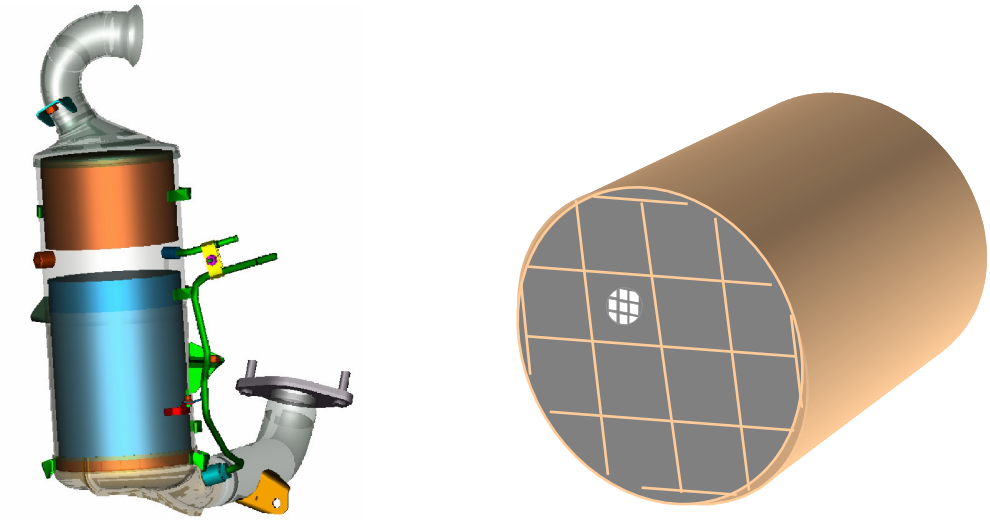
Ford Focus Duratorq TDCI with DPF (Diesel Particulate Filter)

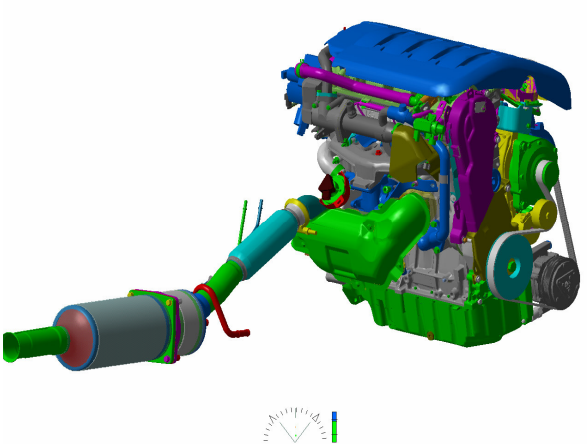
Ford's new, practically particulate-free generation of diesel engines



Complete filter unit as fitted to Ford Duratorq TDCi 1.6 and an individual filter element

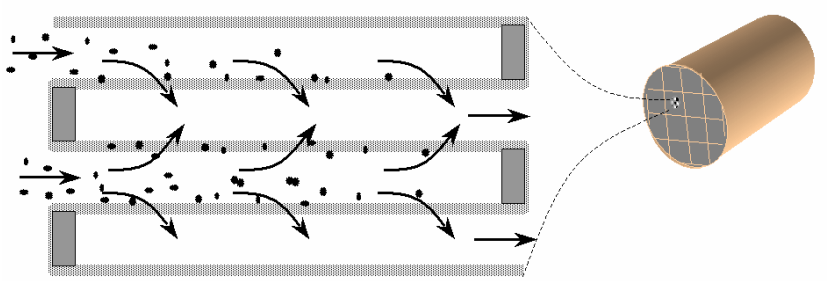
Clean diesel engines at affordable cost – this is what Ford stands for. The Ford Focus range offers two new diesel engines, the 2.0-litre 136-hp Duratorq TDCi and the 1.6-litre 109-hp Duratorq TDCi. Both engines are available with a DPF (diesel particulate filter) at extra cost.

The filter system has been developed jointly by Ford and its development partner PSA (Peugeot/Citroën). DPF technology will be launched on the German and UK markets first and, at a later time, in Scandinavia. Other European markets will follow.



Ford Duratorq TDCi 2.0 with close-mounted catalyst and particulate filter

The diesel particulate filter system (DPF) used in Ford Focus and Focus C-MAX fitted with a Duratorq TDCi engine reduces particulate emissions by up to 98 percent and helps to ensure full compliance with the Euro IV emission standard. On the German market, consumers purchasing a Ford Euro IV-compliant diesel vehicle can save up to 614 euros in taxes until the end of 2005 under a government programme promoting the purchase of low-emission vehicles.



Ford Duratorq TDCi filter system with filter element made from silicon-

The newly developed silicon-carbide ceramic filter is being used in combination with the latest common rail technology operating with up to four injection cycles. While capturing diesel particulate in the fine filter structure of the ceramic element is relatively easy, filter regeneration under the various operating conditions of the vehicle is considerably more difficult and requires an enormous amount of control technology involving the entire diesel engine.

Regeneration refers to the nearly complete reduction of particulate deposit in the filter element. This is accomplished by an engine management system using complex control loops. Depending on the engine load and condition of the filter, this system controls the combustion process of the particulate deposited in the filter. Contrary to the widespread opinion that engine developers need to focus particular attention on emission controls when the engine is operating at peak levels of power and torque, with diesel filter technology the lower load ranges pose higher challenges.

The problem of diesel particulate emission control results from the low exhaust gas temperatures of modern diesel engines. Unlike turbo-charged petrol engines, with exhaust gas temperatures easily exceeding the mark of 1,000 degrees Celsius, diesel units are relatively "cool". In the lower load ranges close to idling speed, exhaust gas temperatures are merely 250 degrees. Even under full load, they never exceed 750 degrees. At this level, under relatively high load, the diesel engine fitted with a particulate filter tends to perform a process called "natural regeneration": This means that the engine completely burns the deposited particulate without any additional means.

As exhaust gas temperatures decrease under lower engine loads, filter regeneration becomes increasingly difficult. However, driving the vehicle at high speeds for a certain period of time is always conducive to the regeneration process. High engine loads will ignite the particulate deposit in the filter, followed by combustion and hence regeneration of the filter. Nevertheless, suggesting to drivers that they should floor the pedal while stuck in urban stop-and-go traffic, or park their diesel-powered vehicle because the filter is full, could hardly be considered a piece of practical advice.

That is why Ford engineers in conjunction with experts from PSA have pulled all the stops to find viable solutions. These consist, on one hand, of heating the exhaust gas of the diesel engine and, on the other, of decreasing the required temperature in the filter. The result is a diesel engine management system that has been successfully used in millions of cars. As this approach has tackled the problem from two sides, the resulting solution is particularly sound.

Ford's development work in the forward-looking field of diesel filter technology has resulted in several patents. Based on Ford patents awarded in the nineteen-eighties, The Focus range uses an additive which helps to substantially reduce the regeneration temperature of the particulate deposit in the filter. This substance, consisting of a liquid mixture of pure iron and the chemical element ceria, is added in microscopically small amounts (measured in parts per million). This suffices to trigger ignition of the particulate at roughly 450 degrees Celsius instead of approximately 650 degrees Celsius, followed by virtually non-residual combustion.

Nevertheless, the diesel engine still has to reliably achieve a temperature level of about 450 degrees Celsius. Consequently, engineers had to use a few "tricks" to raise the unit's natural exhaust gas temperature of 250 degrees whenever and while the filter requires regeneration.

There were several options to be considered for this. These included a combination of pre-injection, main injection and also as one post- and late injection event, respectively. The combination of these injection events made it possible to achieve extremely precise control of the combustion process.

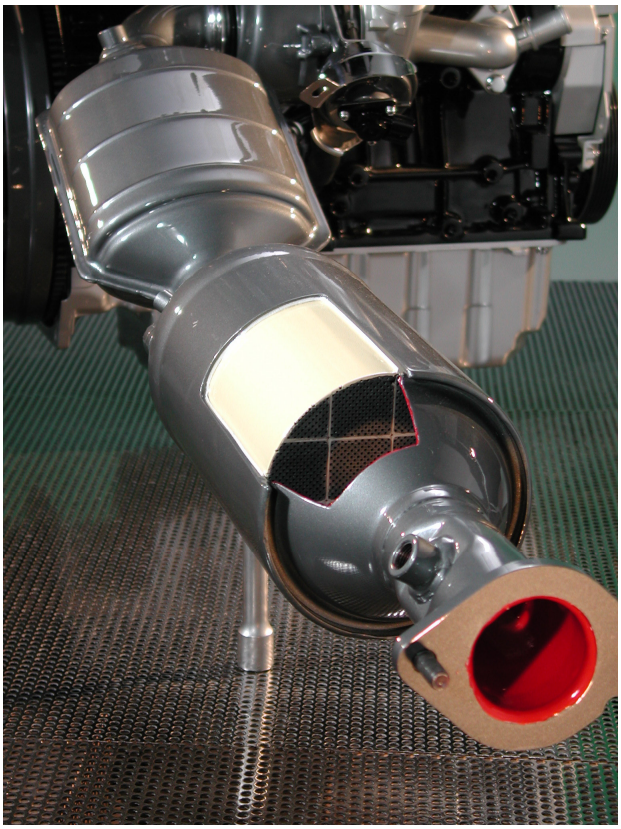
Pre-injection is timed approximately 10 degrees of crank angle earlier than the main injection event and uses merely one cubic millimetre of diesel fuel, which is roughly the same volume as the head of a pin. As with previous generations of Ford diesel engines, this helps to minimise the combustion noise of the Duratorq TDCi units.

Late injection occurs at around 30 degrees ATDC (after top dead centre) at the end of the combustion cycle. This small amount of injected diesel fuel raises the temperature of the exhaust gas immediately after the main combustion process.

Post-injection occurs about 40 degrees ATDC. This post-injected fuel is not burned in the combustion chamber but joins the flow of the exhaust gas through the exhaust manifold and the turbocharger. The fuel is not ignited until it hits the hot catalyst where it will then burn inside the flow channels. This exothermal reaction heats the filter and, in conjunction with the other measures described above, enables complete combustion of the particulate deposit in the filter.

While the engine is operating at extremely low loads, in other words when the car is practically coasting at near idle speed, these measures do not suffice and must be supported by two additional “tricks”. The intake channel can be heated by an electrical heating element that is activated as needed. This also causes a rise in exhaust gas temperature and hence augments the effectiveness of the late and post-injection events by reducing the ignition delay. The result is a gradual rise in pressure and a longer heat release tail in the exhaust system. Intake throttling increases combustion temperature by reducing air flow – practically speaking, this amounts to an engine-controlled exhaust gas heater. Additionally, intake heating and throttling are used to tailor the heat release tail in the combustion and ensure that post and late injection burn reliably.

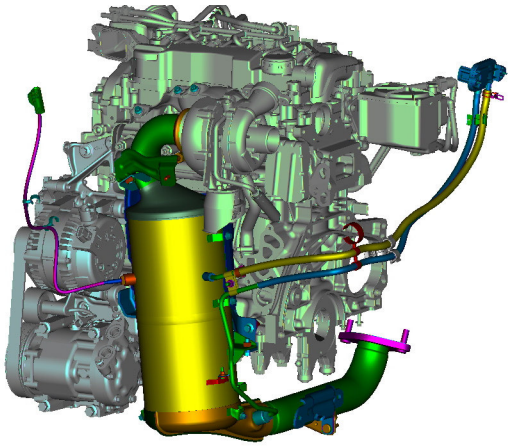
When operating the vehicle in and around urban areas, this four-pronged strategy creates optimum prerequisites for regenerating the filter system. This regeneration process is reliable, except when the engine idles for a longer period of time. Accelerating at a green traffic light, however, suffices to re-initiate the regeneration process. The engine management system will control the process independently – practically without the driver taking any notice. This sophisticated control process does not compromise driveability or the engine’s responsiveness to the driver’s use of the accelerator pedal in the slightest way. The diesel engine will simply run like a charm while the filter is being “purged”.



The diesel particulate trap filter system (dpf) allows the Duratorq TDCi diesel engine of Focus range to operate to the very demanding Euro stage 4 standard. The filter element is located downstream from the catalytic converter and forms a single functional unit with it for regeneration of the particulate filter. The

New Duratorq TDCi engines in the Focus range

Ford Duratorq 1.6-litre TDCi

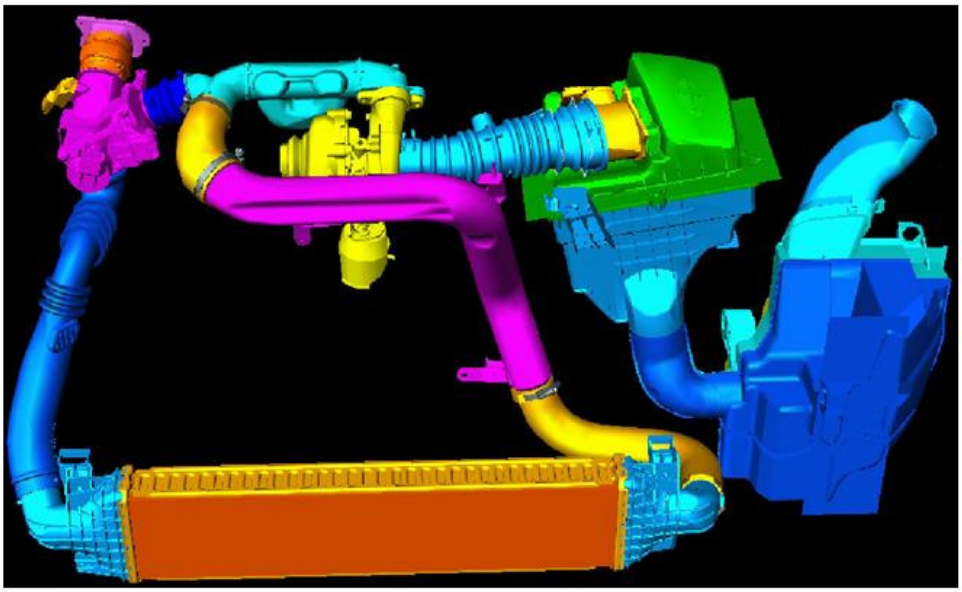


From the cylinder head to the oil pan, Ford Duratorq TDCi 1.6 is made of aluminium. The particulate filter is located directly below the turbocharger, in front of the engine (viewed in the direction of travel).

The range of diesel engines available for Focus range includes a 1.6-litre Duratorq TDCi unit that sets new benchmarks in terms of refinement, driving dynamics and economy. The engine delivers 80 kW/109 hp at 4,000 rpm and develops its peak torque of 240 Newton metres at a mere 1,750 rpm. As is common with Ford Duratorq TDCi engines, torque can be increased temporarily to 260 Newton metres, using overboost control, without causing the engine to overheat.

The specific mean pressure of Duratorq 1.6-litre TDCi is 19.3 bar, raised to 21 bar under overboost. Specific mean pressure is considered a mark of quality regarding the overall efficiency of any engine. It is obtained by dividing peak torque (expressed in Newton metres) by displacement (expressed in litres) and multiplying the quotient by the non-dimensional factor of 0.1257. The result is measured in bar and roughly equates to the mean piston pressure in the engine. Irrespective of the cubic capacity of an engine, this value provides a basis for judging the engine's charging efficiency. For a long time, values around 14 bar were considered the benchmark for modern diesel units. With mean pressures around 20 bar, Ford Duratorq TDCi 1.6 is one of the best engines in the world.

The four-valve diesel unit is completely made of aluminium alloy and uses latest-generation common rail technology with injection pressures up to 1,600 bar. The engine is one of the best power units currently available on the market, combining Ford's diesel competence with the know-how of Ford's French development partner PSA . PSA has particular experience in designing small diesel engines as well as in high-pressure aluminium casting technology. In combination with this engine, Ford offers the option of fitting Focus and Focus C-MAX with Durashift Automatic CVT, a continuously variable transmission, which can be operated with either five or seven gear ratios as well as in a completely stepless mode.

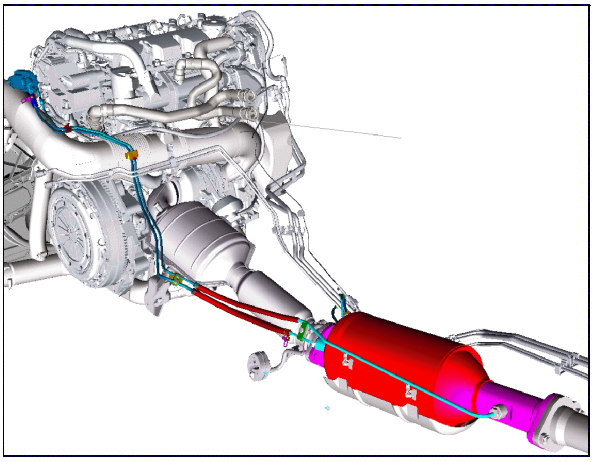


Characteristic for any Ford Duratorq dpf-filter is the inlet manifold with a split flow function. The reason lies in the fact that for the filter regeneration process to function under low driving load all intake air must bypass the intake air cooler. A split valve, controlling this (top center of the picture) is under control of the motor management system.

Characteristic design features of Ford Duratorq TDCi 1.6 include:

- Light-weight aluminium cylinder block and head with cast-in steel liners
- Separate, one-piece aluminium bearing block space frame with cast-in steel bearing shells
- DOHC valve train – the intake camshaft driven by the engine via a toothed belt drives the exhaust camshaft via a simple chain drive with hydraulic tensioner
- Valve train with low-friction roller cam followers and hydraulic plunger
- 3rd-generation common-rail direct fuel injection, 1,600 bar of maximum injection pressure
- Turbocharger with variable geometry
- electric intake throttles
- electric EGR
- Dual-mass flywheel

Ford Duratorq 2.0 TDCi



Ford Duratorq TDCi 2.0 is fitted with a catalyst and particulate filter, designed as two separate components. Viewed in the direction of travel, the catalyst is located behind the engine, close to the turbocharger, the filter roughly below the gearshift lever. This engine uses a

Like the 1.6-litre version, the cylinder head of the 2.0-litre Duratorq TDCi unit available for Ford Focus and Focus C-MAX is completely made of aluminium, while the block is made of cast-iron. The strength and noise-attenuating properties of the cast-iron block help to keep the considerable level of combustion noise produced by the four half-litre cylinders under control. Like the smaller engine, the 2.0-litre unit uses the common-rail system, generating up to 1600 bar of injection pressure, the dual-mass flywheel as well as the low-friction valve train with roller cam followers and hydraulic plunger.

The four-valve diesel engine delivers 100kW/136 hp at 4,000 rpm. Peak torque of 320 Newton metres is developed at 2,000 rpm and can be temporarily raised to 340 Nm by the Ford overboost system without overheating the engine.

The specific mean pressure of Duratorq 2.0-litre TDCi is 19.3 bar, raised to 21 bar under overboost. Specific mean pressure is considered a mark of quality regarding the overall efficiency of any engine. Irrespective of the cubic capacity of an engine, this value provides a basis for judging the engine's charging efficiency. For a long time, values around 14 bar were considered the benchmark for modern diesel units. With mean pressures around 20 bar, Ford Duratorq TDCi 2.0 is one of the best engines in the world.

Ford Duratorq TDCi 1.6 technical specifications

Type	**turbocharged, direct-injection diesel engine** with four cylinders, intercooler and water-cooled exhaust gas recirculation, diesel particulate filter available
Cubic capacity	1,560 cc
Bore x stroke	75.0 x 88.3 mm
Max. power	80 kW, 109 hp at 4000 rpm
Peak torque	**240/260* Nm at 1,750 rpm** *with overboost
Specific mean pressure	19.34 bar / 20.95 bar with overboost
Cylinder head	aluminium, four vertically positioned valves per combustion chamber

DOHC valve train – the intake camshaft driven by the engine via a toothed belt drives the exhaust camshaft via a simple chain drive with hydraulic tensioner; valve train with roller followers and hydraulic plunger

Cylinder block made of aluminium

Separate aluminium space frame for main bearings, with cast-in steel bearing blocks

Bosch common-rail injection system, 3rd generation system with solenoid-controlled injectors, 1,600 bar maximum injection pressure

Garret G 26 turbocharger with variable geometry and intercooler

Dual-mass flywheel

Certified according to Euro IV, with diesel particulate filter, or Euro 3 without diesel particulate filter

Weight, including turbocharger and manifolds: 112 kg

Ford Duratorq TDCi 2.0 technical specifications

Type	**turbocharged, direct-injection diesel engine** with four cylinders, intercooler and water-cooled exhaust gas recirculation, diesel particulate filter available
Cubic capacity	1,998 cc
Bore x stroke	85.0 x 88.0 mm
Max. power	100 kW, 136 hp at 4000 rpm
Peak torque	320/340* Nm at 2,000 rpm *with overboost
Specific mean pressure	20.13 bar / 21.40 bar with overboost
Cylinder head	aluminium, four vertically positioned valves per combustion chamber

DOHC valve train – the intake camshaft driven by the engine via a toothed belt drives the exhaust camshaft via a simple chain drive with hydraulic tensioner; valve train with roller followers and hydraulic plunger

Cylinder block made of GGG cast-iron

Separate aluminium space frame for main bearings, with cast-in steel bearing blocks

Bosch common-rail injection system, 3rd generation system with solenoid-controlled injectors, 1,600 bar maximum injection pressure

Garret G 32 turbocharger with variable geometry and intercooler

Dual-mass flywheel

Certified according to Euro IV, with diesel particulate filter, or Euro 3 without diesel particulate filter

Weight, including turbocharger and manifolds: 120 kg

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Voor meer informatie kunt u contact opnemen met:

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