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2020.0 DEFENDER (LE), 303-01C

ENGINE – INGENIUM I6 3.0L PETROL (G2341923)

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DESCRIPTION AND OPERATION

COMPONENT LOCATION

COMPONENT LOCATION - EXTERNAL VIEW



ITEM	DESCRIPTION
A	Front view
B	Rear view

The Ingenium I6 3.0L petrol engine is an inline 6 cylinder, turbocharged engine that employs advanced modular design principles.

The engine features a split cooling system. The system contains a Powertrain Control Module (PCM) controlled electric thermostat and a fully variable coolant pump. The variable coolant pump enables engine coolant to remain static in the engine to maximize heat transfer during warm up. When engine coolant flow is required for engine cooling, the variable coolant pump provides the minimum coolant flow.

The split cooling thermostat housing limits engine coolant flow in the cylinder block while allowing engine coolant to circulate through cross flow channels in the cylinder head. Parasitic losses are also optimized 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.

The 2 camshafts incorporate the Variable Camshaft Timing (VCT) system. The VCT system allows the timing of the intake and exhaust valves to be adjusted independently of each other. The VCT system is controlled by the PCM using information from the Camshaft Position Sensor (CMP)s.

The Continuous Variable Valve Lift (CVVL) system can adjust the intake valve lift timing. The CVVL system allows the engine to always operate at optimal efficiency. The CVVL system reduces fuel consumption and increases power and torque in the lower speed range. The CVVL system is controlled by the PCM.

The engine uses a Bosch High Pressure (HP) direct injection fuel system. The fuel pressure is provided by a HP fuel pump, which is driven from the intake camshaft. The HP fuel pump supplies the fuel rail, and then the fuel rail supplies the 6 fuel injectors with fuel at a controlled pressure.

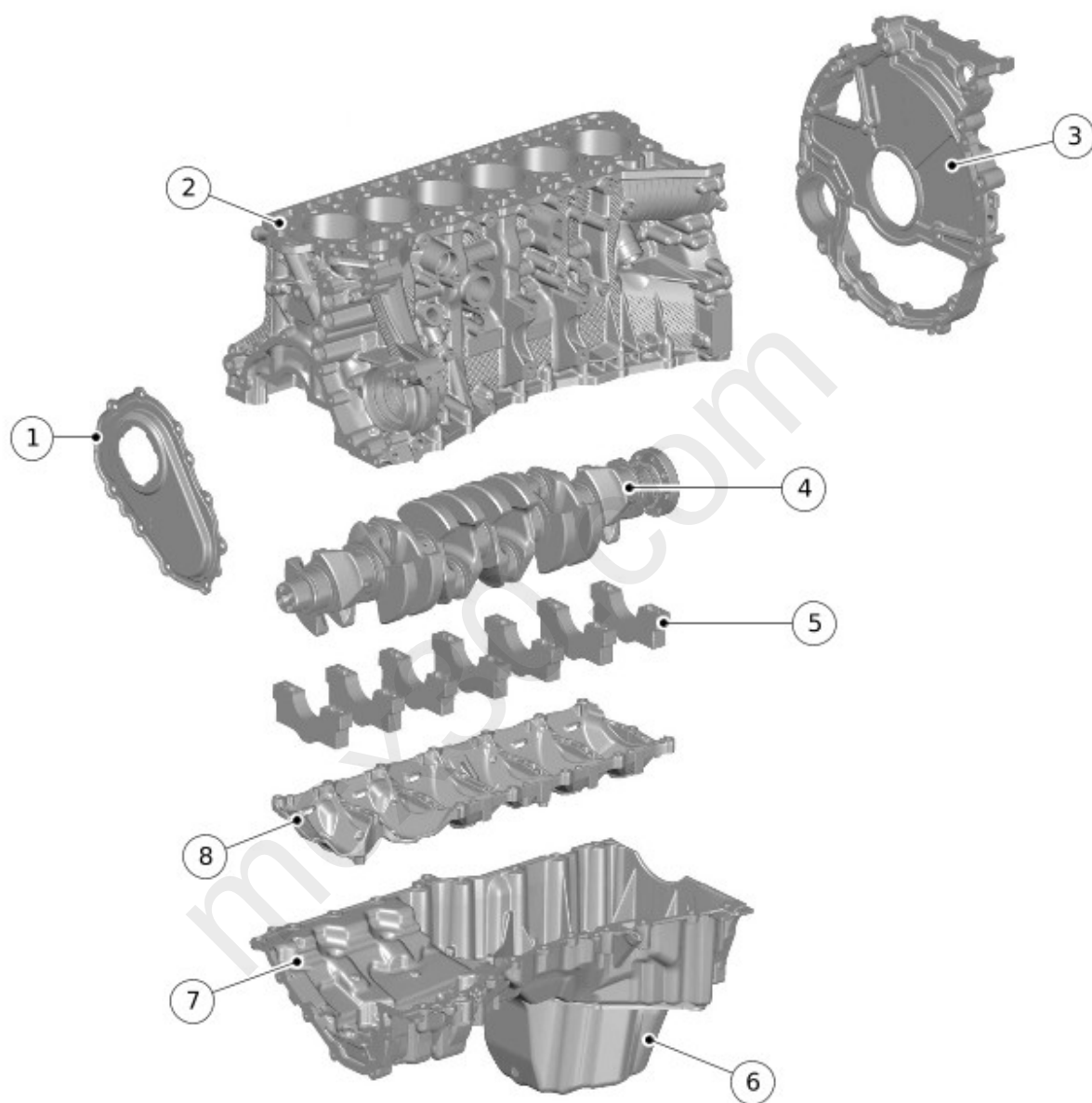
There are many dynamic and static seals on the engine. All seals and gaskets shall be considered single use and if they are removed, shall be replaced.

Various engine systems are located on the engine assembly and driven directly and indirectly by the engine operation. Refer to the relevant section for further information:

- Engine cooling
 - For additional information, refer to: [Engine Cooling](#) (303-03C Engine Cooling - INGENIUM I6 3.0L Petrol, Description and Operation).
- Fuel system
 - For additional information, refer to: [Fuel Tank and Lines](#) (310-01B Fuel Tank and Lines - INGENIUM I6 3.0L Petrol, Description and Operation).
- Air intake system

- For additional information, refer to: [Intake Air Distribution and Filtering](#) (303-12C Intake Air Distribution and Filtering - INGENIUM I6 3.0L Petrol, Description and Operation).
- Engine emission control
 - For additional information, refer to: [Engine Emission Control](#) (303-08C Engine Emission Control - INGENIUM I6 3.0L Petrol, Description and Operation).
- Accessory drive
 - For additional information, refer to: [Accessory Drive](#) (303-05C Accessory Drive - INGENIUM I6 3.0L Petrol, Description and Operation).
- Starting system
 - For additional information, refer to: [Starting System](#) (303-06C Starting System - INGENIUM I6 3.0L Petrol, Description and Operation).
- Turbocharger
 - For additional information, refer to: [Turbocharger](#) (303-04F Fuel Charging and Controls - Turbocharger - INGENIUM I6 3.0L Petrol, Description and Operation).
- Electronic engine controls
 - For additional information, refer to: [Electronic Engine Controls](#) (303-14B Electronic Engine Controls - INGENIUM I6 3.0L Petrol, Description and Operation).

CYLINDER BLOCK COMPONENTS

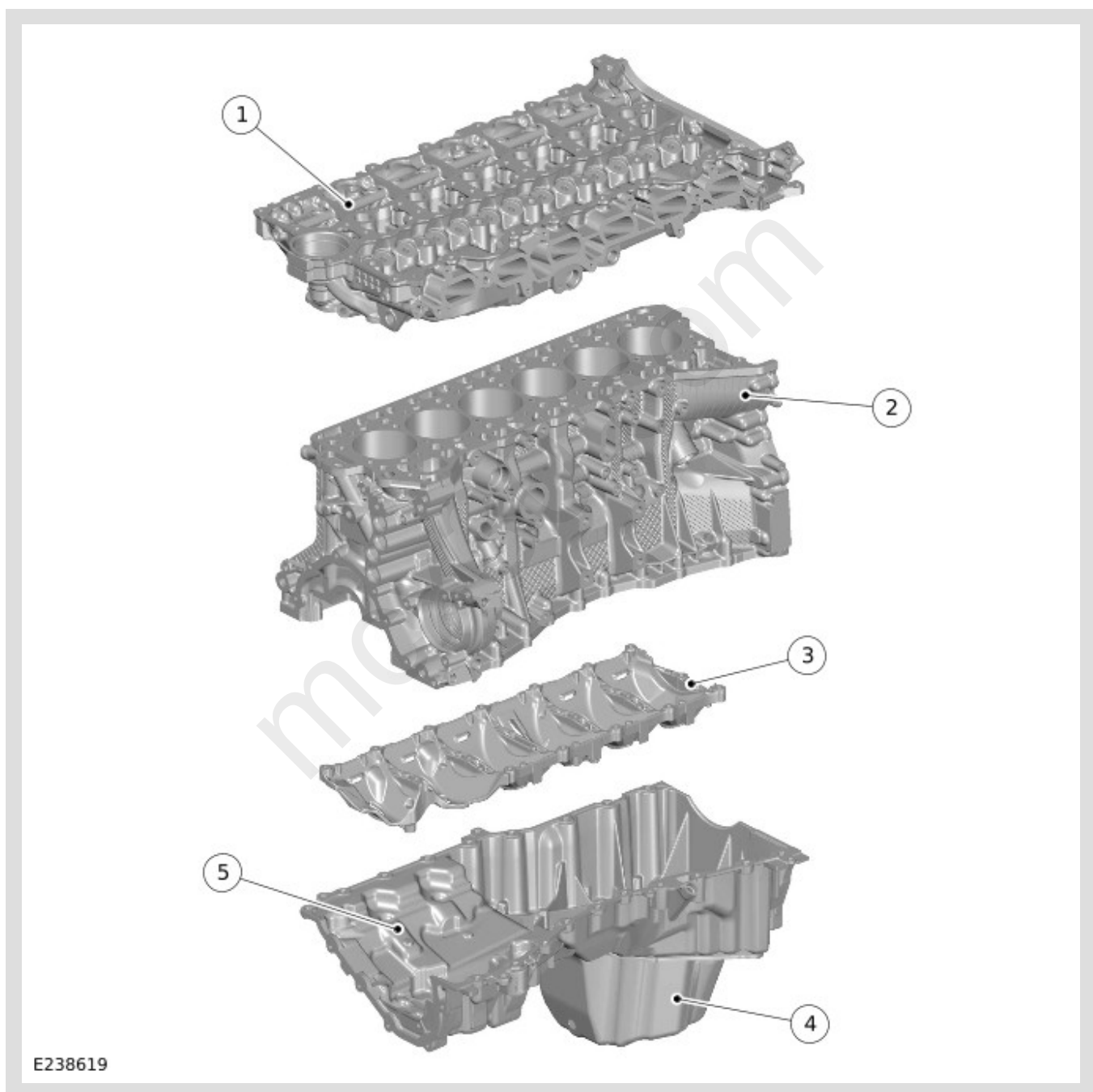


E238613

ITEM	DESCRIPTION
1	Engine front cover
2	Cylinder block
3	Lower timing chain cover
4	Crankshaft

ITEM	DESCRIPTION
5	Main bearing cap (quantity 7)
6	Oil pan
7	Oil pan extension
8	Windage tray

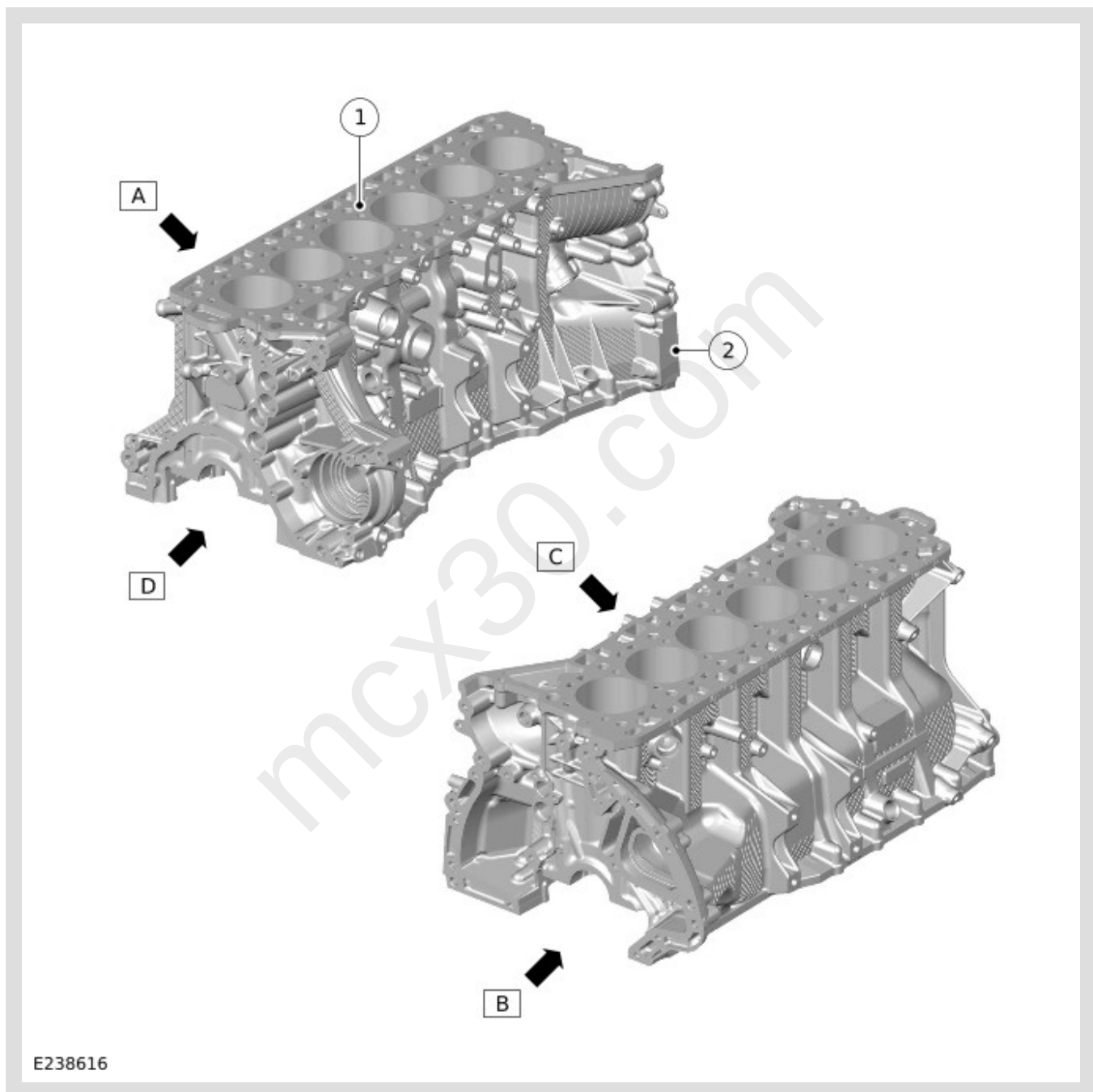
MAJOR STRUCTURAL COMPONENTS



ITEM	DESCRIPTION
1	Cylinder head
2	Cylinder block

ITEM	DESCRIPTION
3	Windage tray
4	Oil pan
5	Oil pan extension

CYLINDER BLOCK



ITEM	DESCRIPTION
A	Right of the engine
B	Rear of the engine
C	Left of the engine

ITEM	DESCRIPTION
D	Front of the engine
1	Cylinder block
2	Engine number location

The deep skirt cast aluminum cylinder block is an inline 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 air inlet side
- And the coolant outlet from the cylinder head on the exhaust side.

Oil from the cylinder head drains back to the oil pan through open apertures. The 10 apertures are located on each side of the cylinder block between each cylinder.

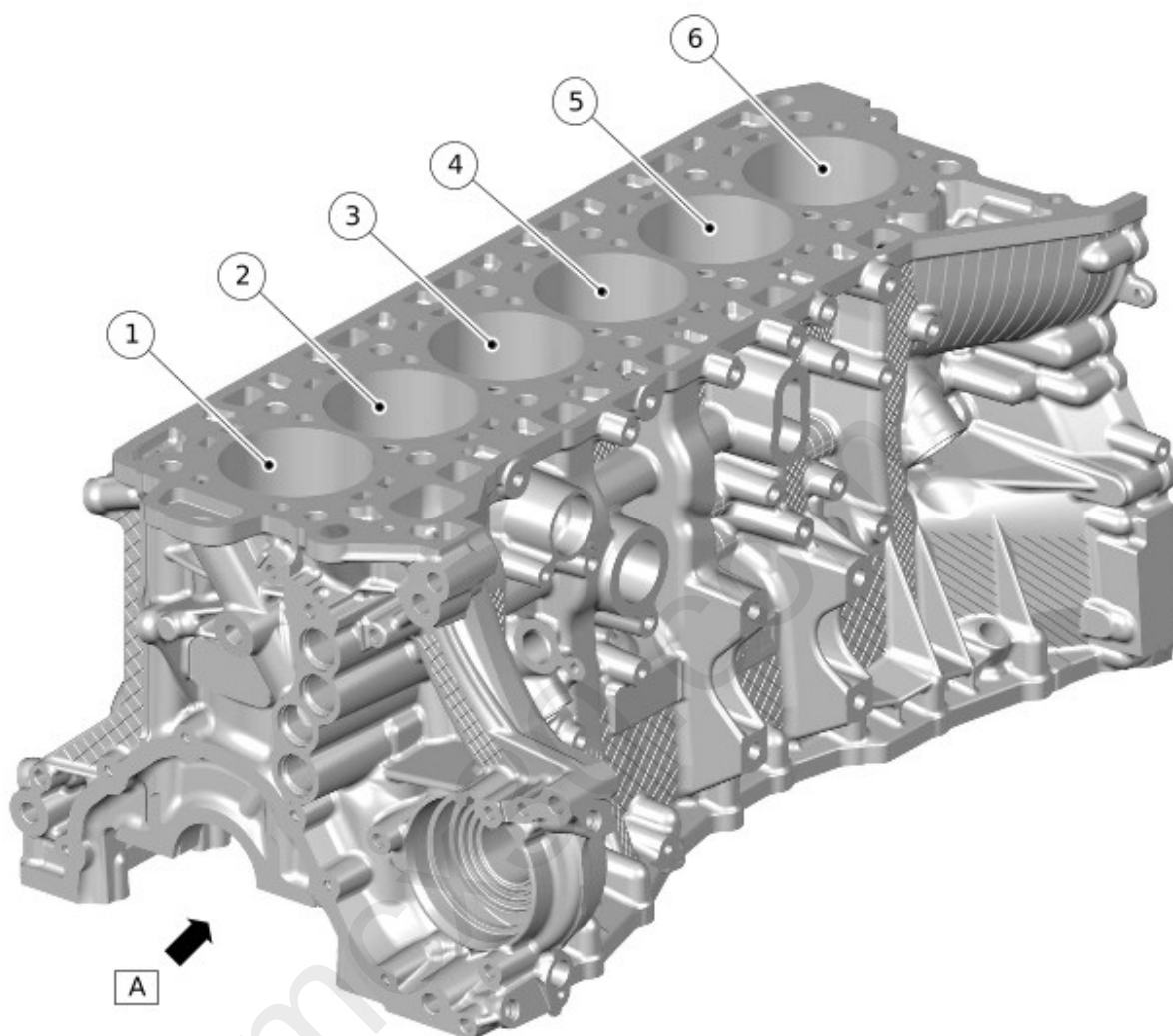
A cast aluminum alloy, structural windage tray is bolted to the bottom of the cylinder block:

- To improve the cylinder block stiffness.
- To minimize Noise, Vibration and Harshness (NVH).
- To 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.

There is a front cover and a rear cover on the engine. Both covers are fixed to the cylinder block by bolts and sealed to the cylinder block with RTV sealant. Both covers contain a flat surface for the oil seal.

CYLINDER NUMBERING

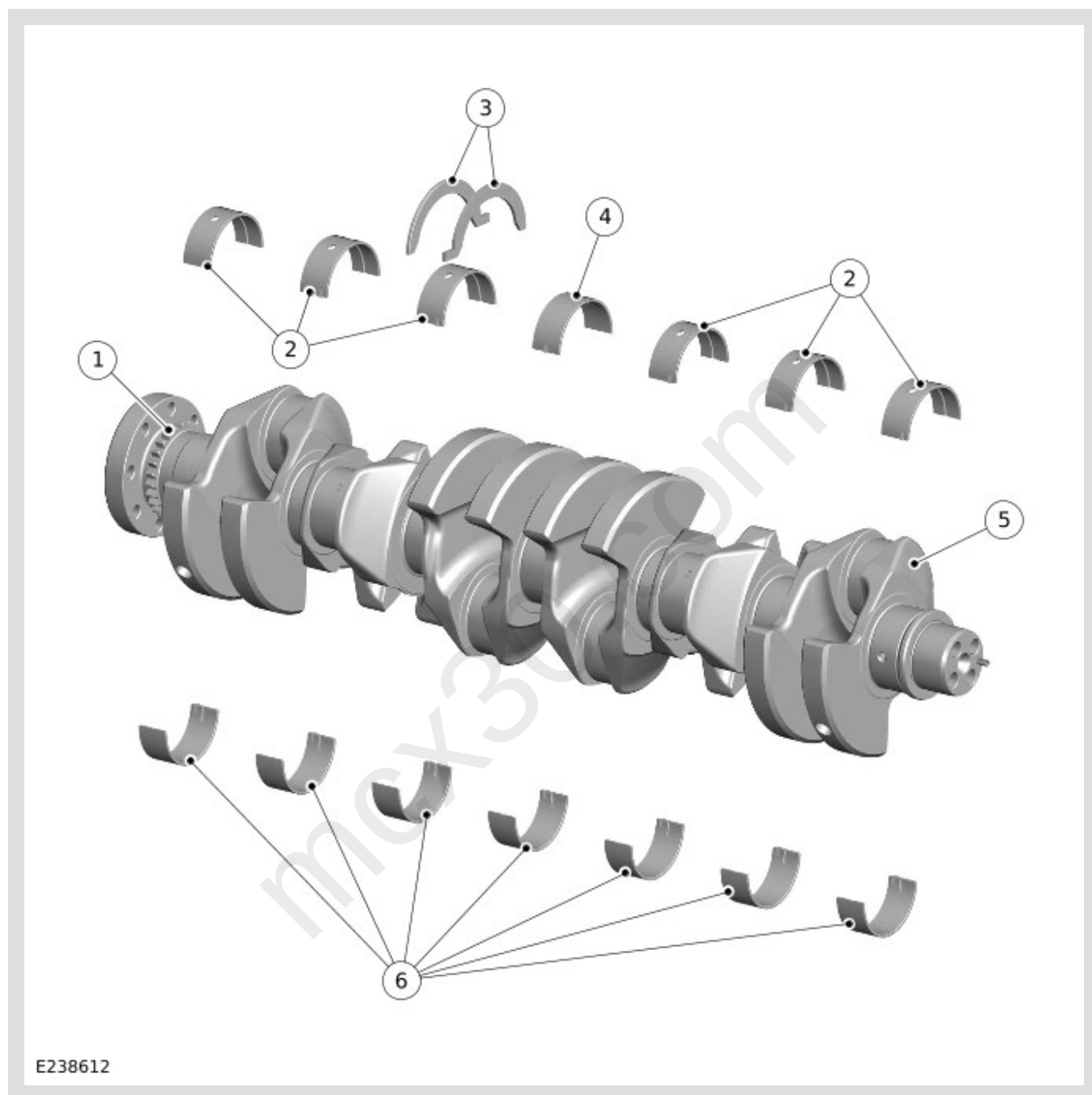


E238617

ITEM	DESCRIPTION
A	Front of the engine
1	Cylinder No. 1
2	Cylinder No. 2
3	Cylinder No. 3
4	Cylinder No. 4
5	Cylinder No. 5
6	Cylinder No. 6

The cylinders are numbered as shown, with cylinder 1 at the front of the engine. The firing order is the following: 1, 5, 3, 6, 2, 4.

CRANKSHAFT



ITEM	DESCRIPTION
1	Timing chain drive sprocket
2	Upper main bearing (quantity 6)
3	Thrust washer (quantity 2)
4	Upper main bearing - Center
5	Crankshaft

ITEM	DESCRIPTION
6	Lower main bearing (quantity 7)

The crankshaft is manufactured from forged carbon steel C38 MOD with induction hardened main and large end bearing journals. The fillets of the main and large end bearing journals are fillet rolled to improve the strength of the crankshaft. The crankshaft is installed in 7 main bearings. The 12 counter-balance weights provide low vibration levels. The 7 main bearing journals are designed to contribute to stiffness.

There are 2 different upper main bearing designs. The fourth upper main bearing does not have an oil groove. The other 6 upper main bearings has an oil groove at each end.

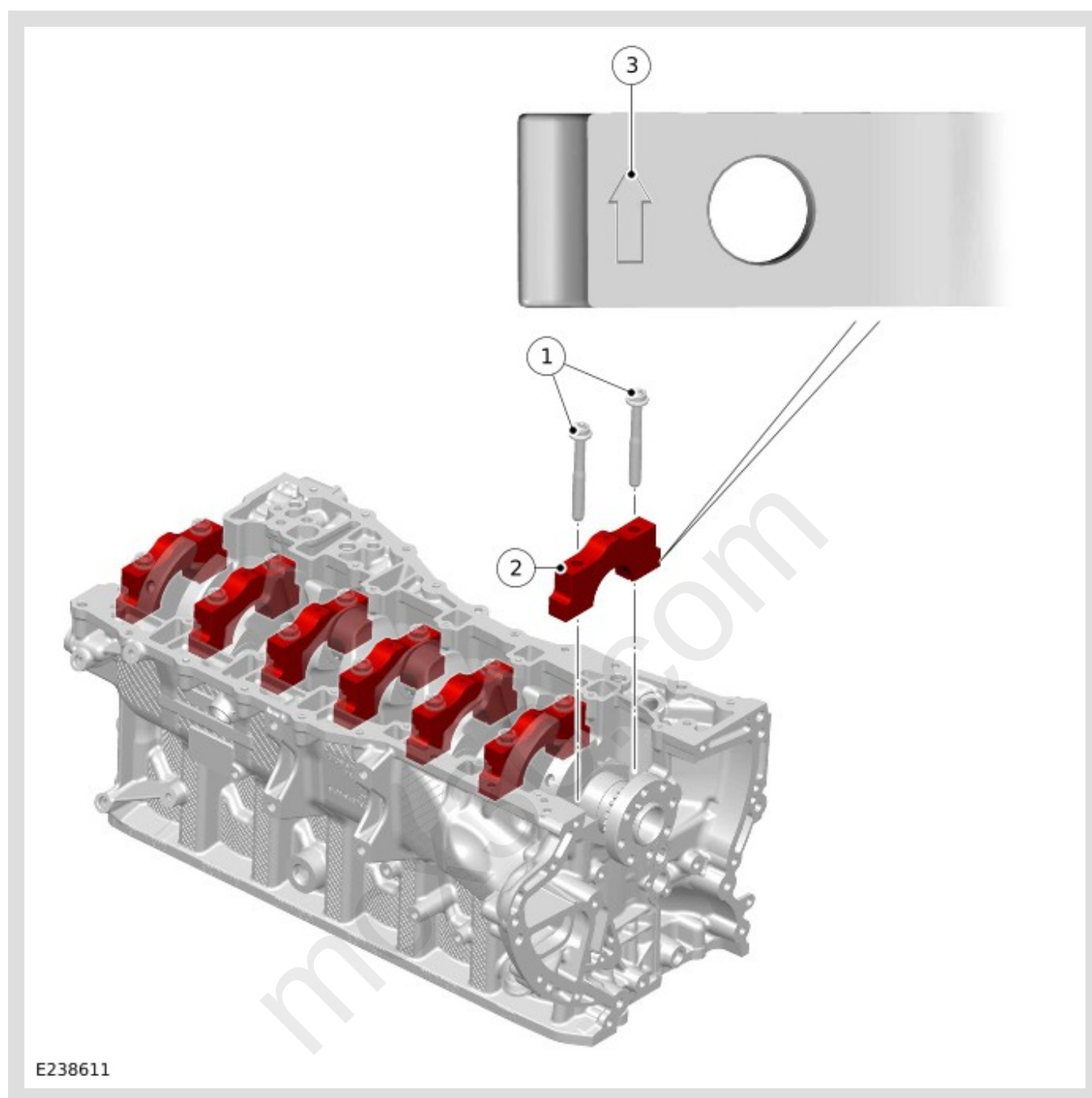
The oil groove on the upper main bearing transfers pressurized engine oil into the crankshaft to lubricate the following:

- The main bearings
- The connecting rod bearings.

The 2 individual thrust washers are located on either side of the fifth main bearing journal panel of the cylinder block. The thrust washers control the crankshaft end float.

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CRANKSHAFT INSTALLATION



ITEM	DESCRIPTION
1	Bolt - Main bearing cap (quantity 14)
2	Main bearing cap (quantity 7)
3	Orientation arrow

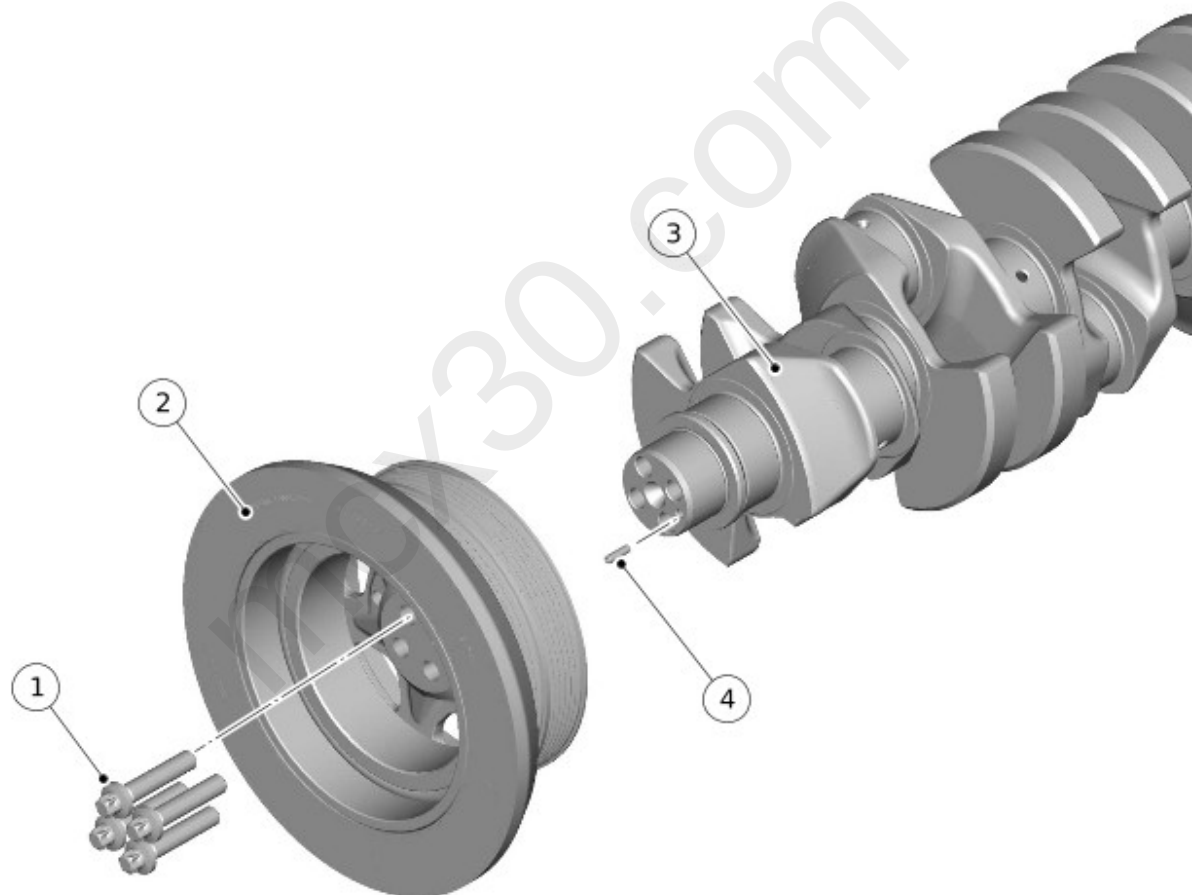
The crankshaft is retained in position by 7 main bearing caps that are manufactured from sintered steel. Each individual main bearing cap has a numbered identification (1-7) and an arrow to make sure of the correct location and orientation. The arrow must face towards the front of the engine.

There are a number of grades of main bearing available. Each size of the main bearings is color coded and inkjet marked with a number on the running face of the bearing. The crankshaft is laser etched with a string of 7 alpha characters in the order of the crankshaft main bearing journals 1-7. A data matrix code contains the same data. The correct main bearings are selected with reference to a selection chart in order to achieve optimum running clearances.

For additional information, refer to: [Specifications](#) (303-01C Engine - INGENIUM I6 3.0L Petrol, Specifications).

Except for the central main bearing, all main bearings in the cylinder block have 2 central holes and an internal groove to allow for main bearing journal lubrication. The central main bearing has only 1 hole, without any internal groove. The main bearings in the main bearing caps are plain with no hole or internal groove.

CRANKSHAFT PULLEY/DAMPER



E237257

ITEM	DESCRIPTION
1	Bolt (quantity 4)
2	Crankshaft pulley
3	Crankshaft
4	Alignment roll pin

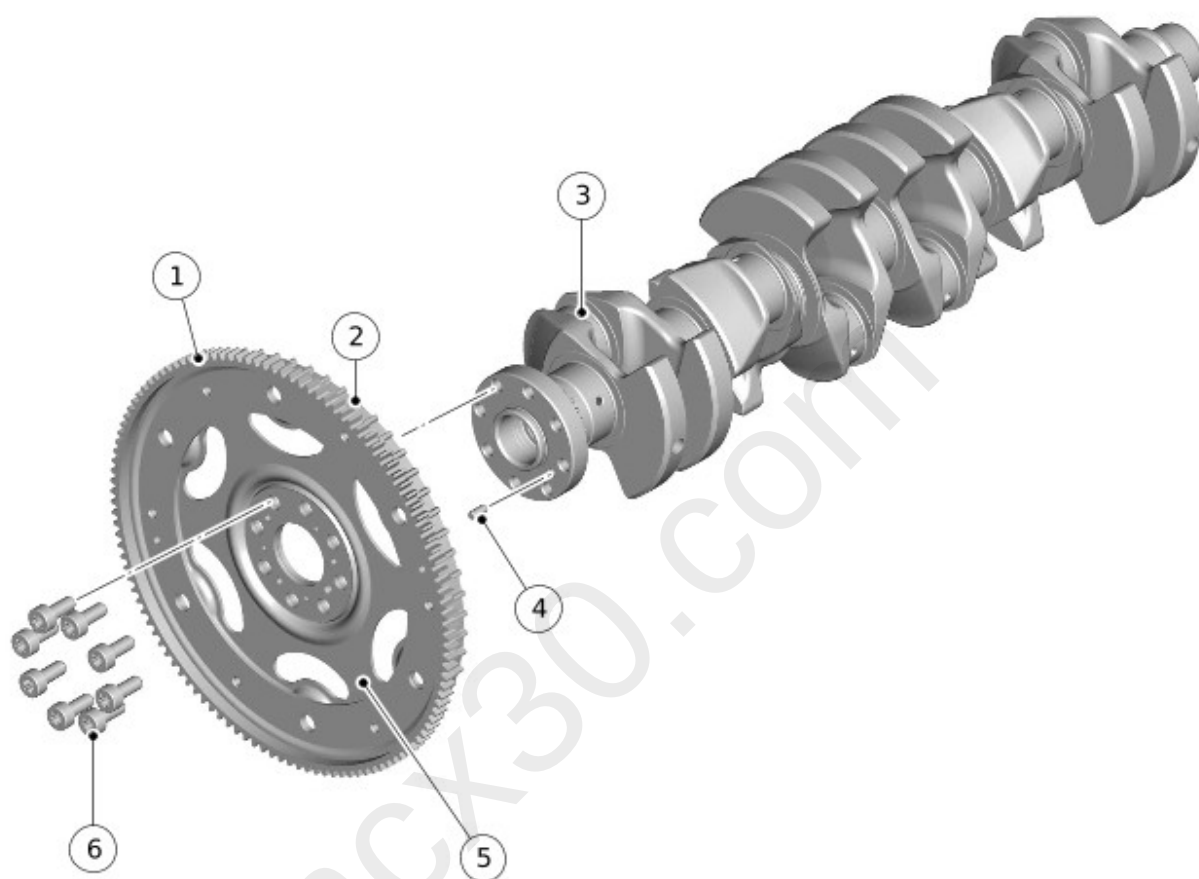
At the front of the crankshaft, a tuned torsional vibration damper is incorporated into the crankshaft pulley/damper assembly. The crankshaft pulley/damper is located over a roll pin that is pressed into the front end of the crankshaft. The 4 bolts secure the crankshaft pulley to the crankshaft. The crankshaft pulley/damper drives the accessory drive belt for the ancillary components.

For additional information, refer to: [Accessory Drive](#) (303-05C Accessory Drive - INGENIUM I6 3.0L Petrol, Description and Operation).

The tuned torsional vibration damper is incorporated into the crankshaft pulley. The torsional vibration damper is designed to reduce peak levels of torsional vibration inside the crankshaft, this is done through viscous and rubber damping technology. An O-ring seal provides a seal between the crankshaft pulley hub bore and the crankshaft nose outer diameter to prevent oil leakage during engine operation.

A timing mark is etched to the crankshaft pulley, which must be aligned to a corresponding timing feature on the front cover assembly. This position aligns the crankshaft to 50° After Top Dead Center (ATDC) on Cylinder 1. The torsional vibration damper assembly is not a serviceable component and must not be disassembled.

DRIVE PLATE



E238618

ITEM	DESCRIPTION
1	Starter ring gear
2	Reluctor ring
3	Crankshaft
4	Dowel pin - Drive plate
5	Drive plate
6	Bolt - Drive plate (quantity 8)

The drive plate is located at the rear of the crankshaft. A dowel pin in the crankshaft makes sure, that the drive plate is indexed correctly.

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 2 components are held together as an assembly by a form of clinching known as Tog-L-Loc®.

The drive plate is secured to the crankshaft with 8 sealant patched bolts. The bolts are single use components and must be replaced if removed. Before replacement bolts are used, the holes must be dry and free from oil.

The drive plate has 3 functions:

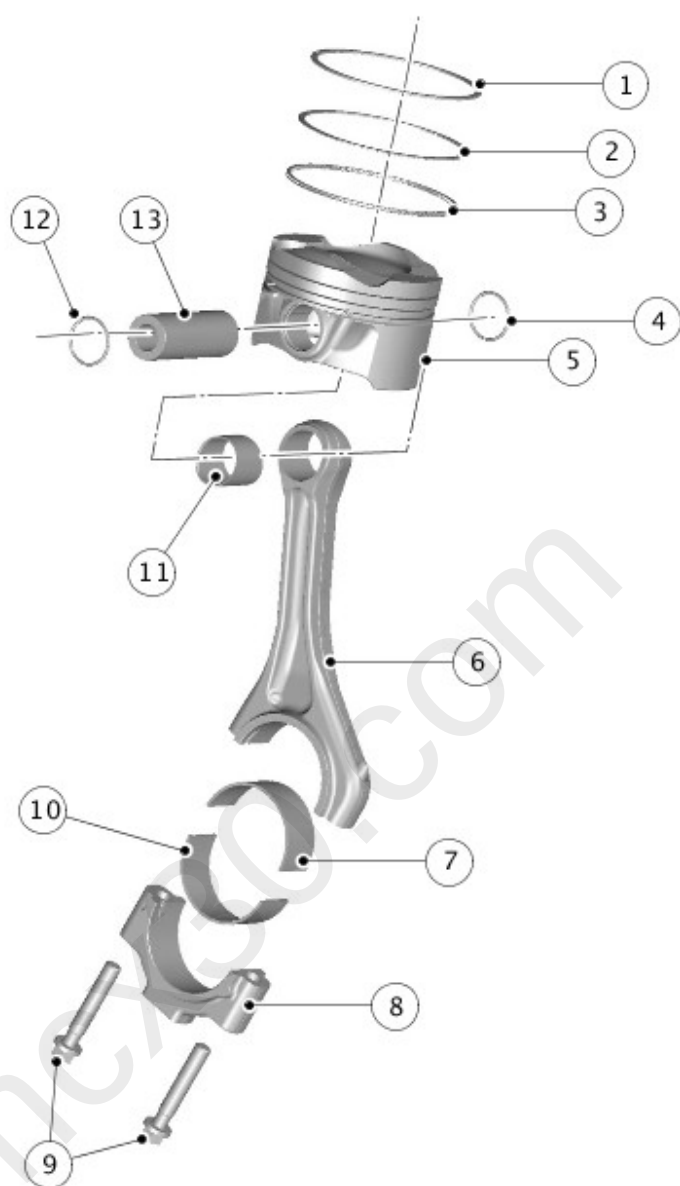
- To transfer drive from the crankshaft to the transmission.
- To transfer drive from the starter motor to the crankshaft.
- To provide the Engine Management System (EMS) with crankshaft speed and position through a reluctor ring and the Crankshaft Position Sensor (CKP).

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

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.

The 6 holes in the drive plate provide for the attachment of the torque converter. The torque converter transfers drive from the crankshaft to the automatic transmission.

PISTONS AND CONNECTING RODS



E195135

ITEM	DESCRIPTION
1	Upper compression ring
2	Lower compression ring
3	Oil control ring
4	Circlip
5	Piston
6	Connecting rod
7	Large end bearing - Upper

ITEM	DESCRIPTION
8	Connecting rod bearing cap
9	Bolt - Connecting rod bearing cap (quantity 2)
10	Large end bearing - Lower
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 provide precision re-assembly for bearing alignment. The connecting rod bearing caps are not selectable. Adjustment to take into account the 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. The crankshaft is laser etched with a string of 6 alpha characters in the order of crankshaft journals 1-6. A data matrix code contains the reference data for each large end bearing, installed to the engine. The correct large end bearings are sized with reference to a selection chart in order to achieve optimum running clearances.

For additional information, refer to: [Specifications](#) (303-01C Engine - INGENIUM I6 3.0L Petrol, Specifications).

There is only 1 grade of piston diameter. The pistons are marked to make sure correct assembly, with the marks facing the front of the engine. The top face of the piston has an arrow that must also point towards the front of the engine. The piston crown has a recess for optimization of the fuel/air mixture and combustion.

A 3 ring piston sealing system is used. The oil control ring is located in the bottom groove. The 2 compression piston rings are located in the upper grooves. The piston ring gaps must be positioned at 120° to each other.

The pistons are cooled with engine oil from 6 piston cooling oil jets installed in the cylinder block.

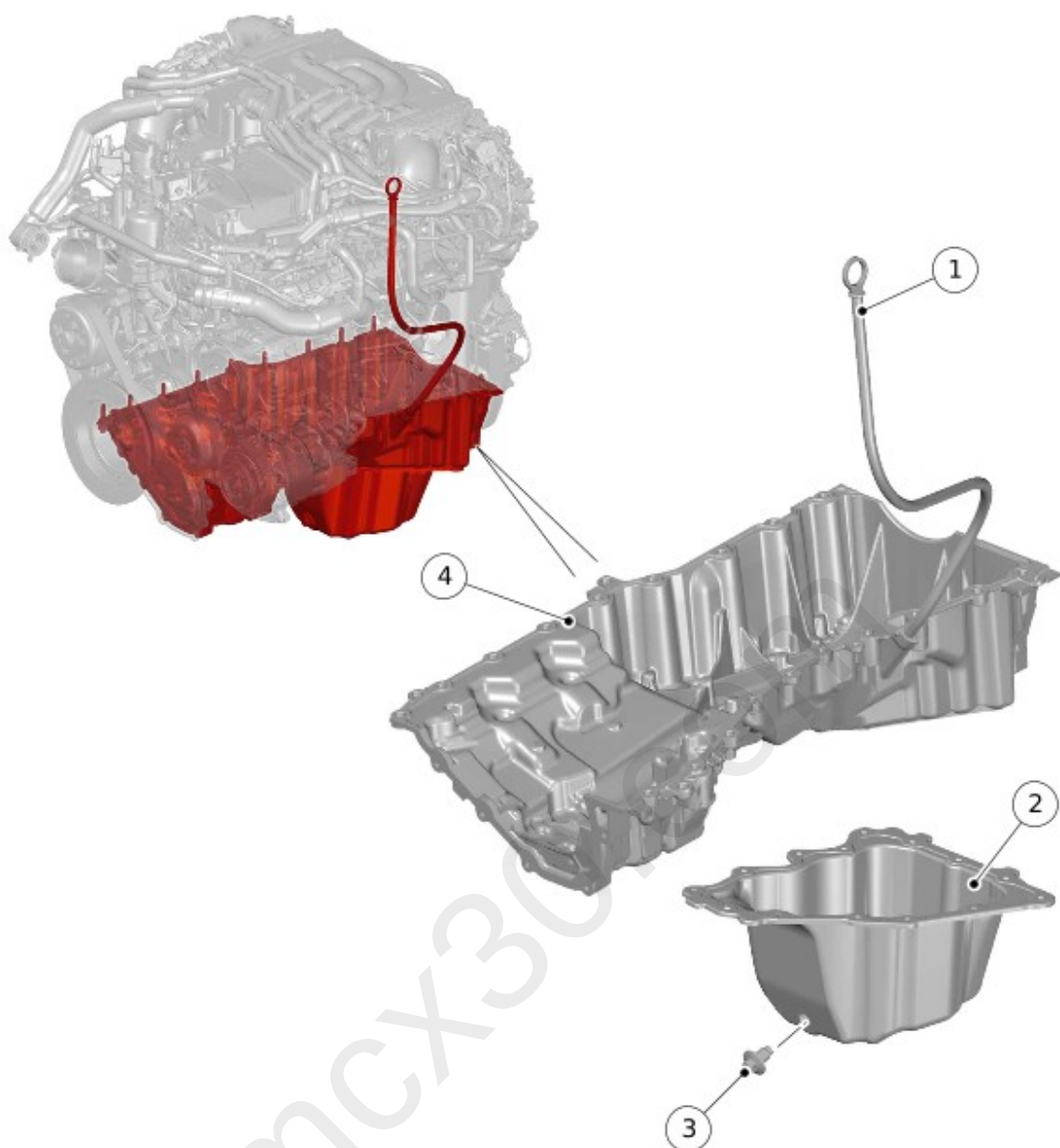
The pistons are attached to the connecting rods with a gudgeon pin, which is secured with 2 circlips. The gudgeon pin is located through the small end bearing in the connecting rod. The gudgeon pin allows the piston to articulate with the linear movement of the connecting rod. The circlips locate in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

OIL PAN



NOTE:

Use a new oil pan drain plug and seal after they are removed.



E238730

ITEM	DESCRIPTION
1	Oil level gauge pipe
2	Oil pan
3	Oil pan drain plug
4	Oil pan extension

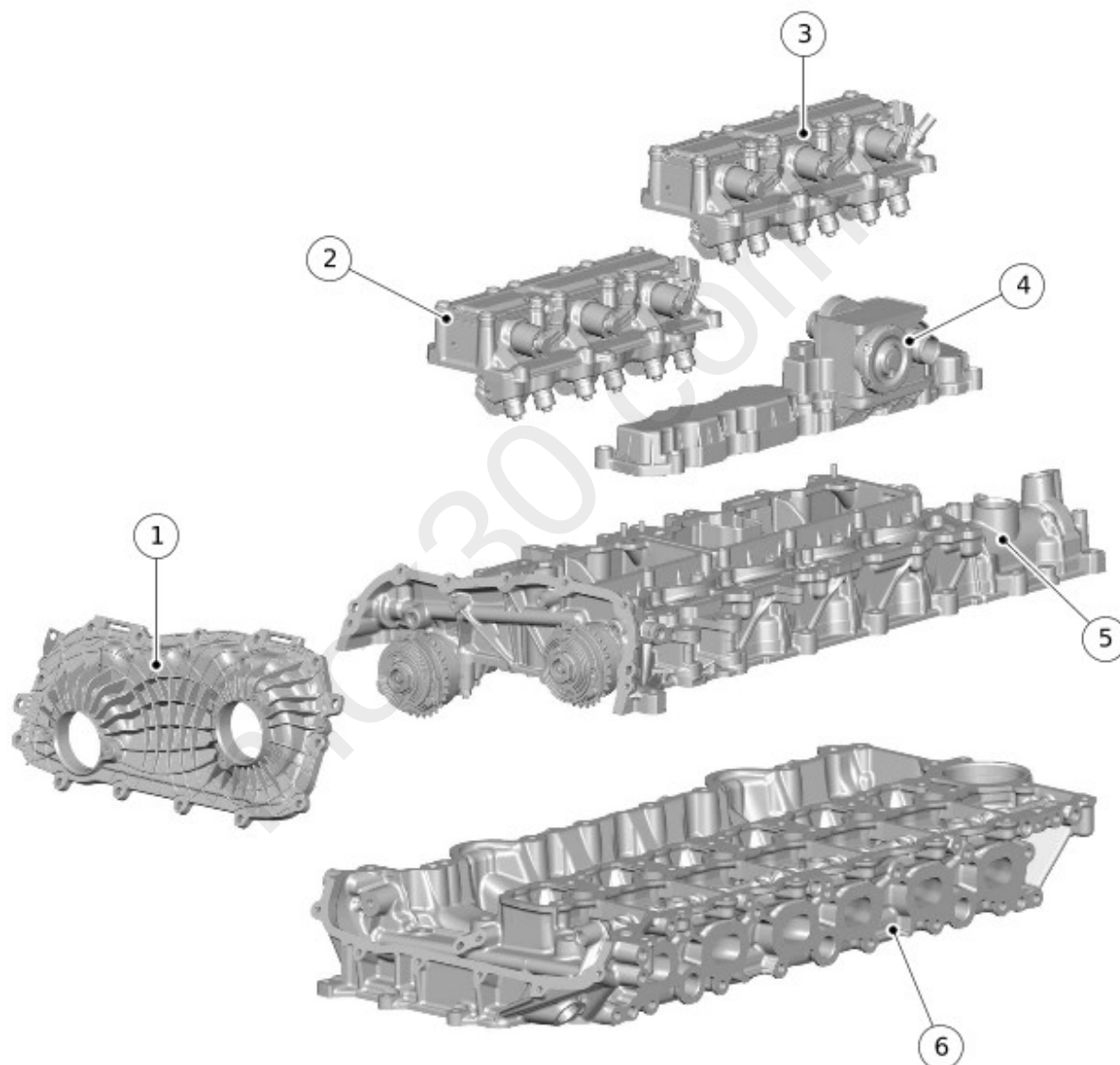
The oil pan is a 2-piece assembly and comprises the oil pan and the oil pan extension. The oil pan extension is cast from aluminum alloy using a high pressure die cast process, and located on the underside of the cylinder block. The oil pan extension is sealed to the cylinder block with a bead of room temperature vulcanization sealant. The oil pan extension is secured with 17 bolts and 2 shoulder bolts, which locate the oil pan extension to the cylinder block.

The oil pan extension covers the windage tray and the variable flow oil pump with integral vacuum pump. The oil pan extension comprises a machined hole, which provides the attachment of the oil level gauge pipe. The oil pan extension also collects engine oil returning from the cylinder heads and crankshaft lubrication.

The pressed steel oil pan is located at the underside of the oil pan extension. The oil pan is sealed to the oil pan extension with room temperature vulcanization sealant, and secured with 14 bolts. The oil pan covers the oil pick-up pipe. The oil drain plug and seal is located at the front of the oil pan.

CYLINDER HEAD

Cylinder Head Structural Components

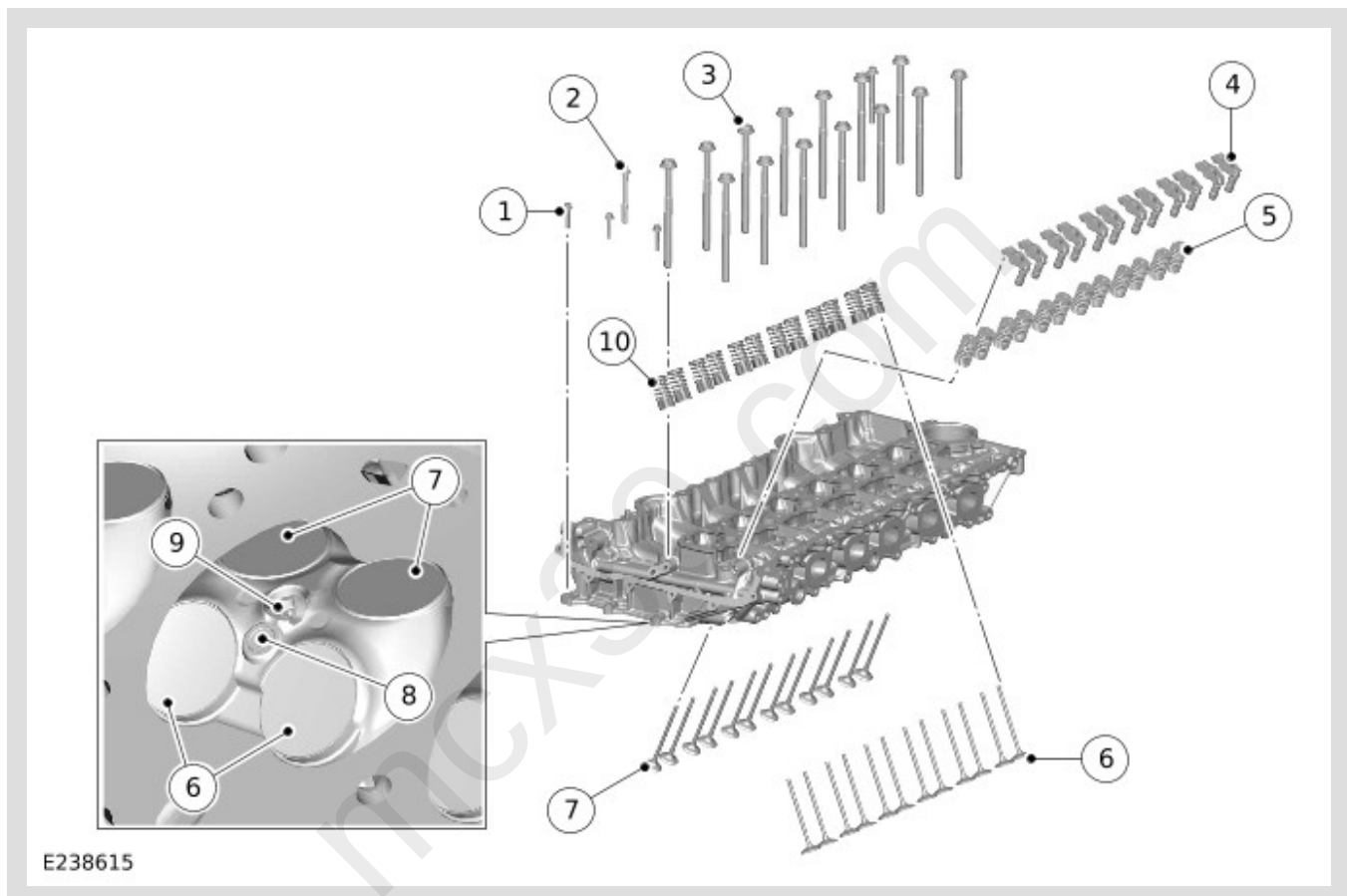


E238614

ITEM	DESCRIPTION
1	Upper timing chain cover

ITEM	DESCRIPTION
2	Rear Continuous Variable Valve Lift (CVVL) assembly
3	Front CVVL assembly
4	Engine vent oil separator
5	Camshaft carrier
6	Cylinder head

Cylinder Head Components



ITEM	DESCRIPTION
1	Bolt (quantity 3)
2	Bolt (quantity 2)
3	Bolt - Cylinder head (quantity 14)
4	Roller finger cam follower and hydraulic valve tappet (quantity 12)
5	Exhaust valve spring (quantity 12)
6	Intake valve (quantity 12)
7	Exhaust valve (quantity 12)

ITEM	DESCRIPTION
8	Fuel injector (quantity 6)
9	Spark plug (quantity 6)
10	Intake valve spring (quantity 12)

The cylinder head is cast from aluminum alloy and heat treated.

The cylinder head provides location for the following components:

- The 24 valves. (4 for each cylinder)
- The 6 fuel injectors.
- The 6 spark plugs.
- The cylinder head temperature sensor.
- The oil filter element.

A single layer water jacket cools the cylinder head.

There are 19 bolts to secure the cylinder head to the cylinder block. The cylinder head bolts are single use components and must be replaced if they are removed. Before replacement bolts are used, the holes must be dry and free from oil.

The cylinder head assembly contains the following components:

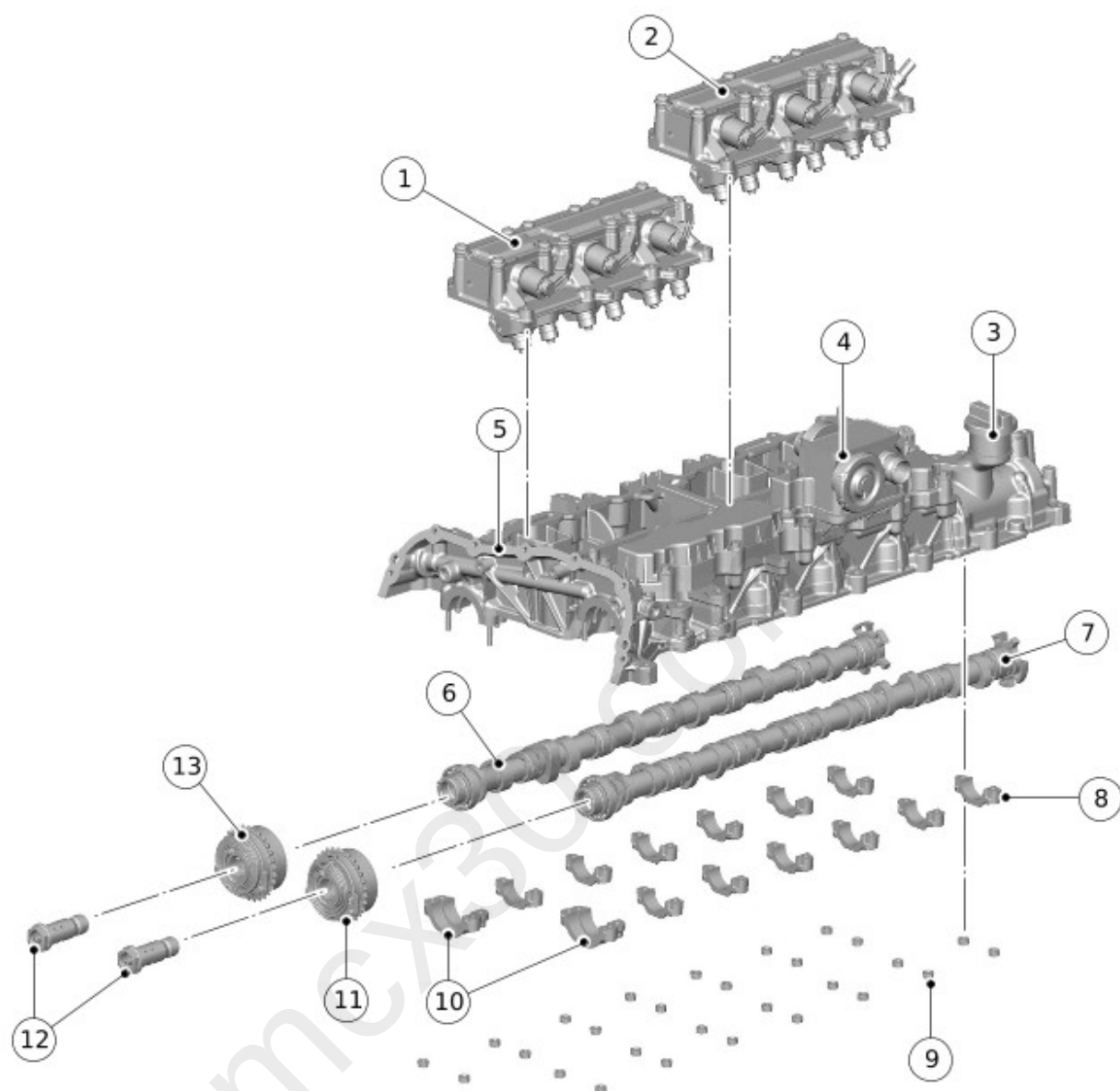
- The cylinder head
- The camshaft carrier
- The 2 Continuous Variable Valve Lift (CVVL) assemblies
- The engine vent oil separator
- The timing chain cover.

Each cylinder is served by 4 valves. To help achieve the required gas flow characteristics, these are arranged asymmetrically around the cylinder bore.

The valves are a conventional arrangement, with a valve and spring assembly retained by a valve collet. The hydraulic valve tappet on the exhaust valves make sure that there is no lash between the camshaft lobe and the roller finger cam follower.

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

CAMSHAFT CARRIER



E238610

ITEM	DESCRIPTION
1	Rear Continuous Variable Valve Lift (CVVL) assembly
2	Front CVVL assembly
3	Oil filler cap
4	Engine vent oil separator
5	Camshaft carrier
6	Intake camshaft
7	Exhaust camshaft

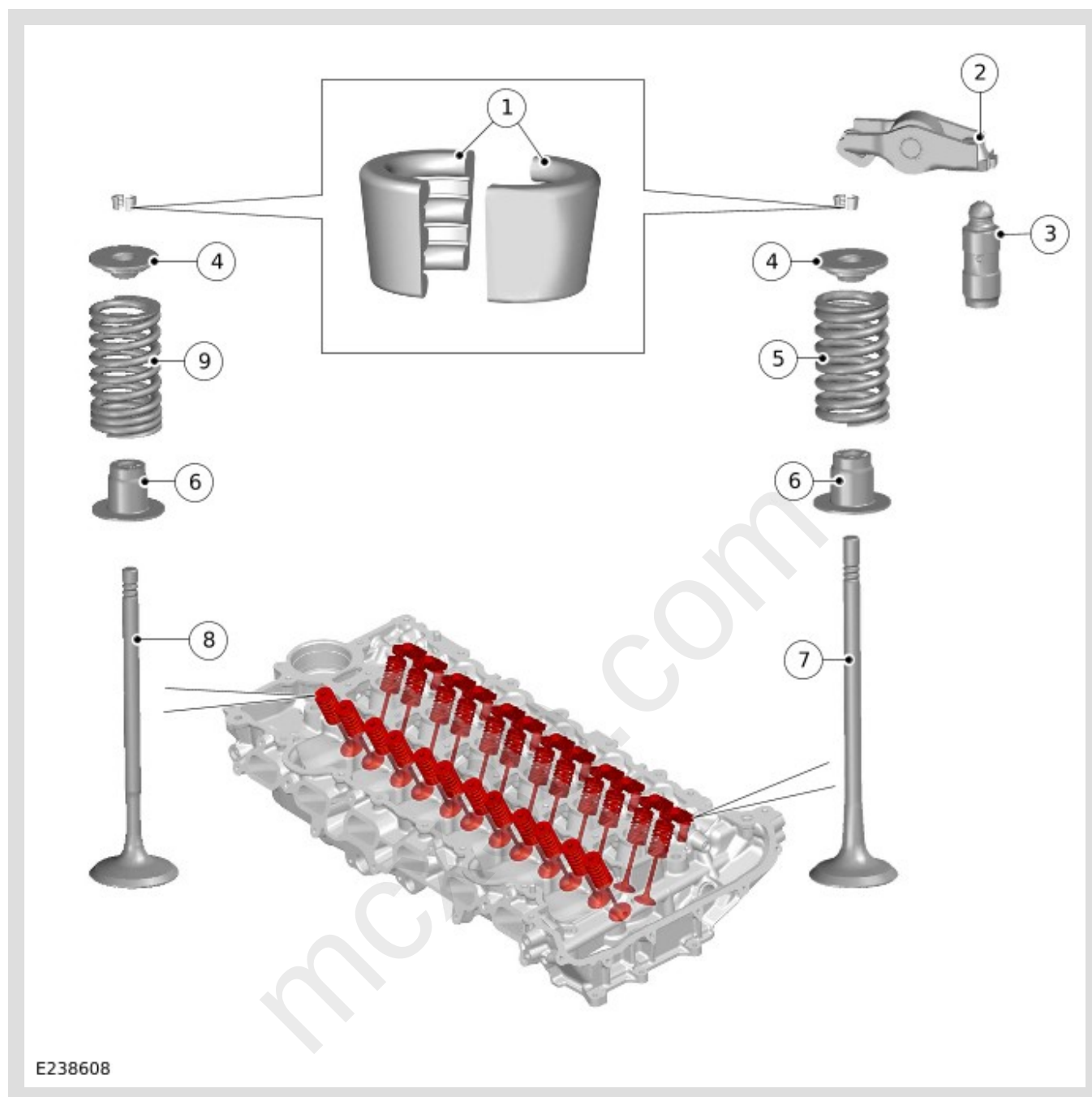
ITEM	DESCRIPTION
8	Camshaft cap (quantity 12)
9	Nut - Camshaft cap (quantity 28)
10	Rear camshaft cap
11	VCT actuator - Exhaust
12	Bolt - VCT actuator
13	VCT actuator - Intake

The structural camshaft carrier is cast from aluminum alloy using a high pressure die cast process. The camshaft carrier is located on 2 dowel pins in the cylinder head and secured with bolts. A steel gasket seals the camshaft carrier to the cylinder head.

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

The camshaft carrier also provides locations for the CMPs, the oil filler pipe and the engine vent oil separator. The camshaft carrier has high pressure oil bores feeding the VCT actuators and provides thrust face lubrication. A low pressure oil gallery returns oil from the engine vent oil separator back to the cylinder block and the oil pan.

VALVES AND ROLLER FINGER CAM FOLLOWERS



ITEM	DESCRIPTION
1	Valve spring collet (quantity 48)
2	Roller finger cam follower (quantity 12)
3	Hydraulic valve tappet (quantity 12)
4	Valve spring retainer (quantity 24)
5	Exhaust valve spring (quantity 12)
6	Valve spring seat and valve stem seal (quantity 24)
7	Exhaust valve (quantity 12)

ITEM	DESCRIPTION
8	Intake valve (quantity 12)
9	Intake valve spring (quantity 12)

The engine uses 24 valves:

- There are 12 intake valves
- There are 12 exhaust valves.

The intake valves are 30 mm (1.18 in) diameter and the exhaust valves are 28 mm (1.10 in) diameter. The larger intake valve size provides better intake air flow into the combustion chamber, which enhance more engine power output at higher Revolutions Per Minute (RPM).

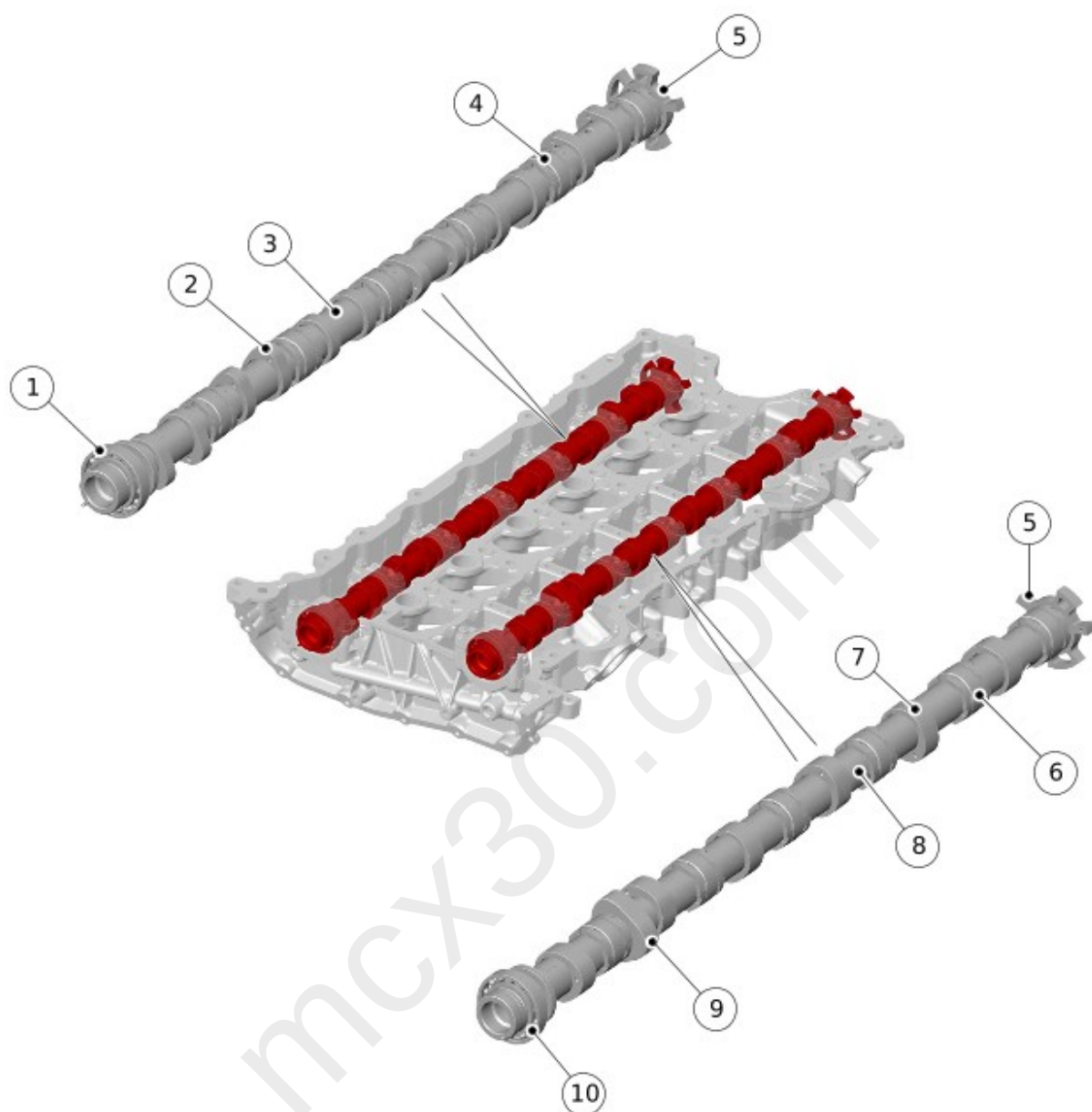
The intake valve stems are 5.47 mm (0.22 in) and exhaust valve stems are 5.46 mm (0.21 in) diameter. These allow reduced flow interruption through the intake and exhaust ports, improving performance and emissions.

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 exhaust valves are opened mechanically by the roller finger cam followers, which operate directly with roller to camshaft lobe rolling contact. The clearance between the roller and camshaft lobe is compensated with the use of the hydraulic valve tappet. This makes sure that all roller finger cam followers are in contact with the camshaft lobes throughout engine operation.

The intake valves are opened by 2 Continuous Variable Valve Lift (CVVL) assemblies, controlled by the PCM.

CAMSHAFTS



E238609

ITEM	DESCRIPTION
1	Ball bearing - Exhaust camshaft
2	Exhaust camshaft lobe (quantity 12)
3	Exhaust camshaft
4	Needle roller bearing - Exhaust camshaft (quantity 6)
5	Reluctor ring - CMP
6	Needle roller bearing - Intake camshaft (quantity 6)
7	Intake camshaft lobe (quantity 6)

ITEM	DESCRIPTION
8	Intake camshaft
9	HP fuel pump lobe
10	Ball bearing - Intake camshaft

The engine is equipped with a Double Overhead Camshaft (DOHC) configuration, which uses 2 camshafts:

- There is 1 intake camshaft
- There is 1 exhaust camshaft.

The lobes on the exhaust camshaft control the opening and closing of the exhaust valves through the roller finger cam followers. There is a lobe that drives the HP fuel pump.

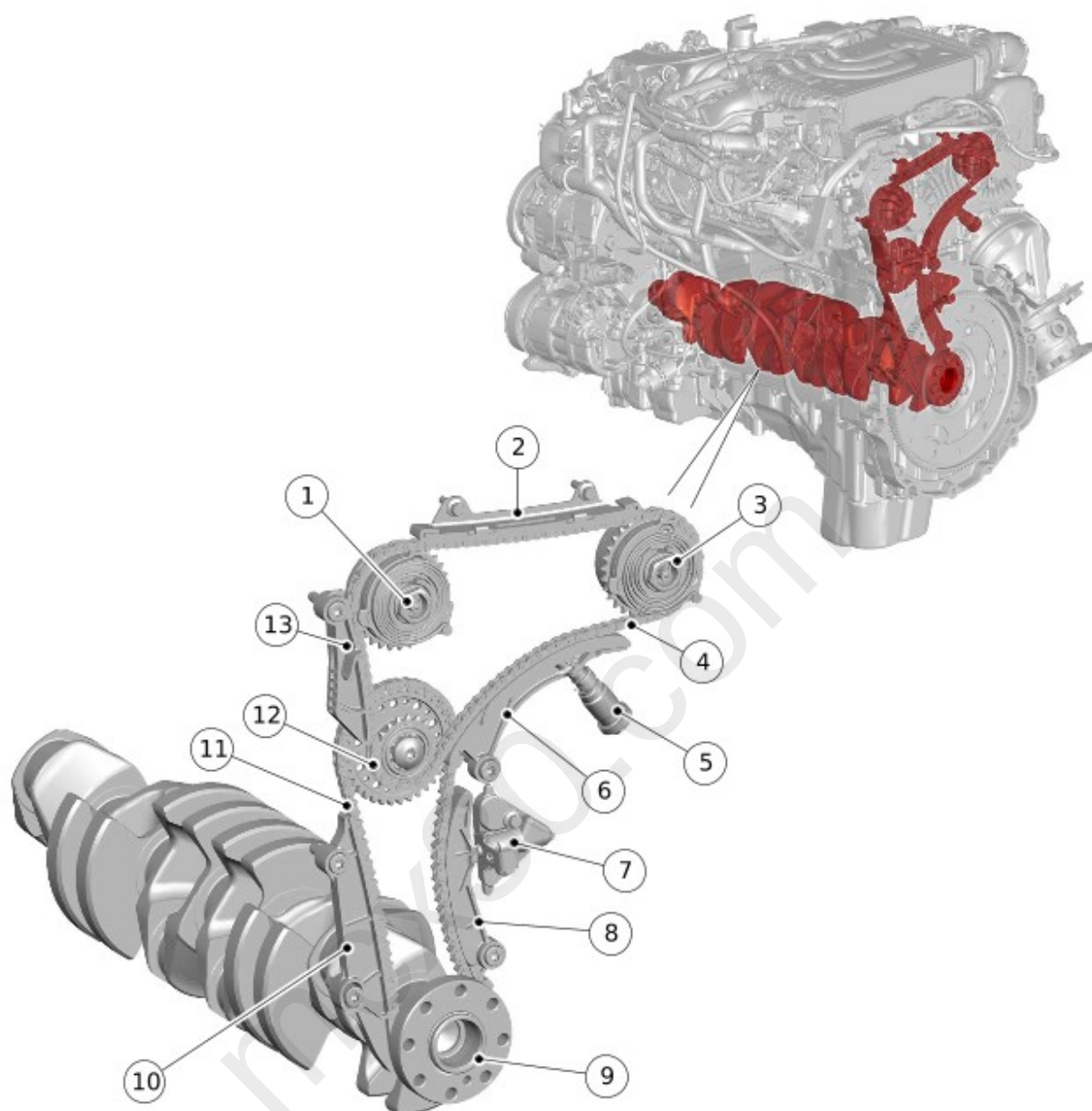
The lobes on the intake camshaft control the opening and closing of the intake valves through the 2 Continuous Variable Valve Lift (CVVL) assemblies.

The camshafts run on needle roller bearings to reduce friction and minimize the breakaway torque on engine startup. 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 support the install 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 forged 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 and the VCT actuator. Each drive adapter is equipped with a timing pin. The timing pin helps to locate and time the rotor of the VCT actuator relative to the camshaft during assembly. Each camshaft has a pressed-on reluctor ring for use with the CMPs.

The VCT sprocket is driven by the crankshaft through the timing chain. The torque is transmitted from the VCT sprocket to the camshaft by hydraulic means. The VCT actuator adjusts the timing of both camshafts, increasing engine efficiency and performance as required. The reluctor wheels are pressed on to the opposite end of the exhaust camshafts which are monitored by the CMP. The CMP signal is used by the PCM and enables the PCM to determine the position of the camshafts. The camshafts can then be phased by the VCT actuators.

CAMSHAFT TIMING - TIMING CHAIN



E238736

ITEM	DESCRIPTION
1	VCT actuator - Intake
2	Secondary timing chain guide - Upper
3	VCT actuator - Exhaust
4	Secondary timing chain
5	Secondary timing chain tensioner
6	Secondary timing chain tensioner guide
7	Primary timing chain tensioner

ITEM	DESCRIPTION
8	Primary timing chain tensioner guide
9	Crankshaft
10	Primary timing chain guide
11	Primary timing chain
12	Idler sprocket
13	Secondary timing chain guide - Lower

There are 2 bushed timing chains used to drive the camshafts through an intermediate idler sprocket. The primary camshaft chain is driven by a sprocket on the crankshaft, which in turn drives the intermediate idler sprocket. The secondary camshaft chain is driven by the intermediate idler sprocket and then passed over the sprockets on the intake and exhaust camshafts. The camshaft sprockets are integrated with the VCT actuator assemblies.

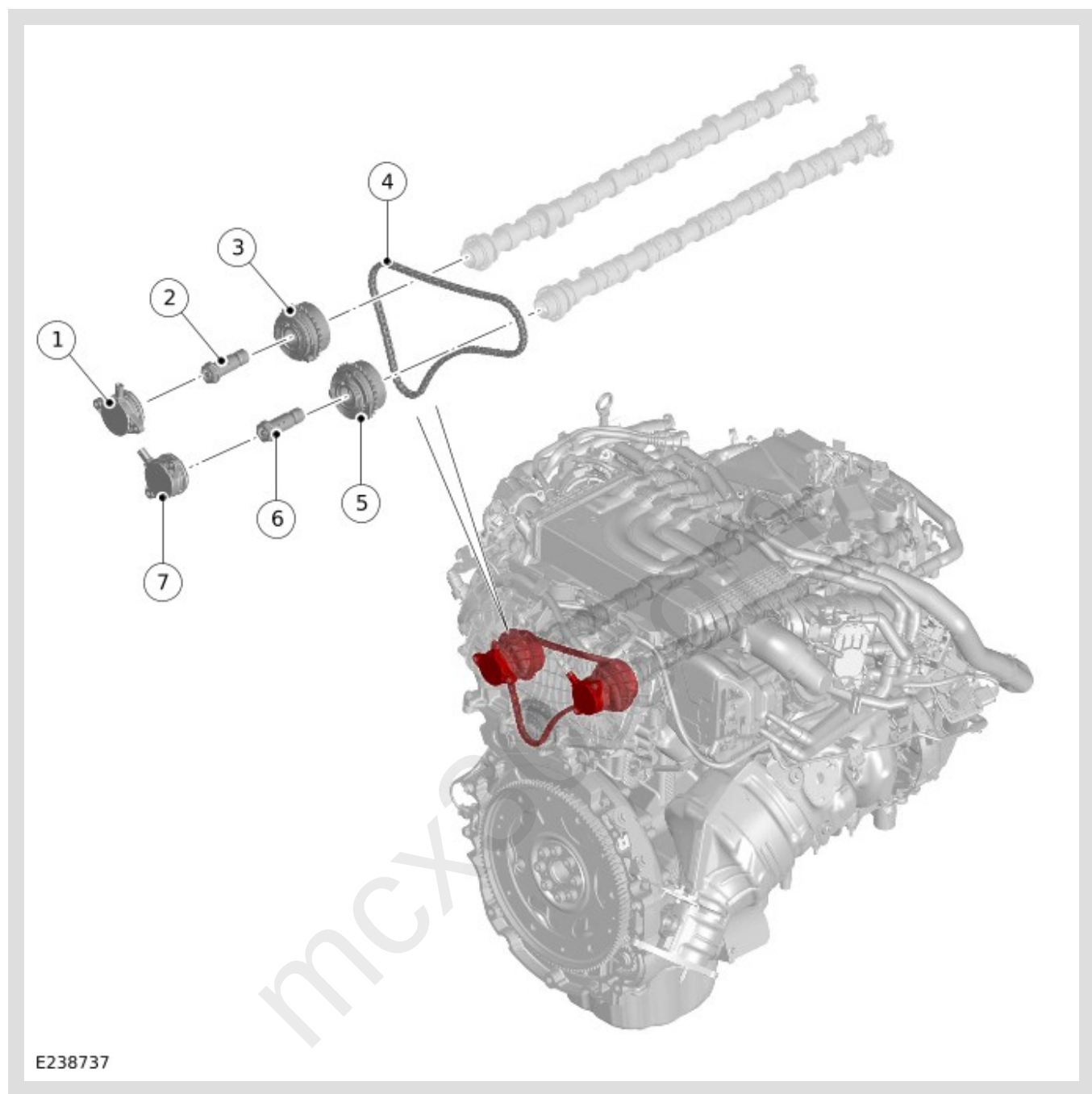
The primary timing chain has a fixed timing chain guide, which is secured to the cylinder block. A chain tensioner is attached to the primary timing chain tensioner guide. The timing chain tensioner guide can rotate around a pivot bolt. The primary timing chain has a mechanical tensioner operated by spring tension to apply a controlled tension to the timing chain. The primary timing chain tensioner receives pressurized engine oil from the variable flow oil pump with integral vacuum pump.

The secondary timing chain has 2 fixed timing chain guides, which are secured to the cylinder head and the camshaft carrier. 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 allow 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 make sure that the correct crankshaft to camshaft timing is achieved. Both the primary and secondary timing chains have gold colored links, which are aligned with timing marks on the sprockets.

VARIABLE CAMSHAFT TIMING



ITEM	DESCRIPTION
1	VCT solenoid - Intake
2	Center bolt - VCT actuator - Intake
3	VCT actuator - Intake
4	Secondary timing chain
5	VCT actuator - Exhaust
6	Center bolt - VCT actuator - Exhaust
7	VCT solenoid - Exhaust

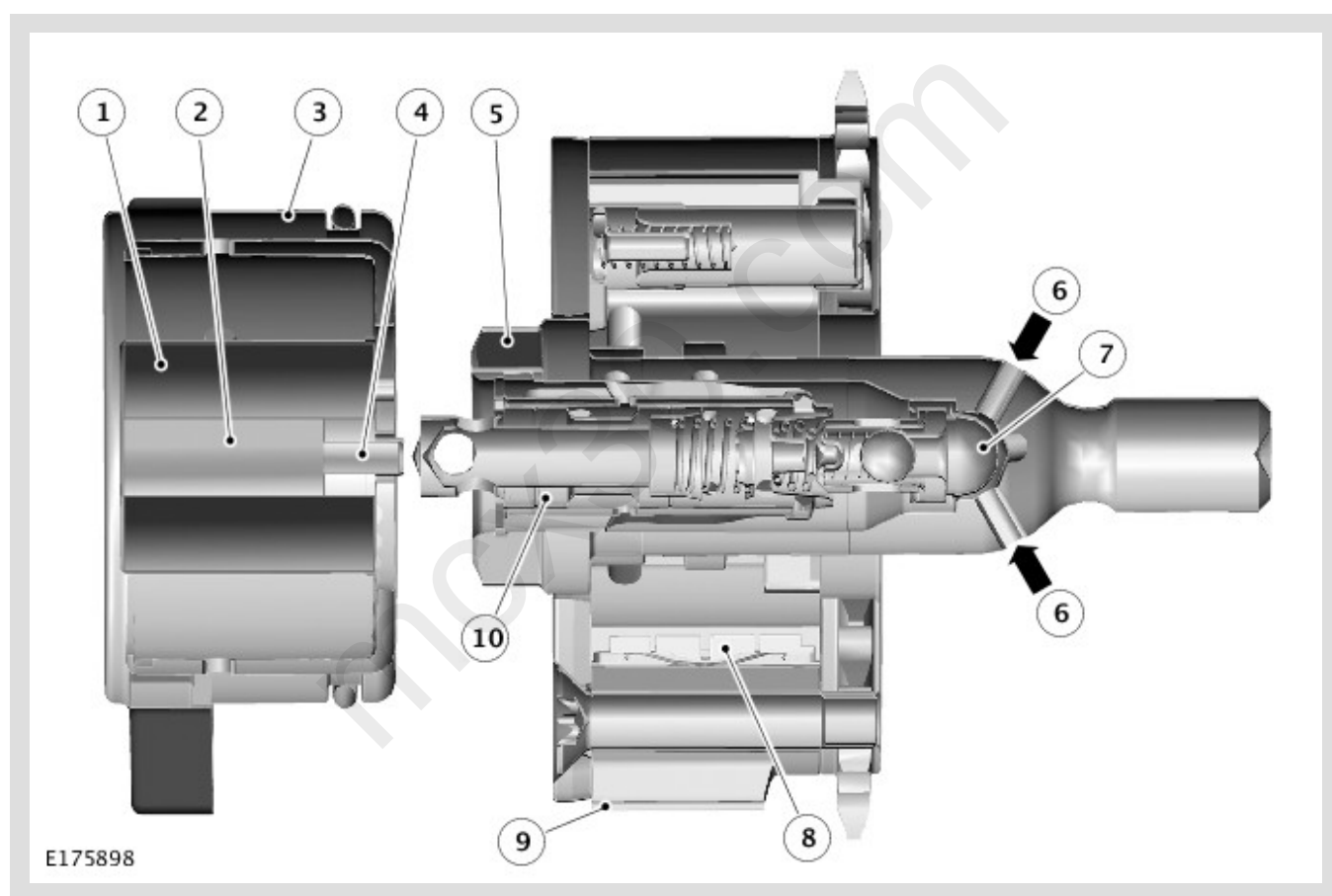
The PCM controls the VCT system using information from the following components:

- The 2 CMPs
- The CKP.

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

Each VCT actuator is located on the camshaft at the rear of the engine and is secured with a center bolt. Each center bolt contains an oil control valve.

Variable Camshaft Timing Actuator



ITEM	DESCRIPTION
1	Solenoid coil
2	Solenoid core
3	VCT solenoid assembly
4	Solenoid pintle pin
5	Center bolt

ITEM	DESCRIPTION
6	Pressurized engine oil supply
7	Filter
8	Rotor
9	VCT actuator assembly
10	Spool valve

The VCT actuators are operated by the VCT solenoids that are controlled by the PCM. The PCM can operate the VCT solenoids to move the pintle pin to a predetermined position to control the flow of pressurized engine oil into the VCT actuators.

When advance or retard camshaft timing is required the PCM operates the VCT solenoid. The VCT solenoid operation extends the pintle pin, which moves the spool valve. The spool valve directs the pressurized engine oil into 1 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.

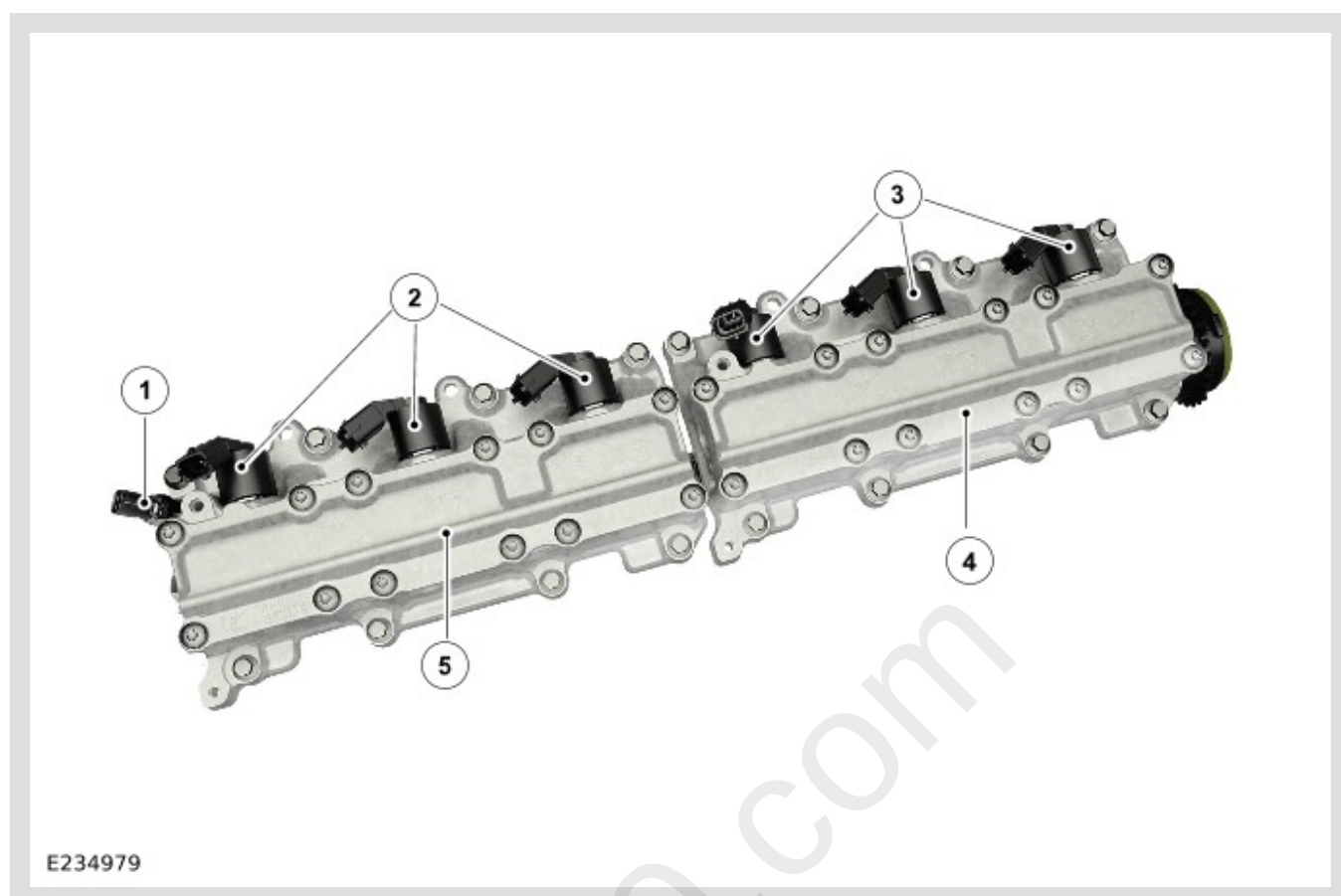
Further movement of the solenoid pintle pin will push the spool valve into a known (controlled) position. The oil will pass through channels within the center bolt into the VCT actuator chambers. The pressurized engine oil rotates the internal rotor in the VCT actuator, which is secured to the camshafts. This in turn changes the engine timing.

The available camshaft adjustment is the following:

- Total 70° crankshaft angle towards advance in the intake camshaft.
- Total 50° crankshaft angle towards retard in the exhaust camshaft.

Each camshaft VCT actuator has 3 hydraulic chambers. Residual camshaft torque is used to make sure the VCT actuator is returned to the 'base' position as quickly as possible. The pressurized engine oil is supplied from the variable flow oil pump and must be mapped to deliver controlled oil pressure to the VCT actuator.

CONTINUOUS VARIABLE VALVE LIFT ASSEMBLY

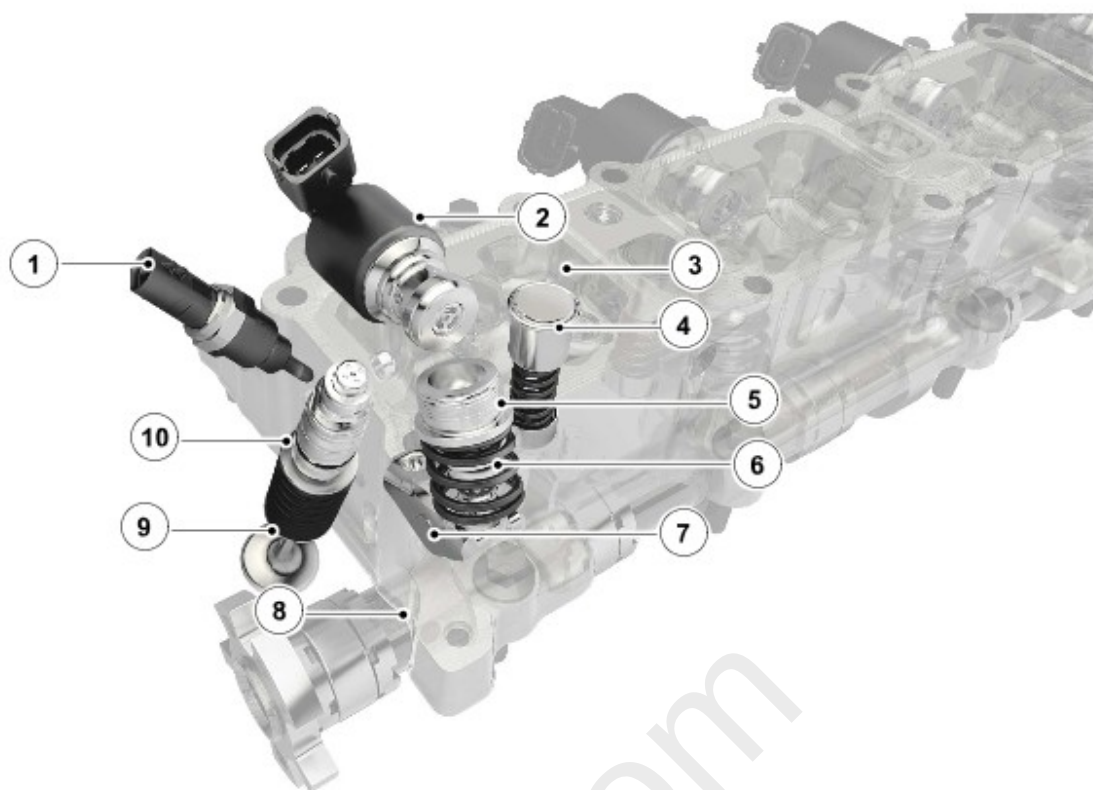


ITEM	DESCRIPTION
1	Temperature sensor
2	Solenoid valve (cylinders 1,2 and 3)
3	Solenoid valve (cylinders 4,5 and 6)
4	Rear CVVL unit
5	Front CVVL unit

The Continuous Variable Valve Lift (CVVL) assembly is a non-serviceable assembly with the exception of the temperature sensor. There are 2 CVVL assemblies attached to the engine. The front CVVL assembly controls the intake valves for cylinder 1 to 3, the rear CVVL assembly controls the intake valves for cylinder 4 to 6. Each CVVL assembly is fixed to the top of the camshaft carrier by 8 bolts.

The CVVL assemblies are a non-serviceable assemblies attached to the front CVVL unit.

There is no mechanical connection between the intake valves and the camshaft. Instead of direct operation, the intake camshaft operates 6 small oil pumps which charge 6 hydraulic accumulators. These act as hydraulic buffers between the camshaft and the intake valves. If less than full valve lift is required, oil is released from each accumulator by an electronic solenoid, reducing the lifting effect of the camshaft.



E234094

ITEM	DESCRIPTION
1	Temperature sensor
2	Solenoid valve
3	Intermediate pressure chamber
4	Pressure accumulator
5	High pressure chamber
6	Pump unit
7	Cam follower
8	Intake camshaft
9	Intake valve
10	Brake unit

As the camshaft rotates the cam lobe lift translates to pump piston movement and creates the hydraulic pressure achieved within the unit. The high pressure chamber is the hydraulic connection between the pump, brake unit and solenoid valve where pressures can be reached up to 150 bar (2,175 psi).

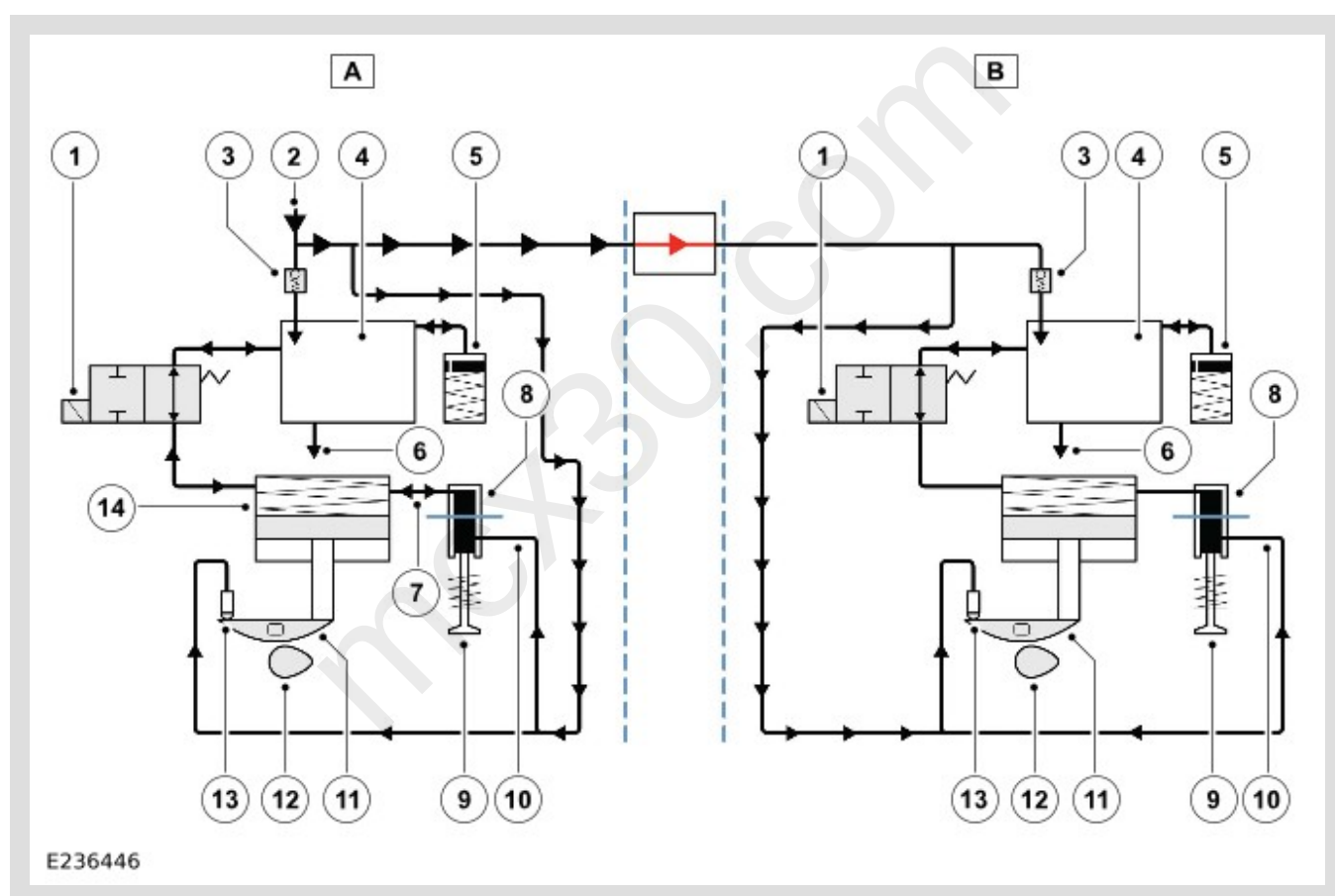
When the solenoid valve is closed the oil operates as a 'hydraulic pushrod' through the brake unit opening the intake valve. When the solenoid valve is opened, some of the oil pressure is relieved from the high pressure chamber back in

to the intermediate pressure chamber. This is effectively 'shortening' the length of the 'hydraulic pushrod' and the amount of valve lift.

When the solenoid valve is opened, the pressure accumulator feeds the relieved oil back to the high pressure chamber. This oil feed makes sure the chamber has a constant de-aerated oil supply.

The brake unit, as well as acting as a hydraulic valve lash adjustment, also regulates the valve closing speed. When the solenoid is opened for early intake valve closing, the valve spring causes the valve to enter a 'ballistic flight phase'. That is an 'uncontrolled' period of travel as the valve does not close by following the cam profile. To prevent excessive closure speeds that can cause damage to the valve, the brake unit acts as a hydraulic brake to provide a gentle, controlled seating of the valve.

The solenoid switching time is controlled by the PCM based on calculated engine load values from existing sensors. The CVVL temperature sensor is the only additional sensor for the system.



ITEM	DESCRIPTION
1	Normally open solenoid
2	Engine oil supply
3	Check valve
4	Intermediate chamber
5	Pressure accumulator

ITEM	DESCRIPTION
6	Oil return
7	CVVL oil temperature sensor
8	Brake unit
9	Intake valve
10	Engine oil supply
10	Engine oil supply
11	Roller finger cam follower
12	Camshaft
13	Hydraulic tappet
14	Pump unit
A	Front CVVL unit
B	Rear CVVL unit

⚠ CAUTION:

Use only engine oil that meets Jaguar Land Rover specification. Using incorrect engine oil can cause the CVVL system to malfunction.

The CVVL assembly ultimately allows the control of air in to the cylinder by delaying the valve opening, or by closing the valve early.

There are 4 CVVL operating modes:

- Full lift mode - the valves are fully opened and closed as during conventional control by the camshaft. This mode is used at high engine speeds to obtain maximum engine power.
- Late Intake Valve Opening Mode (LIVO) - the opening of the intake valves are delayed when starting the engine and during the engine idle. The valves open for a shorter period and at a lower lift providing precise control of the exact amount of air entering the cylinder. As a result, fuel economy is improved during idling periods. During a cold start, only a small amount of cold air enters the cylinder, meaning the engine starts more easily.
- Early Intake Valve Closing Mode (EIVC) - is activated during low to medium engine speeds. The intake valves are closed hydraulically before the camshaft profile would normally allow. This reduce pumping losses, increases the engine output and prevents an undesirable backflow of the fuel mixture into the intake ports.
- Composite mode - at very low engine speeds and loads, a combination of the LIVO mode and the EIVC mode is used as it provides a stable combustion.

Continuous Variable Valve Lift Solenoid Valve

 NOTE:

The Continuous Variable Valve Lift (CVVL) solenoids cannot be replaced individually. In the event of a solenoid failure, the entire CVVL unit is to be replaced.



There are 6 solenoids in the CVVL system. Each solenoid is supplied with power supply and ground from the PCM. The PCM controls the solenoid position, using Pulse Width Modulated (PWM) signals.

To enable the rapid action of the solenoid valve, a special operating strategy was developed with the lowest possible current requirements. This resulted in a current profile consisting of several phases.

The solenoid normally has no power supply and is in the open position. At the first phase of activation the solenoid valve is supplied with a current, which pre-magnetise the solenoid but does not switch the valve.

In order to allow a rapid and precise energizing procedure, an increased current is applied at the exact time of switching. This is determined by the PCM depending on sensor input for the current operating conditions.

After the CVVL solenoid valve is fully activated, the current is reduced to a holding current, which maintains the solenoid valve in the closed position. Depending on operating conditions, the PCM software controls the point in time at which the solenoid opens by completely switch off the holding current.

In the event of a CVVL solenoid failure, a total loss of valve lift occurs on the related cylinder and the engine enters a 'limp-home' mode, running on the 5 remaining cylinders. In this case, the driver can experience misfires and a reduction in engine performance.

Continuously Variable Valve Lift Brake Unit



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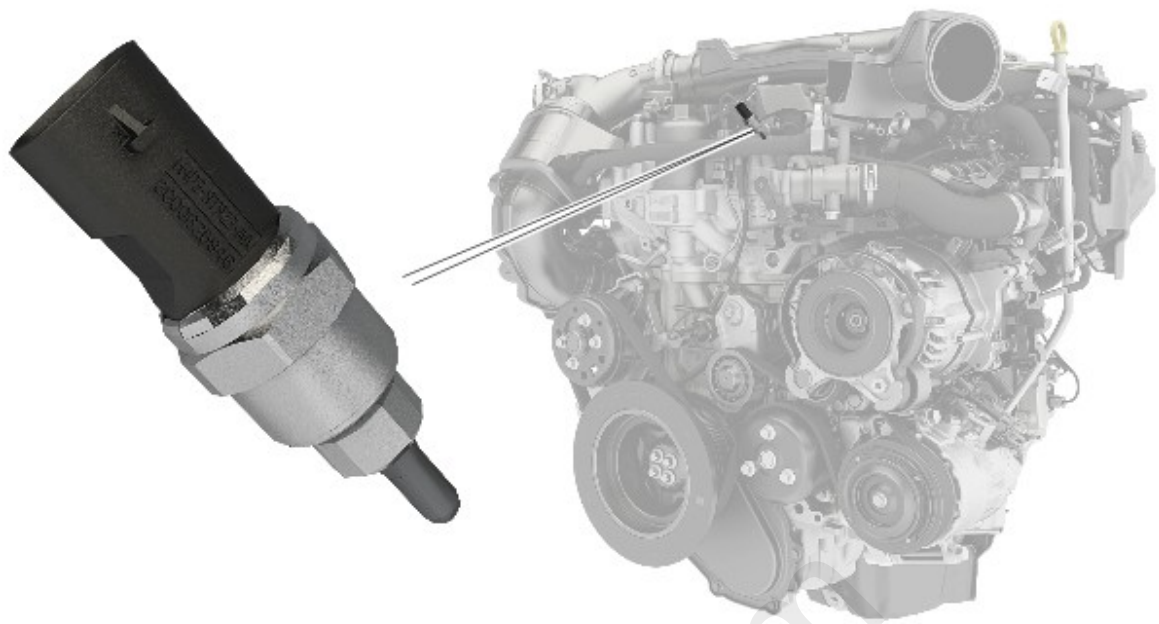
The CVVL brake unit is a slave cylinder that converts the hydraulic pressure into the intake valve movement. The pump unit hydraulic pressure is converted through a hydraulic valve lash adjustment element in the CVVL brake unit. The brake unit design not only gives a controlled closure of the valve but also enables a rapid opening speed. The rapid opening is because as the braking element of the unit is by-passed by the use of a check valve during the opening phase.

It is a critical part of the unit set up that the valve lash adjustment is reset. The valve lash adjustment must be completed when the unit is removed from the cylinder head.

Where it is necessary to remove and reinstall the CVVL assembly, the brake pistons must be reset. After the CVVL assembly installation the CVVL software calibration must be completed using the Jaguar Land Rover (JLR) approved diagnostic equipment.

For additional information, refer to: [Continuous Variable Valve Lift](#) (303-01C Engine - INGENIUM I6 3.0L Petrol, Removal and Installation).

Continuously Variable Valve Lift Oil Temperature Sensor



E234095

The CVVL oil temperature sensor is located on the front CVVL assembly. The sensor provides feedback to the PCM on the temperature of the high pressure oil in both CVVL assemblies.

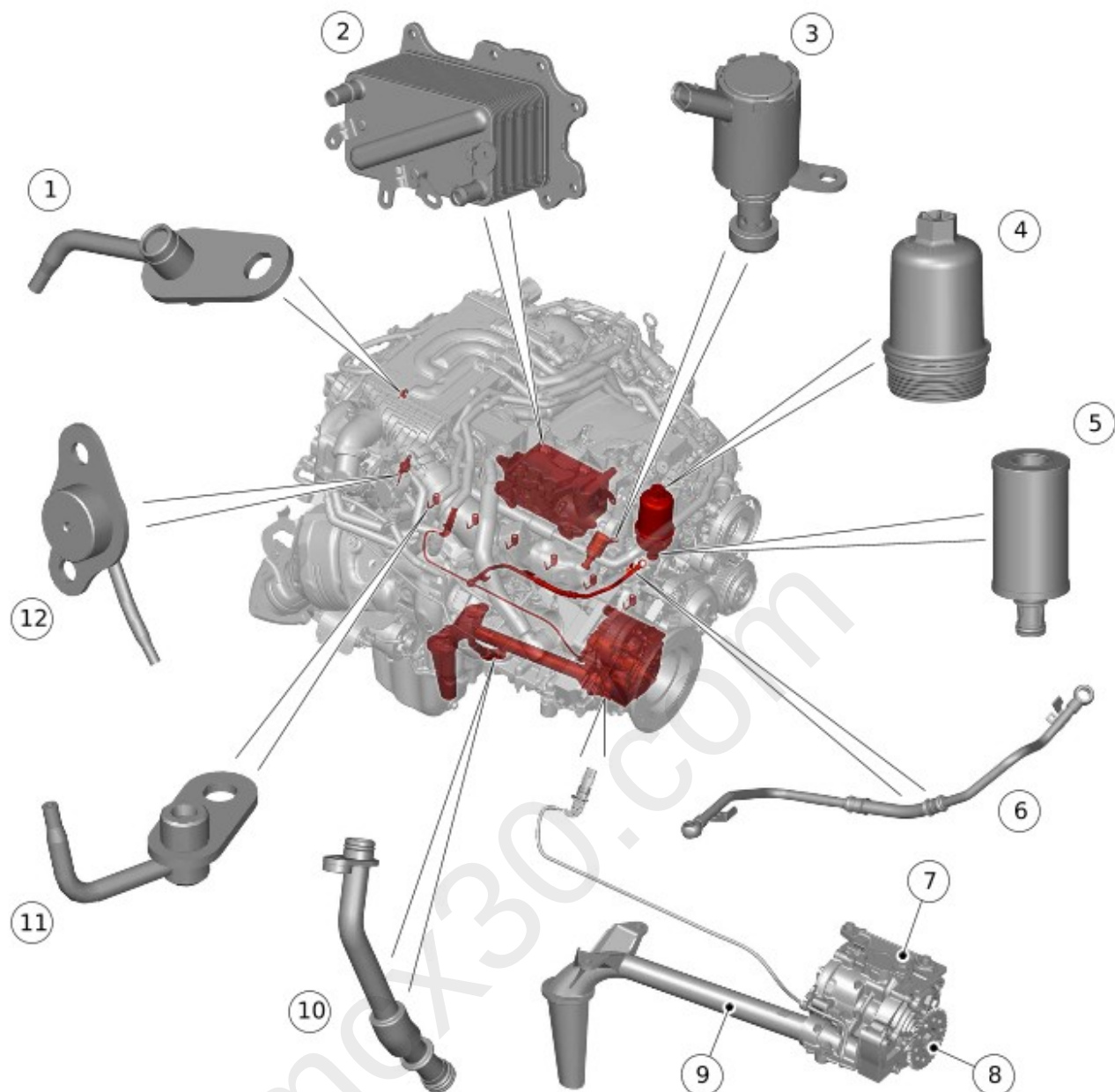
The PCM determines the oil viscosity and allows accurate solenoid switching time compensation across a wide engine temperature range -40°C (-40°F) to 150°C (302°F).

The sensor has a 2 pin connector which provides a temperature signal input to the PCM and a ground connection. The sensor has a Negative Temperature Coefficient (NTC) element and is specifically calibrated for use at low temperatures.

When the CVVL oil temperature sensor fails, there is reduced accuracy in the control of the CVVL system. The reduced accuracy causes a slight reduction in performance and fuel economy.

LUBRICATION SYSTEM

Lubrication System Components



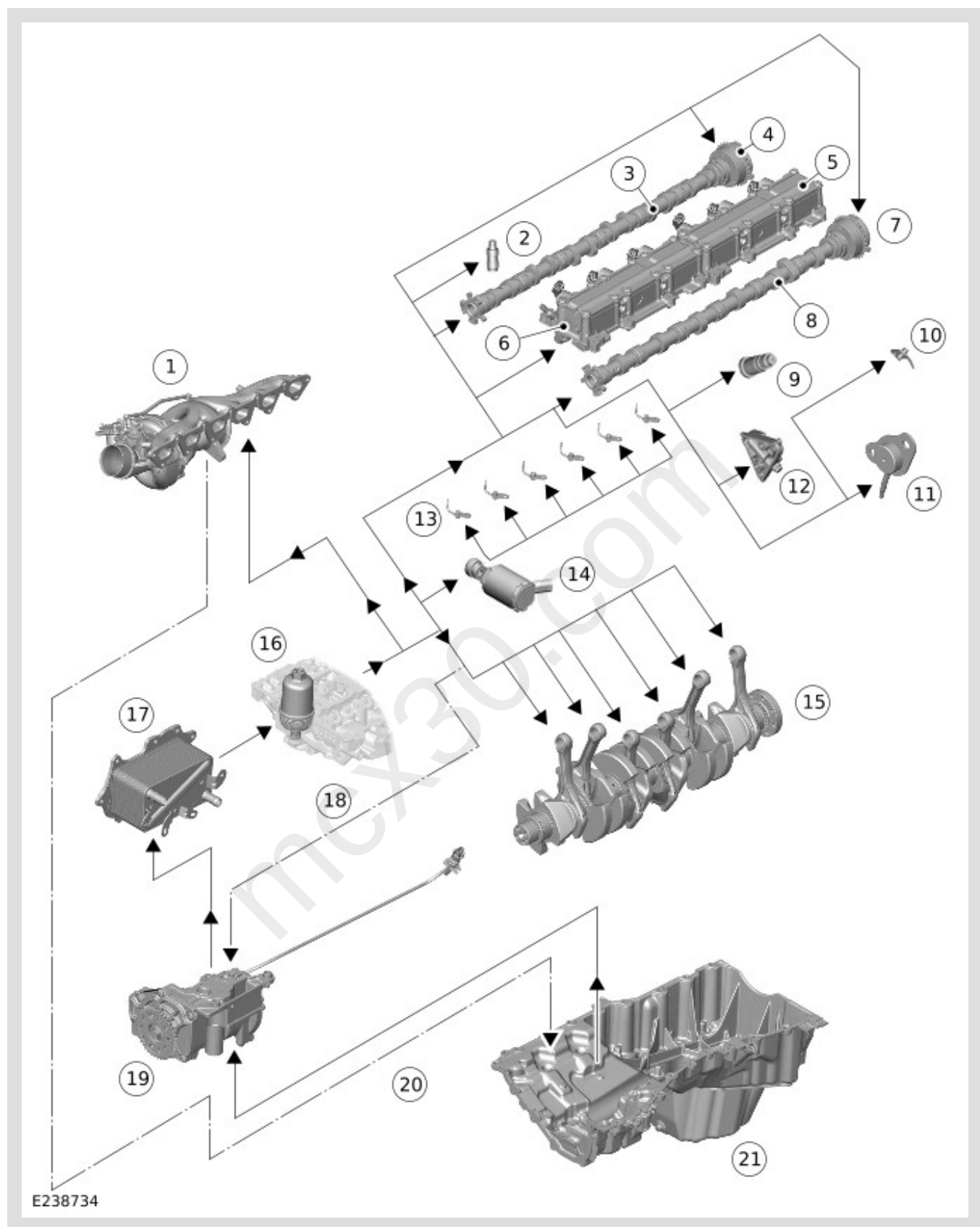
E238731

ITEM	DESCRIPTION
1	Secondary timing chain oil jet
2	Oil cooler
3	Piston cooling oil jet solenoid
4	Oil filter cap
5	Oil filter element
6	Oil supply pipe - Turbocharger
7	Variable flow oil pump with integral vacuum pump
8	Variable flow oil pump sprocket

ITEM	DESCRIPTION
9	Variable flow oil pump inlet pipe
10	Oil return pipe - Turbocharger
11	Piston cooling oil jet (quantity 6)
12	Primary timing chain oil jet

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LUBRICATION SYSTEM FLOW DIAGRAM



ITEM	DESCRIPTION
1	Turbocharger

ITEM	DESCRIPTION
2	Exhaust hydraulic valve tappet (quantity 12)
3	Exhaust camshaft
4	VCT actuator - Exhaust
5	Rear Continuous Variable Valve Lift (CVVL) assembly
6	Front CVVL assembly
7	VCT actuator - Intake
8	Intake camshaft
9	Secondary timing chain tensioner
10	Secondary timing chain oil jet
11	Primary timing chain oil jet
12	Primary timing chain tensioner
13	Piston cooling oil jet (quantity 6)
14	Piston cooling oil jet solenoid
15	Crankshaft
16	Oil filter element and cap
17	Oil cooler
18	Oil gallery pressure feedback to the variable flow oil pump with integral vacuum pump
19	Variable flow oil pump with integral vacuum pump
20	Oil return pipe from the turbocharger to the oil pan
21	Oil pan

The engine 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 distributed through the oil bores.

The output from the oil filter is distributed through oil bores in the cylinder heads and the cylinder block. All moving parts are lubricated by pressured or splashed oil.

Pressurized oil is also provided for:

- The VCT system
- The piston cooling oil jets
- The timing chain oil jets

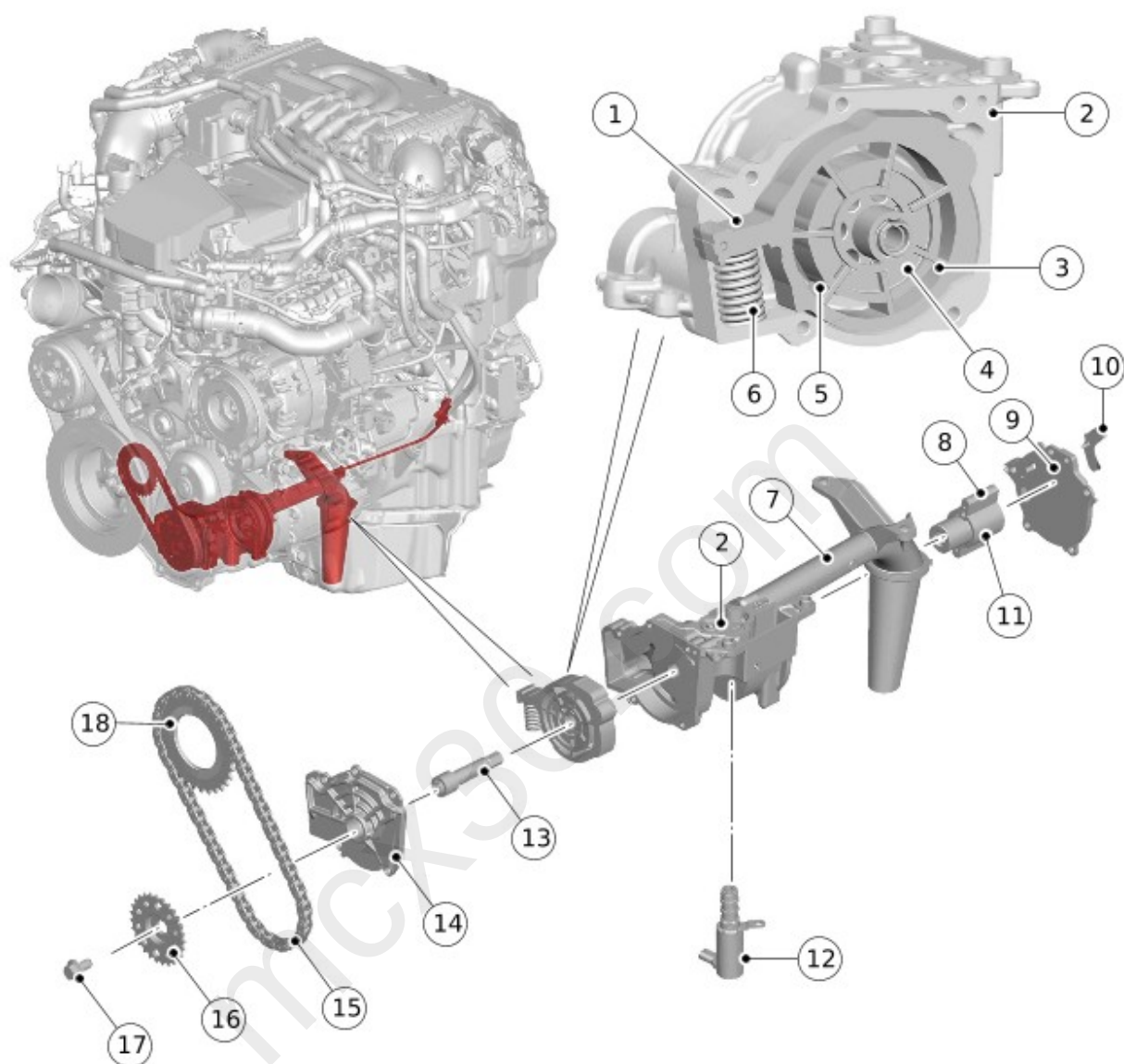
- The turbocharger
- The hydraulic valve tappets
- The Continuous Variable Valve Lift (CVVL) assemblies
- The timing chain tensioner.

The engine oil pressure is fed back to the variable flow oil pump through a drilling in the cylinder block. The variable flow oil pump uses this pressure signal to regulate the oil flow and pressure. The PCM can control the variable flow oil pump electrically, requesting a pressure held in the engine oil pressure map. The engine oil pressure map 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 make sure that the engine oil returns rapidly to the oil pan. System replenishment is through the oil filler cap on the camshaft cover. An oil pan drain plug is installed at the front of the oil pan.

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VARIABLE FLOW OIL PUMP WITH INTEGRAL VACUUM PUMP



E243947

ITEM	DESCRIPTION
1	Control ring oil pressure surface
2	Housing
3	Oil pump vane (quantity 7)
4	Oil pump rotor
5	Oil pump control ring
6	Control spring
7	Oil pump inlet pipe

ITEM	DESCRIPTION
8	Vacuum pump vane (quantity 2)
9	Vacuum pump cover
10	Vacuum exhaust valve
11	Vacuum pump rotor
12	Oil pressure control solenoid
13	Shaft
14	Oil pump cover
15	Auxiliary chain
16	Oil pump sprocket
17	Bolt
18	Drive sprocket - Crankshaft

The variable flow oil pump with integral vacuum pump is attached to the cylinder block with 3 bolts. The input shaft of the variable flow oil pump with integral vacuum pump is equipped with a sprocket. The sprocket is driven from the front of the crankshaft. The sprocket is driven by an auxiliary chain, at 0.87 times engine speed.

Variable Flow Oil Pump

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

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.

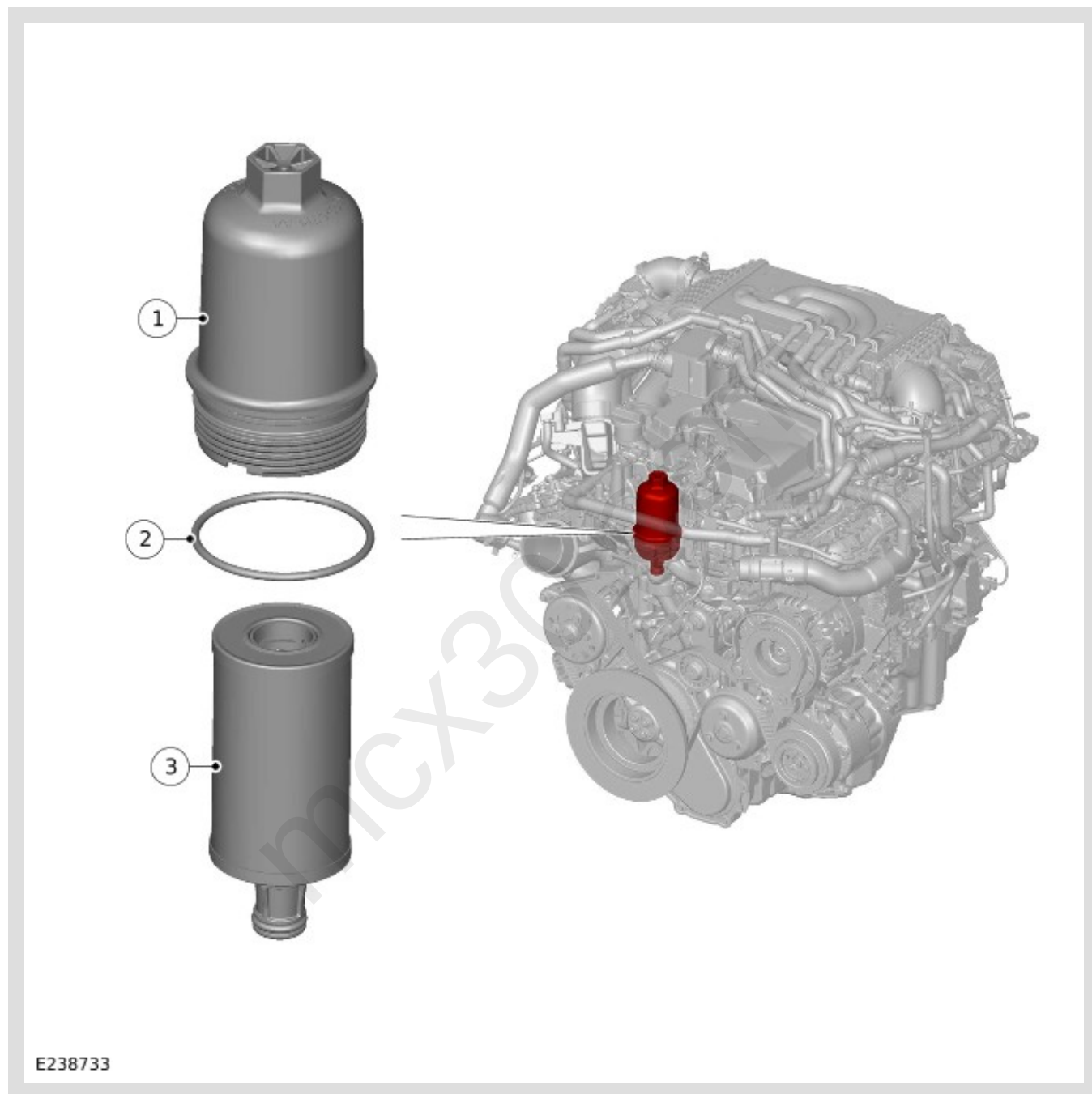
The eccentricity of the control ring can be decreased or increased, with increasing eccentricity increasing the output flow. The output of the variable flow oil pump is adjusted appropriate to engine load and speed to reduce load on the engine. An oil pressure control solenoid adjusts the oil pressure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

Vacuum Pump

The vacuum pump is tandem to the oil pump, connected to the vacuum harness through a drilling in the cylinder block and a vacuum connector. The vacuum produced by the vacuum pump is used to provide a vacuum for the active engine mounts.

The vacuum pump extracts air through a vacuum pipe from the active engine mounts and a port in the cylinder block. The extracted air flows through the vacuum pipe connector which is equipped with a 1-way valve. The 1-way valve prevents oil ingress into the active engine mount system. The air is vented into the cylinder block through a vacuum exhaust valve.

OIL FILTER ELEMENT



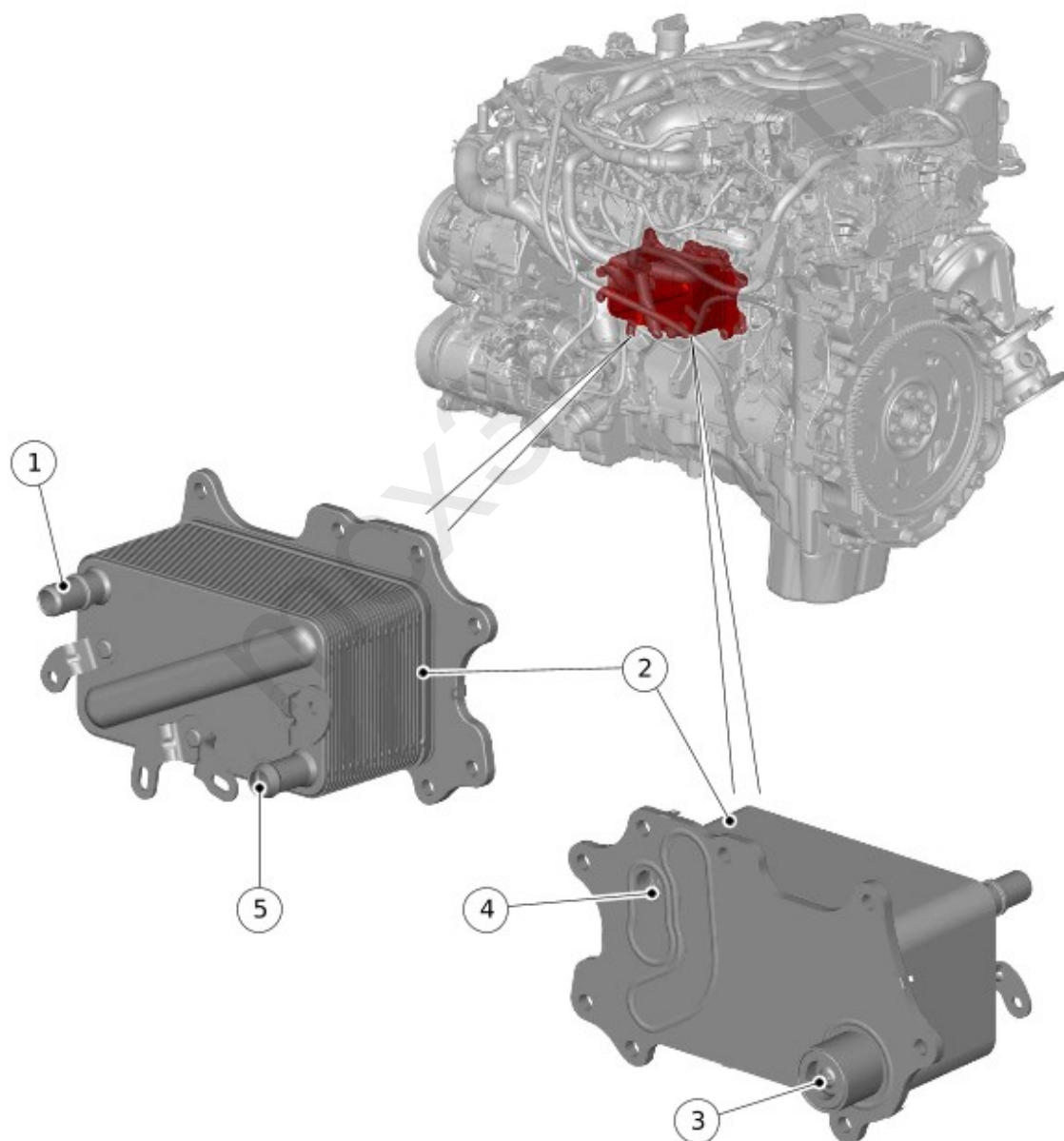
ITEM	DESCRIPTION
1	Cap - Oil filter
2	Seal
3	Oil filter element

A replaceable cartridge oil filter element is located in the cylinder head. A plastic cap seals the oil filter element to the cylinder head.

The cylinder head has 2 ports, which connect with the corresponding ports on the cylinder block. The first port provides the oil supply connection from the oil cooler. The second port is the oil supply connection to the oil distribution bore in the cylinder block.

The oil filter plastic cap is equipped with an integral bypass valve. If the oil filter element becomes contaminated, to the point that oil flow is restricted, the bypass valve opens. The bypass valve allows oil to flow through the oil filter plastic cap to avoid starving the engine of engine oil.

OIL COOLER



E238732

ITEM	DESCRIPTION
1	Engine coolant outlet connection
2	Oil cooler
3	Engine oil inlet - Anti-drain valve
4	Engine oil outlet
5	Engine coolant inlet connection

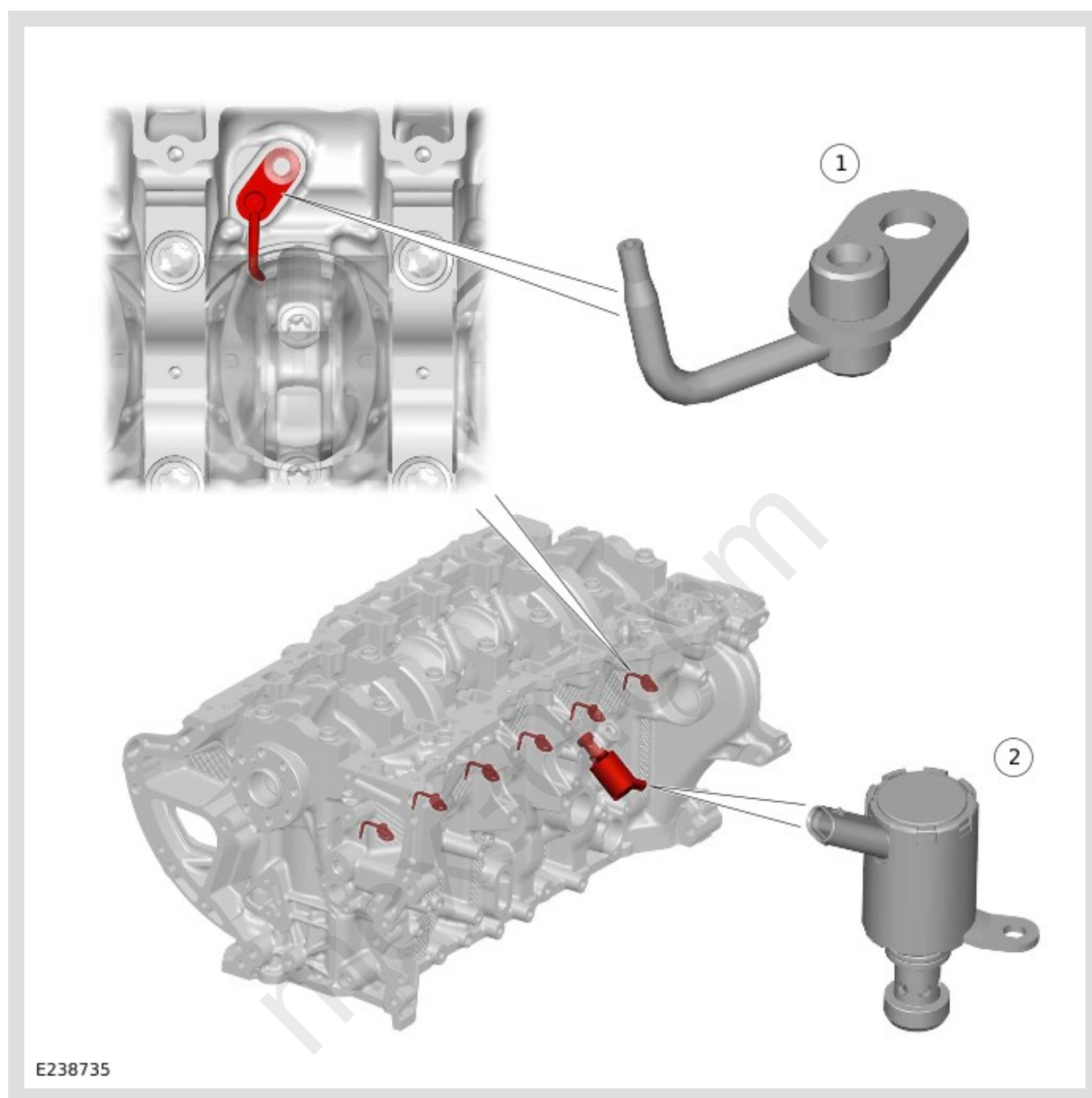
The oil cooler is located on the side of the cylinder block, below the intake manifold. The oil cooler is sealed to the cylinder block with a metal gasket and secured with 7 bolts.

The engine oil inlet and outlet connections are located on the inner side of the oil cooler. The coolant inlet and outlet connections are located on the outer side of the oil cooler.

The oil cooler is an aluminum housing comprising louvered fins and plates. The plates allow a cross-flow of oil and engine coolant through the cooler but keep the 2 fluids separate. The plates are immersed in engine coolant from the variable coolant pump. The variable coolant pump provides cooling of the oil by the temperature differential between the oil and the engine coolant.

An anti-drain valve is located in the engine oil inlet connection, which prevents the oil draining from the oil cooler when the engine is not running.

PISTON COOLING OIL JET



ITEM	DESCRIPTION
1	Piston cooling oil jet (quantity 6)
2	Piston cooling oil jet solenoid

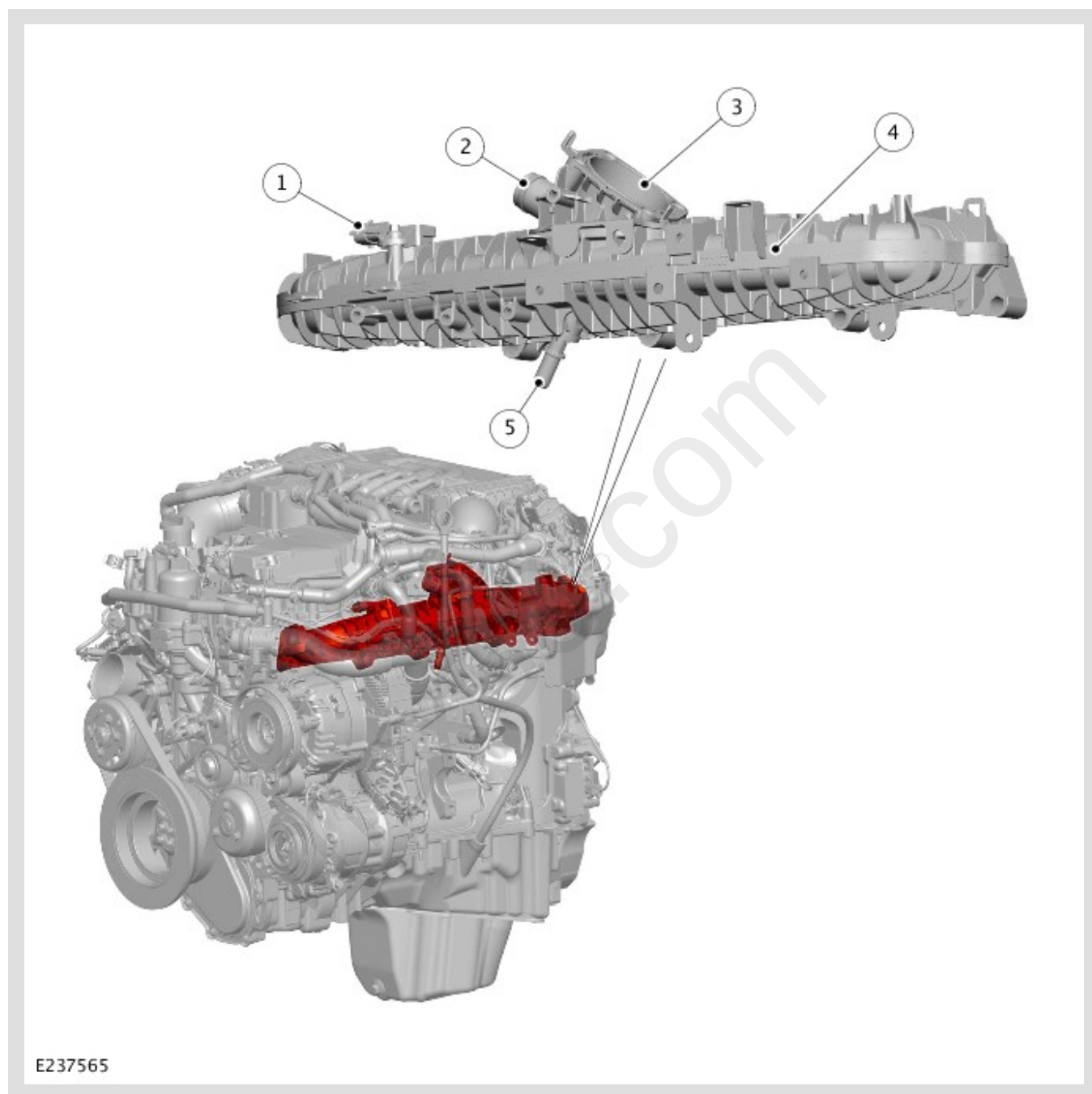
The 6 piston cooling oil jets are located in the cylinder block. Each piston cooling oil jet is located adjacent to a cylinder and secured in the cylinder block with a bolt.

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 by pressurized oil from the variable flow oil pump with integral vacuum pump through 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 PCM. The piston cooling oil jet solenoid can open and close the oil supply depending on engine speed and load.

In addition to supply oil to the piston cooling bore the oil lubricates the small end bearing and the gudgeon pin.

INTAKE MANIFOLD



ITEM	DESCRIPTION
1	Manifold Absolute Pressure and Temperature sensor (MAPT)
2	Breather hose connection
3	Electric throttle adapter
4	Intake manifold

ITEM	DESCRIPTION
5	Purge hose connection

The intake manifold is a plastic injection molded assembly made from 2 shells vibration-welded together. The intake manifold is mounted directly to the cylinder head with 9 bolts and sealed with 6 flexible seals.

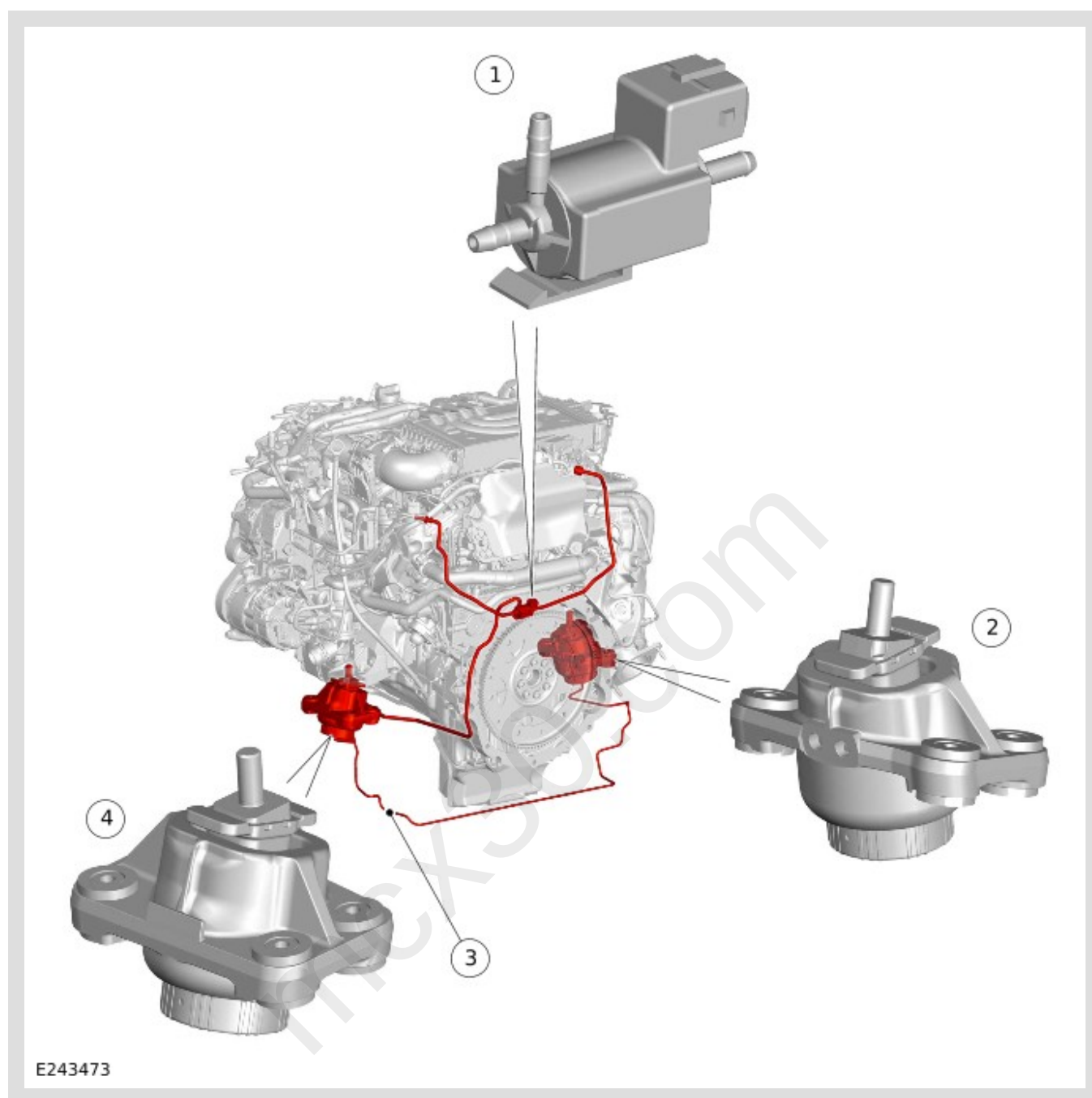
The main function of the intake manifold is to evenly distribute intake air into the combustion chamber of each cylinder.

The MAPT is located on the top of the intake manifold and secured with a screw. The MAPT sensor signal is used by the PCM 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 4 screws. A gasket seals the joint between the electric throttle and the intake manifold.

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ACTIVE ENGINE MOUNT SYSTEM



ITEM	DESCRIPTION
1	Active engine mount solenoid
2	Active engine mount - Right
3	Vacuum pipe
4	Active engine mount - Left

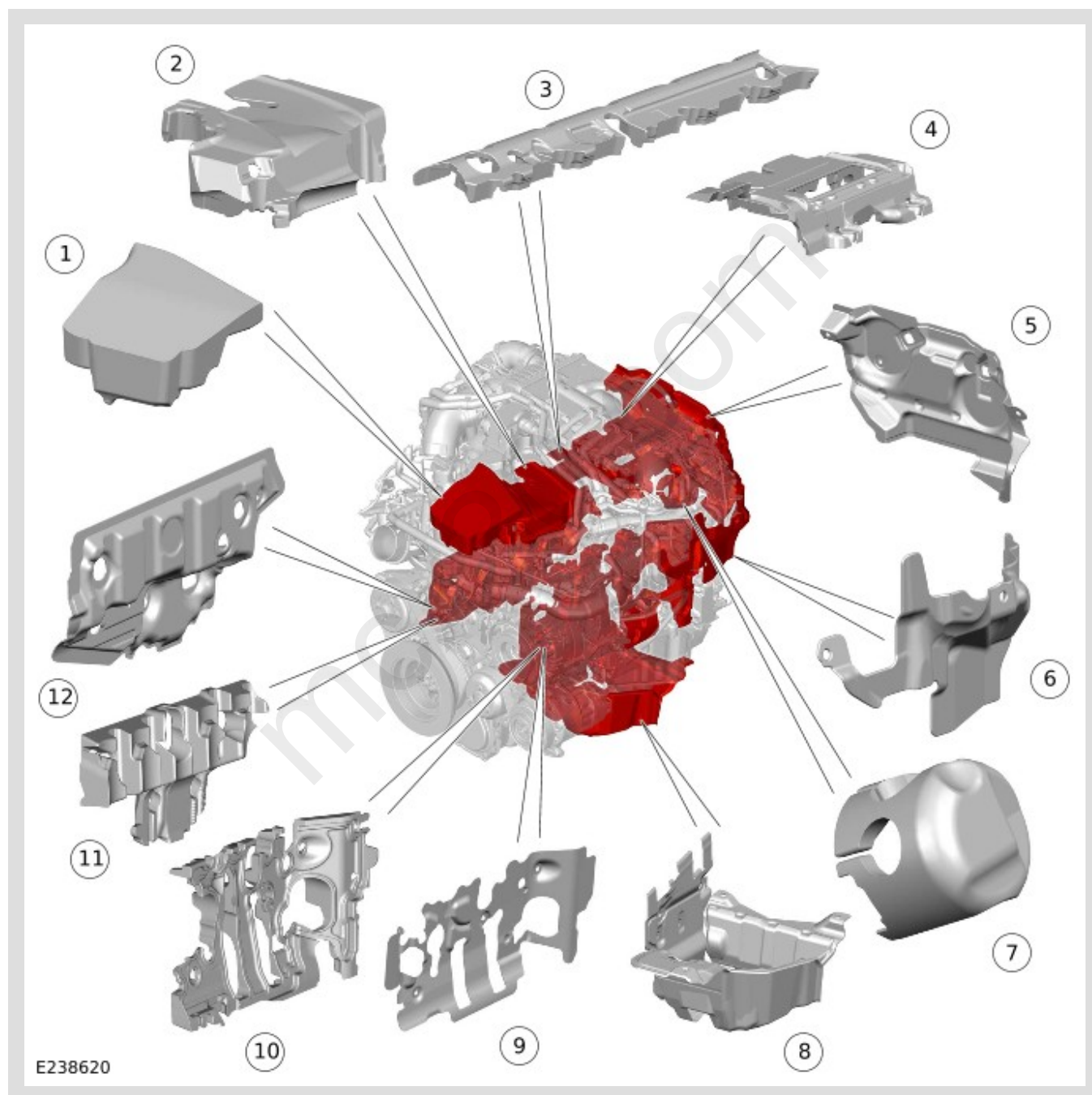
The active engine mount system comprises the following components:

- The 2 active engine mounts

- The active engine mount solenoid
- Connecting vacuum pipes.

The PCM controls the vacuum operated engine mounts through an active engine mount solenoid. If the active engine mount solenoid is activated the active engine mounts became soft. The active engine mounts operate at idle speed, and are switched off when the engine speed goes above a predetermined threshold. The active engine mounts are switched off when the engine speed increases to 1,250 RPM.

NOISE, VIBRATION AND HARSHNESS PADS



ITEM	DESCRIPTION
1	NVH pad - Cylinder head top
2	NVH pad - Front Continuous Variable Valve Lift (CVVL) assembly

ITEM	DESCRIPTION
3	NVH pad - Fuel rail
4	NVH pad - Rear CVVL assembly
5	NVH pad - Upper timing chain cover
6	NVH pad - Intake manifold
7	NVH pad - HP fuel pump
8	NVH pad - Oil pan
9	NVH pad - Cylinder block left
10	NVH foam - Cylinder block left
11	NVH foam - Cylinder block right
12	NVH pad - Cylinder block right

The NVH pads are attached to the Ingenium I6 3.0L petrol engine to reduce the NVH, experienced by the driver or passenger(s). The pads are made of a multi-layer mixed fiber and resin laminate composite depending on application.

The NVH package consists the following:

- An NVH pad with a foam insert for each side of the engine cylinder block.
- A pad located above the fuel rail.
- A pad located above the HP fuel pump.
- There are 2 pads, which located above the Continuous Variable Valve Lift (CVVL) assemblies.
- A pad located above the oil filter plastic cap.
- A pad located at the rear section of the intake manifold.
- A pad located above the timing chain cover.
- A pad located around the oil pan.
- An engine cover located on the top of the engine.