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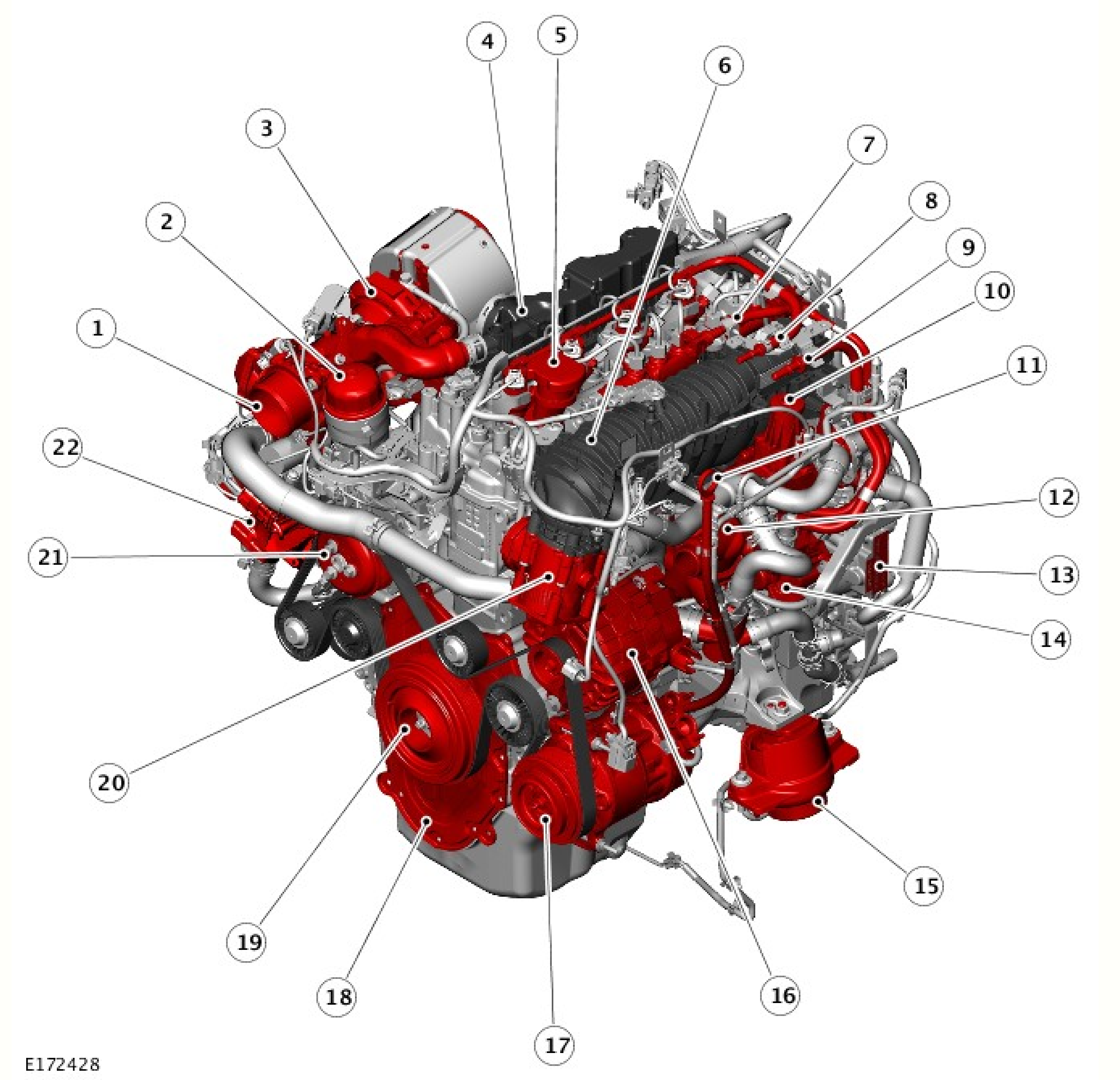
Engine - INGENIUM I4 2.0L Diesel - Engine

Description and Operation

COMPONENT LOCATION

E172427

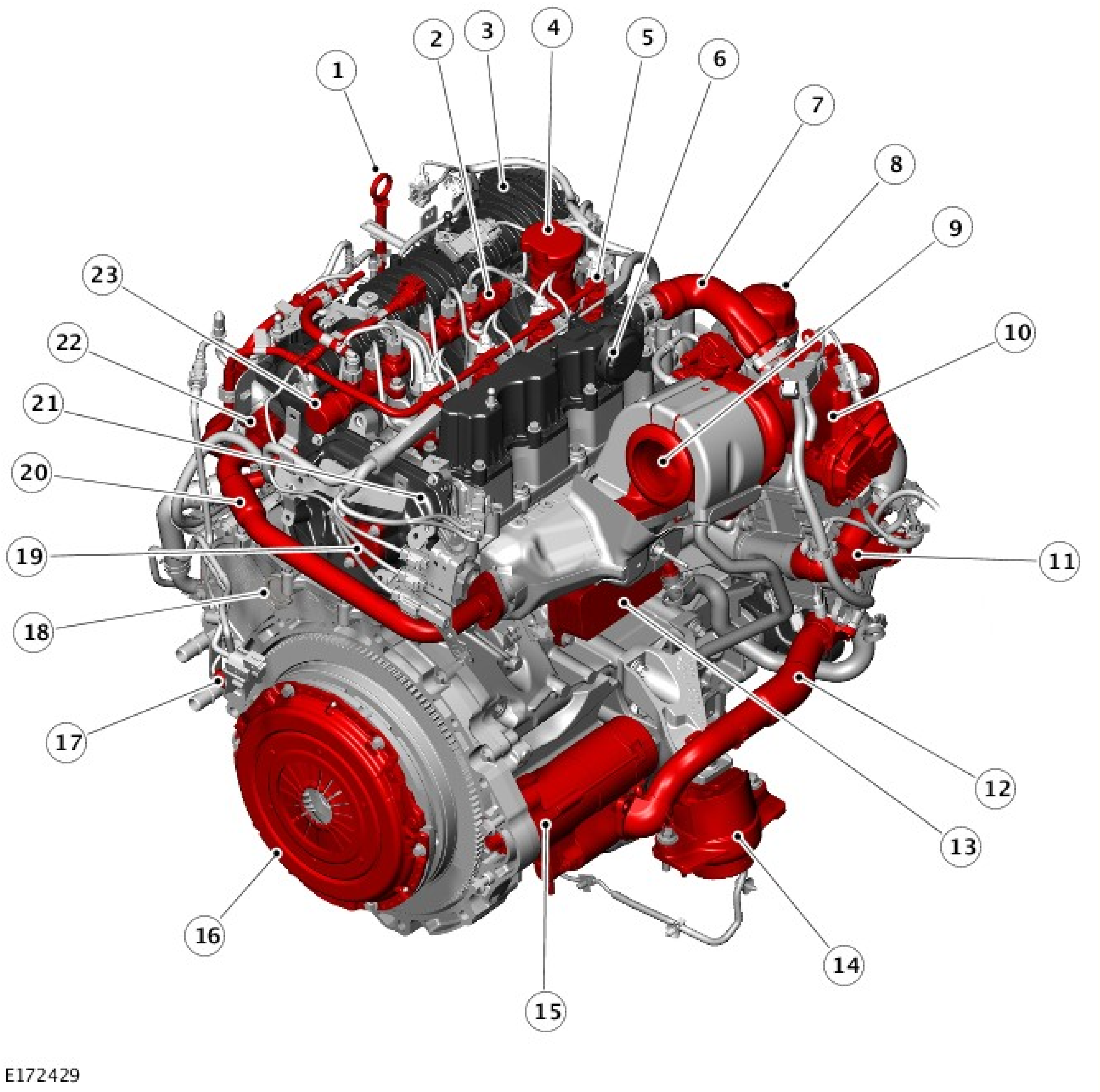
COMPONENT LOCATION - EXTERNAL COMPONENTS SHEET 1 OF 2



Item	Description
1	Turbocharger low pressure inlet
2	Oil filter and housing assembly
3	Variable Geometry Turbocharger (VGT)
4	Camshaft cover and positive crankcase ventilation
5	Oil filler cap
6	Intake manifold
7	Fuel return to fuel tank
8	Fuel return from fuel rail to fuel cooler
9	High Pressure (HP) fuel pump fuel inlet from fuel filter
10	High Pressure (HP) Exhaust Gas Recirculation (EGR) valve (All models)
11	Oil level gauge
12	Electric thermostat
13	Engine data location
14	High Pressure (HP) fuel pump
15	Left active engine mount
16	Generator

17	Air conditioning (A/C) compressor
18	Engine front cover
19	Crankshaft pulley/mass damper
20	Throttle body
21	Variable coolant pump
22	LP EGR cooler (EU5/6 and NAS only)

COMPONENT LOCATION - EXTERNAL COMPONENTS SHEET 2 OF 2



Item	Description
1	Oil level gauge
2	Fuel rail
3	Intake manifold
4	Oil filler cap
5	Fuel injector (4 off)
6	Camshaft cover and positive crankcase ventilation
7	Camshaft cover breather
8	Oil filter and housing assembly

9	Variable Geometry Turbocharger (VGT)
10	LP EGR valve (EU5/6 and NAS only)
11	Engine coolant inlet
12	EGR outlet pipe
13	Oil cooler
14	Right active engine mount
15	Tandem Solenoid Starter (TSS) motor
16	Clutch and flywheel assembly (manual transmission) or Drive plate (automatic transmission)
17	Crankshaft Position (CKP) sensor
18	Lower timing chain cover
19	Variable Camshaft Timing solenoid (exhaust camshaft only)
20	EGR inlet pipe
21	Cylinder head cover assembly
22	HP EGR valve assembly (All models)
23	Fuel rail pressure sensor

OVERVIEW

The Ingenium I4 2.0L Diesel is an in-line four cylinder, turbocharged engine which employs advanced modular design principles. Two variants of the Ingenium I4 2.0L Diesel four-cylinder engine have the following power and torque outputs: 163PS/380Nm and 180PS/430Nm. Both engines meet EU6 emission regulations.

The engine features a split-cooling system; an Engine Control Module (ECM) controlled electric thermostat and a fully variable coolant pump. The variable coolant pump enables engine coolant to remain static in the engine to maximise heat transfer during warm up. When engine coolant flow is required for engine cooling, the minimum flow is provided by the variable coolant pump. The split cooling thermostat housing maintains static coolant in the cylinder block while allowing engine coolant to circulate through cross-flow channels in the cylinder head. Parasitic losses are also optimised when the variable coolant pump is delivering reduced flow.

An electronically controlled variable flow oil pump with integral vacuum pump matches its flow rate according to engine speed, load and temperature. Oil flow to the piston cooling oil jets is solenoid controlled and operates only when needed.

Variable Camshaft Timing (VCT) on the exhaust camshaft enables faster catalytic converter heating, minimising harmful emissions during the critical warm-up phase. The VCT system is controlled by the Engine Control Module (ECM) using information from CMP (camshaft position) sensors.

The engine uses a Bosch high pressure direct injection, common rail fuel system with fuel pressure provided by a high pressure fuel pump which is chain driven from the crankshaft. The high pressure fuel pump supplies the fuel rail at a pressure of 1800 bar (26106 lbf/in^2), the fuel rail then supplies the four fuel injectors with fuel at a controlled pressure. The high pressure fuel system provides low noise, high efficiency and excellent fuel mixture formation within the combustion chambers.

The engine incorporates a sophisticated Exhaust Gas Recirculation (EGR) system which further assists to ensure emissions are below the limits set by Euro 6 regulations. The engine meets EU6 emission regulations in Europe and Rest of World (ROW). EU6 compliance is achieved using Selective Catalyst Reduction (SCR).
For additional information, refer to: Selective Catalyst Reduction (SCR) (309-00B Exhaust System - INGENIUM I4 2.0L Diesel, Description and Operation).

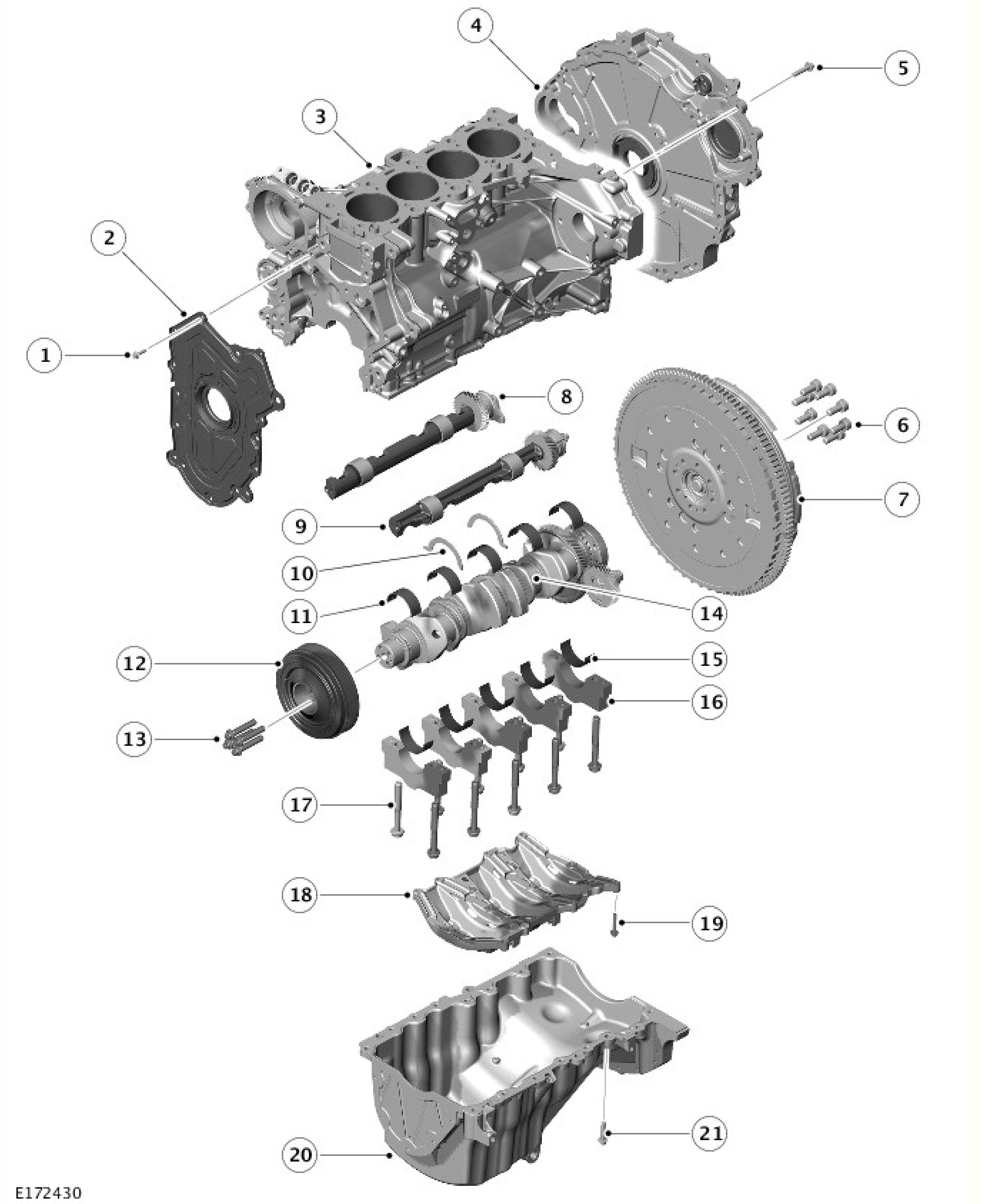
The turbocharger design utilises a high temperature cast iron exhaust manifold with a Mitsubishi Variable Geometry Turbocharger (VGT).

Ingenium I4 2.0L Diesel engines are characterised by the rapid build-up of torque from very low engine speeds, enabled by highly efficient Variable Geometery Turbocharger (VGT). Maximum torque is maintained over a wide engine speed range, ensuring instantaneous response and strong acceleration whenever the driver demands it.

Description	Specification Ingenium I4 2.0L Diesel 163PS	Specification Ingenium I4 2.0L Diesel 180PS
Configuration	In-line four cylinder	In-line four cylinder
Displacement cm ^{3}	1998.68	1998.68
Bore and stroke	83 X 92.35	83 X 92.35
Maximum power	163 PS (120 KW) @ 4000 Revolutions Per Minute (RPM)	180 PS (132 KW) 4000 RPM
Maximum torque	380 Nm (280 lb/ft) @ 1750-2500 RPM	430 Nm (317 lb/ft) @ 1750-2500 RPM
Compression ratio	15.5:1 +/- 0.5	15.5:1 +/- 0.5
Firing order	1,3,4,2	1,3,4,2
Boosting System	Single Variable Geometry Turbine turbocharger	Single Variable Geometry Turbine turbocharger
Fuel pressure	1800 bar (26106 lbf/in ^{2})	1800 bar (26106 lbf/in ^{2})

DESCRIPTION

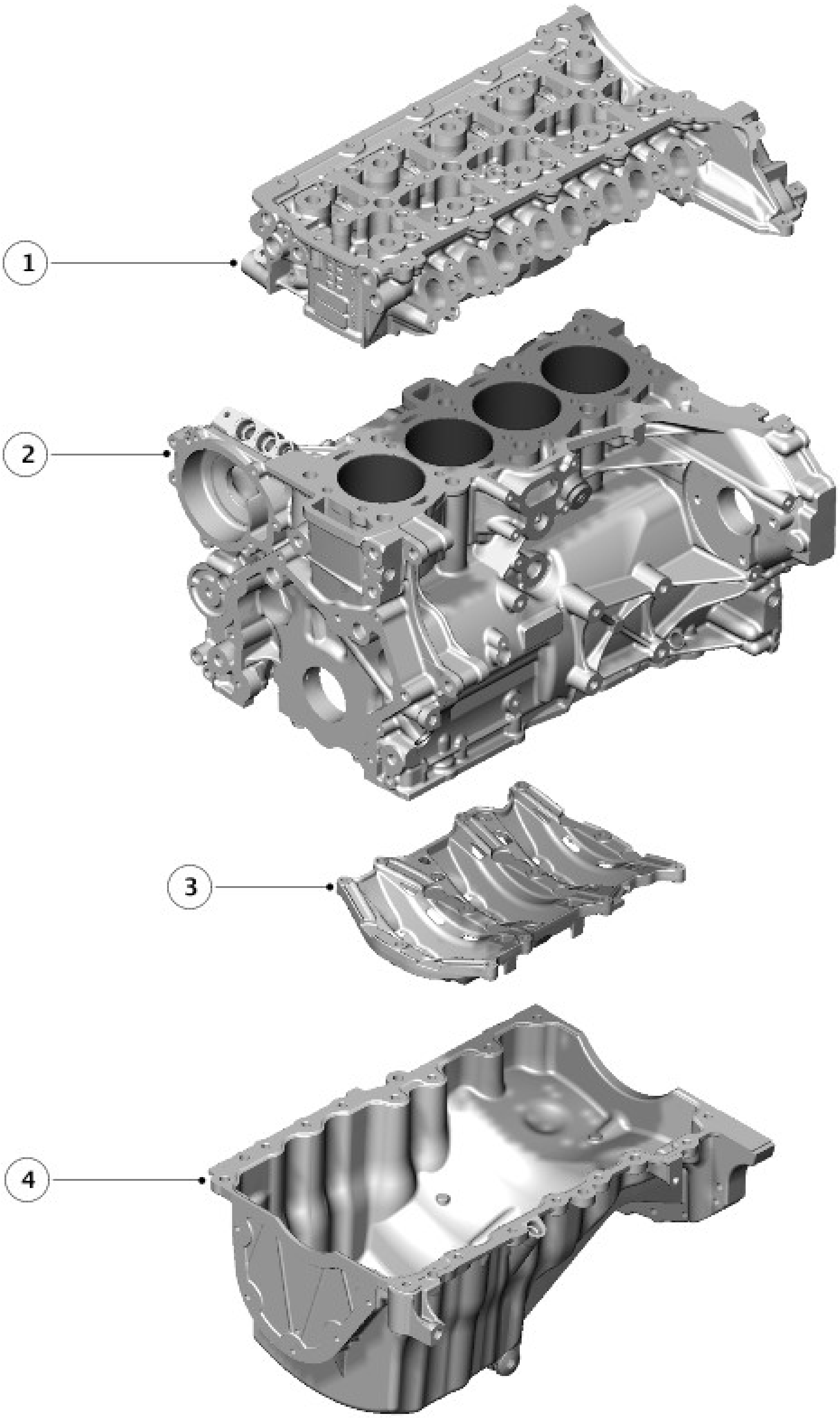
Cylinder Block Components



Item	Description
1	M6 bolt (13 off), M10 bolt (1 off)
2	Engine front cover
3	Cylinder block
4	Lower timing chain cover
5	M8 screw (16 off)

6	M10 bolt (8 off)
7	Dual mass flywheel (manual transmission) or drive plate (automatic transmission)
8	Right dynamic balancer
9	Left dynamic balancer
10	Thrust washer (2 off)
11	Upper main bearing (5 off)
12	Crankshaft pulley / mass damper
13	M10 bolt (4 off)
14	Crankshaft
15	Lower main bearing (5 off)
16	Main bearing cap (5 off)
17	M12 bolts (10 off) Main bearing caps
18	Windage tray
19	M6 screw (12 off)
20	Oil pan
21	M8 screw (16 off)

Major Structural Components



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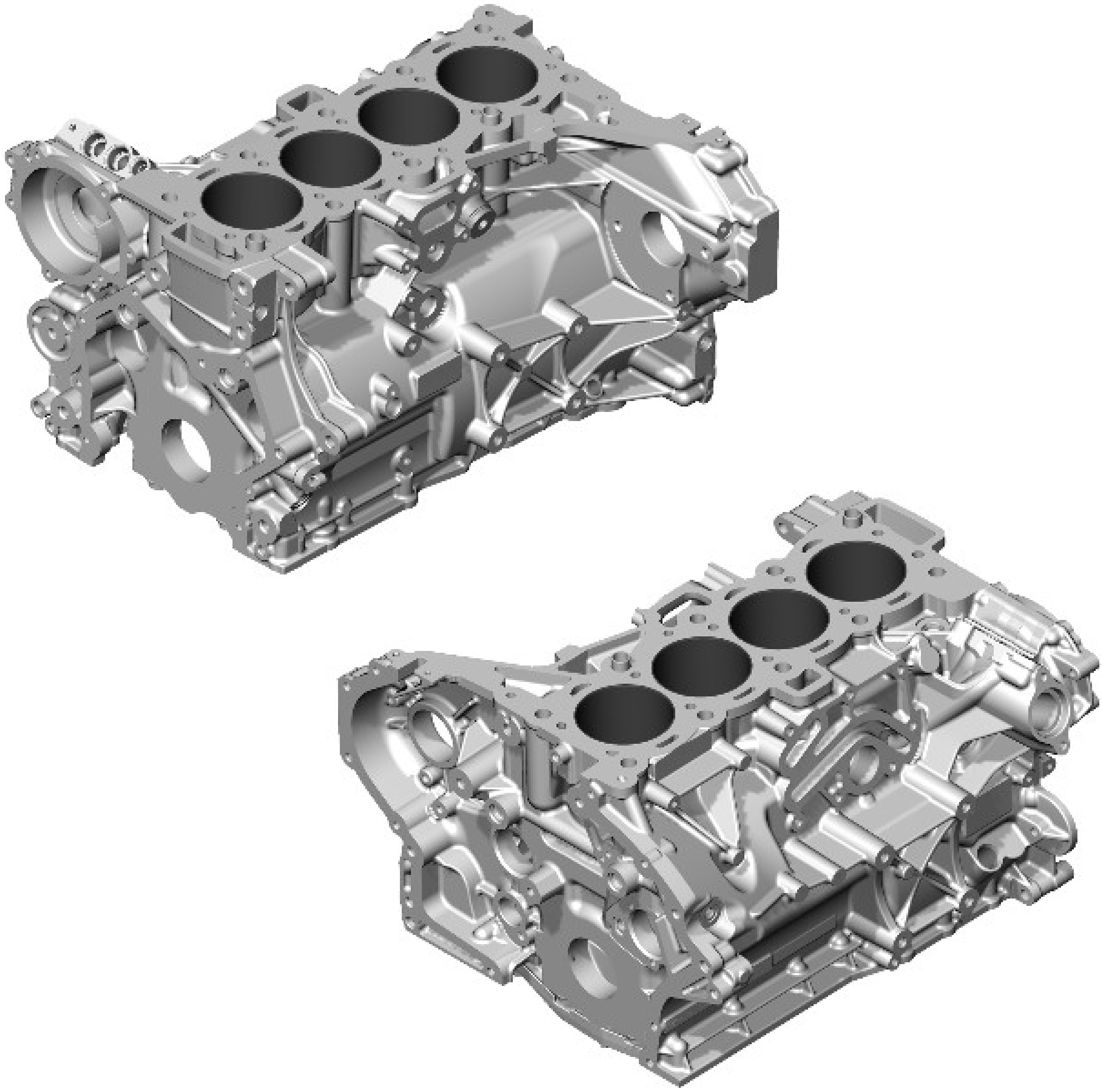
Item	Description
1	Cylinder head
2	Cylinder block
3	Windage tray
4	Oil pan

Cylinder Block



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The deep skirt cast aluminium cylinder block is an in-line configuration. Thin wall, interference fit cast iron liners provide optimum weight, cylinder bore roundness and robustness. The low volume coolant jacket gives good warm-up times. The cylinder block is a cross flow design with the coolant inlet to the cylinder head on the exhaust side and the coolant outlet from the cylinder head on the air inlet side.

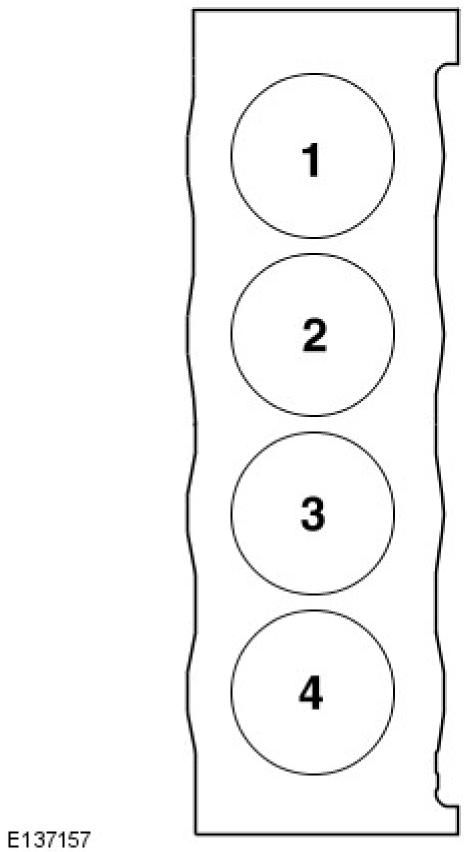
Oil from the cylinder head drains back to the oil pan through open apertures; one located at the front of the cylinder block and one at the rear of the cylinder block between the timing chain and the lower timing chain cover.

A cast aluminium alloy, structural windage tray is bolted to the bottom of the cylinder block to further improve the cylinder block stiffness, minimize Noise, Vibration and Harshness (NVH) and help reduce oil foaming.

Various machining ports in the cylinder block are sealed with cup plugs and threaded plugs. Removal of these is not necessary for service procedures.

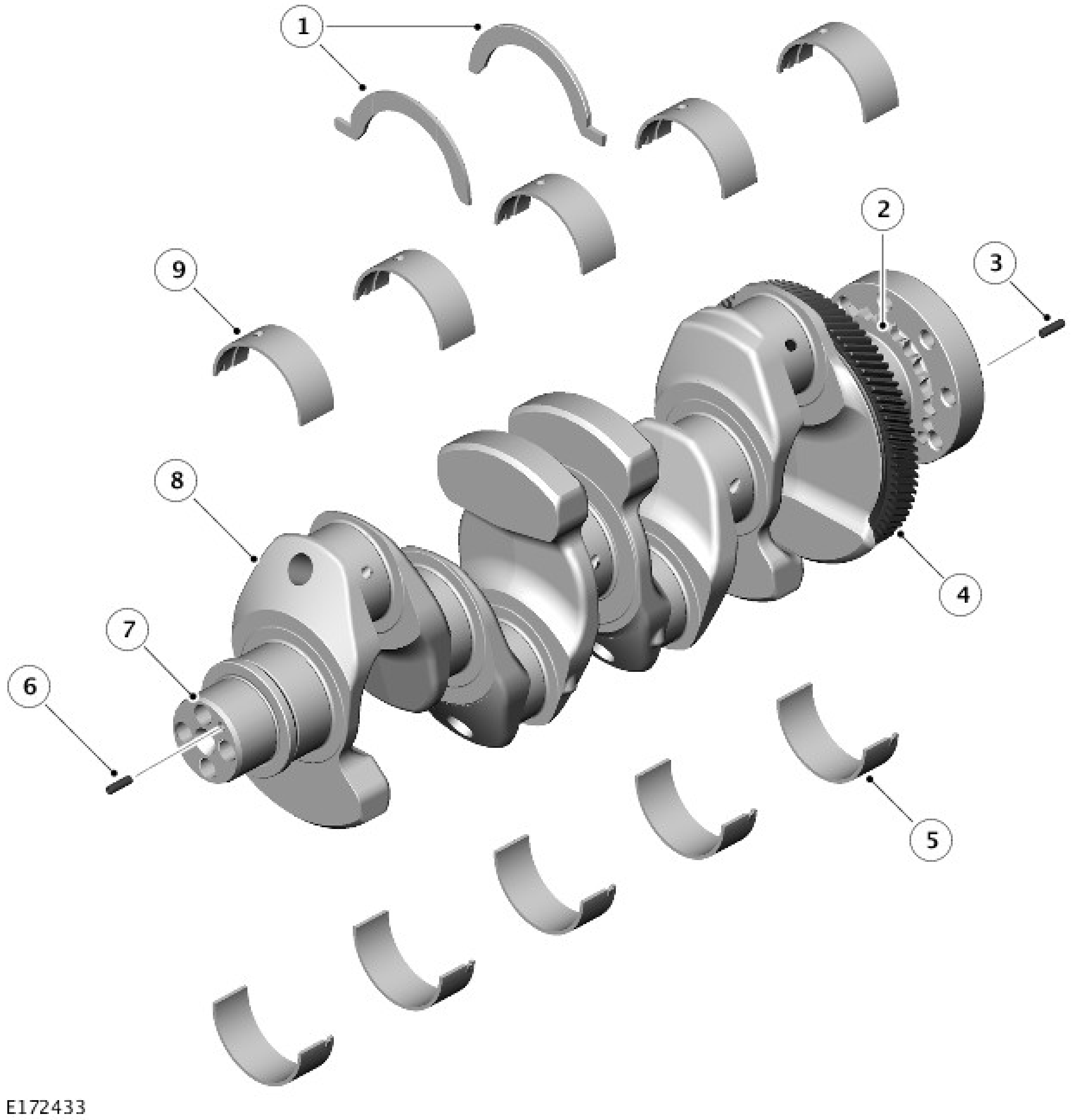
In cold climate markets a block heater is fitted to the cylinder block. The heater is screwed into a threaded bore on the cylinder block, which is normally sealed with a threaded plug.

Cylinder Numbering



The cylinders are numbered as shown, with cylinder 1 at the front of the engine

Crankshaft



Item	Description
1	Thrust washers (2 off)
2	Timing chain drive sprocket
3	Pin - dual mass flywheel (manual transmission) or drive plate (automatic transmission) location
4	Dynamic balancer drive gear
5	Lower main bearings (5 off)
6	Alignment roll pin - Crankshaft pulley / mass damper location
7	Crankshaft pulley / mass damper location
8	Crankshaft
9	Upper main bearings (5 off)

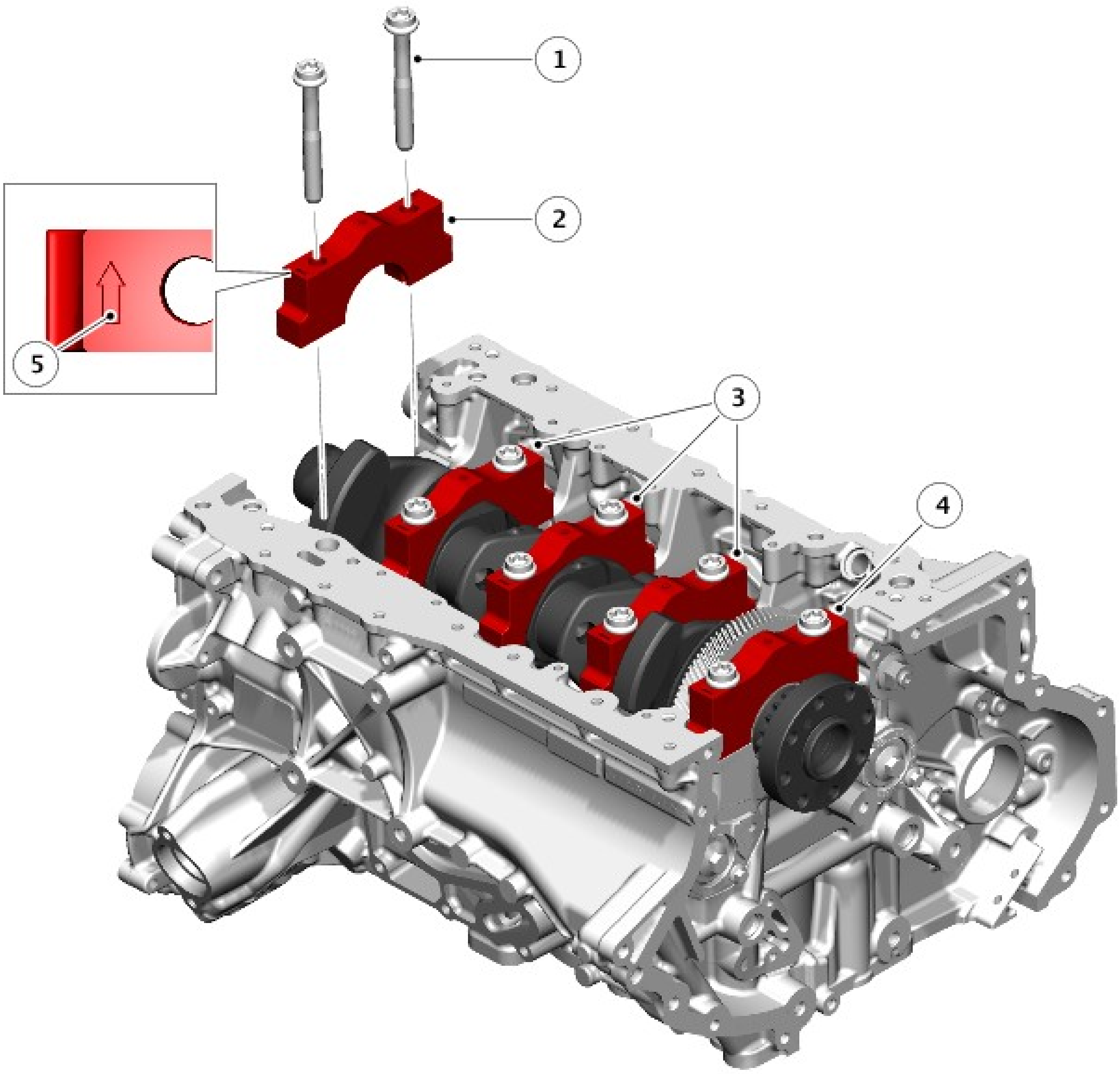
The crankshaft is manufactured from forged carbon steel C38 with induction hardened main bearing journals. The fillets of the main journals are fillet rolled to improve the strength of the crankshaft.

A five counterweight design has been used to balance bearing loads to give class-leading vibration levels.

An oil groove in the upper half of each main bearing transfers pressurised engine oil into the crankshaft for lubrication of both the main bearings and connecting rod bearings. The crankshaft assembly comprises the bare crank and a dynamic balancer shaft system drive gear. This gives direct drive at a ratio of 2:1 of the two counter-rotating dynamic balancer shafts.

Two individual thrust washers are located on either side of the central main bearing journal panel of the cylinder block to control crankshaft end float.

Crankshaft Installation



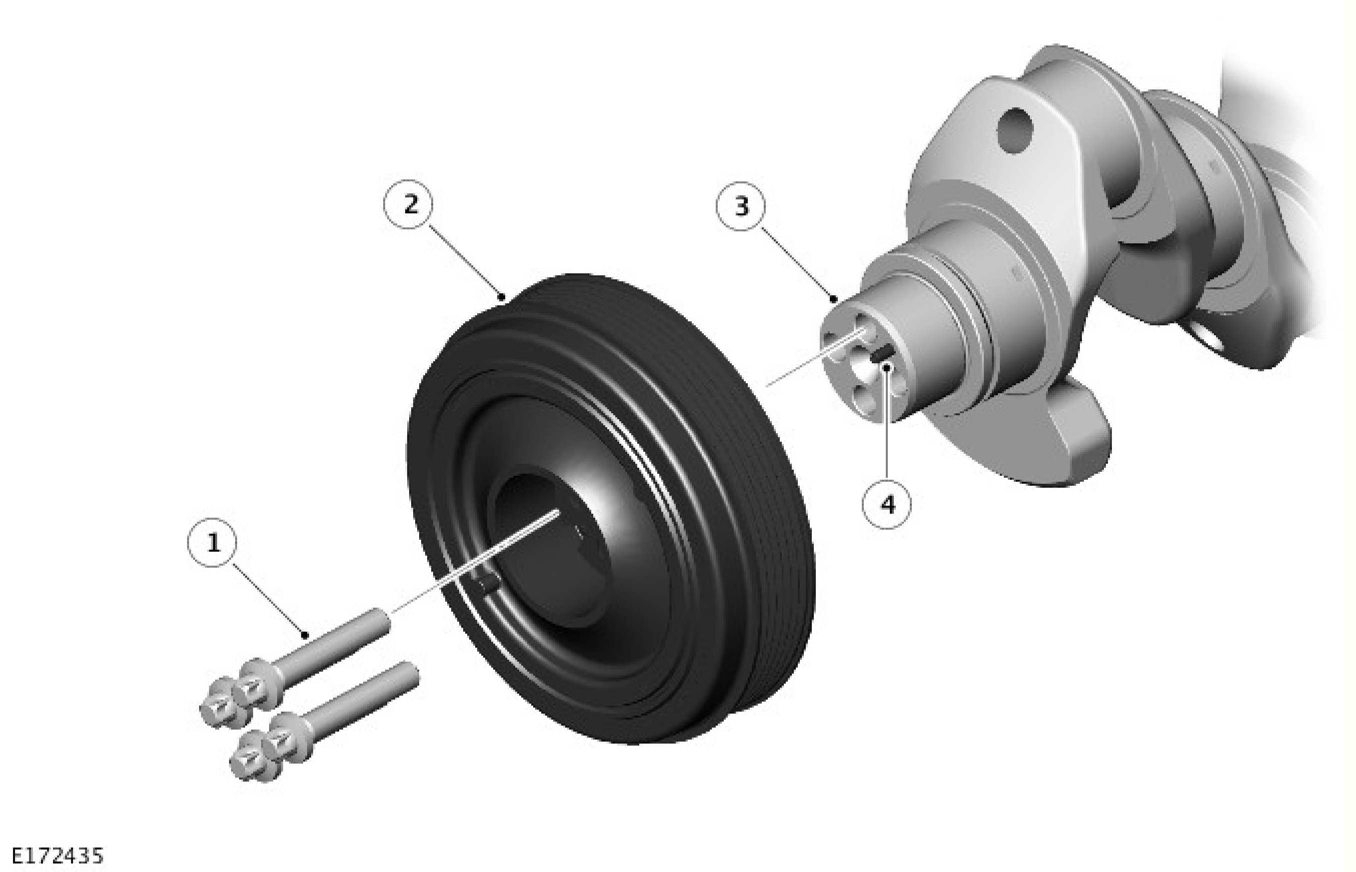
Item	Description
1	Main bearing cap bolts
2	Front main bearing cap
3	Main bearing caps (3 off)
4	Rear main bearing cap
5	Orientation arrow

The crankshaft is retained in position by five main bearing caps that are manufactured from sintered steel. Each individual main bearing cap has a numbered identification (1-5) and an arrow to ensure correct location and orientation; the arrow must face towards the front of the engine.

There are a number of grades of main bearing available. Each main bearing shell is colour coded and inkjet marked with a number on the running face of the bearing. The crankshaft is laser etched with a string of five alpha characters in the order of crankshaft main bearing journals 1-5 and a data matrix code containing the same data. The correct main bearing shells are selected with reference to a selection chart in order to achieve optimum running clearances.
For additional information, refer to: Specifications (303-01A Engine - INGENIUM I4 2.0L Diesel, Specifications).

The main bearing shells in the cylinder block have a central hole and an internal groove to allow for main bearing journal lubrication. The main bearing shells in the main bearing caps are plain with no hole or internal groove.

Crankshaft Pulley / Mass Damper



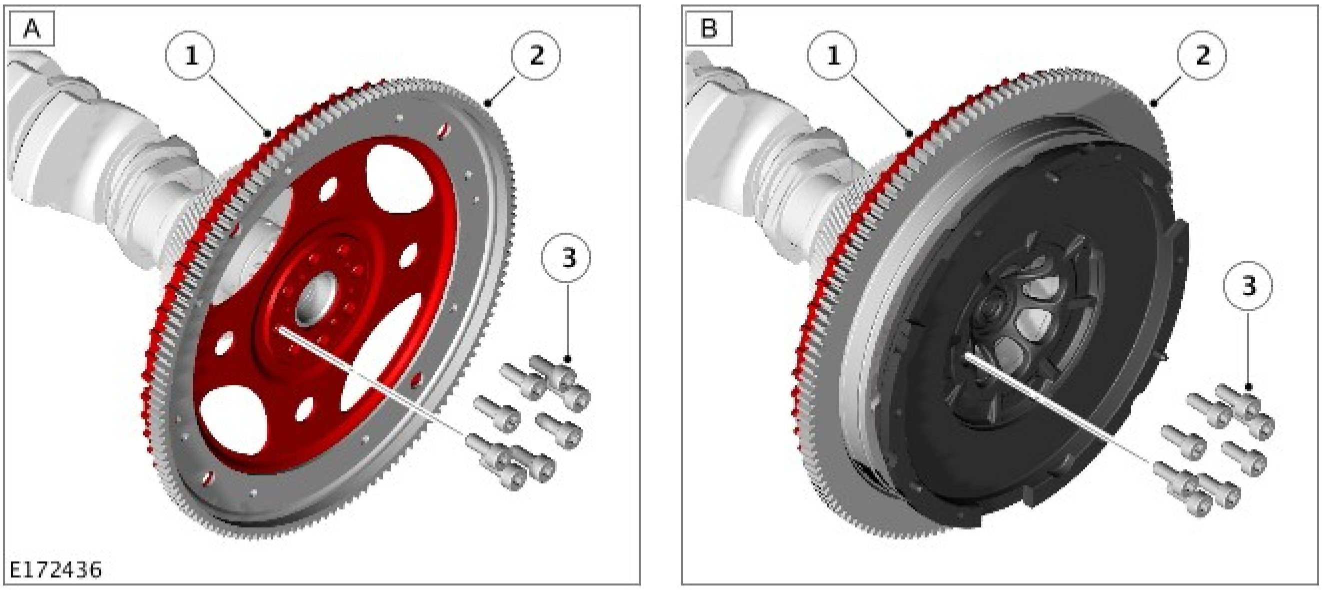
Item	Description
1	M10 bolt (4 off)
2	Crankshaft pulley / mass damper / torsional isolator
3	Crankshaft
4	Alignment roll pin

At the front of the crankshaft is a crankshaft pulley/mass damper which drives the primary drive belt for the ancillary components. A tuned torsional mass damper is incorporated into the crankshaft pulley which dampens vibration in the crankshaft produced by the combustion process. Each time a cylinder fires, torque is applied to the crankshaft via the pistons and connecting rods. The crankshaft deflects in reaction to the torque which creates a vibration when the torque is dissipated. The mass damper absorbs the vibration reducing fatigue damage to the crankshaft.

A torsional isolator is incorporated into the crankshaft pulley to provide isolation and reduce primary drive belt loads to the ancillary components. The crankshaft pulley is located over an alignment roll pin that is press-fitted into the crankshaft nose. Four bolts, that are torqued to yield, secure the crankshaft pulley to the crankshaft. An O-ring seal provides a seal between crankshaft pulley hub bore and the crankshaft nose outer diameter to prevent oil leakage during engine running conditions.

The crankshaft pulley has a timing mark that, when aligned to a corresponding timing feature on the front cover assembly, aligns the crankshaft to 50° After Top Dead Centre (ATDC) on Cylinder 1. The crankshaft pulley/mass damper assembly is not a serviceable component and must not be disassembled.

Drive Plate / Dual Mass Flywheel



Item	Description
A	Drive plate - automatic transmission
B	Dual mass flywheel - manual transmission
1	Reluctor ring
2	Ring gear - Tandem solenoid starter (TSS) motor
3	M10 bolt (8 off)

The drive plate or dual mass flywheel is located at the rear of the crankshaft. A dowel in the crankshaft ensures that drive plate or dual mass flywheel is indexed correctly.

Eight sealant patched bolts secure the drive plate or dual mass flywheel to the crankshaft. The bolts can only be used once and must be replaced if removed. Before replacement bolts are used, the holes must be dry and free from oil.

The drive plate or dual mass flywheel has three functions; to transfer drive from the crankshaft to the transmission, to transfer drive from the starter motor to the crankshaft and to provide the engine management system with crankshaft speed and position via a reluctor ring and a Crankshaft Position (CKP) sensor.

The reluctor ring has 58 teeth with 2 teeth missing to provide a gap. A Crankshaft Position (CKP) sensor is located in the lower timing chain cover and measures rotational speed and position as the reluctor ring rotates.

Drive Plate

The drive plate is used for automatic transmissions only.

The drive plate is a fabrication, which comprises a formed steel starter ring gear which is attached to the drive plate and reluctor ring. The two components are held together as one assembly by a form of clinching known as Tog-L-Loc®.

The reluctor ring has a service tool slot used during engine service procedures. The drive plate incorporates a steel starter ring gear which enables the starter motor to start the engine.

Four holes in the drive plate provide for the attachment of the automatic transmission torque converter to transfer drive from the crankshaft to the automatic transmission.

Dual Mass Flywheel

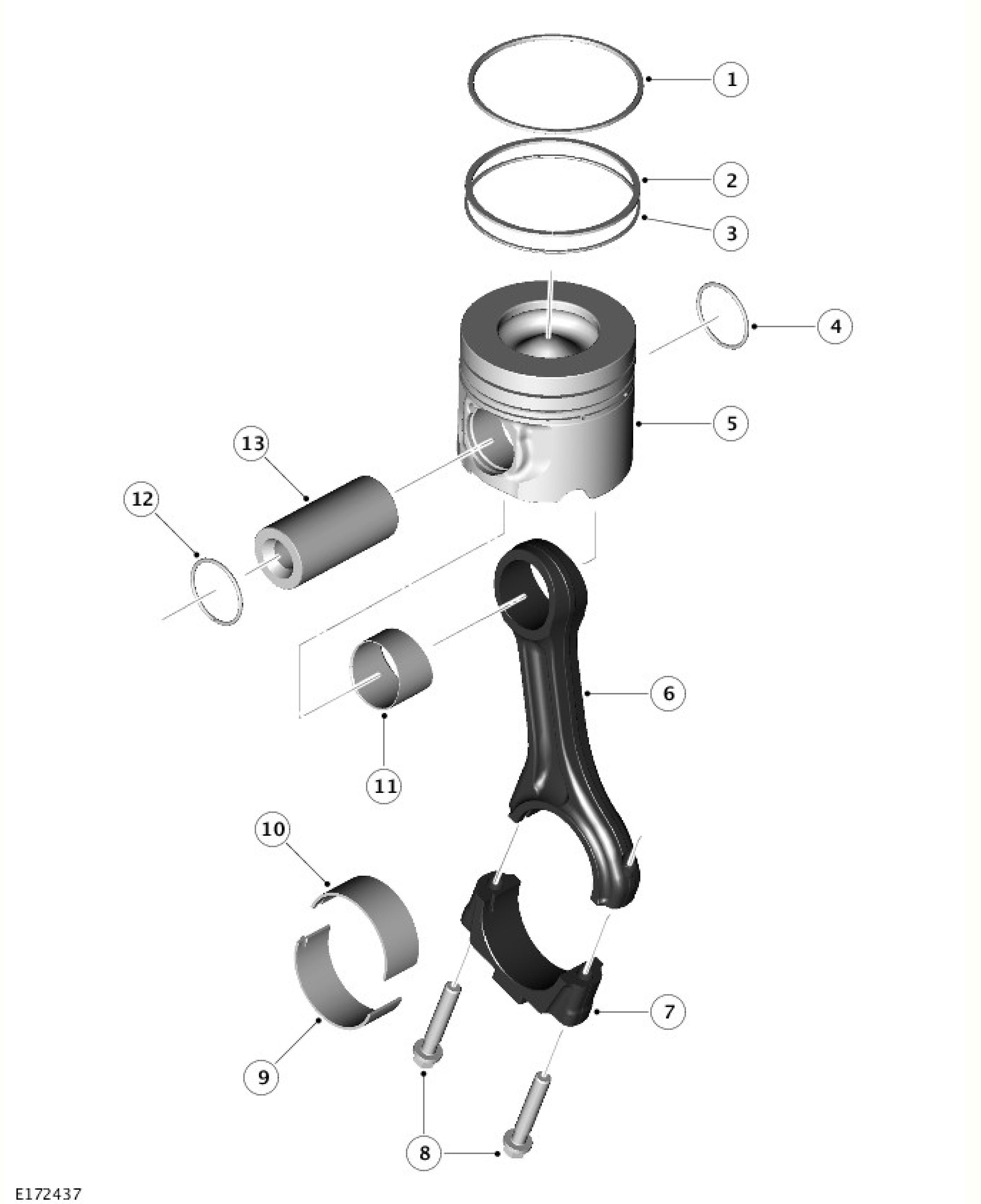
The Dual Mass Flywheel (DMF) is used for manual transmissions only.

The dual mass flywheel comprises two main components; the primary side which is attached to the engine crankshaft and the secondary side to which the clutch cover assembly is attached. The primary and secondary side are divided by a multi-spring damping system and centrifugal pendulum vibration damper. This provides a multi-stage characteristic curve designed to ensure optimal vibration isolation.

The primary side of the dual mass flywheel is a pressed steel fabrication and incorporates a reluctor ring.

The secondary side of the DMF is cast steel onto which the clutch cover assembly is located on dowels and secured with six bolts. The secondary side has the smooth friction surface on which the driven plate friction material engages.
For additional information, refer to: Clutch (308-01 Clutch, Description and Operation).

Pistons and Connecting Rods



Item	Description
1	Upper piston ring
2	Lower compression piston ring
3	Oil control ring
4	Circlip
5	Piston
6	Connecting rod
7	Connecting rod bearing cap

8	Bolt (2 off)
9	Lower large end bearing
10	Upper large end bearing
11	Small end bearing
12	Circlip
13	Gudgeon pin

The connecting rods are manufactured from forged steel and have fracture split connecting rod bearing caps to ensure precision re-assembly for bearing shell alignment. The connecting rod bearing caps are not selectable. Adjustment for large end bearing journal size is made by selecting the correct large end bearings after measuring the crankshaft journals.

There are a number of grades of large end bearing available, each being colour coded and inkjet marked with a letter on the running face of the bearing. The crankshaft is laser etched with a string of four alpha characters in the order of crankshaft journals 1-4 and a data matrix code containing the same data. The correct large end bearing shells are selected with reference to a selection chart in order to achieve optimum running clearances.
For additional information, refer to: Specifications (303-01A Engine - INGENIUM I4 2.0L Diesel, Specifications).

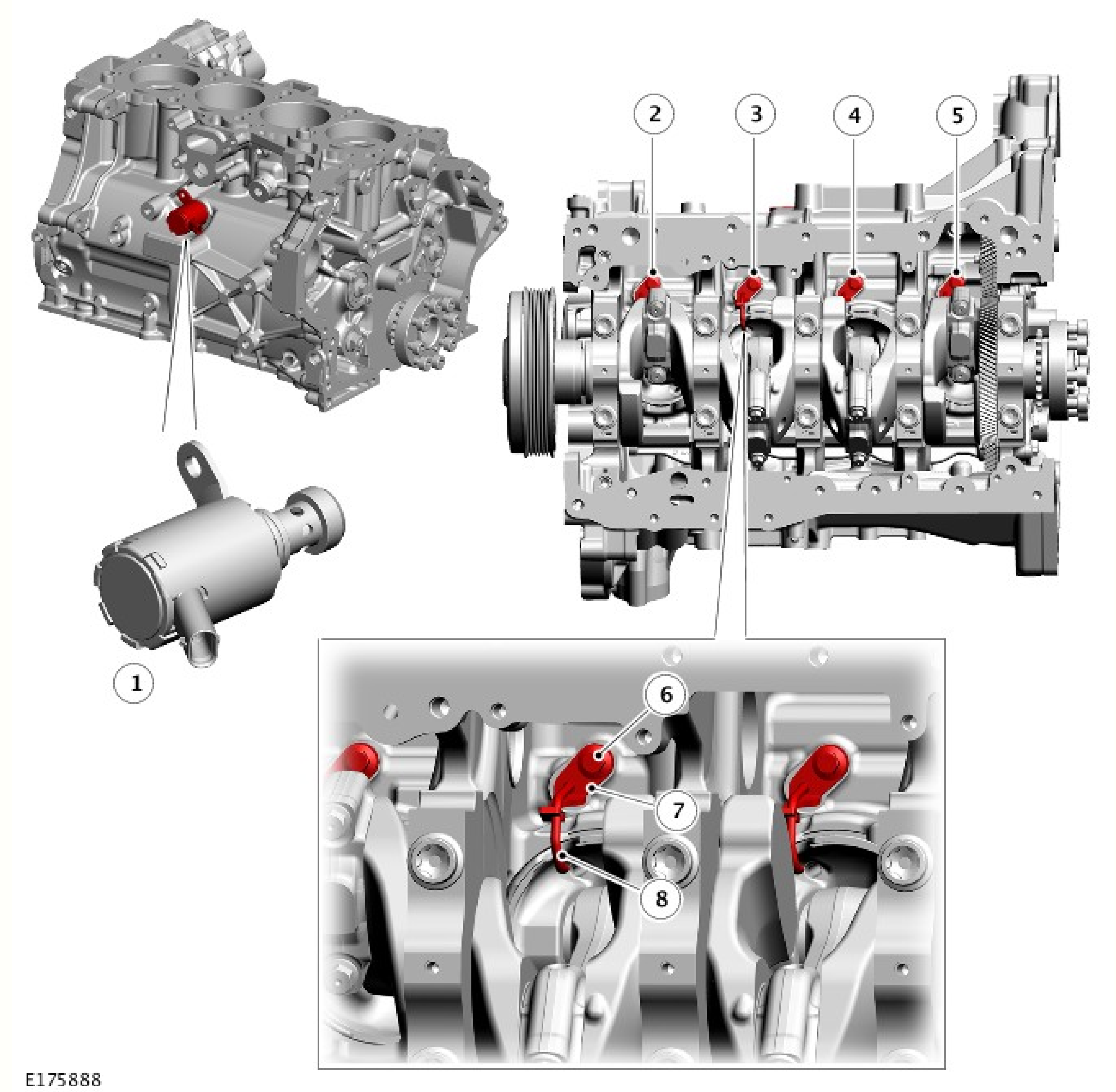
There is only one grade of piston diameter. The pistons are marked to ensure correct assembly, with the marks facing the front of the engine. The top face of piston has an arrow which must also point towards the front of the engine. The piston crown has a recess for optimisation of the fuel / air mixture and combustion.

A three-ring piston-sealing system is used. An oil control ring is located in the lower groove. Two compression piston rings are located above the oil control ring. The piston ring gaps must be positioned at 120 degrees to each other.

The pistons are cooled with engine oil from four piston cooling oil jets installed in the cylinder block.

The pistons are attached to the connecting rods with a gudgeon pin, which is secured with 2 circlips. The gudgeon pin is located through the small end bearing in the connecting rod which allows the piston to articulate with the linear movement of the connecting rod. The circlips locate in grooves in the piston.

Piston Cooling Oil Jets



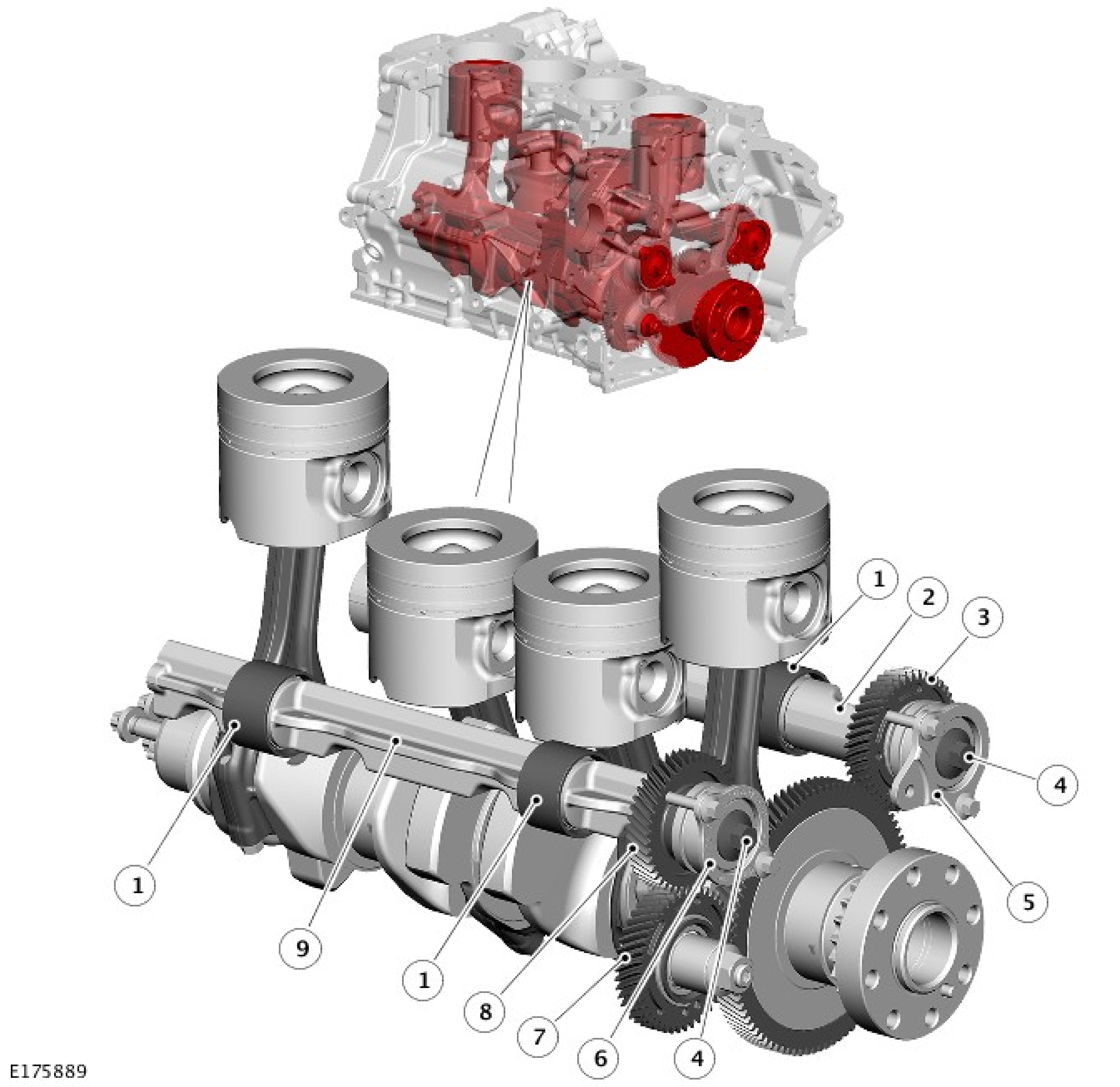
Item	Description
1	Piston cooling oil jets solenoid
2	Piston cooling oil jet - cylinder 1
3	Piston cooling oil jet - cylinder 2
4	Piston cooling oil jet - cylinder 3
5	Piston cooling oil jet - cylinder 4
6	Bolt
7	Support bracket
8	Oil jet outlet nozzle

Four piston cooling oil jets are located in the cylinder block. Each jet is located adjacent to a cylinder and secured in the cylinder block with a bolt. The oil jet outlet nozzle and the support bracket are an assembly.

The piston cooling oil jets provide piston and gudgeon pin cooling and lubrication. Each piston cooling jet has a single outlet nozzle which sprays oil into the cooling chamber in the piston. The jets are supplied pressurized engine oil from the variable flow oil pump with integral vacuum pump via a drilling in the cylinder block. The oil supply to the drilling is controlled by a piston cooling oil jets solenoid which is controlled by the Engine Control Module (ECM). The solenoid can open and close the oil supply depending on engine speed and load.

In addition to supplying oil to the piston cooling gallery the oil lubricates the small end bearing and gudgeon pin.

Dynamic Balance Shafts



Item	Description
1	Needle roller bearing outer race (4 off)
2	Dynamic balancer
3	Dynamic balancer gear
4	Flange bolt (2 off0
5	Bearing housing
6	Bearing housing
7	Idler gear
8	Dynamic balancer gear
9	Dynamic balancer

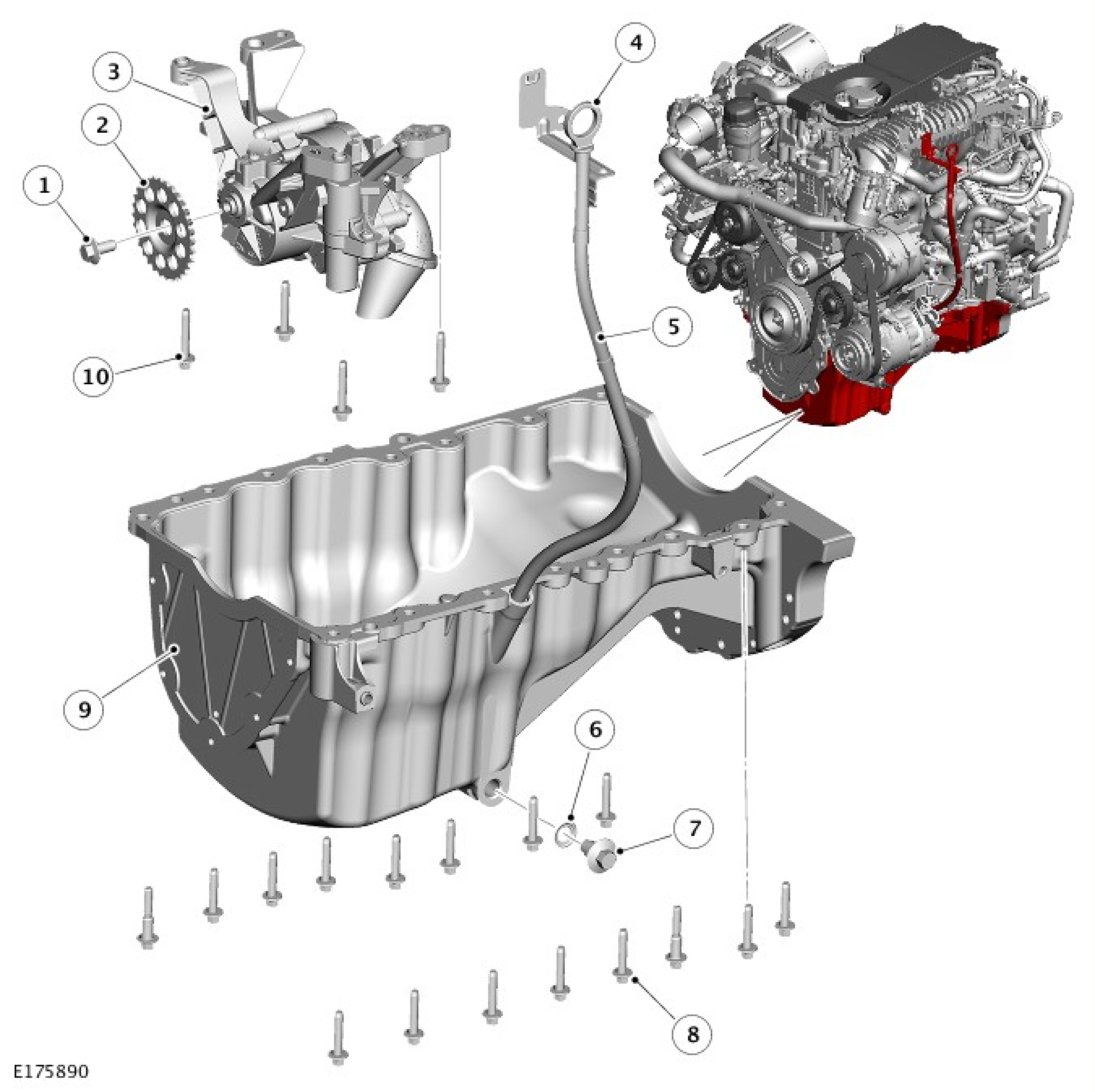
The engine balance system consists of two eccentric weighted dynamic balancer shafts which oppose vibrations created by the engine's reciprocating components. The dynamic balancers are mounted into machined bores inside the cylinder block. The two dynamic balancers rotate in opposite directions, driven at twice the speed of the crankshaft by a dynamic balancer gear pressed onto the crankshaft. The equally sized eccentric weights are phased so that the inertia reaction to their counter-rotation cancels out vibration caused by the engine.

One of the dynamic balancers is driven off an 86-teeth dynamic balancer ring gear located on the crankshaft which rotates a 43-teeth driven gear on the driven dynamic balancer. The second dynamic balancer is driven off the same ring gear through a 45-teeth idler gear which rotates the 43-teeth driven gear on the driven dynamic balancer.

The idler gear is mounted on to the cylinder block using a steel idler bush which is pressed into the cylinder block. Driven gears on one of the dynamic balancers and the idler gear are anti-backlash “scissor” gears in order to minimize noise. All the gears are helical to ensure smooth operation. The dynamic balancers are located on needle roller bearings which run on outer races installed in the cylinder block machined bores. The bearings are lubricated by oil mist during engine operation.

It is important to make sure that each dynamic balancer is timed correctly in respect to the crankshaft using specialised alignment tool(s).

Oil Pan

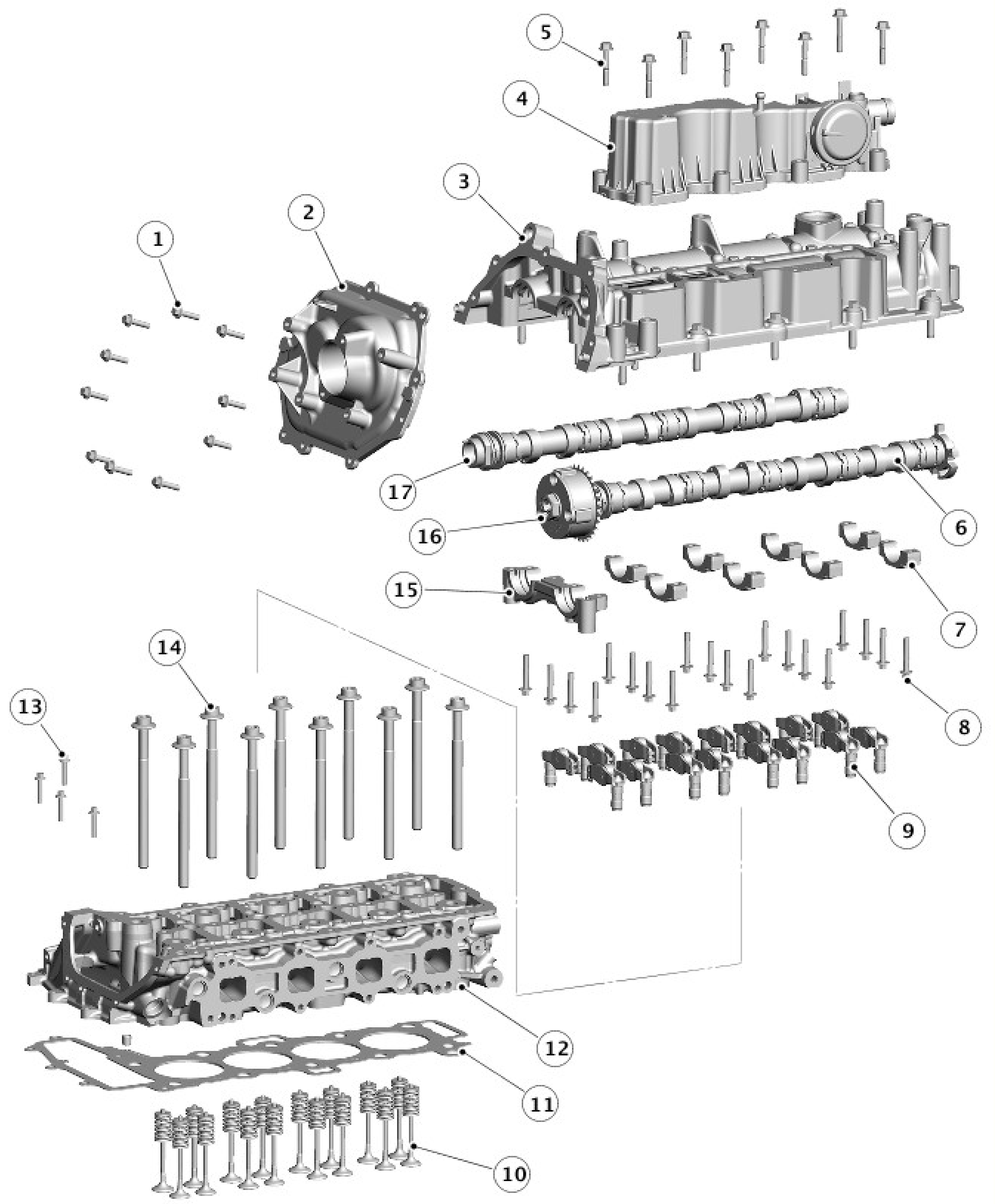


Item	Description
1	Flange bolt
2	Sprocket
3	Variable flow oil pump with integral vacuum pump
4	Oil level gauge
5	Oil level gauge tube
6	Sealing washer
7	Drain plug
8	Bolt (16 off)
9	Oil pan

10	Bolt (4 off)

The oil pan is cast from aluminium alloy using a high pressure die cast process and is located on the underside of the cylinder block. It is sealed to the cylinder block with a 3 mm bead of RTV sealant and secured with fourteen bolts and two shoulder bolts that help locate the oil pan to the block. The oil pan contains the variable flow oil pump with integral vacuum pump, pick up pipe, windage tray and dipstick. The oil is drained via removal of a drain plug and washer located on the side of the oil pan.

Cylinder Head



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Item	Description
1	Screw (10 off)

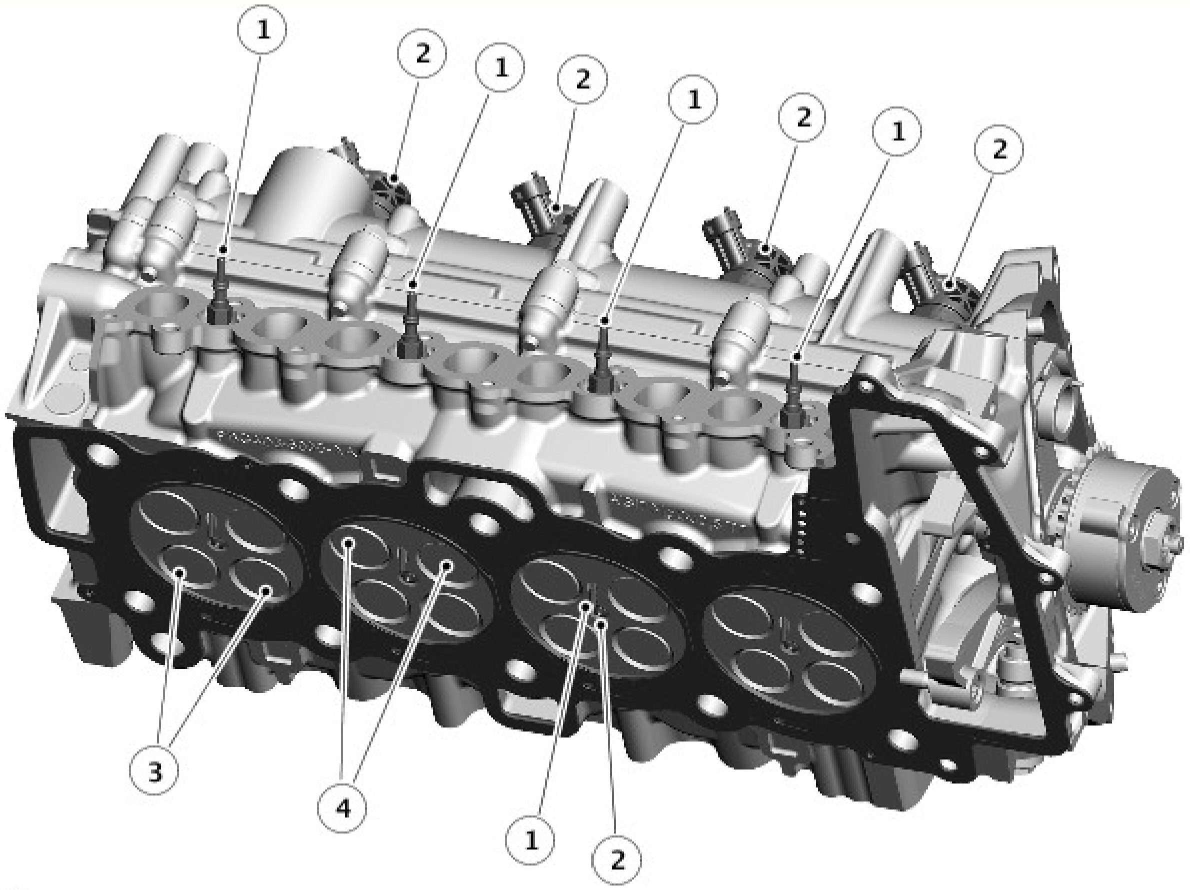
2	Chain cover and gasket
3	Camshaft carrier
4	Engine vent module
5	Screw (8 off)
6	Exhaust camshaft
7	Camshaft caps (8 off)
8	Screw (20 off)
9	Roller finger cam follower (16 off)
10	Inlet and exhaust valve assemblies (16 off)
11	Cylinder head gasket
12	Cylinder head
13	Screw (4 off)
14	Cylinder head bolt (10 off)
15	Camshaft cap
16	Variable Camshaft Timing (VCT) actuator
17	Inlet camshaft

The cylinder head is cast from aluminium alloy and heat treated. The cylinder head provides location for sixteen valves, four injectors, four glow plugs and one cylinder head temperature sensor. The cylinder head is cooled by a double layer water jacket. Each cylinder has four valves.

Each cylinder is served by four valves. To help achieve the required gas-flow characteristics, the cylinder head has two inlet ports and two exhaust ports arranged asymmetrically around each cylinder bore. The four centrally mounted injectors are located on the upper side of the cylinder head and direct fuel into the combustion chamber. The injectors are retained in the cylinder head by injector clamps and screws located on the camshaft carrier.

To help achieve the required gas-flow characteristics, the fuel injectors are mounted centrally in the combustion chamber.

Four glow plugs are located in the cylinder head. The glow plugs fit into threaded ports between the inlet port for each cylinder, allowing the tip of each glow plug to protrude into the combustion chamber.



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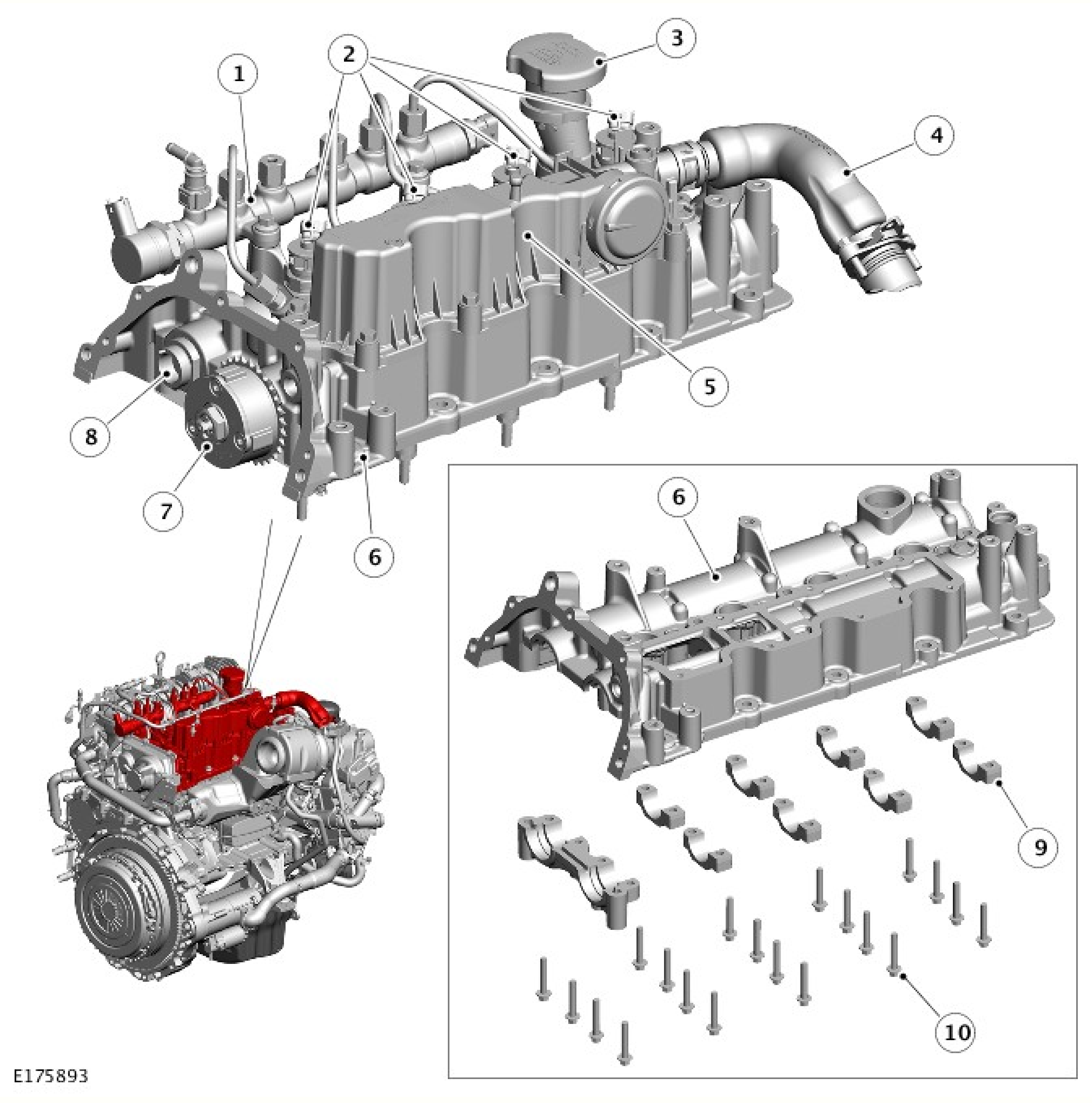
Item	Description
1	Glow plug (4 off)

2	Fuel injector (4 off)
3	Inlet valves (8 off)
4	Exhaust valves (8 off)

The aluminium cylinder head is designed to react to the high diesel combustion cylinder pressures, while also providing a platform onto which the structural camshaft carrier can be mounted.

The cylinder head gasket is of a multi-layer steel construction.

Camshaft Carrier



Item	Description
1	Fuel rail
2	Fuel injector (4 off)
3	Oil filler and cap assembly
4	Engine breather
5	Engine vent module
6	Camshaft carrier
7	Exhaust camshaft and Variable Camshaft Timing (VCT) actuator
8	Inlet camshaft

9	Camshaft cap (9 off)
10	Bolts (20 off)

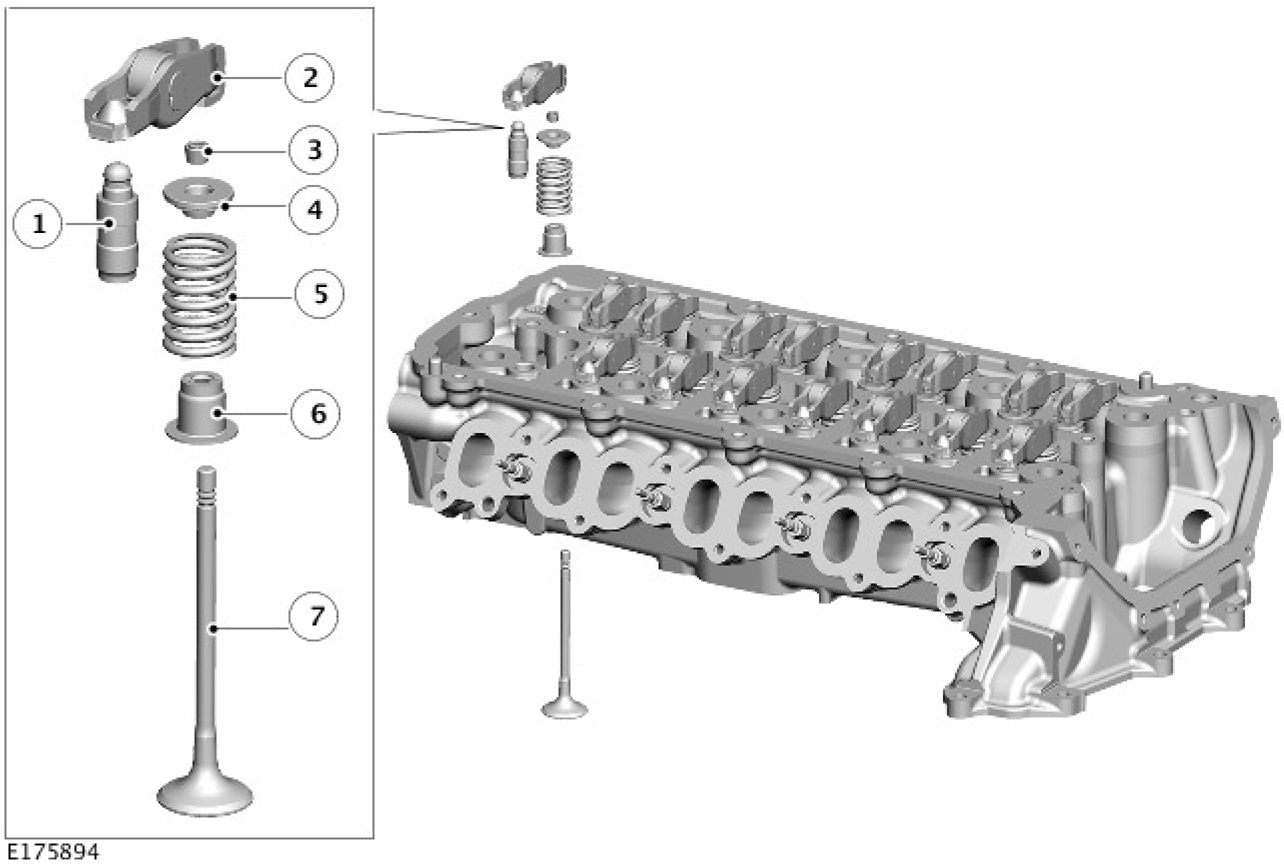
The structural camshaft carrier is cast from aluminium alloy using a high pressure die cast process. The camshaft carrier is located on two dowels in the cylinder head and secured with bolts. A gasket seals the camshaft carrier to the cylinder head.

The primary function of the camshaft carrier is to house and secure the inlet and exhaust camshafts. The camshaft bore geometry is bored in a single machining operation to ensure optimum friction reduction and each camshaft cap is uniquely identified and must be matched to its related bore.

The camshaft carrier also provides locations for the Camshaft Position (CMP) sensor, the oil filler pipe and the engine vent module. The camshaft carrier has high pressure oil galleries feeding the Variable Camshaft Timing (VCT) actuator and provides thrust face lubrication. A low pressure oil gallery returns oil from the engine vent module back to the cylinder block and oil pan.

The camshaft carrier also provides the locations for the fuel rail, engine breather and the oil filler cap.

Valves and Roller Finger Cam Followers



Item	Description
1	Hydraulic lash adjuster (16 off)
2	Roller finger cam follower (16 off)
3	Valve spring collets (32 off)
4	Valve spring retainer (16 off)
5	Valve spring (16 off)
6	Valve spring seat (16 off)
7	Valves (8 off inlet, 8 off exhaust)

The engine uses sixteen chrome plated steel valves; eight intake and eight exhaust. The intake valves are 27.3mm diameter and the exhaust valves are 25.7mm diameter. The larger the intake valve size, the more the engine can breathe. This will enhance more engine power output at higher Revolutions Per Minute (RPM). The intake valve stems are 5.47 mm diameter and exhaust valve stems are 5.463mm diameter. These allow reduced flow interruption through the intake and exhaust ports, improving performance and emissions.

The valves are located in conventional, non-serviceable valve guides in the cylinder head. A valve stem seal with integral spring seat is located in the cylinder head. The valve spring is retained in a compressed state on the valve stem by a valve spring retainer and a pair of valve spring collets. The valves are opened mechanically by a roller finger cam follower design which is operated directly with roller to camshaft lobe rolling contact. The clearance between the roller and camshaft lobe is compensated with the use of a hydraulic lash adjuster. This ensures that all roller finger cam followers are in contact with the camshaft lobes throughout engine operation.

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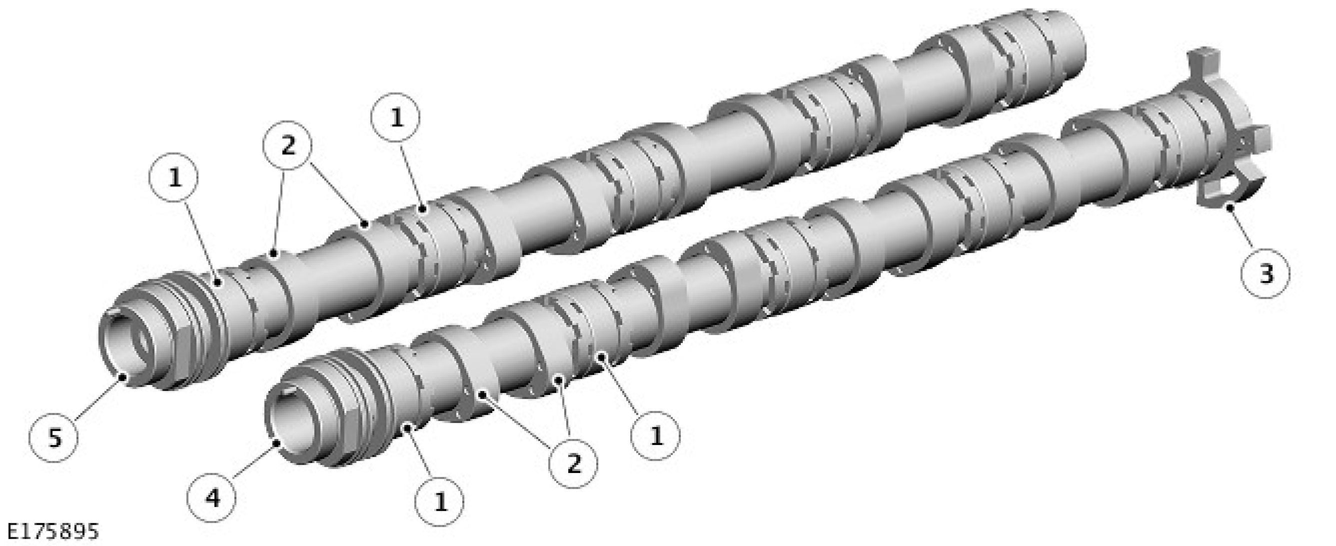
Camshafts



Item	Description
1	Needle roller bearings
2	Camshaft lobes
3	Reluctor ring - CMP sensor
4	Exhaust camshaft
5	Inlet camshaft

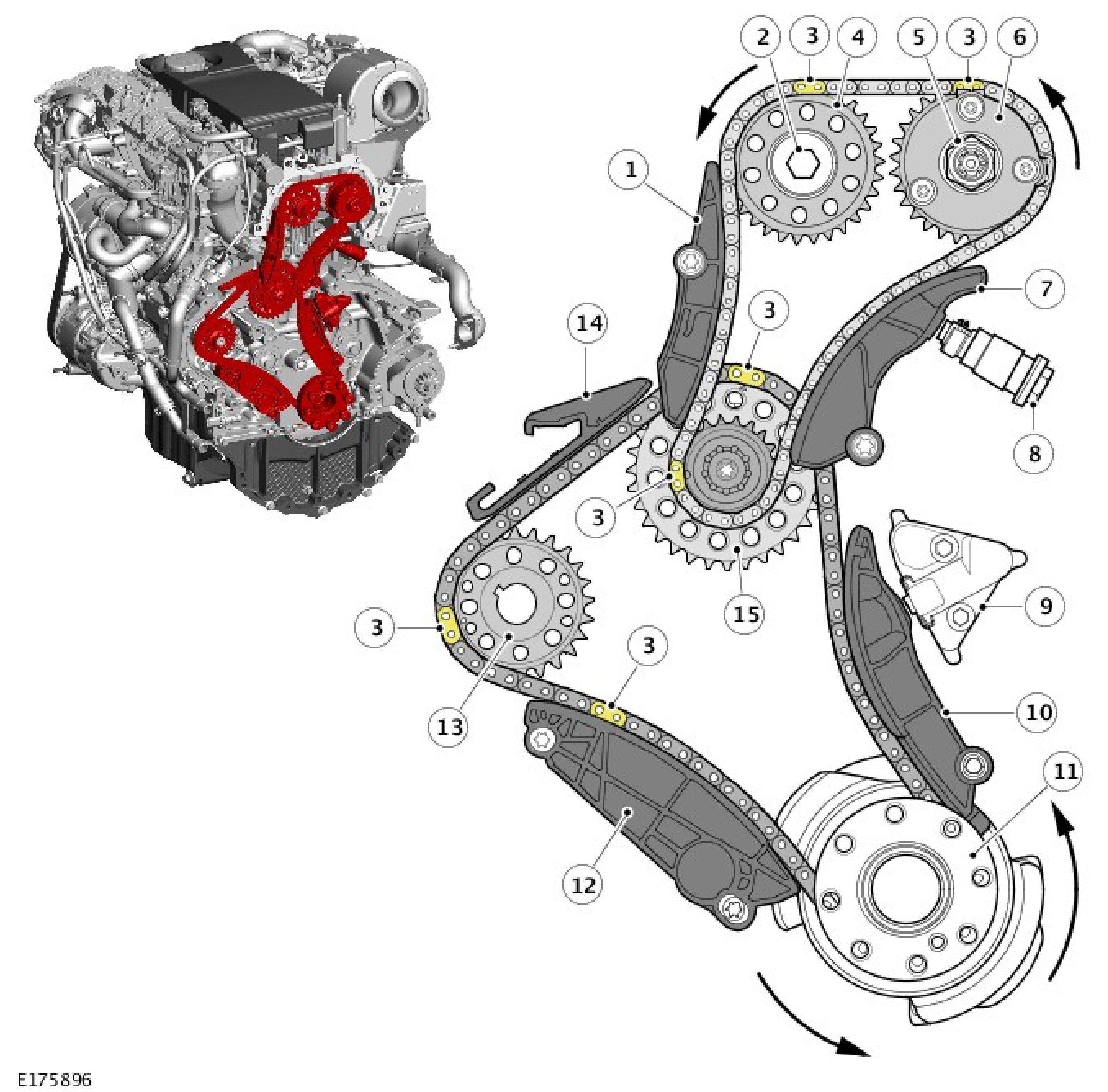
The engine is fitted with a Double OverHead Camshaft (DOHC) configuration which uses two camshafts; one inlet and one exhaust. The lobes on the camshafts control the opening and closing of the valves via a roller finger cam follower valve train system.

The camshafts run on needle roller bearings to reduce friction and minimise the breakaway torque on engine start-up. The needle roller bearings are housed in the camshaft carrier and the camshaft caps are marked with ‘I’ and E’ to denote inlet and exhaust. The camshaft caps are also numbered to ensure assembly in the correct position in the camshaft carrier; for example ‘I4’ or ‘E1’.

The camshafts are of a hollow steel tube construction, with pressed on sintered lobes and needle roller bearings. The hollow tube design provides reduced weight for increased engine performance. Each camshaft has a pressed on drive adapter which locates a drive sprocket on the inlet camshaft and the Variable Camshaft Timing (VCT) actuator on the exhaust camshaft. The drive adapter on each camshaft is fitted with a timing pin to locate the drive sprocket and the VCT actuator on the camshaft relative to the lobe positions. The exhaust camshaft has a pressed on reluctor ring for use with the Camshaft Position (CMP) sensor.

The exhaust camshaft is fitted with a Variable Camshaft Timing (VCT) actuator. The actuator contains a sprocket which drives the camshaft via a timing chain, driven from the crankshaft. The VCT actuator adjusts the timing of the exhaust camshaft, increasing engine efficiency and performance as required. A reluctor wheel is pressed on to the opposite end of the exhaust camshaft which is monitored by the CMP sensor. The CMP sensor signal is used by the ECM and enables the ECM to determine the position of the exhaust camshaft. The exhaust camshaft can then be phased by the VCT actuator to provide increased performance and efficiency.

Camshaft Timing Chain



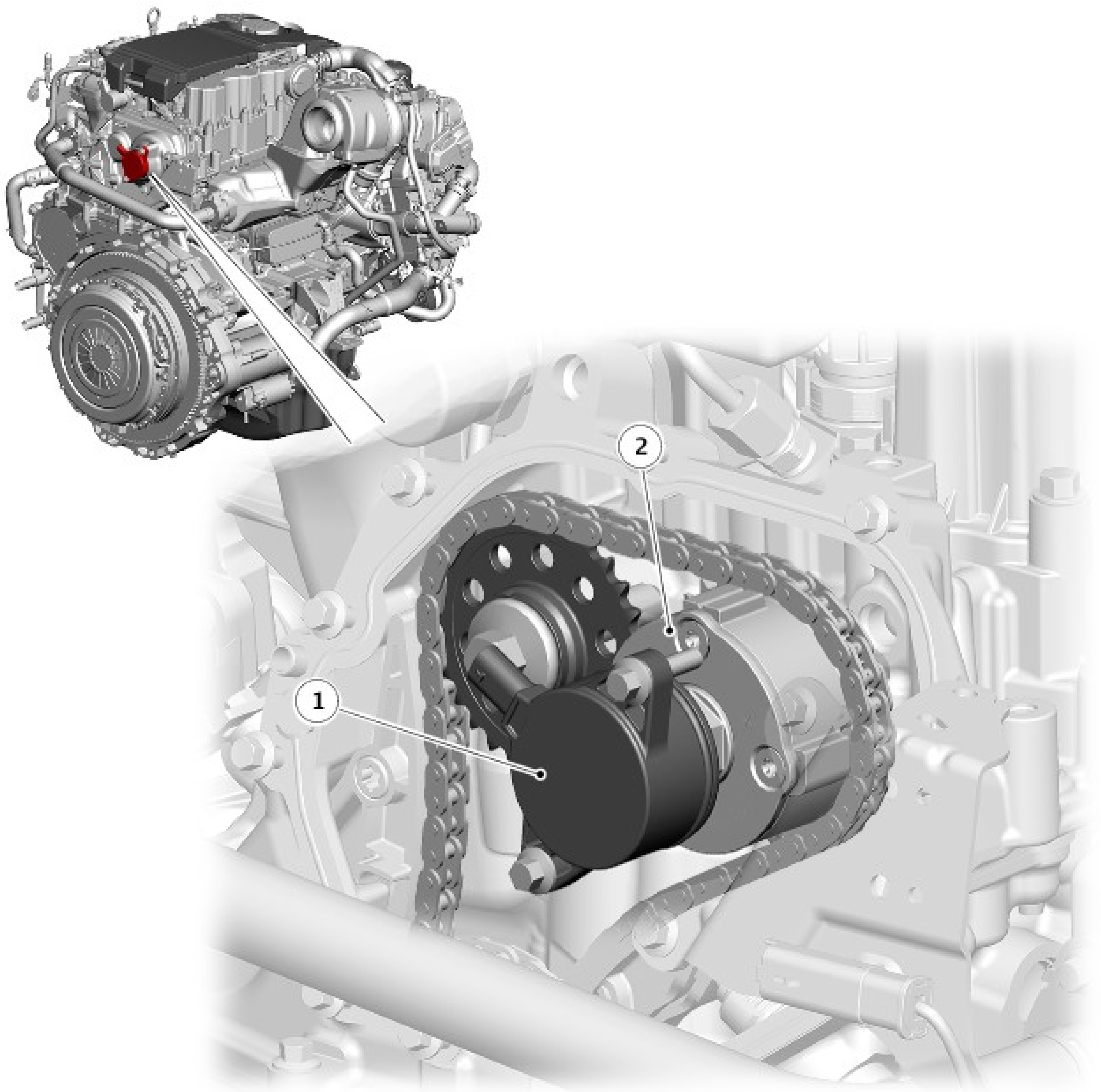
Item	Description
1	Secondary chain guide
2	Inlet camshaft
3	Timing mark link plate
4	Sprocket
5	Exhaust camshaft
6	Variable Camshaft Timing (VCT) actuator
7	Secondary chain tensioner guide
8	Secondary chain tensioner
9	Primary chain tensioner
10	Primary chain tensioner guide
11	Crankshaft
12	Primary chain guide
13	High pressure fuel pump sprocket
14	Primary chain guide
15	Idler sprocket

Two bushed timing chains are used to drive the camshafts via an intermediate idler sprocket. The primary camshaft chain is driven by a sprocket on the crankshaft which in turn drives the fuel pump and the intermediate idler sprocket. The fuel pump sprocket is a non-round sprocket that is timed to the crankshaft to reduce chain loads. The secondary camshaft chain is driven by the intermediate idler sprocket and then passed over the sprockets on the inlet and exhaust camshafts. The camshaft sprocket is integral with the VCT actuator assembly.

Each timing chain has a fixed timing chain guide which is secured to the cylinder block. A chain tensioner is fitted to each timing chain which can rotate around a pivot bolt. The primary timing chain has a mechanical tensioner operated by spring tension to apply a controlled tension to the timing chain. The secondary timing chain has a hydraulic secondary chain tensioner which receives pressurized engine oil from the variable flow oil pump with integral vacuum pump. The tensioners maintain the timing chains at the correct tension and allows for and dampens backlash in the chain tension due to engine deceleration. The timing chains and tensioners are maintenance free components.

A procedure and special tools are required to ensure that the correct crankshaft to camshaft timing is achieved. Both the primary and secondary timing chains have gold coloured links which are aligned with timing marks on the sprockets.

Variable Camshaft Timing (VCT) - Exhaust Camshaft Only



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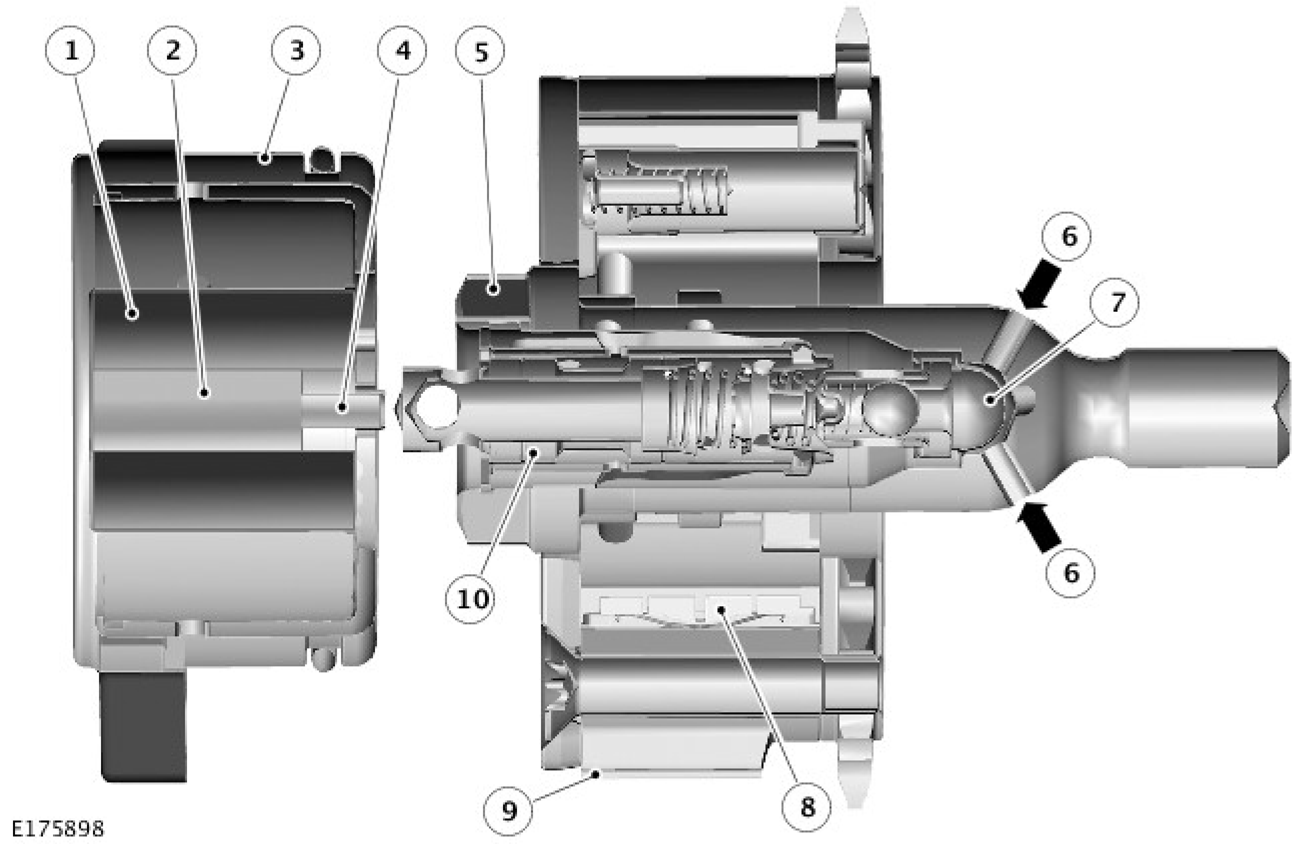
Item	Description
1	Exhaust VCT solenoid
2	Exhaust VCT actuator

The timing of the exhaust camshaft can be adjusted independently by an oil pressure controlled torsional assist VCT system. The VCT solenoid which is controlled electrically determines the position of the VCT actuator which has a direct interface with the exhaust camshaft.

The VCT actuator is located on the exhaust camshaft at the rear of the engine and is secured with a center bolt. The center bolt contains an oil control valve. A slot in the VCT actuator locates over a timing pin on the exhaust camshaft and is used to maintain the timing of the VCT actuator relative to the exhaust camshaft lobe position.



Item	Description
1	Solenoid coil
2	Solenoid core
3	VCT solenoid assembly
4	Solenoid pintle pin
5	Center bolt
6	Pressurized engine oil
7	Filter
8	Rotor
9	VCT actuator assembly
10	Spool valve

The VCT actuator is operated by a VCT solenoid which is controlled by the Engine Control Module (ECM). The ECM can operate the VCT solenoid to move the pintle pin to a pre-determined position to control the flow of pressurized engine oil into the VCT actuator

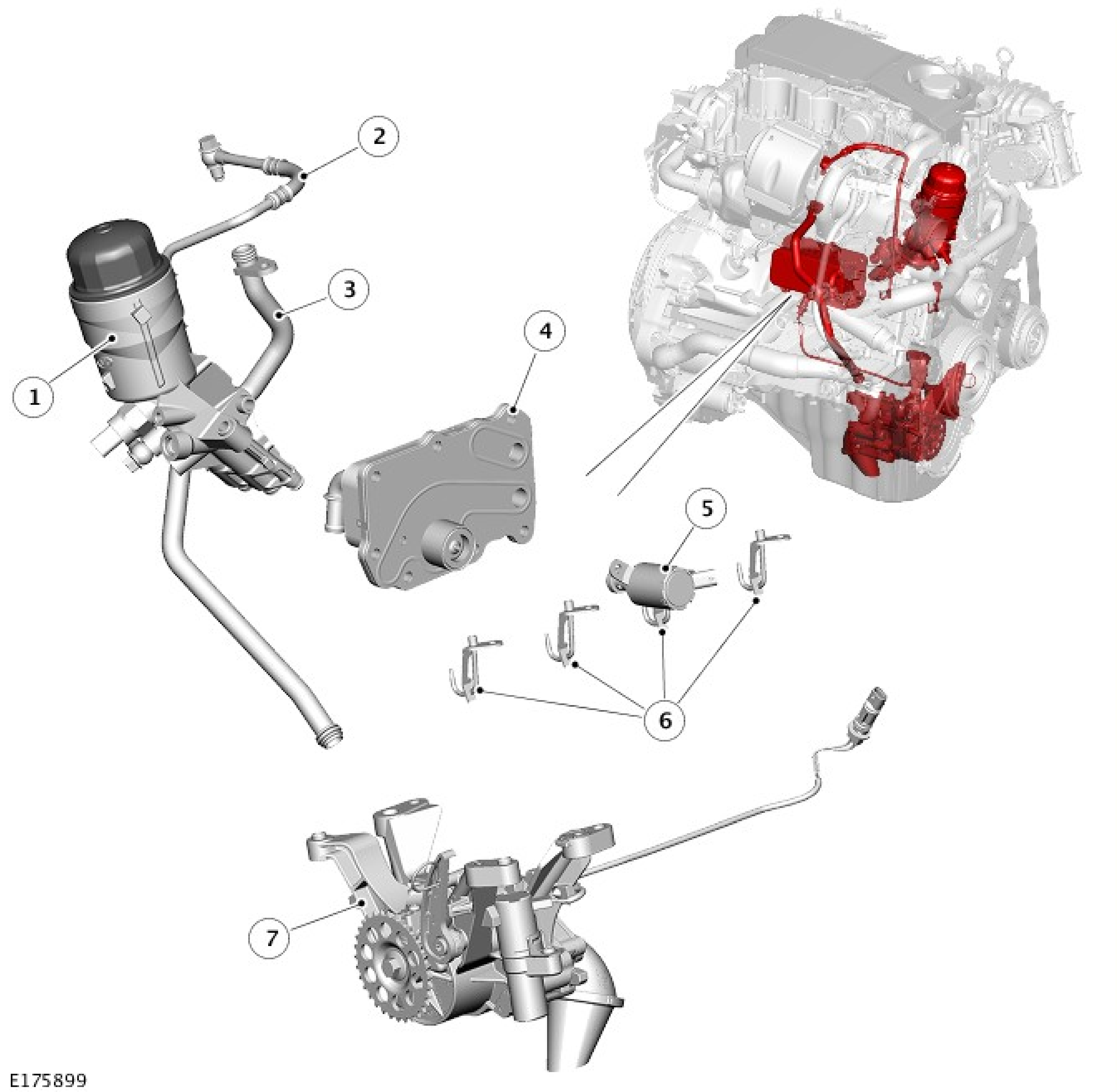
When advance or retard of the exhaust camshaft timing is required, the VCT solenoid operates, extending the pintle pin and moving the spool valve to direct pressurized engine oil into one side or the other of the central rotor chambers in the VCT actuator. The solenoid pintle moves towards the spool valve located in the center bolt and makes contact.

Further movement of the solenoid pintle pin will push the spool valve into a known (controlled) position and oil will pass through channels within the center bolt into the VCT actuator chambers. The pressurized engine oil rotates the internal rotor in the VCT actuator which is secured to the exhaust camshaft. This in turn changes the engine timing. The total available camshaft advance adjustment is 50º Crankshaft Angle towards advance.

The exhaust camshaft VCT actuator has three hydraulic chambers. Residual camshaft torque is used to ensure the VCT actuator is returned to the 'base' position as quickly as possible. The pressurized engine oil is supplied from the engine variable flow oil pump with integral vacuum pump and must be mapped to deliver a controlled oil pressure to the VCT actuator to ensure VCT performance and response times are maintained.

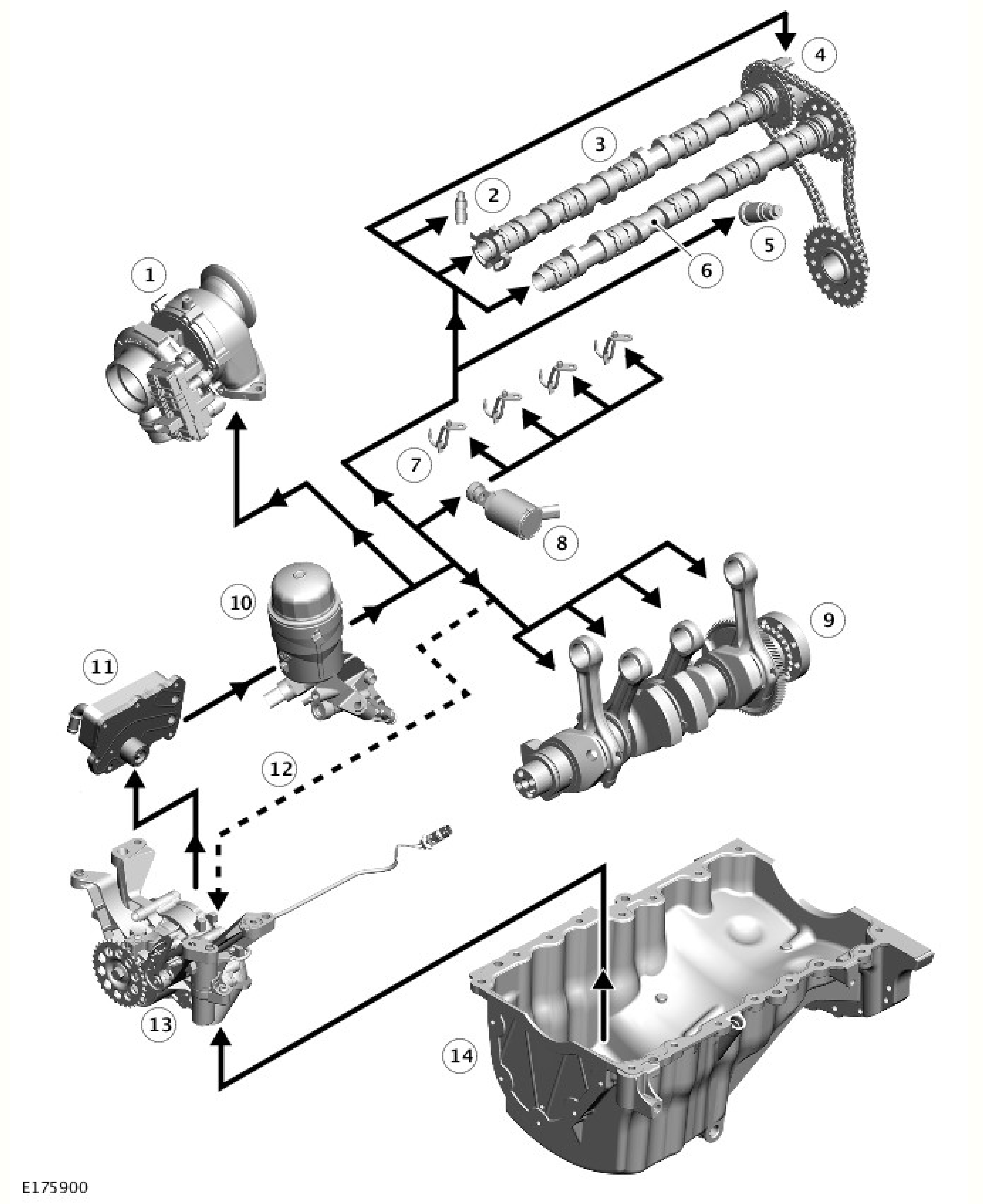
There is no VCT system on the intake camshaft.

Lubrication System



Item	Description
1	Oil filter and housing assembly
2	Turbocharger oil feed pipe
3	Turbocharger oil drain pipe
4	Engine oil cooler
5	Piston cooling oil jets solenoid
6	Piston cooling oil jets
7	Variable flow oil pump with integral vacuum pump

Lubrication System Flow Diagram



Item	Description
1	Turbocharger
2	Hydraulic lash adjusters
3	Exhaust camshaft
4	Variable camshaft timing (VCT) actuator
5	Secondary chain tensioner
6	Inlet camshaft
7	Piston cooling oil jets

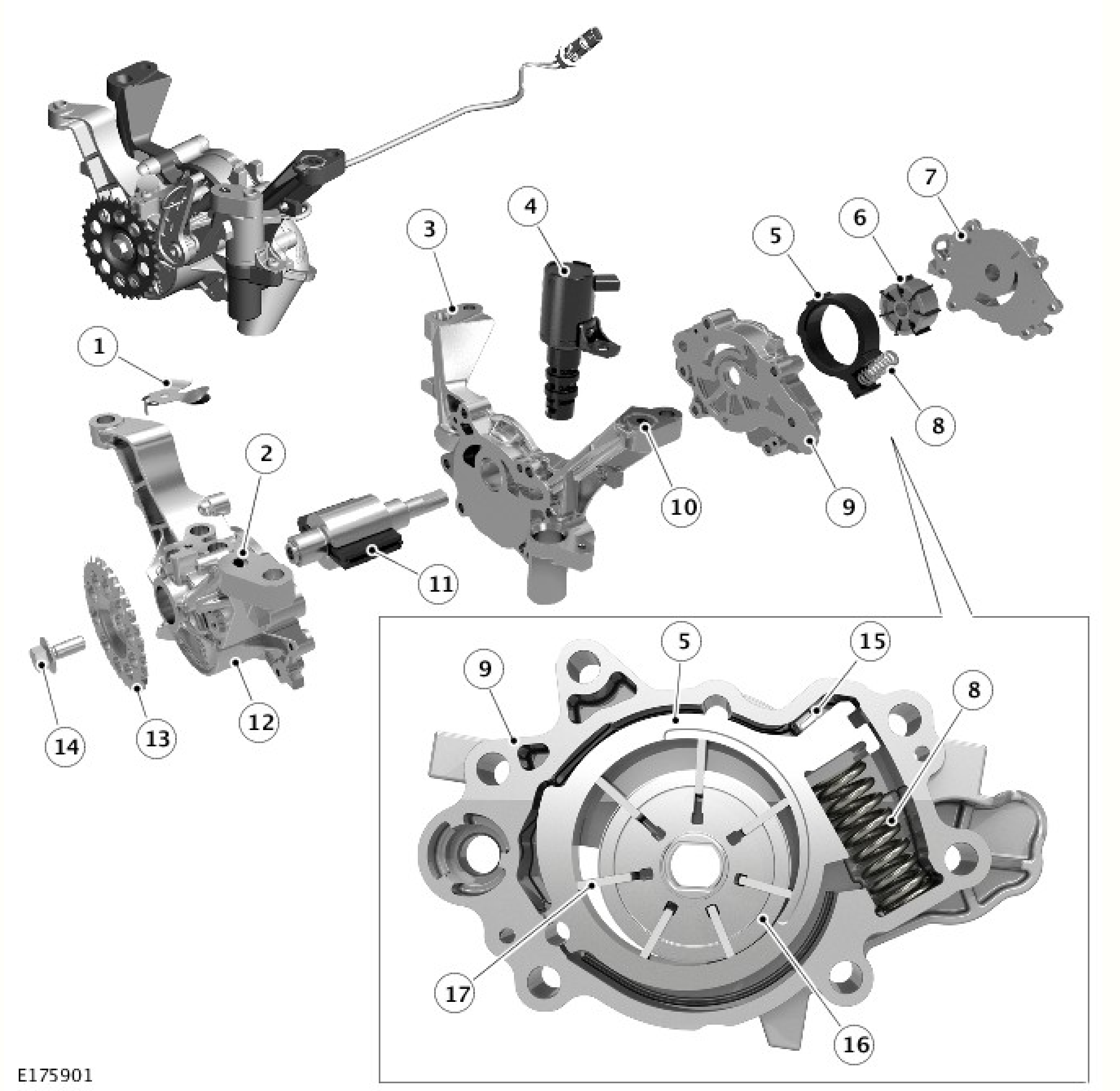
8	Piston cooling oil jets solenoid
9	Crankshaft
10	Oil filter and housing assembly
11	Engine oil cooler
12	Oil gallery pressure feedback to variable flow oil pump with integral vacuum pump
13	Variable flow oil pump with integral vacuum pump
14	Oil pan

Oil is drawn from the oil pan and pressurized by the variable flow oil pump with integral vacuum pump. The output from the variable flow oil pump with integral vacuum pump is then filtered through the oil filter and housing assembly and distributed through internal oil passageways in the cylinder block and cylinder head.

The output from the oil filter is distributed through oil galleries in the cylinder heads and the cylinder block. All moving parts are lubricated by pressure or splash oil. Pressurized oil is also provided for the VCT system, the piston cooling jets, turbocharger, hydraulic lash adjusters and chain tensioner. The gallery pressure is fed back to the variable flow oil pump via a drilling in the cylinder block and the variable flow oil pump uses this pressure signal to regulate the oil flow and pressure. The Engine Control module (ECM) can control the variable flow oil pump electrically, requesting a pressure held in engine oil pressure map which is dependent on engine speed and load.

The oil returns to the oil pan under gravity. Large drain holes through the cylinder head and the cylinder block ensure the rapid return of the oil to the oil pan. System replenishment is through the oil filler cap on the camshaft cover. An oil drain plug is installed in the side of the oil pan.

Variable Flow Oil Pump with Integral Vacuum Pump



Item	Description
1	Vacuum exhaust valve
2	Pressurized oil outlet to cylinder block
3	Center plate
4	Oil pressure control solenoid
5	Control ring
6	Vanes and rotor assembly
7	Oil pump cover
8	Control spring
9	Oil pump housing
10	Vacuum port connection to cylinder block
11	Vacuum pump vanes
12	Vacuum pump housing
13	Pump drive sprocket
14	Bolt
15	Control ring oil pressure surface
16	Rotor

17	Vanes

The variable flow oil pump with integral vacuum pump is attached to the cylinder block with four bolts. The input shaft of the variable flow oil pump with integral vacuum pump is fitted with a sprocket and is driven from the front of the crankshaft, by an auxiliary chain, at 0.84 times engine speed.

Variable Flow Oil Pump

The variable flow oil pump draws oil from the oil pan through a centrally mounted pick-up pipe. The oil is pressurized and pumped through a bore in the cylinder block. After passing through an anti-drain valve and a plate type oil cooler, the oil is filtered by a replaceable oil filter element installed in an oil filter housing.

The variable flow oil pump is a vane cell pump with an eccentrically mounted control ring. The variable flow oil pump has a volumetric flow control mechanism to reduce the required drive output. The flow delivery can be adjusted using the control ring. Applying oil pressure to the control ring allows it to be adjusted against the force of an opposing control spring.

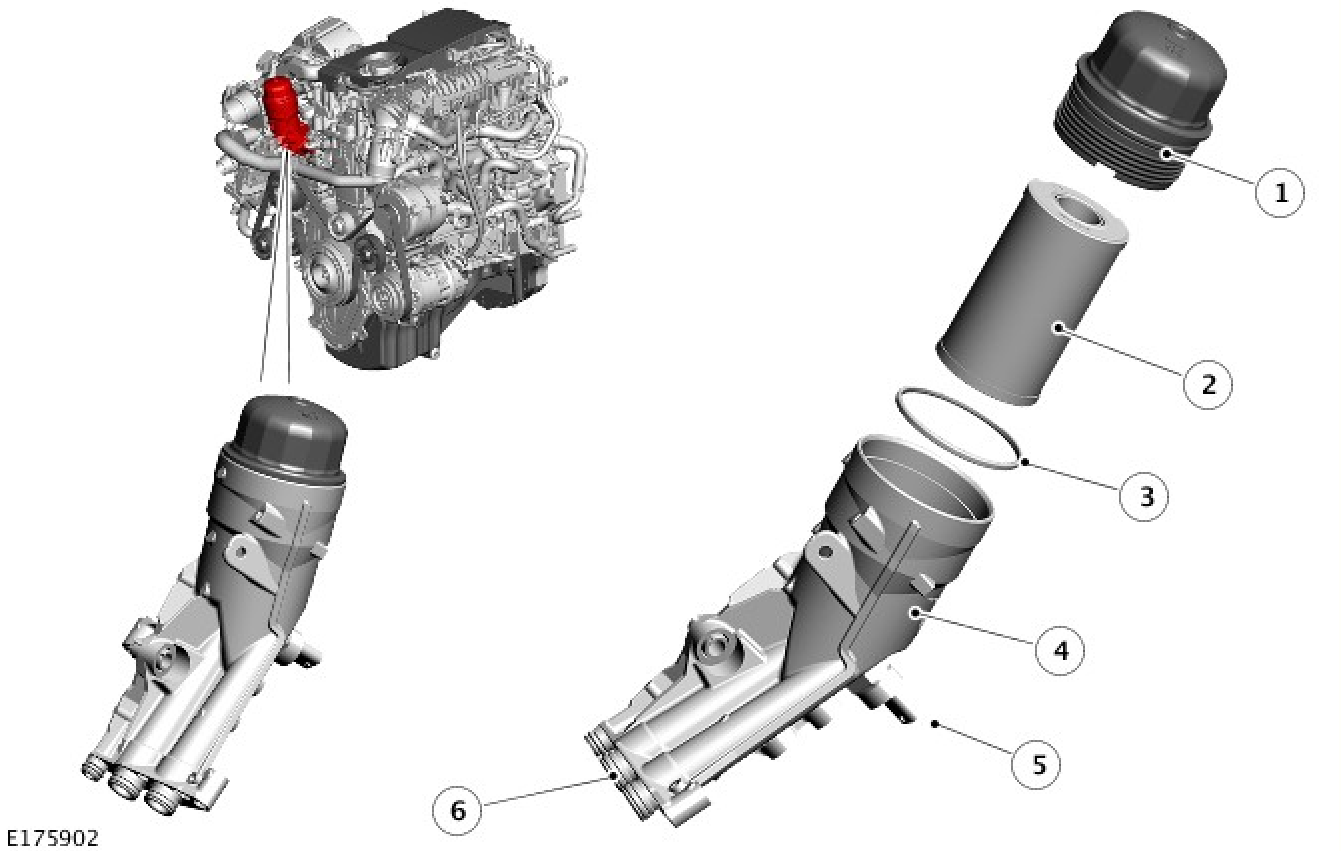
The eccentricity of the control ring can be decreased or increased, with increasing eccentricity increasing the output flow. The output of the variable flow oil pump is adjusted appropriate to engine load and speed to reduce load on the engine. An oil pressure control solenoid, operated by a Pulse Width Modulation (PWM) signal from the ECM, adjusts the oil pressure to the control ring to adjust the output flow.

Vacuum Pump

The vane type vacuum pump is tandem to the oil pump, connected to the vacuum harness via a drilling in the engine block and a vacuum connector. The vacuum produced by the vacuum pump is used to provide a vacuum for the brake booster on the braking system, the active engine mounts and the EGR cooler by-pass valve (EU4 and NAS only).

The vacuum pump extracts air from the brake servo through a vacuum pipe from the servo and a port in the cylinder block. The air extracted from the brake servo flows through the vacuum pipe connector which is equipped with a one way valve to prevent oil ingress into the brake system. The air is vented into the cylinder block via a vacuum exhaust valve.

Oil filter and Housing Assembly



Item	Description
1	Cap
2	Oil filter element
3	Seal
4	Oil filter housing
5	Oil pressure and temperature sensor
6	Cylinder block connections

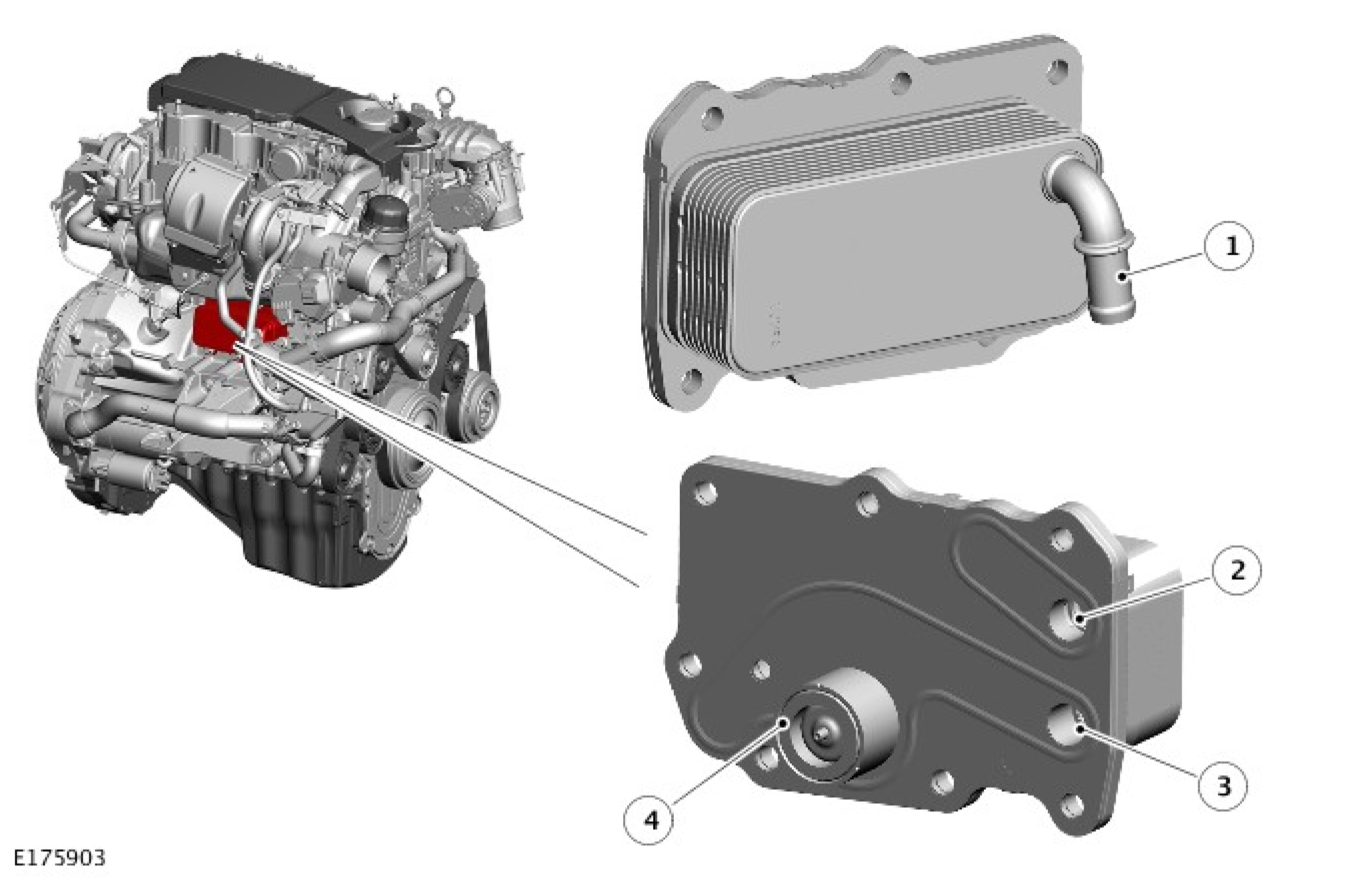
The oil filter and housing assembly is a casting which is mounted on the front of the cylinder block. The housing is secured to the cylinder head and cylinder block with three bolts.

The oil filter housing has three ports which connect with corresponding ports on the cylinder block. Two ports provide the oil pressure inlet and outlet connections and are sealed with floating tube seals. The third port is for service oil drain when the oil filter element is replaced.

A replaceable cartridge oil filter element is located in the oil filter housing. A plastic cap seals the oil filter element to the oil filter housing. The oil filter element is fitted with an integral by-pass valve. If the oil filter element becomes contaminated, to the point that oil flow is restricted, the by-pass valve opens to allow oil to flow through the oil filter housing to avoid starving the engine of engine oil.

The oil filter housing has a service drain facility. When the cap is unscrewed 3-4 turns, a drain hole is opened allowing oil to drain into the crankcase. This allows the oil filter element to be removed with no oil contamination of the engine or surroundings.

Oil Cooler



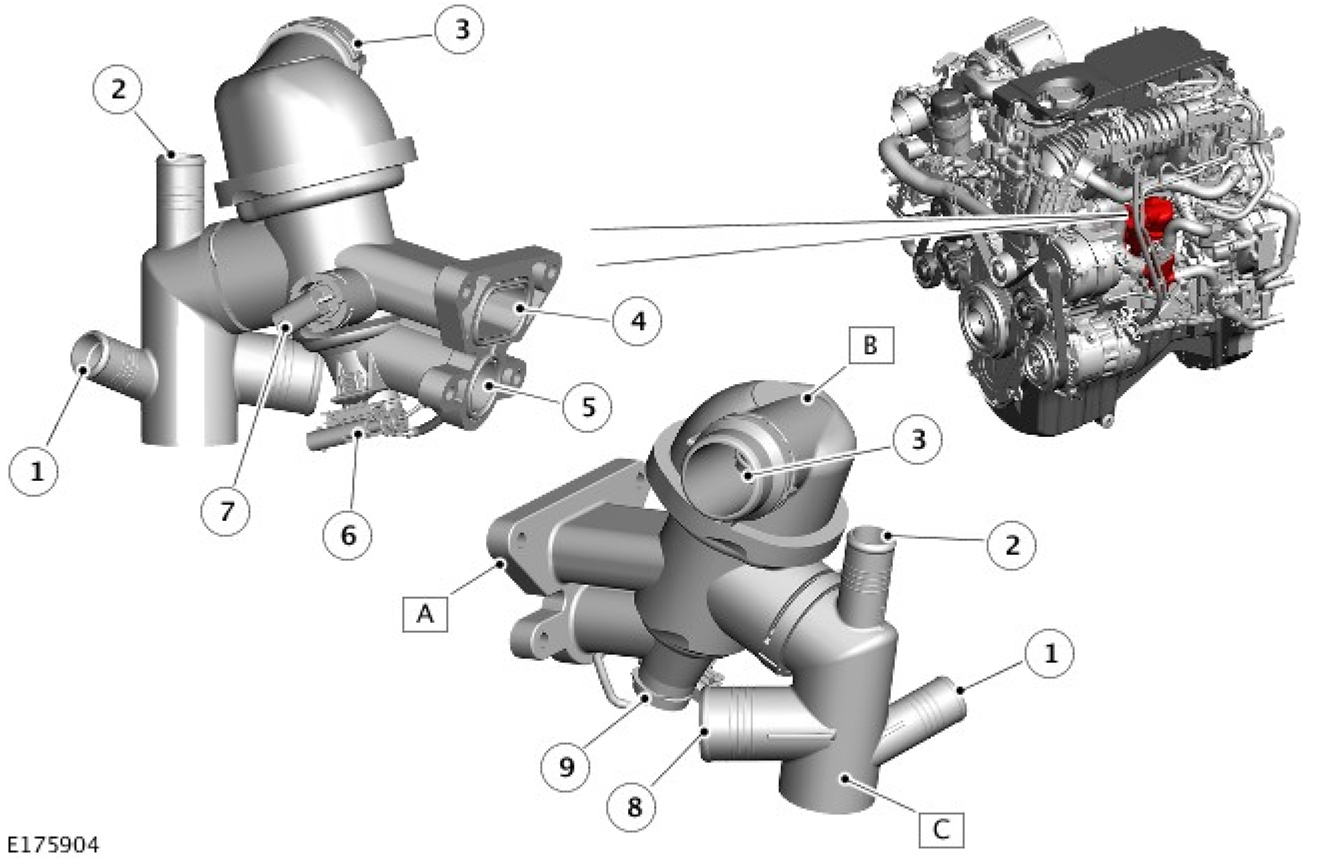
Item	Description
1	Engine coolant outlet
2	Engine coolant inlet from cylinder block
3	Oil pressure outlet to cylinder block
4	Oil pressure inlet / Anti-drain valve

The engine oil cooler is located on the side of the cylinder block, below the turbocharger and exhaust manifold. The oil cooler is sealed to the cylinder block with a metal gasket and secured with seven bolts.

There are four ports on the underside of the cooler; an engine oil inlet and outlet and an engine coolant inlet and outlet. The engine oil cooler is an aluminium housing comprising louvered fins and plates. The plates allow a cross-flow of engine oil and engine coolant through the cooler but keep the two fluids separate. The plates are immersed in engine coolant from the engine variable coolant pump which provides cooling of the engine oil by the temperature differential between the engine oil and the engine coolant.

An anti-drain valve is located in the cylinder block and prevents the oil draining from the engine oil cooler when the engine is not running.

Thermostat Housing



Item	Description
A	Main housing
B	Top cover
C	By-pass housing
1	Heater core return inlet
2	EGR cooler supply outlet
3	Radiator upper hose outlet
4	Cylinder head outlet
5	Cylinder block outlet
6	Electric thermostat electrical connector
7	Engine Coolant Temperature (ECT) sensor
8	Thermal by-pass outlet to water inlet
9	Electric thermostat

The plastic thermostat housing is located on the side of the cylinder block below the intake manifold. The thermostat housing is secured to the cylinder block with four bolts and sealed with a rubber gasket. The thermostat is contained within the housing.

The plastic thermostat housing comprises a main housing, a welded top cover with the connection for the upper hose to the radiator and by-pass housing.

A by-pass valve is located in the by-pass housing attached to the main body of the thermostat. The by-pass valve has the function of limiting the by-pass flow when engine is cold and at low speed, below 1500rpm. The by-pass valve ensures that coolant flow is circulated through the heater core providing heated coolant to warm the vehicle interior.

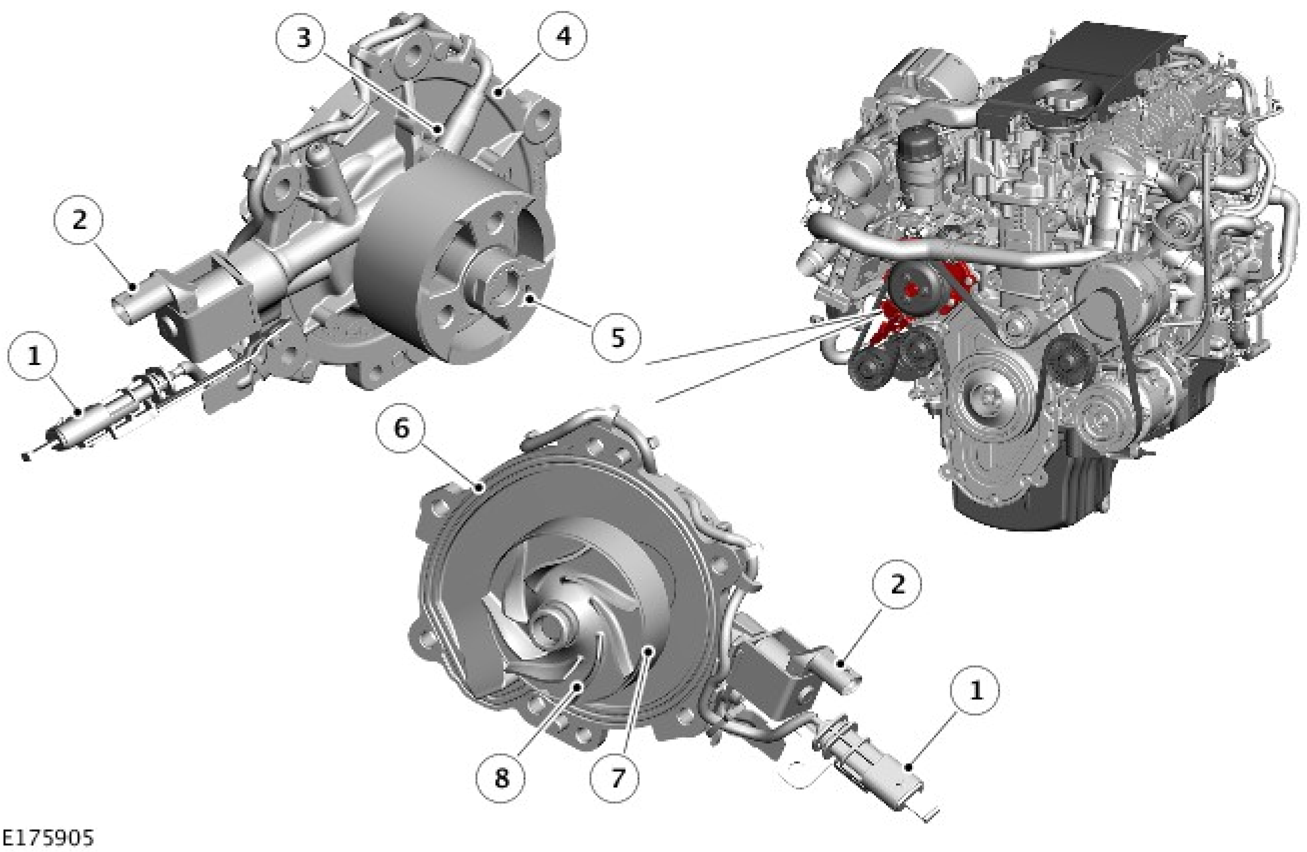
The thermostat housing provides locations for the Engine Coolant Temperature (ECT) sensor and also has a connection for the electric thermostat which is located in the thermostat housing. The ECT sensor is used by the Engine Control Module (ECM) to determine the engine coolant temperature.

The function of the electric thermostat is to control the operating temperature of the engine. In economy (low load) conditions, the engine will operate at 98ºC (208.4ºF). At high load, the engine temperature is reduced for engine protection.

The electrical control is also used to control the thermostat opening to protect the cylinder block from over-temperature events.

The electric thermostat is not a serviceable component. Failure of the electric thermostat requires replacement of the thermostat housing.

Variable Coolant Pump



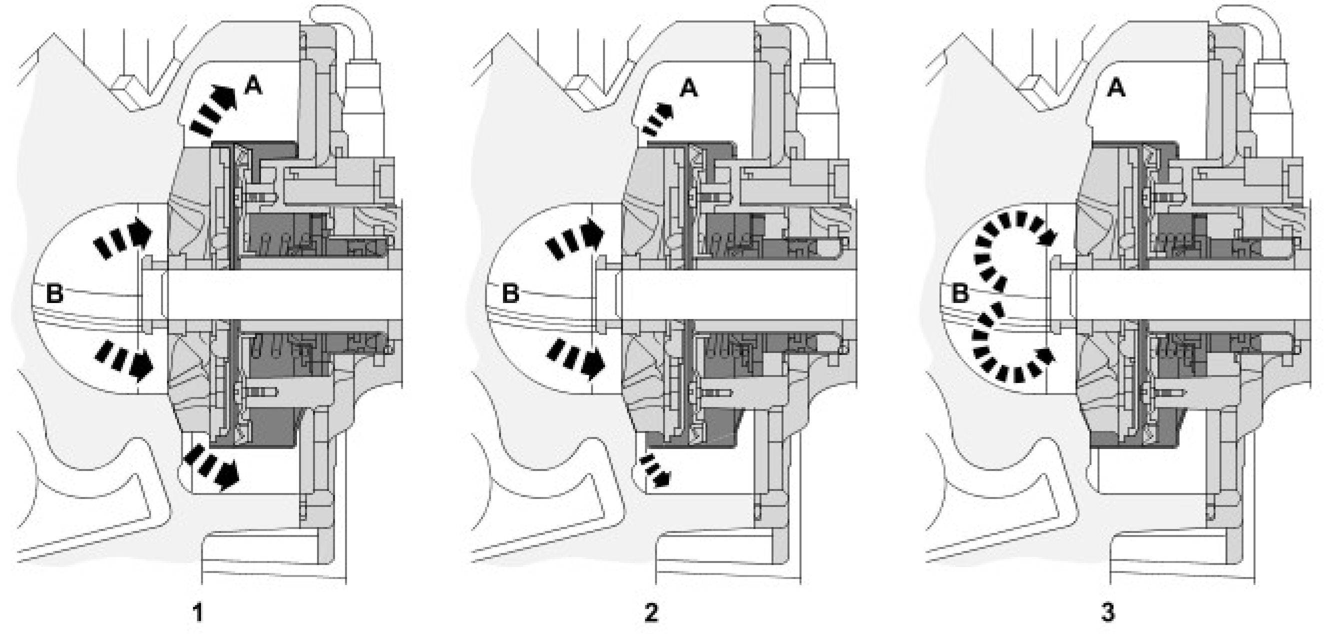
Item	Description
1	Electrical connector - ECM position sensor 5V supply
2	Electrical connector - shroud control solenoid 12V supply
3	Position sensor
4	Variable coolant pump body
5	Drive pulley hub
6	Seal
7	Shroud
8	Pump impeller

The variable coolant pump is located on the upper left side of the engine within a cavity in the cylinder block. The pump is attached to the cylinder block with six bolts and uses a silicon bead seal. The pulley connects to the variable coolant pump hub using three bolts and is driven by the primary drive belt. The variable coolant pump has two electrical connectors for operation of the solenoid and shroud position feedback to the Engine Control Module (ECM).

Coolant flow control enables the use of fast engine warm up strategies and optimum temperature control of critical engine components utilising a patented internal control mechanism to modulate the flow output from the pump.

The variable coolant pump has a shroud that slides over the impeller to reduce the flow of engine coolant being pumped into the cylinder block. The solenoid controlled shroud is used to reduce the flow provided to the cylinder block. The solenoid operates in combination with an internal hydraulic pump to generate hydraulic pressure which is used to move the shroud to restrict flow through the cylinder block. Pressure is generated with every rotation of the pump impeller. The pressure is diverted either to the shroud assembly or leaked back to the coolant system, controlled by a solenoid valve. The shroud will not move if there is no rotation of the pump impeller. Requests from 0 – 100% flow can be fulfilled at most engine speeds to contribute to the whole engine thermal management strategy.

The solenoid operates in combination with an internal hydraulic pump to generate hydraulic pressure which is used to move the shroud to restrict flow through the cylinder block



Item	Description
A	To engine coolant outlet
B	From engine coolant inlet
1	100% open - Full flow
2	50% open - Restricted flow
3	0% open - Zero flow

The Engine Control Module (ECM) receives input signals from other engine control components to determine the required level of cooling such as cylinder head metal temperature, EGR temperatures, ambient temperatures, drive mode, coolant temperature and minimum flow map. The calibration is able to control the variable coolant pump flow in five steps and is controlled by an open-loop map.

Flow modes: 0 = zero flow, 4 = Full Flow

The control of the shroud solenoid is by a Pulse Width Modulation (PWM) signal from the ECM. The internal pressure within the pump acts against a return spring in the housing. Without a signal from the ECM the solenoid is de-energized, the shroud is at its default position held under return spring force, resulting in full flow from the pump.

During an engine cold start, the impeller is fully covered by the shroud (flow mode 0), therefore no coolant is circulated through the cylinder block. As the engine coolant temperature increases, the flow requirement will increase in 4 stages (flow mode 1-4). The variable coolant pump is controlled by the ECM to provide the minimum flow to support all cooling requests from the engine systems. When the engine coolant temperature reaches 85ºC (185ºF), the solenoid is de-energized and the shroud will move to its default fully open position (flow mode 4) allowing maximum circulation through the cylinder block. Temperature control and flow is then managed by the ECM and the electric thermostat.

High Pressure (HP) Fuel Pump and Fuel Injectors

The fuel system is of a common rail design consisting of a high pressure pump, fuel rail and injectors with associated low and high pressure pipes.

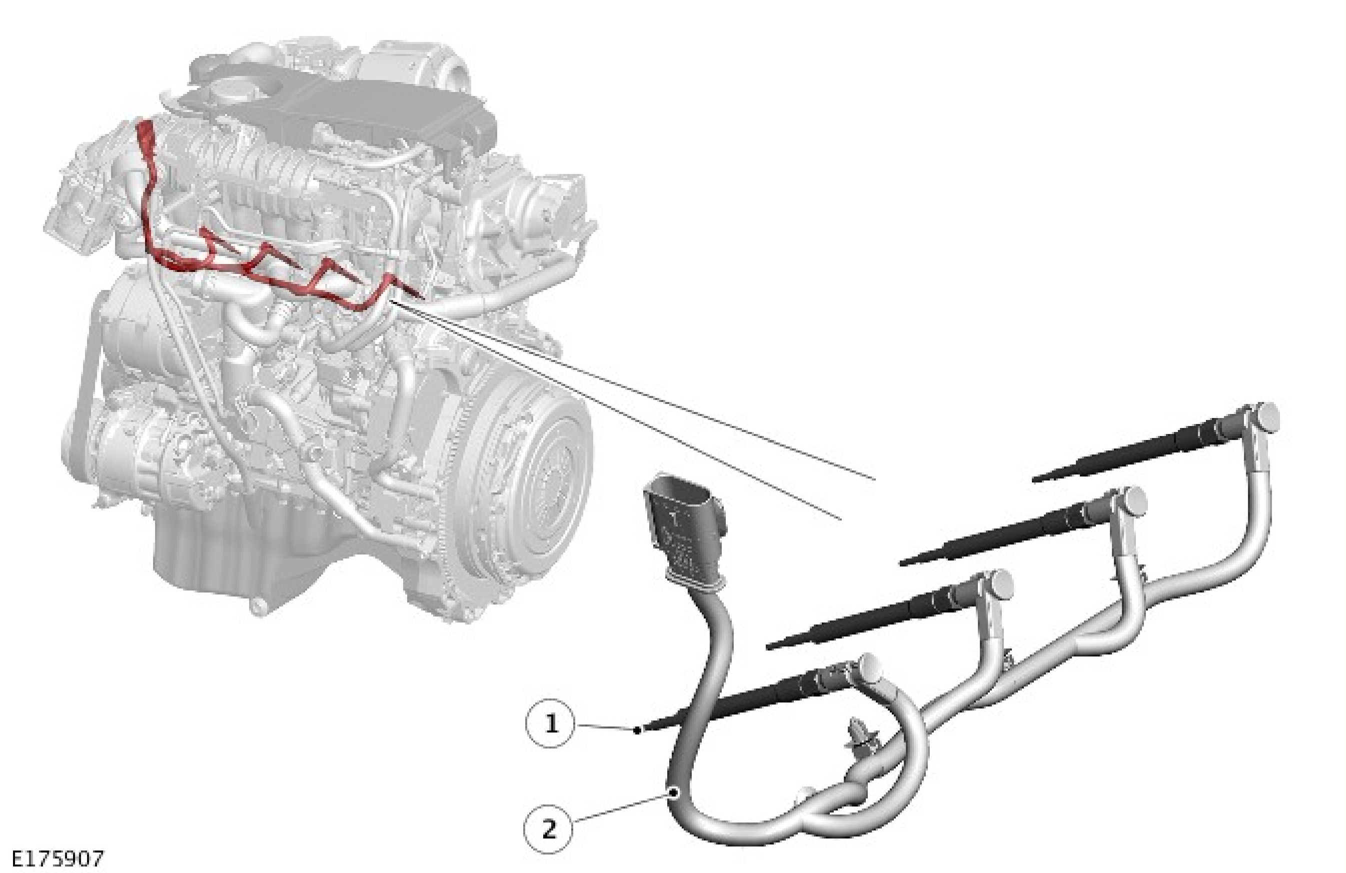
The high pressure fuel pump is located at the rear of the engine and is driven by a chain drive from the crankshaft at engine speed. The fuel pump is mounted on the cylinder block and secured with three bolts. The high pressure fuel pump is a single cylinder design which regulates the fuel pressure according to demand requirements for correct fuel injection. The delivery rate of the fuel pump is adjustable by means of a fuel metering valve which is controlled by the ECM. Fuel is used to lubricate the moving components of the pump before being returned to the fuel tank.

High pressure fuel is supplied via a high pressure feed pipe to the fuel rail which is located on the camshaft carrier. The fuel rail is a pressure reservoir which provides the fuel supply to the injectors. The fuel rail also houses a fuel pressure sensor and a fuel pressure control valve. The fuel pressure control valve is utilised by the ECM in conjunction with the fuel pump metering valve to ensure that the correct pressure is maintained within the fuel rail. The ECM software determines which valve, or combination of the two valves, is appropriate to maintain the correct pressure. Excess fuel, bypassed from the pressure control valve operation, is returned to the inlet side of the fuel filter. The raised temperature of this fuel assists with fuel filter heating in cold ambient temperatures.

Pressurized fuel is supplied from the fuel rail via steel pipes to each individual injector. The engine uses solenoid injectors which are mounted centrally in the combustion chamber and retained with clamps. The injector does not inject the entire quantity of fuel it is supplied; a small amount of fuel from the injector is collected by a low pressure injector leak-off pipe and returned to the fuel tank along with the fuel pump's return.

It is important to note that the fuel injector specifications may vary in respect to the power output of the specific engine variant.

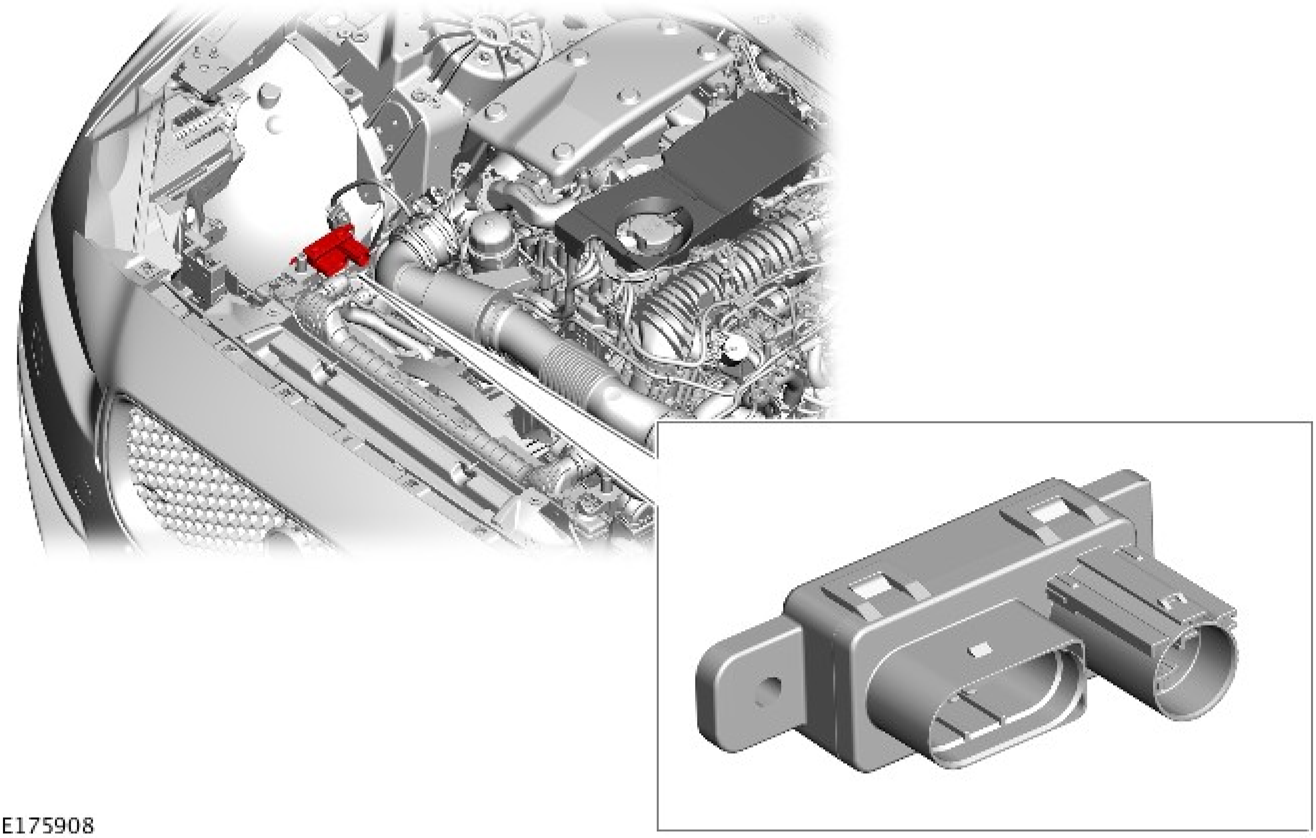
Glow Plugs



Item	Description
1	Glow plug (4 off)
2	Glow plug harness

The glow plug system has a glow plug installed in the inlet side of each cylinder. The glow plugs heat the combustion chambers before and during cranking, to aid cold starting, and after the engine starts to reduce emissions and engine noise when idling with a cold engine. The glow plugs are connected by a common harness which is connected into the main engine harness. The glow plugs are connected directly to a glow plug control module which is controlled by glow plug software contained within the Engine Control Module (ECM). The glow plug control module is located in the right side of the engine compartment, below the Engine Junction Box (EJB).

Glow Plug Control Module Location



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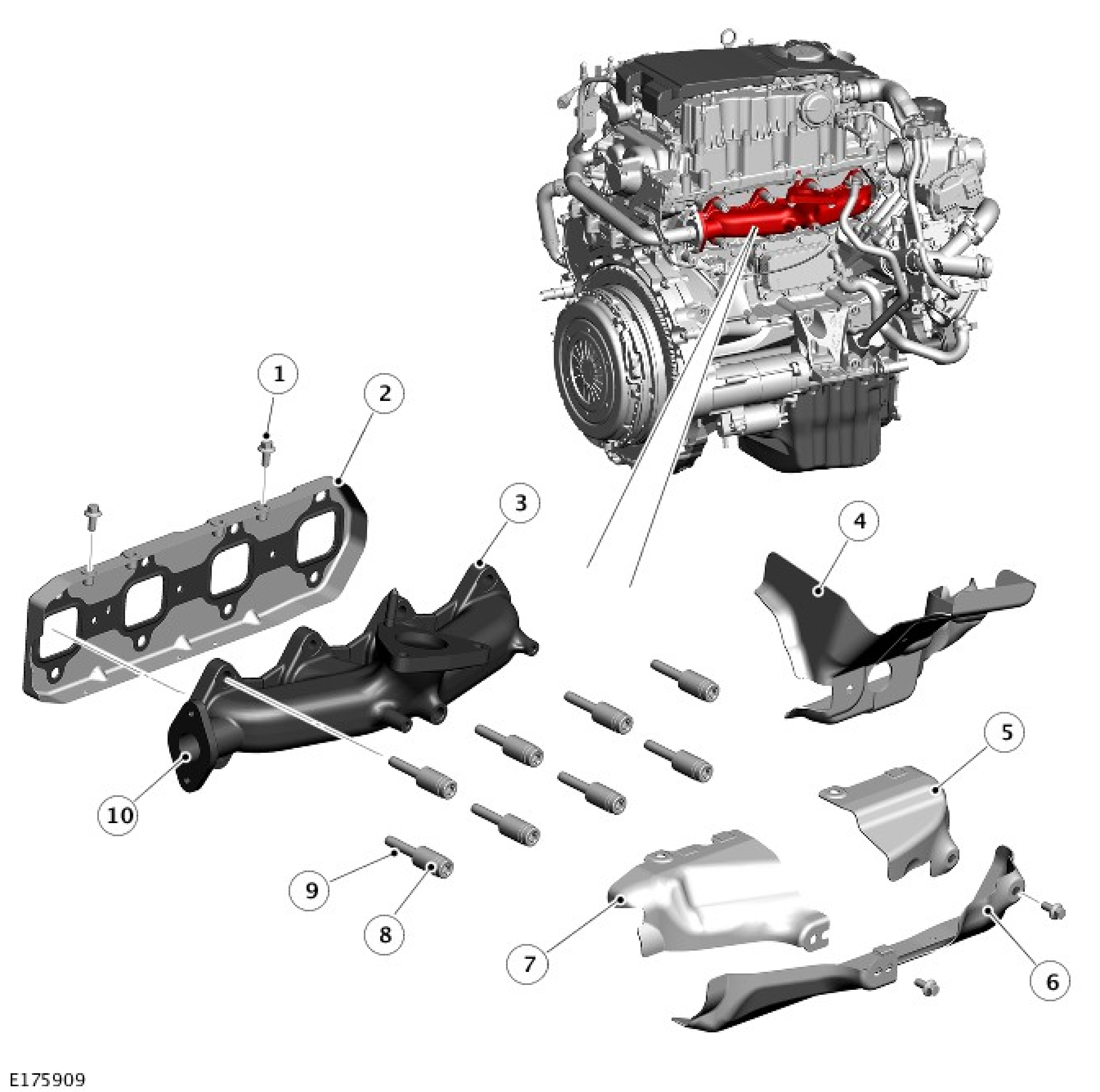
Each glow plug is a tubular heating element which contains a spiral filament encased in magnesium oxide powder. At the tip of the tubular heating element is the heater coil. Behind the heater coil, and connected in series, is a control coil. The control coil regulates the current to the heater coil to safeguard against overheating.

In the event of glow plug failure, the engine may be difficult to start and excessive smoke emissions may be observed after starting.

Exhaust Manifold



Item	Description
1	Screw (4 off)
2	Gasket assembly
3	Exhaust manifold
4	Heat shield - turbcharger
5	Heat shield - upper
6	Heat shield - lower
7	Heat shield - upper
8	Spacer (8 off)
9	Bolt (8 off)
10	Output to Exhaust Gas Recirculation (EGR) valve

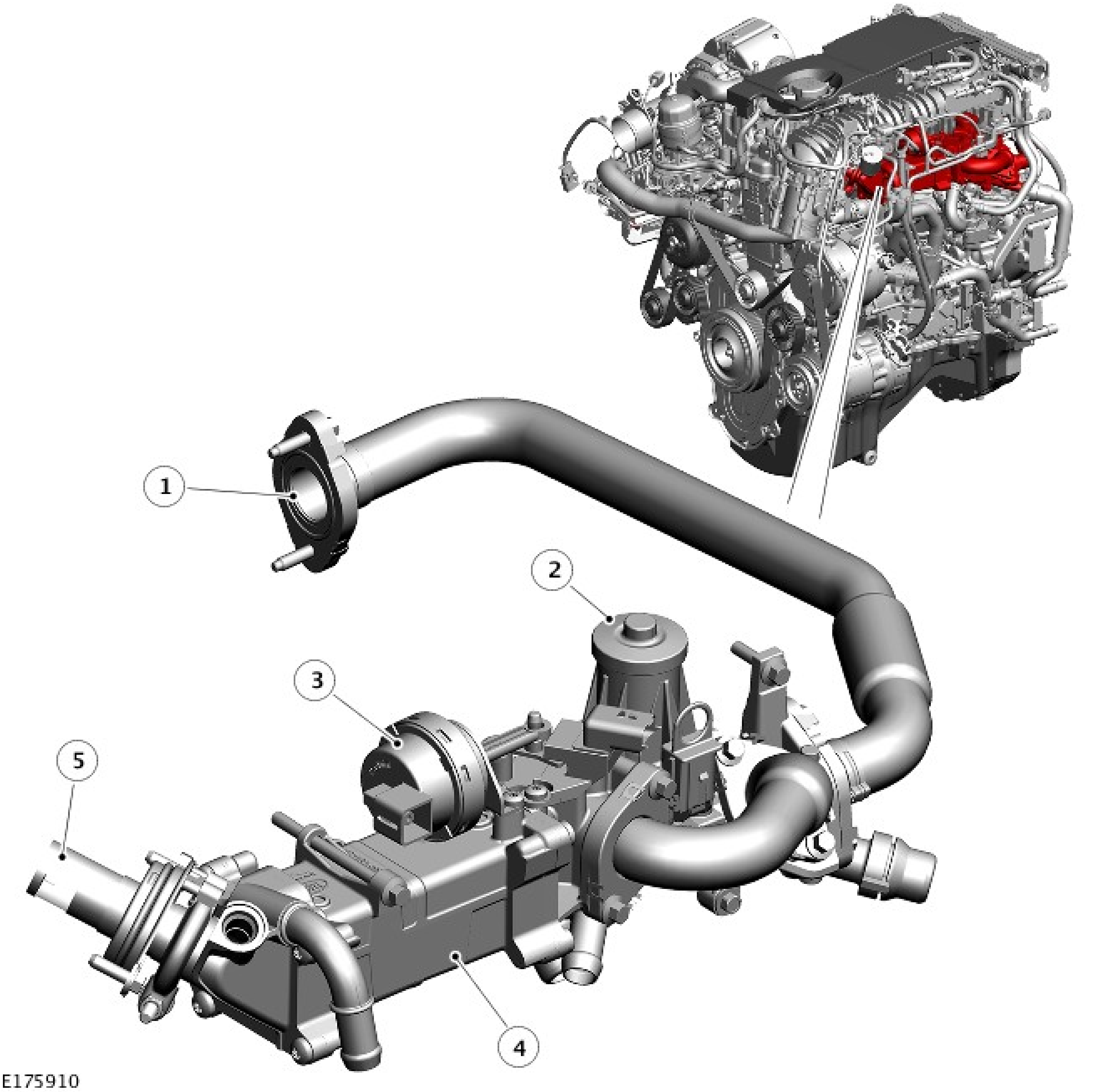
The exhaust manifold is cast from an iron alloy with a high nickel content giving excellent heat and corrosion resistance properties. The manifold is sealed to the cylinder head by means of a steel gasket and heat shield assembly. Spacers on the securing bolts allow the manifold to expand and retract with changes of temperature while maintaining the clamping loads.

The exhaust manifold has a connection for the Exhaust Gas Recirculation (EGR) transfer pipe to the High Pressure (HP) EGR valve.

The engine is fitted with a variable geometry turbocharger which is located on the top of the exhaust manifold on a three hole flange mounting and sealed with a steel gasket.

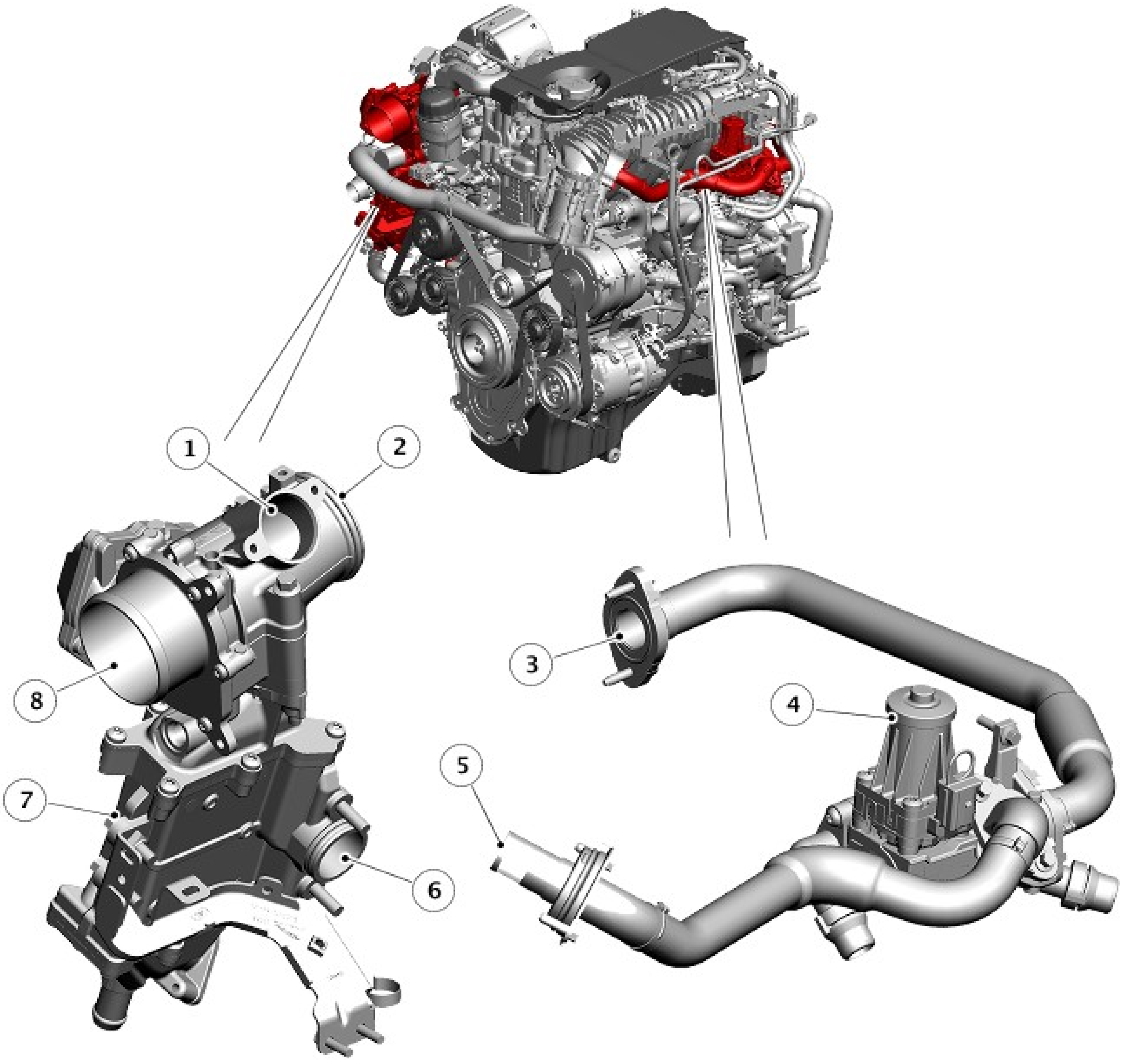
Exhaust Gas Recirculation (EGR)

EGR EU4 Markets



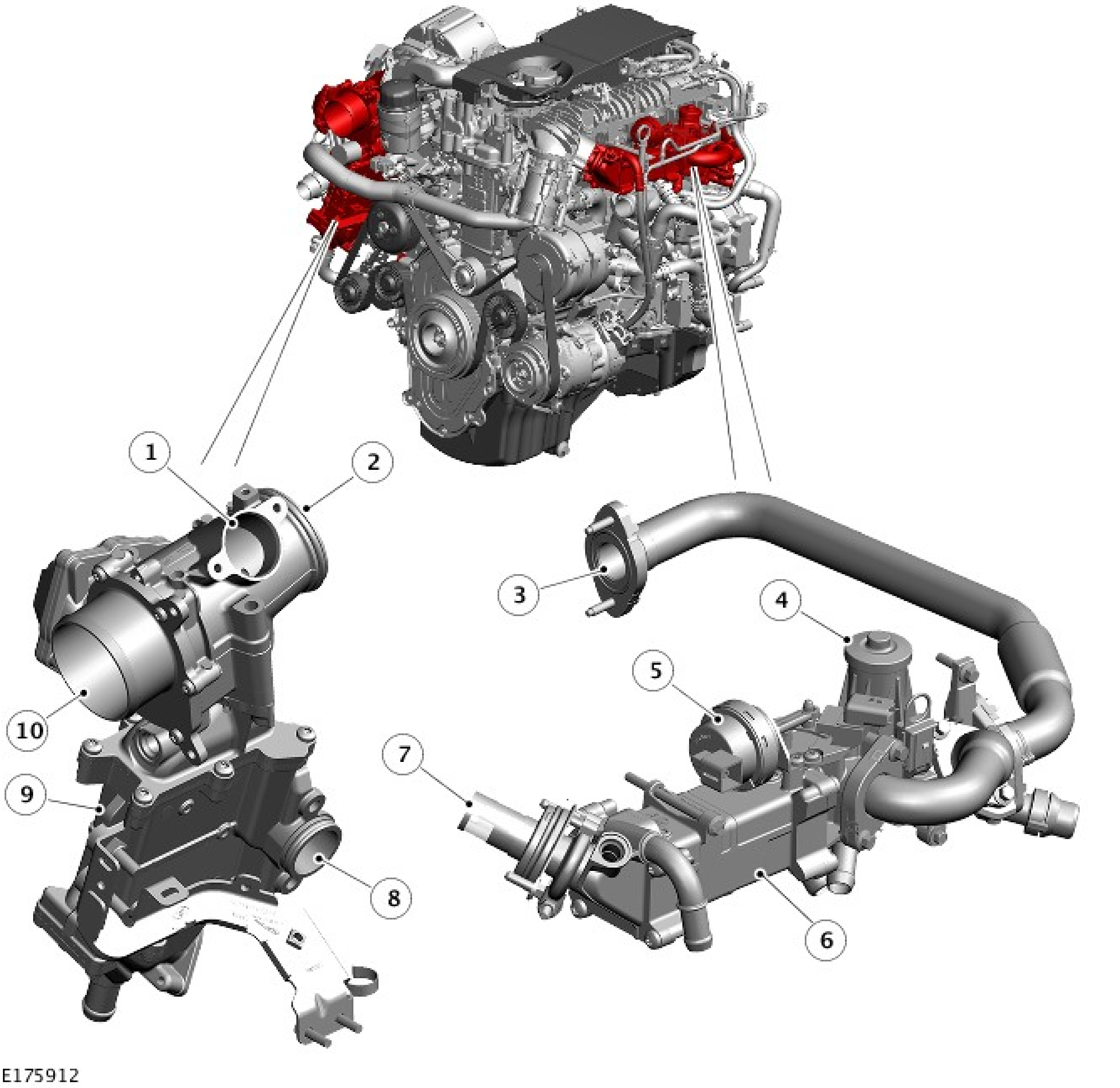
Item	Description
1	EGR tube from exhaust manifold
2	HP EGR valve and actuator
3	HP EGR cooler by-pass actuator
4	HP EGR cooler
5	EGR outlet to intake manifold

EGR EU5 and EU6 Markets



Item	Description
1	Breather pipe inlet from engine vent module
2	Turbocharger attachment
3	HP EGR tube from exhaust manifold
4	HP EGR valve and actuator
5	HP EGR outlet to intake manifold
6	Engine coolant connection with cylinder block
7	LP EGR cooler
8	LP EGR Valve

EGR NAS Markets



Item	Description
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5	HP EGR cooler by-pass actuator
6	HP EGR cooler by-pass actuator
7	HP EGR outlet to intake manifold
8	Engine coolant connection with cylinder block
9	LP EGR cooler
10	LP EGR Valve

There are two main external Exhaust Gas Recirculation (EGR) systems that are used on the engine – High Pressure (HP) EGR and Low Pressure (LP) EGR.

EGR is used to cool the combustion in the cylinders by introducing exhaust gases without oxygen (exhaust gas). This in turn allows the use of smaller fuel injections, improving emissions and fuel economy.

The following systems are used for specific markets:

- EU4 markets - use a HP EGR valve and cooler.

- EU5/6 markets - use both HP and LP EGR valves. The LP system uses an EGR cooler, there is no cooler for the HP system.
- North America Specification (NAS) markets - use both HP and LP EGR valves. Both the HP and LP systems use an EGR cooler.

HP EGR

The HP EGR valve is attached to the intake manifold. Exhaust gases are routed to the EGR valve from the exhaust manifold. The EGR valve is cooled using engine coolant in the passenger compartment heater core circuit; this is to protect the electrical components from over-heating. The HP EGR valve controls the amount of EGR exhaust gas flow depending on the Engine Control Module (ECM) map. The exhaust gases are passed directly into the intake manifold via a simple EGR pipe on EU5/6 market vehicles. The design of the EGR pipe attachment to the inlet manifold helps mix the exhaust gasses with the main fresh air intake and also insulates the plastic intake manifold from the hot EGR pipe.

On EU4 and NAS market vehicles, a separate EGR pipe attachment is used to connect between the intake manifold and the EGR cooler. The exhaust gasses are passed through the EGR cooler before being passed through the EGR pipe to the intake manifold.

LP EGR

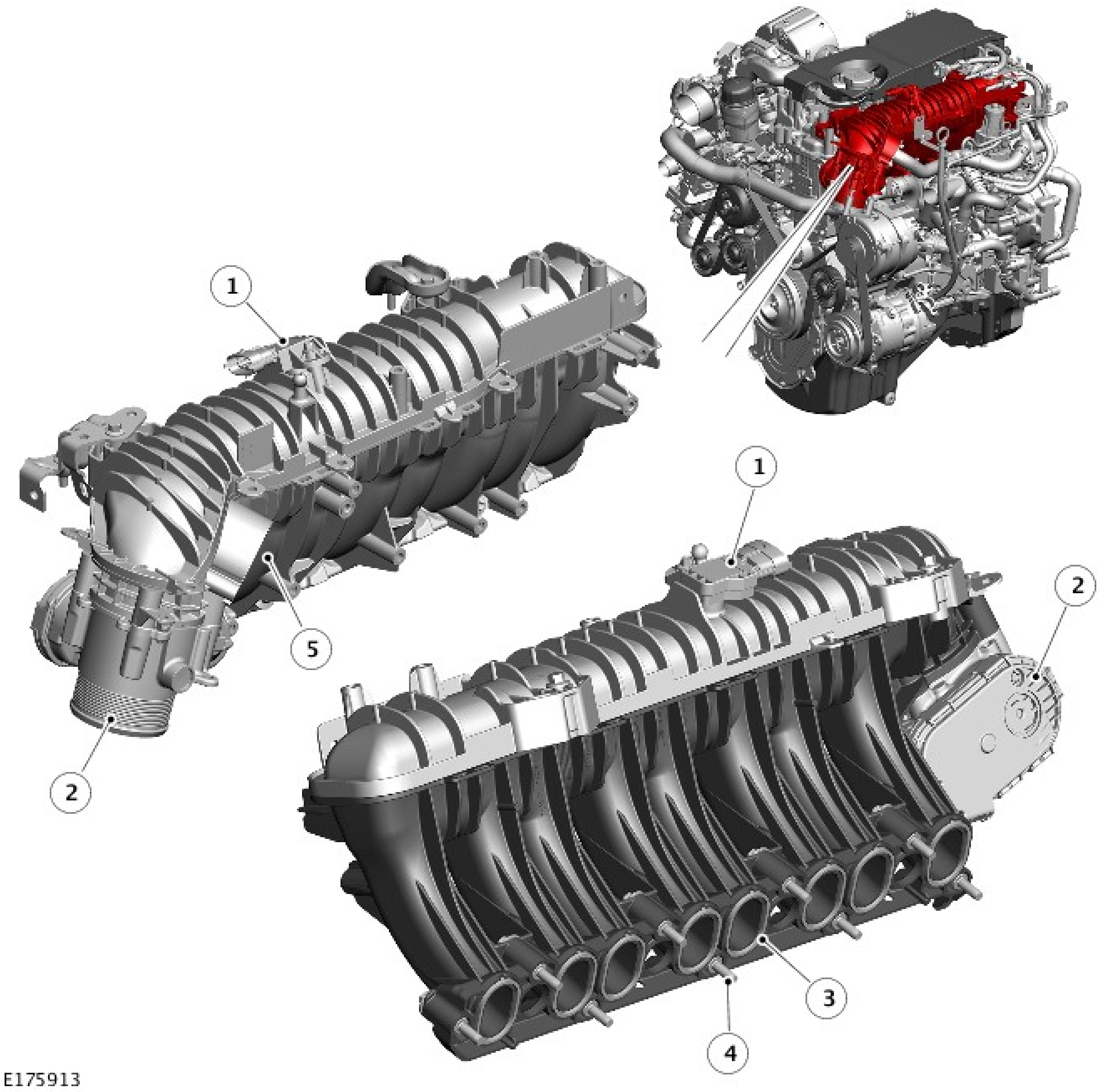
The LP EGR system is used on EU5 and 6 and NAS market vehicles only. The LP system takes exhaust gases from the exit of the catalytic converter and Diesel Particulate Filter (DPF) assembly, and mixes it with the fresh air intake into the turbocharger.

The gases are transported from the catalytic converter and Diesel Particulate Filter (DPF) assembly outlet to the LP EGR cooler via a pipe. The LP cooler has no bypass mode, cools all exhaust gas passing through it. There is a simple mesh filter fitted before the gasses reach the outlet of the cooler that prevents larger particles of soot etc. from entering the turbo charger system. The mesh filter is non-serviceable.

The cooled gases are then directed through the LP EGR valve via a butterfly valve. The valve consists of a tube between the fresh air duct and the turbocharger, with the butterfly valve covering the EGR inlet, in the centre bottom of the EGR valve. The butterfly valve opens into the fresh air stream, promoting thorough mixing before the gas enters the turbocharger, and also provides ‘suction’ to drive the LP EGR gas through the system.

For additional information, refer to: Engine Emission Control (303-08A Engine Emission Control - INGENIUM I4 2.0L Diesel, Description and Operation).

Intake Manifold



Item	Description
1	Manifold Absolute Pressure and Temperature (MAPT) sensor
2	Electric throttle
3	Seal (8 off)
4	Bolt (9 off)
5	EGR inlet

The inlet manifold is a plastic injection moulded assembly made from two shells vibration-welded together. The intake manifold is mounted directly to the cylinder head with nine bolts and sealed with eight flexible seals.

The main function of the intake manifold is to evenly distribute intake air from the air filter and intake distribution system into the combustion chamber of each cylinder.

A Manifold Absolute Pressure and Temperature (MAPT) sensor is located on the top of the intake manifold and secured a screw. The MAPT sensor is used by the Engine Control Module (ECM) to calculate air density and temperature and determine the engine's air mass flow rate.

The electric throttle is attached to the intake manifold with four screws. A gasket seals the joint between the electric throttle and the intake manifold.

Noise, Vibration and Harshness (NVH) Pads

Noise, Vibration and Harshness (NVH) pads are fitted on the Ingenium I4 2.0L Diesel engine in order to reduce NVH experienced by the driver or passenger(s). The pads are made of either a PUR foam or a multi-layer mixed fibre and resin laminate composite depending on application.

The NVH package consists of a pad for each side of the engine cylinder block, an engine cover located on the top of the engine and an oil pan cover.