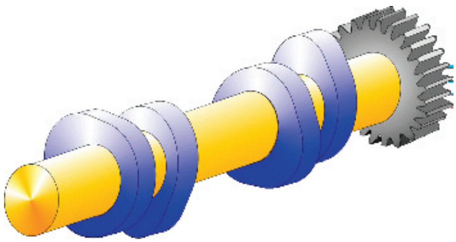


VALVE GEAR

The inlet and exhaust valves have to be opened and closed once every two revolutions of the crankshaft. They are operated by a shaft (the camshaft) running at half the rotational speed of the engine.

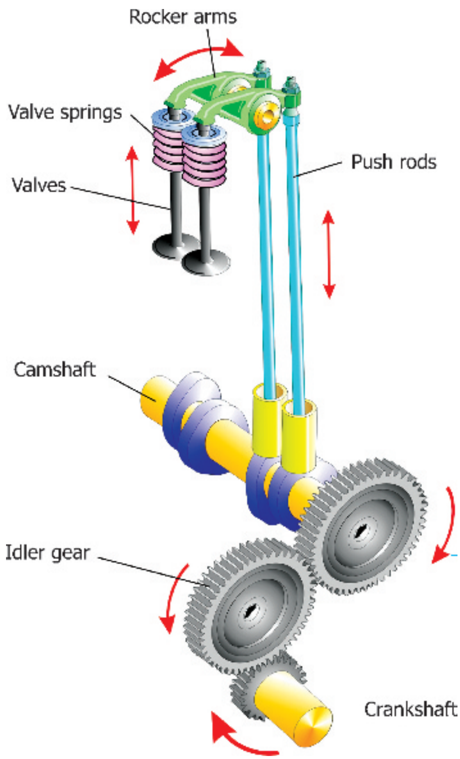
A cam is a circle with a ‘bump’ on it. As the bump rotates, it is able to operate a mechanical device. A number of cams are machined onto a *camshaft*.





Push-rod-operated valves

The camshaft is mounted low in the engine and is gear driven. Long push rods operate the overhead valve gear. This is a cheap and efficient option, but the inertia of the push rods make it unsuited to high-speed engines. Where the engine is based on an industrial engine or is a dedicated marine engine, this will be the norm. Adjustment of valve clearance is easy, (see Chapter 14).



Overhead camshaft-operated valves

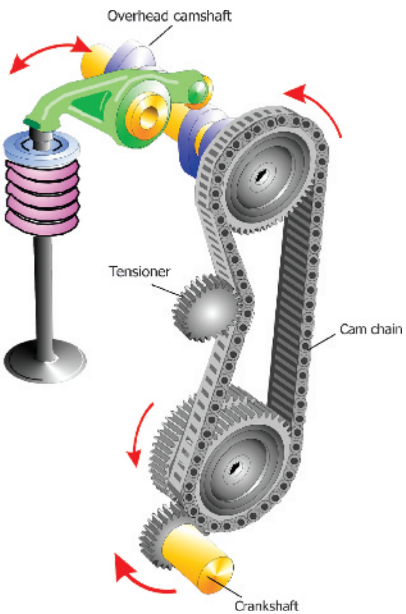
Engines designed for high rpm will be fitted with one or more overhead camshafts. These engines will be derived from car diesel engines. The overhead camshaft will be driven by a gear train, chain and sprocket or by a rubber cam-belt.

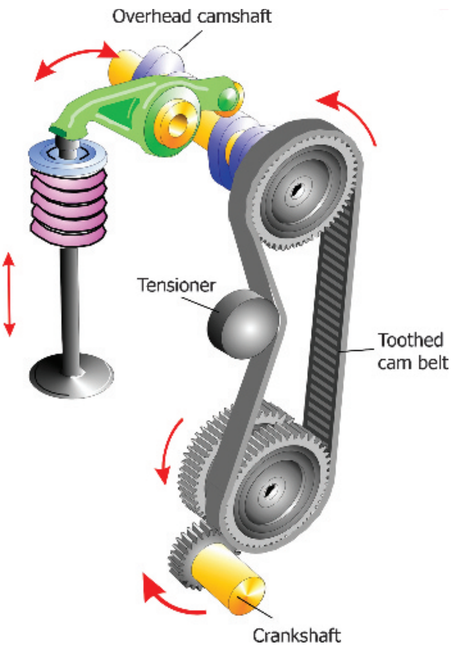
Gear-driven overhead camshaft

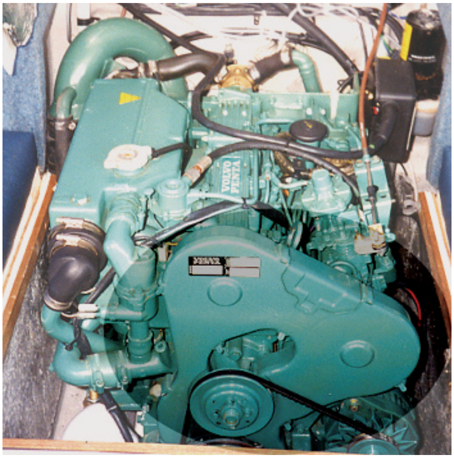
This is reliable, heavy and expensive. It is the ideal.

Chain-driven camshaft

This is lighter and cheaper than using gears. It uses engine oil pressure to operate the automatic







chain tensioner and, provided that the engine oil is changed at least as regularly as specified, it is reliable.

Rubber cam-belt drive

The cheapest and least reliable option is the use of a rubber cam-belt. This has long been popular in the car industry but requires the cam-belt to be changed at regular intervals if hugely expensive engine repair bills are to be avoided. Independent car experts agree that the cam-belt should be changed at 40 000 mile intervals, whatever the manufacturer says, and that the tensioner, if plastic, should be changed at the same time. The Ford Escort engine (which forms the basis of some marinised engines) requires a cam-belt change at 30 000 mile intervals. (40 000 road miles equates to around 800 engine hours at sea.)

How do we know if we have a rubber cam-belt? Look at the front of the engine. If the camshaft drive cover is held in place by easily removed clips or screws, your engine has a cam-belt.

Marinised engines that have a rubber cam-belt include the Volvo Penta MD22, Ford 1.5 and 1.8 derived engines and VW Golf-derived engines. Some Vetus engines may also incorporate rubber cam-belts.

If you have an engine with a cam-belt and its history is unknown, you would be well advised to have the belt changed.

In order to meet future emission controls, some car manufacturers are returning to chain-driven camshafts because the slight stretching of the rubber cam-belt gives less precision to the valve and ignition timing.

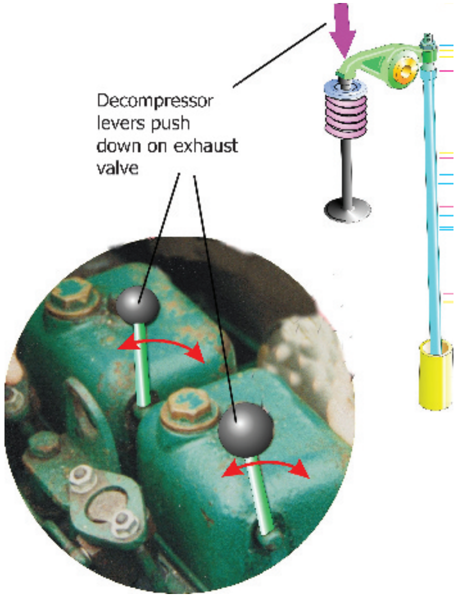
DECOMPRESSORS

Older non-automotive engines have decompressors. These allow the engine to be turned over with no compression as an aid to starting or for maintenance by partially opening the exhaust valve. It's essential that this is adjusted so that there's no contact between the exhaust valve stem and the decompressor arm when in the 'parked' position to avoid damage.

You can't hand start a diesel against compression, but if the decompressor(s) is/are used, the engine can be rotated by hand up to a speed at which it will start. Closing the decompressors will then allow the engine to start. Some multi-cylinder engines allow cylinders to be decompressed individually. When up to speed, close only one decompressor until the engine starts on one cylinder, then close the rest.

With a low battery, starting with the decompressors open will allow the depleted battery to turn the engine fast enough to start, the decompressors can then be closed.

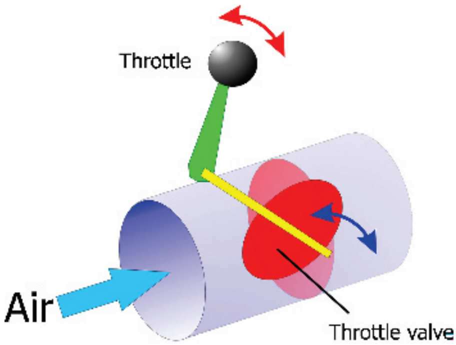
Note that although the Volvo Penta 2000 series engines have only one decompression lever, in the fully up position, all cylinders are decompressed. With the lever moved to the left, only one cylinder is compressed to allow starting on one cylinder.



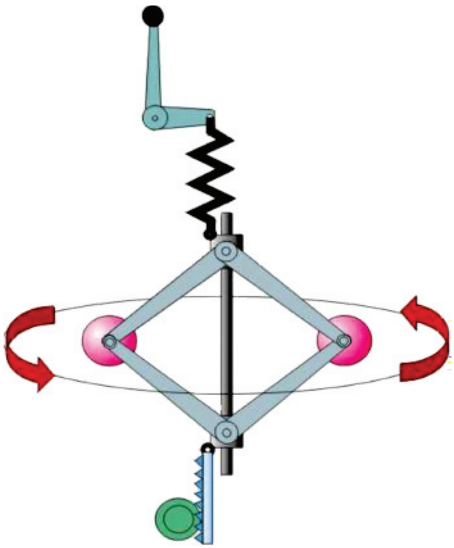
DIESEL ENGINE SPEED CONTROL

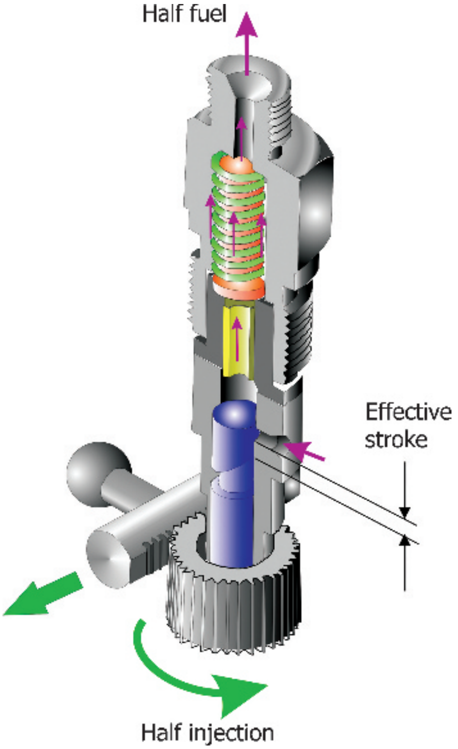
Unlike a petrol engine, a diesel engine has no throttle. A petrol engine uses a valve in the air intake manifold to control the amount of air entering the cylinder. Fuel is added to this controlled volume of air to give a constant air/fuel ratio of around 17:1 for normal running at constant speed. For increased power, more air is sent to the cylinder by 'opening the throttle', requiring more fuel, which in turn delivers more power.

If we were to restrict the air entering the cylinder of a diesel engine, compressing the restricted amount of air would fail to achieve combustion temperature and the engine would not run. A DIESEL ENGINE CANNOT HAVE A THROTTLE. Every induction stroke 'sucks' in a full cylinder of air.



Throttle valve position determines how much air (and hence fuel) enters the cylinder of a petrol engine



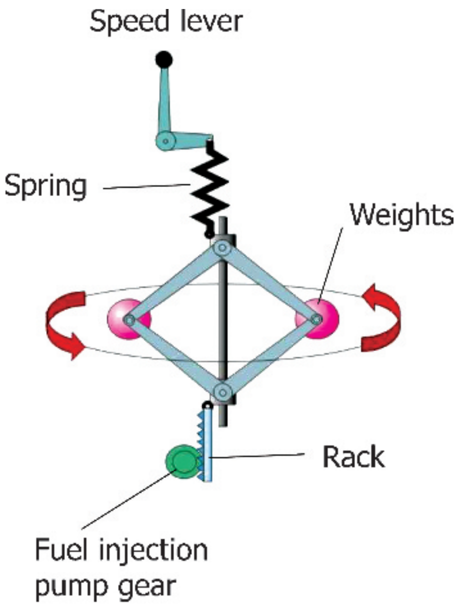


In a diesel engine, power output is controlled in a roundabout way. The engine speed is controlled by the speed lever ('throttle', gas pedal, or whatever you wish to call it). Just sufficient fuel is added to overcome the load on the engine to maintain the requested engine speed (rpm). This is achieved by a speed *governor* (regulator) working in conjunction with the fuel injection pump.

The governor

- A set of weights is spun round, driven by the crankshaft.
- The faster these weights are spun round, the further they want to fly out under the influence of centripetal or centrifugal force.
- Springs control how far these weights fly out.
- The tension of these springs is adjusted by the speed control lever ('throttle').
- The force on the springs is balanced by the centripetal force on the weights to control the speed of the engine.
- Any movement of the weights inwards or outwards forces a fuel control 'rack' to move.
- Movement of the rack causes a fuel control 'pinion' to rotate.
- The angular position of the pinion shaft determines the quantity of fuel delivered by the fuel injection pump.
- If the rpm falls, the springs pull the weights inwards.
- This inward movement signals the fuel injection pump to supply more fuel.
- If the speed rises, the centripetal force pulls the weights outwards.
- This outward movement signals the fuel injection pump to reduce the supply of fuel.

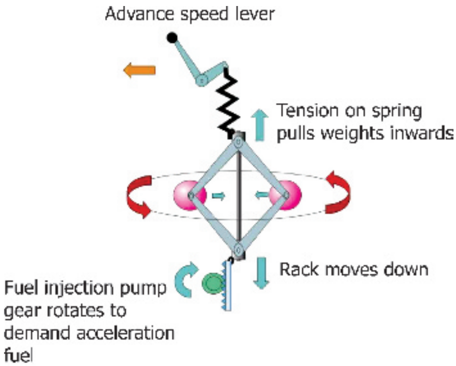
- The system is in ‘balance’ when the outward force of the weights is balanced by the inward pull of the springs.
- The engine rpm is then that which has been requested by the speed lever.
- *The speed lever determines the speed that the engine should run.*
- The fuel injection pump delivers just sufficient fuel to overcome the load on the engine to maintain the requested rpm.



Idle RPM

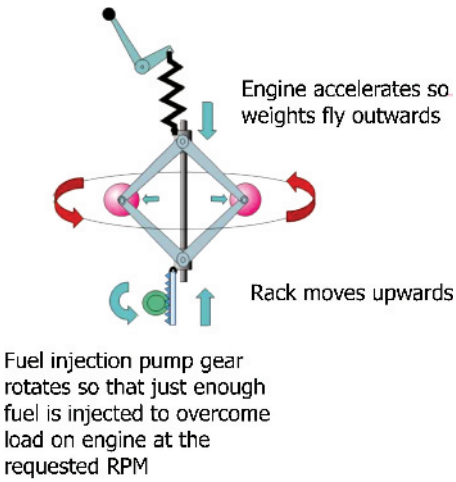
Accelerating the engine

- To signal a request to increase engine speed, say from idle to 2500 rpm, the speed lever is moved (‘opened’) to the approximate position to give the required engine rpm.
- This opens the rack to the ‘maximum fuel’ position to accelerate the engine.



Acceleration

- As the engine rpm approaches the requested rpm, the governor takes over and controls the fuel input to balance the load on the engine.



Steady RPM

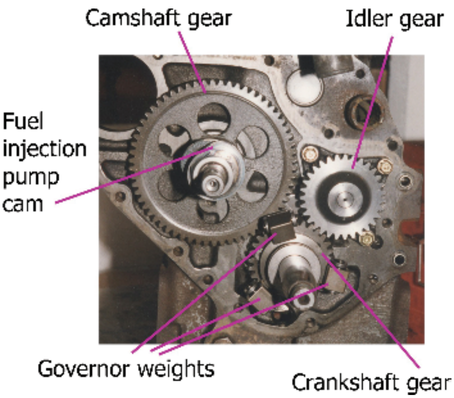
Slowing the engine

- The speed lever is ‘closed’ to the idle position.
- This moves the rack to the idle position.

- Pre-set idle fuel is supplied to the engine.
- The engine slows under the influence of the load to idle rpm.

Too much load

If the load is so great that the requested rpm cannot be achieved, the governor will not control engine speed and acceleration fuel will continue to be supplied to the engine, even though the engine is running at a constant (too low) rpm.



Where is the governor?

If the fuel injection pump is mounted on the engine casing and driven directly by the engine camshaft, the governor is inside the timing gear-case of the engine.

If the fuel injection pump is a separate unit, mounted externally to the engine, the governor will be mounted inside the pump casing. Some of these fuel injection pumps may have a hydraulically controlled governor.

Engines with electronically controlled fuel injection will have electronic governors.

SMOKE IN THE EXHAUST

Once the engine has reached normal operating temperature, its exhaust should be free of visible smoke. However, some engines, such as the Volvo Penta 2000 series, always seem to have a slight bluish haze, even when the engine is in good condition.

When troubleshooting a diesel, always note the colour of any exhaust smoke, as this is a powerful diagnostic tool.

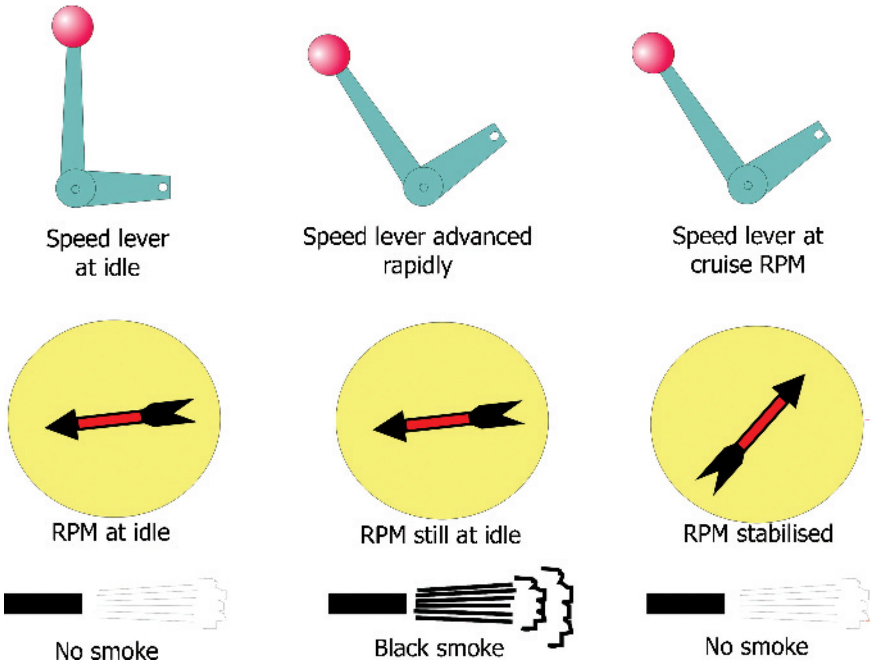
Black smoke

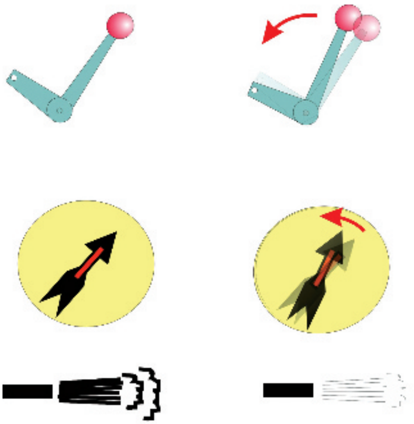
Black smoke is caused by *all* the fuel being incompletely burnt due to insufficient air for complete combustion. This black smoke comprises small carbon particles, which, in extreme cases, can form an ‘oil-like’ layer on the surface of the water. Don't be misled, this is carbon and not oil.

As we discussed earlier, a diesel engine sucks in a full cylinder of air on each induction stroke. Fuel is added to produce the required power to overcome the load to achieve the selected rpm. If too much fuel is added, such that there is insufficient air in the cylinder to burn it, black smoke will result. This black smoke represents fuel injected but not producing any power, and so is fuel wasted. This can happen under several circumstances.

Acceleration black smoke

If the speed lever is opened too rapidly, full acceleration fuel will be injected. It takes time for the engine rpm to increase, and so initially there will be insufficient air to burn all this fuel. Black smoke will result. Open the speed lever slowly. Electronic fuel management prevents this by matching fuel injected to engine





If overload black smoke occurs, ease back speed lever to reduce requested rpm and thus fuel input until black smoke ceases.

acceleration, resulting in a clean exhaust, however fast the speed lever is opened.

Overload black smoke

If more rpm is demanded than the engine has power to produce, black smoke will be produced. If the requested rpm is not achieved, acceleration fuel will be injected under the control of the governor, because the governor will not be 'in balance', even though the rpm is not accelerating. Because of the restricted rpm, insufficient air will be sucked in to provide complete combustion, resulting in black smoke. Closing the speed lever until the rpm *just* starts to reduce will ensure that there is sufficient air to burn the fuel and black smoke will cease, ensuring all the fuel injected is producing useful power, thus removing the overload condition.

Overload can result from a fouled hull or propeller, towing another boat, running in gear when moored or proceeding into heavy seas. With a marine engine it is due mainly to the use of a fixed pitch propeller. It is equivalent to driving up a hill in too high a gear in a car. Overloading can cause engine damage and in any case wastes fuel.

Other black smoke

Black smoke can be the result of insufficient air reaching the cylinders due to a restriction in the air supply. This restriction may be caused by a blocked air filter, or insufficient air getting into the engine compartment. This latter can be checked by opening the engine compartment and checking if the black smoke ceases.

On a turbo-charged engine, a faulty turbo-charger delivering insufficient air for combustion can cause black smoke.

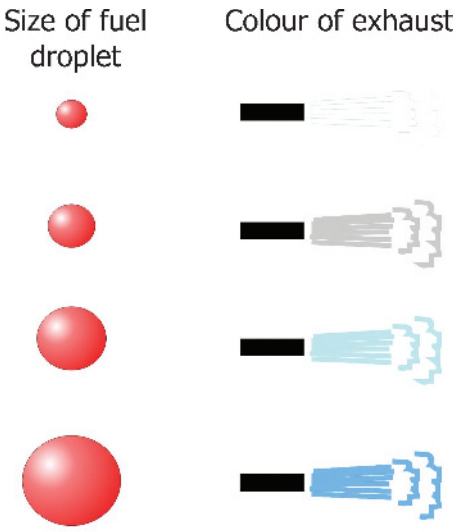
One case I came across was caused by delamination of a rubber pipe connecting the air filter to the inlet manifold.

Blue smoke

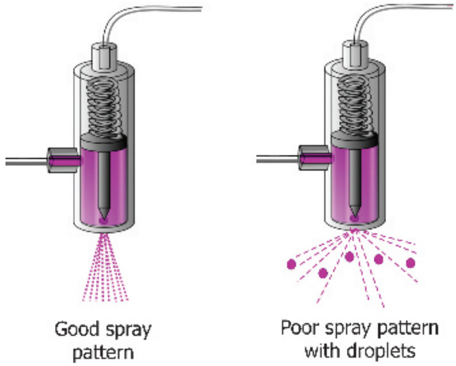
Blue smoke comes in a number of different shades and hues. It ranges from a light hazy almost white colour through to dark blue. Watching a big diesel start shows a mixture of all possible hues!

Blue smoke is often an indication of burning lubrication oil in a worn engine, but fuel can give blue smoke as well. Blue smoke results because some of the fuel droplets (or lubricating oil) do not burn at all. This is because if a fuel droplet is too large in diameter it will not burn (this is a function of its surface area and mass). The size of the unburned droplet determines the shade of blue.

The fuel injected by a serviceable injector has droplets of the correct size to burn properly. When the engine is cold, some of this fuel may condense on cold surfaces of the combustion chamber and cylinder and form larger droplets that will not then burn. As the engine warms up, these condensed droplets will become smaller and, at some stage, will become small enough to burn. An engine running at light load may have some fuel condensation producing some droplets too large to burn, giving visible smoke.



Effect of size of fuel droplet on colour of exhaust smoke



Worn injector with poor spray pattern giving rise to a smoky exhaust, poor starting and high fuel consumption

A worn injector may produce a deformed spray, producing some fuel droplets too large to burn.

A fuel injection pump with incorrect timing may supply some of the fuel to the injector too early or too late. Fuel supplied at the wrong time may reach the cylinder when the temperature is too low for combustion (too early) or there is too little oxygen left (too late). This fuel will be unburned and will result in blue smoke.

White smoke

White smoke is water vapour. Lots of white smoke is lots of water vapour!

When a car is first started on a cold, damp day you see white vapour coming from the exhaust. This is water vapour condensing in the exhaust, because for each gallon of petrol or diesel fuel burned, you get a gallon of water as a product of combustion.

On a boat with a water-cooled exhaust, the cooling water being injected into the exhaust system masks this relatively small amount of water vapour. Some people expect a cylinder-head gasket leak to show up as water vapour in the exhaust, but the quantity of water would be just too small to be seen on a boat.

Normally, a small engine would not have visible water vapour in the exhaust. A powerful engine being run at high speed, such as on a planing motor cruiser, would have a fair amount of water vapour visible in the exhaust, and this is quite normal.

Some books describe the smoke from fuel injection problems as being ‘white’. To me this is actually ‘light grey’, but the difference is small. Watch a diesel, especially a big one, being started from cold and you will see quite a lot of varying colour smoke. The lightest of this is ‘light grey’. You would not expect ‘white’ water vapour when starting from cold. Noting this should help to distinguish between the two.

CYLINDER BORE GLAZING

Certain operating conditions cause *cylinder bore glazing*, which reduces compression and increases oil consumption. Many yachtsmen deny the existence of this phenomenon, so I went to three of the world's leading engine manufacturers, who all came up with very similar descriptions of what happens and why.

Basically, they all said: 'don't run a diesel engine under light load – ideally aim for a minimum of 60% load – and don't run the engine too cool.' They all made the comment that working a diesel engine lightly and letting it warm up too slowly was actually being cruel, rather than kind, to the engine.

Compression

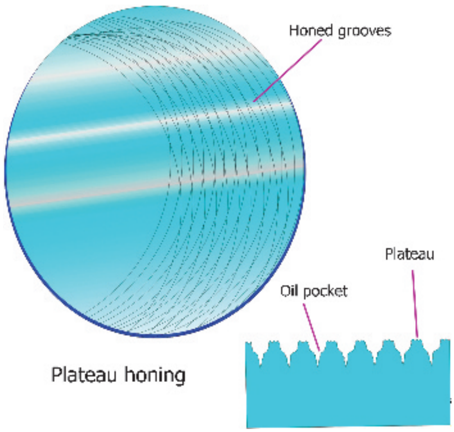
The surface finish of the inside of the diesel engine cylinder is not highly polished, as one might imagine. It has a network of shallow grooves machined on the surface, reminiscent of a surface that has been lightly sanded in a regular manner. This is called *honing*.

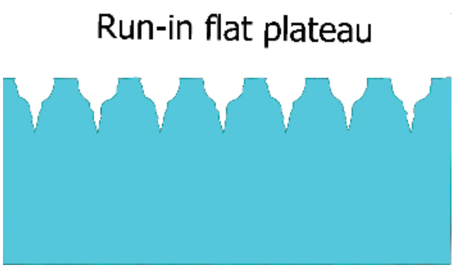
The purpose of this honing is to hold lubricating oil to enhance the sealing of the piston rings to the cylinder wall, to stop air blowing past the piston rings during the compression stroke. Without the oil-filled honing grooves, the compression would be insufficient to achieve ignition temperature in a diesel engine.

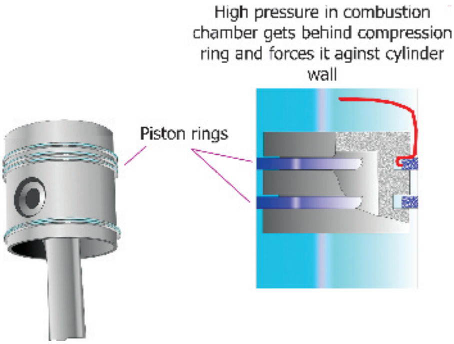
Cylinder bore glazing occurs when these grooves become filled with carbonised lubricating oil, so that they are no longer able to hold liquid oil to enhance compression.

Initially the outer surface of these honed grooves is not completely uniform and forms a slightly 'rough' surface. This surface needs to be 'run in' during the first

Reproduced with permission from Volvo.





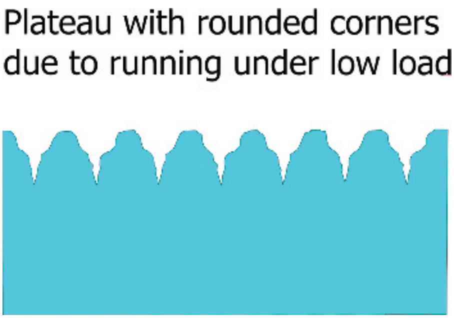


few hours of the engine's service to give a flat plateau between the grooves.

Glazing

The top, 'compression', piston ring is designed to allow combustion pressure to get behind it to push the ring outwards into firm contact with the cylinder wall.

If this pressure is insufficient, the corners of the honed grooves will become rounded instead of square, increasing oil consumption because oil will be able to migrate upwards towards the combustion chamber. As far as oil consumption is concerned, the first 40 hours of engine running are the most critical. New engines should be filled with running-in oil, which is replaced by normal lubricating oil, as specified by the engine manufacturer, at the first service. This running-in oil allows the honing to bed in properly.



When dispatched from the factory to the boat builder, the engine may have no oil in the sump. The builder may then fill the engine with normal engine oil that will prolong the running-in period and in normal leisure use, the engine may never become properly run-in. Use of a higher grade of oil than specified for normal use may also prevent the engine from becoming properly run-in.

If this pressure is insufficient, combustion gases can pass between the cylinder wall and the piston ring, carbonising the oil in the honed grooves. This is an ongoing process throughout the life of the engine. Once the honing grooves are full of carbonised lubricating oil, compression is reduced, giving difficult starting.

Bore polishing

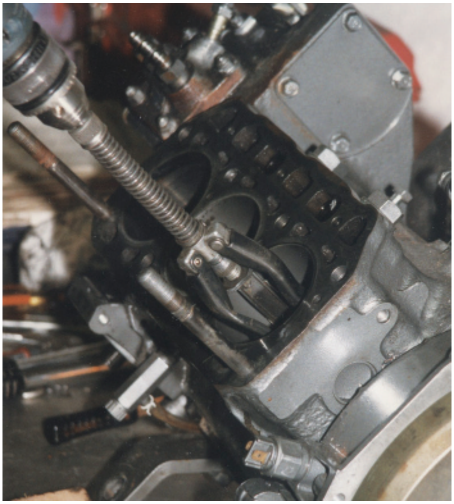
Prolonged cold running of the engine can result in considerable carbon build-up on the piston crown and the portion of the piston above the compression ring. This carbon can become baked onto the piston with hotter running, and it then forms an abrasive surface which wears the cylinder.

Prevention of bore glazing and polishing

Diesel engines should always be run under load so that combustion pressure is sufficient to force the piston rings into firm contact with the cylinder bores. The combustion pressure depends on the power being produced, which in turn depends on the fuel flow. Low fuel flow equals low combustion pressure.

- The propeller should be 'moving water'.
- Ideally, a marine diesel with a fixed pitch propeller should be cruised at around 70% (or more) of its rated rpm.
- 75% rpm with a fixed pitch propeller equates to about 50% engine power (or load).
- Motor-sailing at low rpm is bad – the engine should be contributing a reasonable amount of 'drive'.
- Battery charging in neutral at any rpm is bad – get the prop 'moving water', because even a high output (120 amp at 12 volt) alternator requires only around 3 hp to drive it.
- High rpm in neutral has low fuel flow and hence low combustion pressure – the engine is not under load.
- 'Warming up' at idle for more than two minutes is bad – if you need to warm up for longer, do it in gear with the prop moving water at around 1800 rpm if the local conditions allow.
- Don't use super oils in a leisure marine application unless the engine manufacturer recommends it.
- I once stated in *Practical Boat Owner* (henceforth PBO) that synthetic oil should not be used on a particular engine. I was at once challenged by the PR department of a major supplier of synthetic oil, who said that their product was the proper oil to use. I asked him to confirm that they would indemnify the user against damage when used in the marine leisure environment and all went very quiet!

Whether or not bore glazing will occur in a particular engine seems to some extent to be influenced by other factors as well. I have known engines to suffer after all the preventative rules have been followed and also the reverse, where terribly abused engines seem to come to no harm. However, following the rules will give you the best chance of avoiding bore glazing.



Should your engine's bores become glazed, they can be deglazed by re-honing. This requires engine removal and removal of the pistons from the cylinders so that the proper procedure may be applied. In the early stages of the problem, changing to running-in oil for the next 50 hours and running the engine as hard as possible may arrest the progress of the problem, but again, it may not.

Re-honing

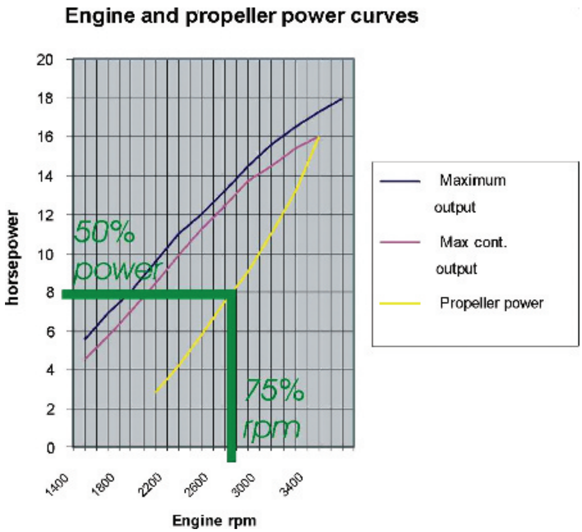
This is best left to the expert, who will use a re-honing tool. This is used in a powerful, slow-revving hand-drill. Using a suitable 'honing fluid', such as brake fluid, the tool is used in the bore in a reciprocating motion to cut new honing grooves.

ENGINE POWER

There is a great difference between the power an engine is capable of delivering and what it is actually delivering at any time.

The marine engine manufacturer gives a graph of engine power and rpm. On this there will be two curves:

one showing what the engine is capable of delivering at full load at all rpm, and a second showing what a fixed pitch propeller can harness if it is matched correctly to the boat's maximum speed and engine's maximum power and rpm. This curve is known technically as the *propeller law power*. Different authorities use different shaped curves, as it's an inexact science and the curve will, in any case, be specific to the design of propeller. We will see that at 75% rpm, the propeller is harnessing only about 50% of the engine's maximum power. When cruising, you won't be far wrong if you cruise at the rpm giving maximum torque.

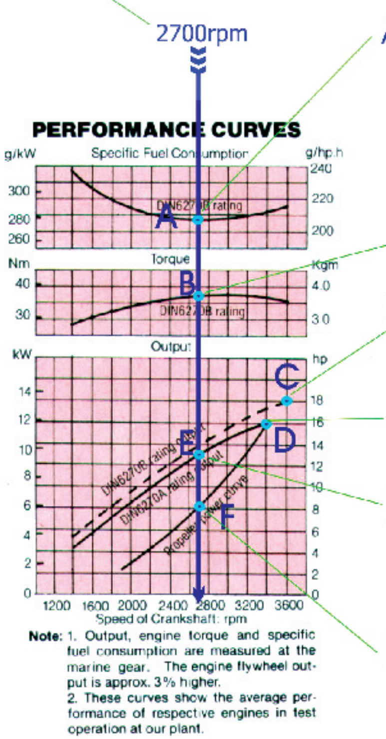


Some manufacturers give other graphs as well. *The specific fuel consumption curve* is a means of estimating the fuel consumption at different rpm. It gives fuel consumption per hour and doesn't take into account boat speed, so can't tell you how far you can travel. It's only fully valid when the engine is producing its maximum achievable power at any given rpm, but as this is the only information ever available, you have to use this when applying the propeller law power. *The torque curve* indicates the 'force' turning the propeller. A 'flat' curve indicates that the engine is more capable of accelerating the engine from low speed when under load.

What the manufacturer's figures mean

These performance curves are taken from the Yanmar 2GM20F data sheet

A suitable cruising rpm
(75% max. rpm)



A

SPECIFIC FUEL CONSUMPTION.
To get real fuel consumption you need to multiply this by the horsepower being absorbed by the prop.
In this case, looking at the bottom curve (F) we see that at 2700 rpm, the prop power is 8 hp. So, multiply 208 grams per hour by 8 hp and you get 1664 grams per hour. This works out as 0.46 gallons per hour.

B

TORQUE
Don't worry too much about this.

C

RATED POWER
The maximum power of the engine and the rpm that it's achieved. 18 hp at 3600 rpm

D

MAXIMUM CONTINUOUS POWER
The maximum power (and speed) you can use continuously. 16 hp at 3400 rpm

E

POWER CURVE
This is the maximum continuous power the engine can develop at any given engine speed.
Here it's 13 hp at 2700 rpm.

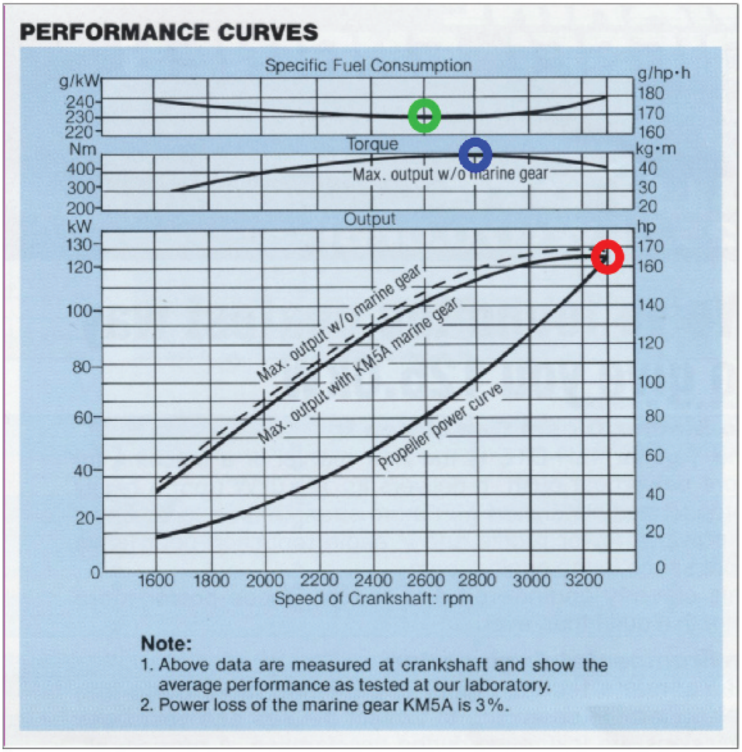
F

PROPELLER CURVE
Because a fixed pitch prop is fully efficient only at its designed speed (in this case 3400 rpm), it can't absorb all the engine's output at any other speed.
Here it can harness only 8 hp at 2700 rpm (and not the full 13 hp the engine is capable of at 2700 rpm), so only 8 hp is available to drive the boat. Fortunately, it's using only 8 hp's worth of fuel as well.

NOTE:

Yanmar gives output at the gearbox, most others give output at the crankshaft and overstate their power by 3%. A further 3 to 5% needs to be deducted to allow for the stern gear.

Manufacturer's performance curves
for YANMAR 4LH-DTE 160 hp diesel

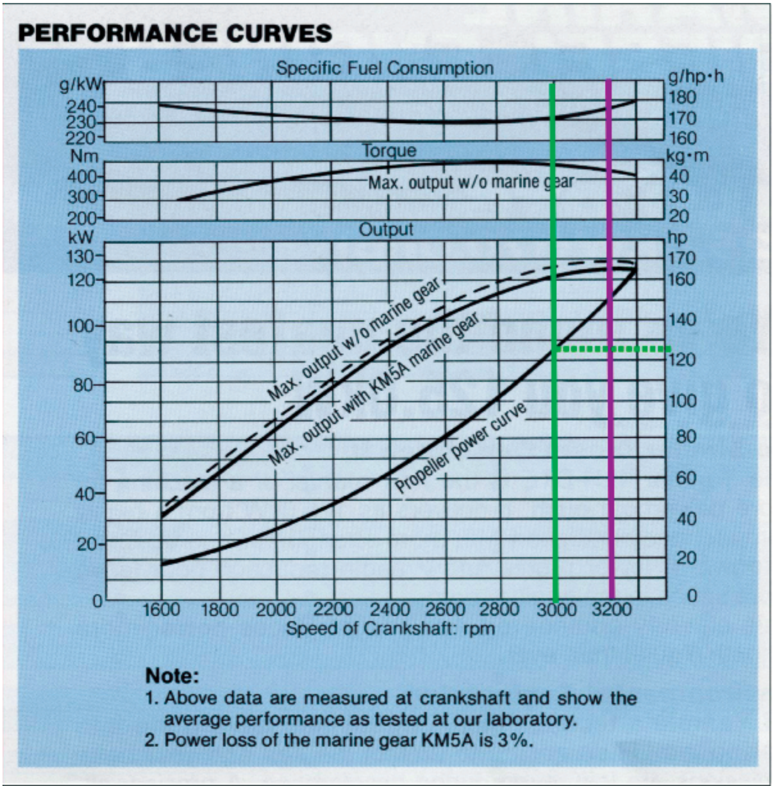


- RPM for best specific fuel consumption
- RPM for best torque
- Maximum power

Motor cruisers

The engine handbook tells you the maximum engine speed. This is normally for a maximum of one hour. For longer times than this you must observe the 'maximum continuous' rpm. In the Yanmar engine curve shown, this is 3200 rpm, only 100 rpm less than maximum.

However, for maximum cruising speed it is normal to 'throttle back' by at least 300 rpm from the maximum that can be achieved on a power boat. This will equate to approximately 75% power. Endeavour not to cruise at less than 75% maximum rpm.

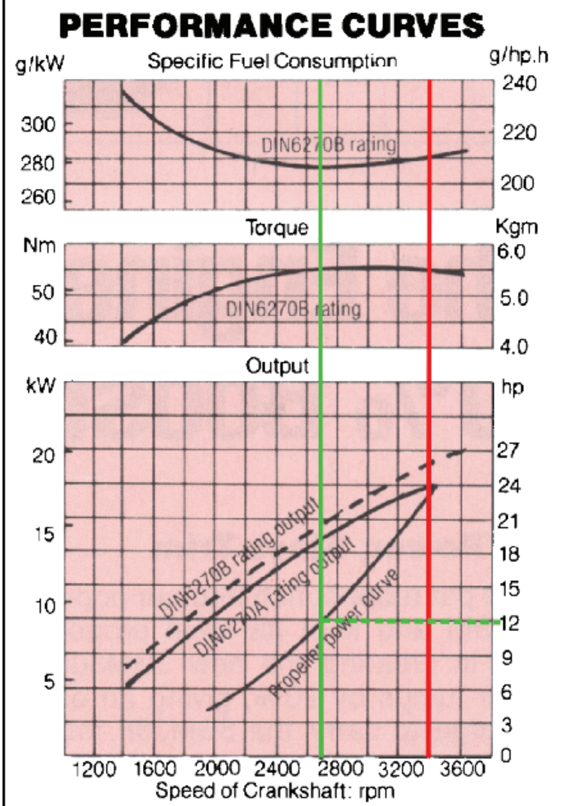


Normal and maximum cruising–power

Sailing yachts

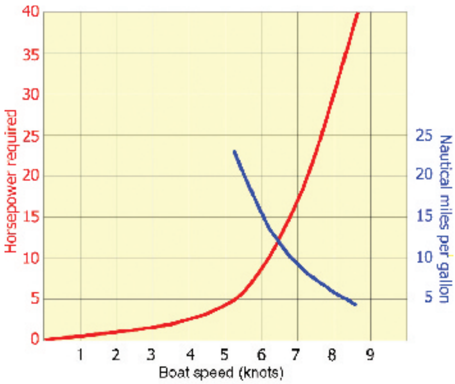
It should be your aim to cruise at around 75% maximum rpm, i.e. about 50% power.

Modern sailing boats are often fitted with a more powerful engine than is desirable.



Note: 1. Output, engine torque and specific fuel consumption are measured at the marine gear. The engine flywheel output is approx. 3% higher.
2. These curves show the average performance of respective engines in test operation at our plant.

Cruising and maximum power – sail



Power required to propel an easily driven 36-foot sailing boat of 6 tonnes displacement in calm conditions. Cruising at 6.3 knots needs 10 horsepower, so at half power for cruise you need a 20 horsepower engine installed. This gives a maximum speed of 7.2 knots in calm conditions. The cruising fuel consumption would be around 12 mpg. Fit a 30 hp engine and you have to cruise at 6.8 knots for half power and get only 10 mpg, or cruise at only 33% power. Go up to 40 hp and things just get silly, with 7.2 knots and 8 mpg, or cruising at only 25% power.

FUEL CONSUMPTION

Fuel consumption can be deduced from the engine maker's curves, which will give the *specific fuel consumption* (SFC). Multiply the SFC (often in grams per hour) by the *propeller horsepower* to get the consumption per hour at that rpm. If you've got two engines, multiply that by two. A gallon of diesel weighs about 8 lbs – about 4.2 kg (4200 g) and there are about 4.5 litres to a gallon, so you can do the sums in your units of choice.

There's a very convenient rule of thumb, so you don't need to get involved with the graphs. A diesel engine uses around 5 gallons per hour for every 100 horsepower. If you cruise at 75% rpm, that's about 50% maximum power. So, for every 100 rated (maximum) horsepower, you should use two and a half gallons per hour at cruising rpm. If you average much less than that, you are not loading your engine really sufficiently.

OPERATION OF THE ENGINE

You can prolong the engine's life and ensure maximum reliability by operating it correctly.

- Warm the engine up for only a couple of minutes if you are initially going to use only low power – you need 60 °C for full power.
- Once you have started the engine, don't stop it until the engine is warm (about 10 minutes or so).
- Run the engine under load – ideally cruise at around 75% rpm on a displacement boat.
- Planing boats will need to be cruised at around 300 rpm less than maximum to obtain optimum performance.
- Open the 'throttle' slowly.
- When changing gear, pause in neutral (count 1 second when in neutral).
- On a twin engine boat, if forced to run at slow speed, run on one engine if possible.
- Run the engine at idle for a couple of minutes prior to shutting it down, but don't leave it running while you tidy up the boat.

READ THE BOOK

Men tend not to read instruction books, yet your diesel engine handbook contains essential information and will not take long to read. I have come across a huge number of Volvo Penta 2000 series engine owners who are completely unaware of the correct cold start procedure, due entirely to their unwillingness to read the book.

A few questions may well illustrate the point:

- What is the cold start procedure for your engine?
- When sailing should you lock the prop shaft?
- How long should you remain in neutral when changing from forward to reverse?
- What is the normal oil pressure?
- What is the normal water temperature?
- Do you have any engine anodes; if so, where are they?
- What engine oil and gearbox oil should be used – are they different?
- Where should you check the cooling water level?
- Should the engine alarm sound when you stop the engine?

WHERE IT'S ALL GOING

We saw at the start of the book how simple the concept of the diesel engine is. Indeed, for many years the diesel maintained this simplicity, so that maintenance, troubleshooting and repair were comparatively easy.

Today, marine diesels of up to about 50 hp retain this simplicity, but from then up, complexity is added for the sake of greater efficiency, greater power from small packages and better emission control, so that today's larger engines are difficult and expensive to maintain, difficult to troubleshoot and expensive to repair.

For the impecunious or DIY yachtsman, or those straying from places where repair facilities abound, this decline in simplicity will become more burdensome.