GIULIA

# TECHNICAL TRAINING
# QUADROFOGLIO
# MECHANICAL SYSTEMS

"Learning how to learn is life's most important skill."

Tony Buzan

PROFESSIONAL

TRAINING MANUAL

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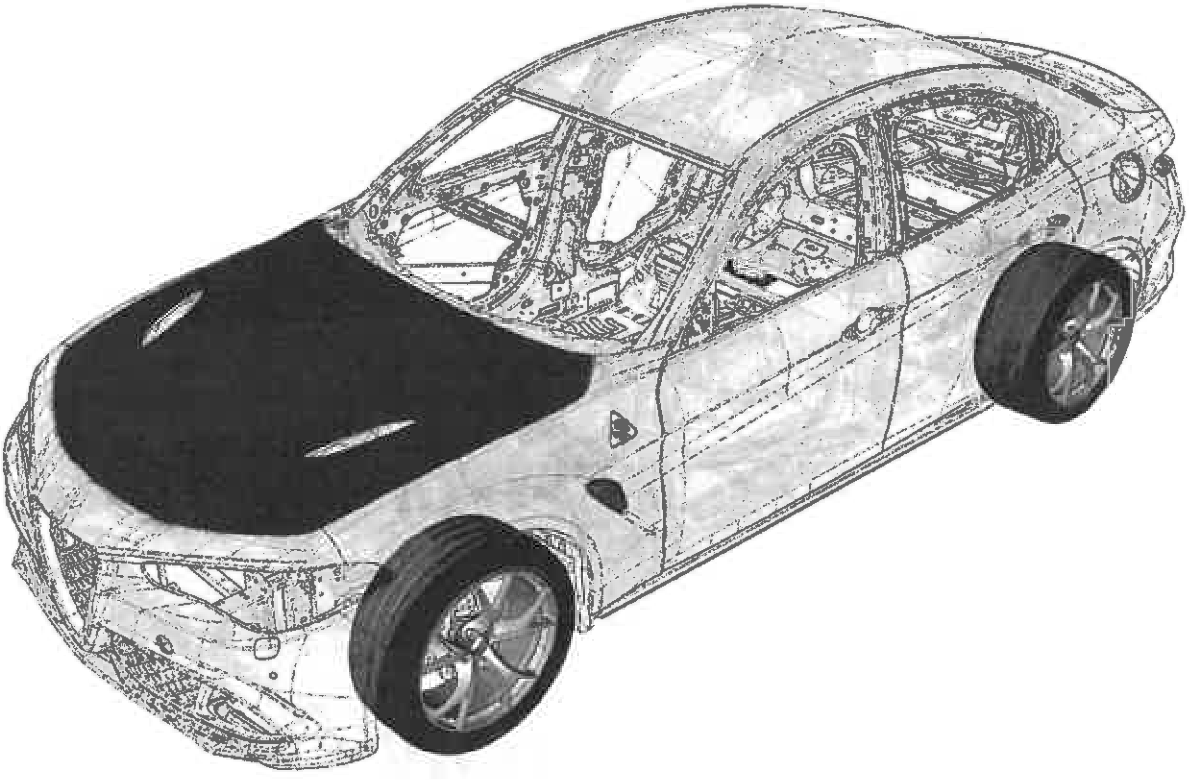
# CHASSIS ELEMENTS SPECIFIC TO THE QUADRIFOGLIO VERSION.

This chapter covers the chassis elements specific to the Quadrifoglio version. Some of them are simply covered by a list and description (see the Quadrifoglio version carbon components), while for others, the functional logic is covered (see the front aerodynamic splitter).

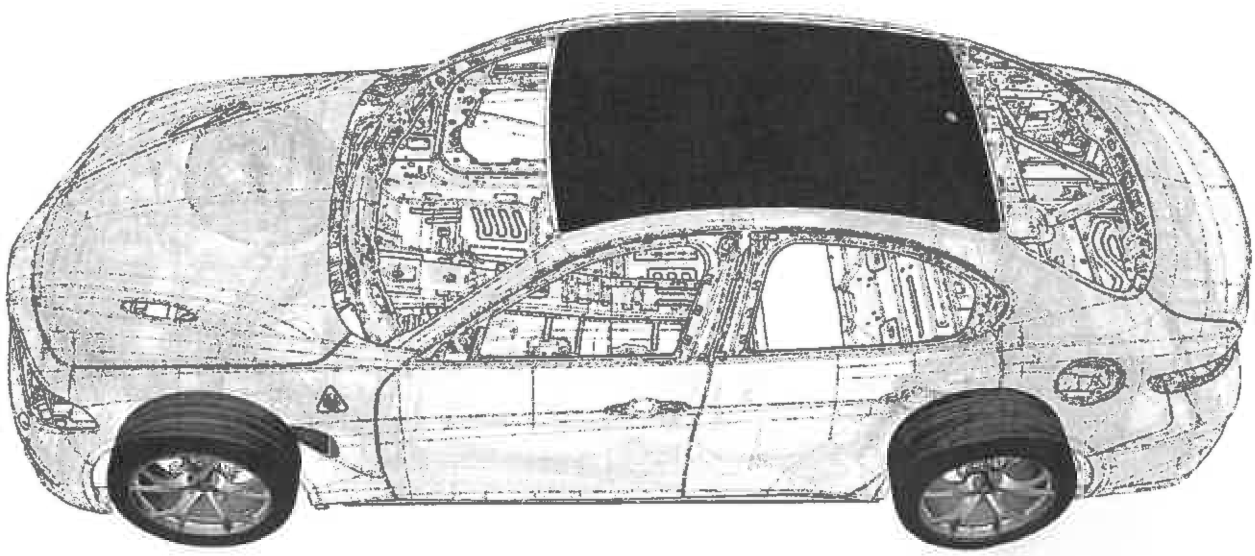
**Carbon fibre components.**

**Bonnet**



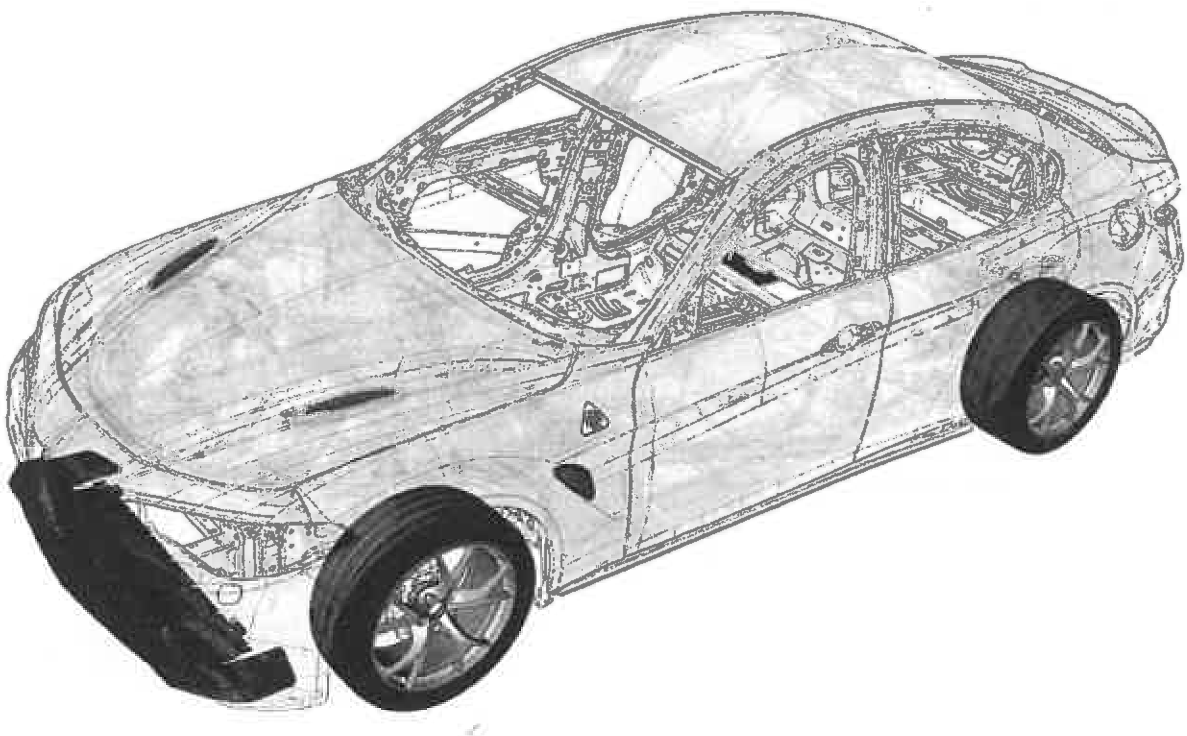
Weight ~ 5.1 Kg

**Roof**



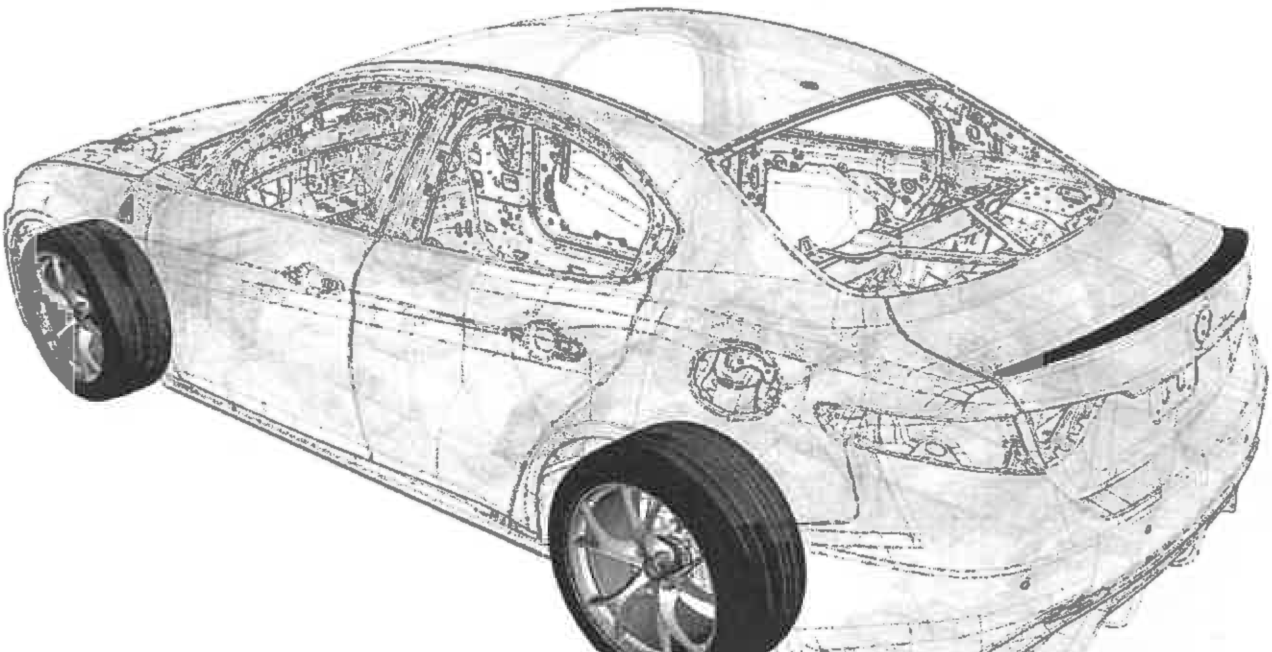
Weight ~ 9.1 kg

**Front aerodynamic splitter**



Weight ~ 2.287 kg

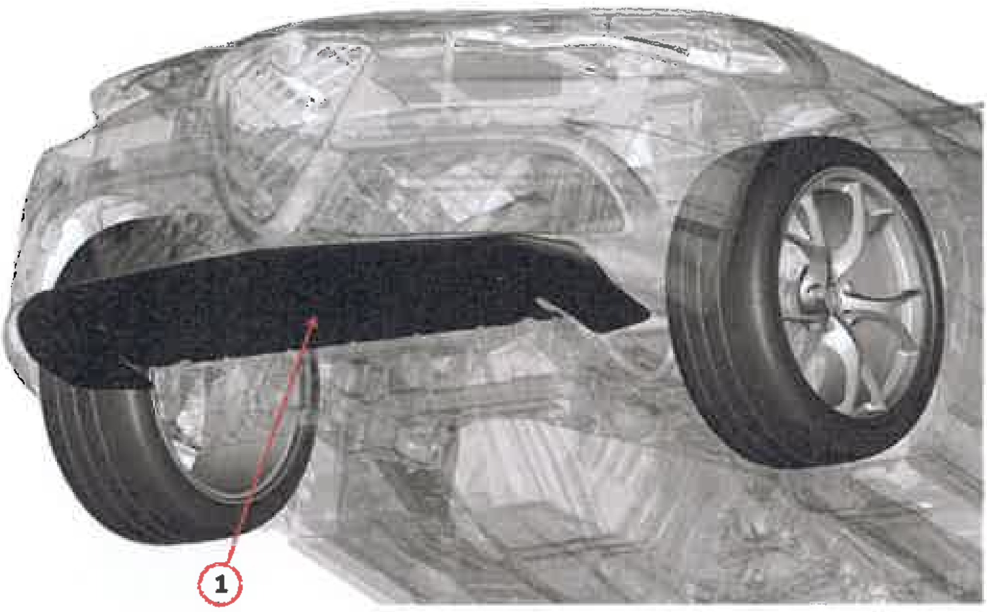
**Rear spoiler**



Weight ~ 2.1 kg

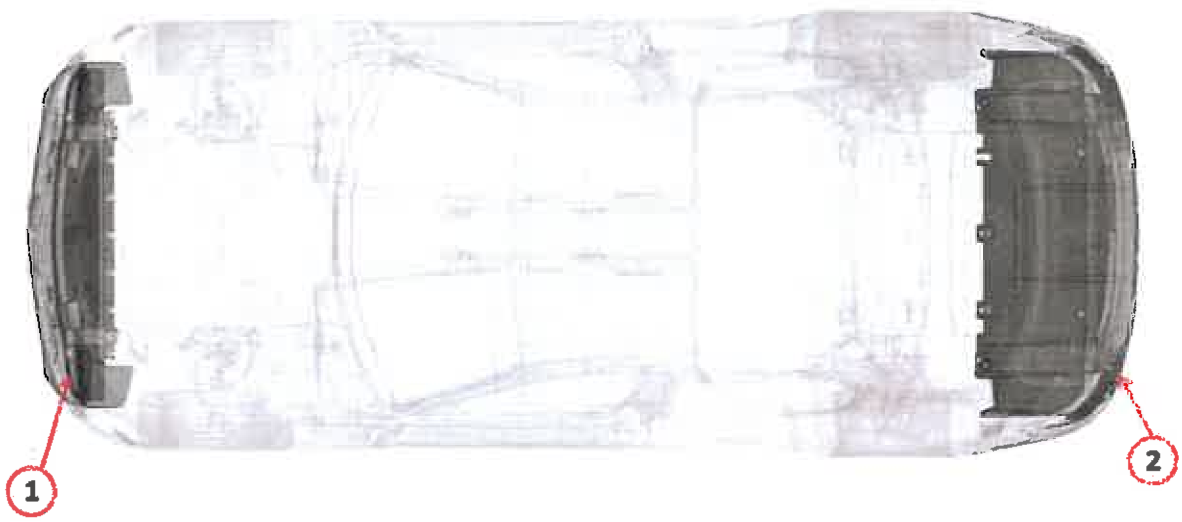
**Front aerodynamic splitter.**

The Quadrifoglio version has an aerodynamic splitter in the bottom part of the front bumper.

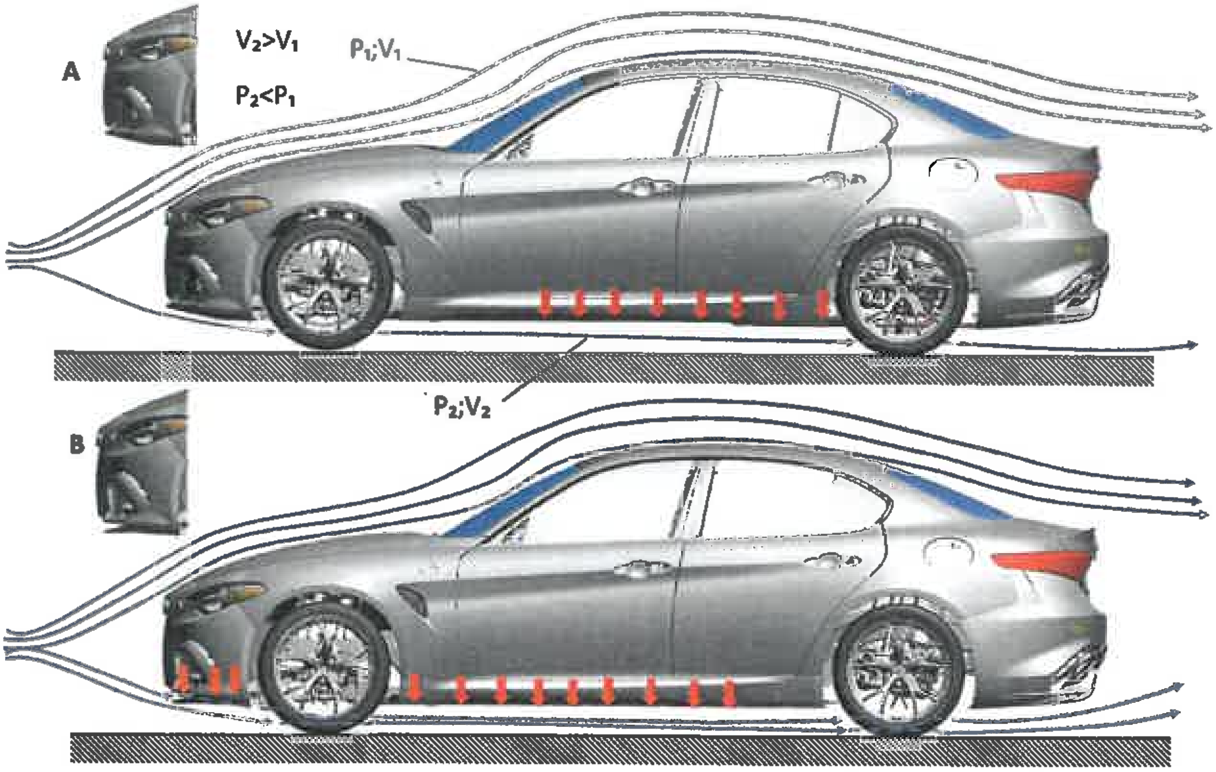



Key:
1 – Front aerodynamic splitter.

The front aerodynamic splitter has the purpose of imposing a deviation of air flow that is channelled into the under-body area of the vehicle with the purpose of increasing grip and the aerodynamic load on the front.




Key:
1 – Front aerodynamic splitter.
2 – Rear extractor.

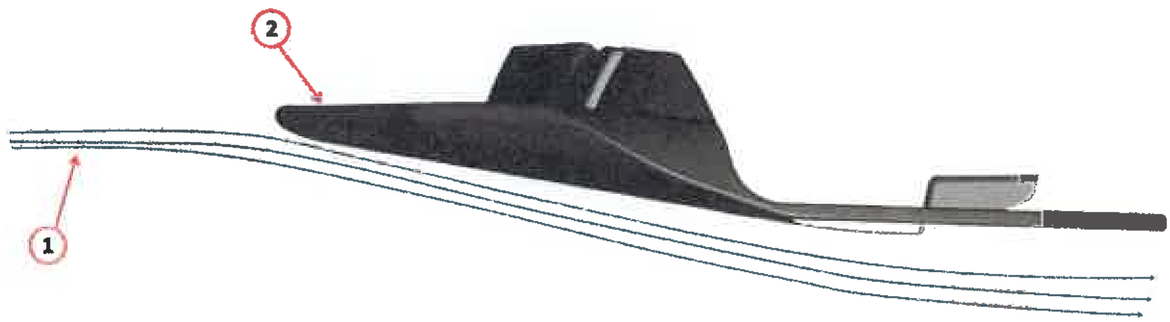



The front Splitter is activated only when the Dynamic or Race driving modes are selected. When other driving modes are selected, the Splitter is not activated.
In Dynamic and Race modes, activation of the Splitter occurs in the range of speed between 100km/h and 230km/h. Outside of said speed range, the Splitter is always closed.

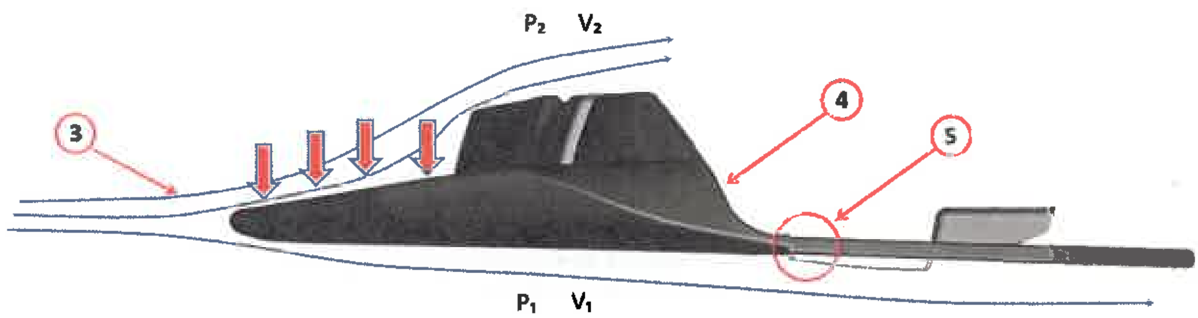
The Quadrifoglio version has the so-called flat bottom in the lower part of the floor. It creates a channel the cross-section of which gradually converges and then begins to diverge in the area next to the rear extractor, thus forming a "Venturi tube" effect. The flat bottom favours the creation of Venturi effect. In the area of the under-body where there is the minimum cross-section, the maximum value of the speed $V_2$ of the air flow and the minimum pressure value $P_2$, are reached.
The pressure P2 is lower than the pressure of the air flow present in the upper part of the body $P_1$. This pressure difference generates a downward force (force) that pushes the vehicle towards the ground, consequently increasing grip and road holding strength. When the vehicle speed exceeds 100km/h, the Splitter opens, imposing a deviation of the air flow that is heading in the area under the floor of the vehicle. Opening the Splitter also implies amplifying the "Venturi" effect.

**NOTE:** In order to avoid continuous movements of opening and closing of the Splitter in the case where the vehicle speed oscillates around the limit values of the range of speed (100km/h and 230km/h), in the CDCM module, the values of hysteresis are implemented. This means that the Splitter does not open exactly at 100km/h but will open to a speed value of 100 + Xkm/h. The parameter X (≈15km/h) is the hysteresis to be taken into account. Similarly, for the threshold of 230km/h, in deceleration, the Splitter does not close at 230km/h but to 230 – Xkm/h.

The opening of the Splitter, beyond accentuating the Venturi effect, primarily allows shifting of the aerodynamic load toward the front bringing about a more responsive character to the vehicle. The shifting towards the front of the aerodynamic load is due to the deflection of the flow around the Splitter that, in the open position, behaves like a reversed wing.




1 – Development of air flow with Splitter closed.
2 – Splitter in the closed position.

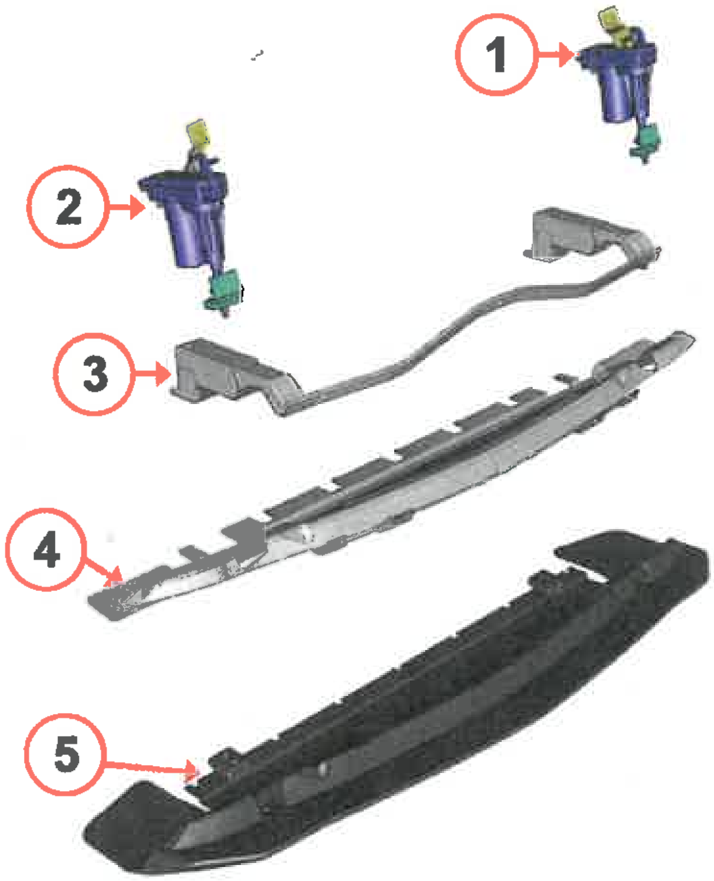



3 – Air flow diverted following opening of the Splitter.
4 – Splitter in the closed position.
5 –Zone of the Splitter in which the material (carbon) is slightly deformed under the thrust of the actuators.

When the Splitter is closed, most of the aerodynamic load is shifted towards the rear.

**Splitter mechanism**

The front Splitter is piloted by two actuators. One is located in the right part of the deflector (Master actuator) and the other on the left side (Slave actuator).




Key:

1 – Left actuator

2 - Right actuator

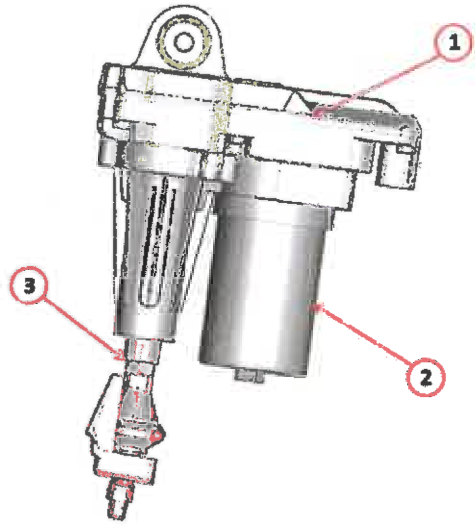
3 - Transverse support.

4 – Shell protection

5 – Front aerodynamic splitter made of carbon fibre.

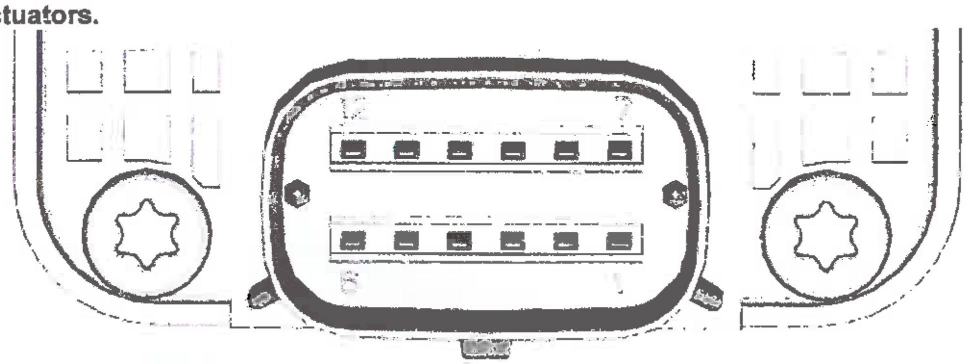
## Actuators

The right and left actuators, integrate an electronic data processing unit with the mechanical part. The electronic unit is equipped with a CAN interface, a microprocessor and position sensor which detect the small movement piston's vertical displacement. The mechanical part contains a small electric motor and a reduction gear assembly through which the small electric motor moves an irreversible trapezoidal screw. The right MASTER actuator receives movement commands from the car dynamics control module CDCM.




Key:
1 - Electronic control unit
2 – Small brushless electric motor
3 – Handling stem

**Pin out actuators.**



Right actuator (Master) – AAMR.

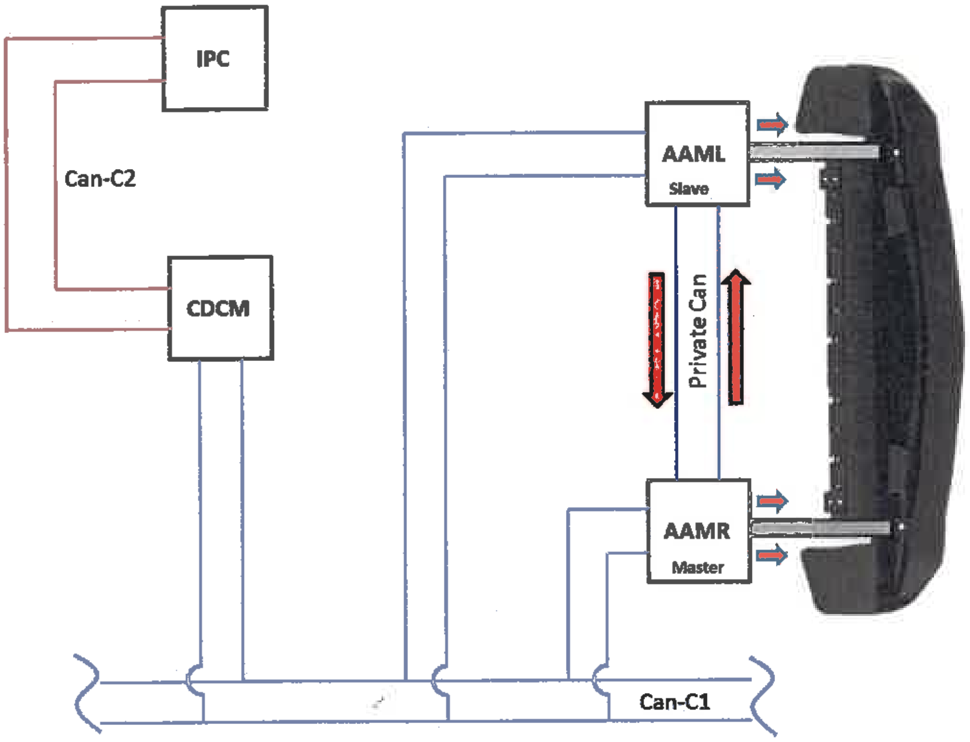
| Pin | Description |
|---|---|
| 1 | Power supply +30 by battery |
| 2 | Earth |
| 3 | Power supply +15 by battery |
| 4 | Power supply +30 by battery |
| 5 | CAN-H (private) |
| 6 | CAN-C2 (High) vehicle |
| 7 | Power supply +30 by battery |
| 8 | Earth |
| 9 | Earth (master) |
| 10 | n.c. |
| 11 | CAN-L (private) |
| 12 | CAN-C2 (Low) |

Left actuator (Slave) – AAML.

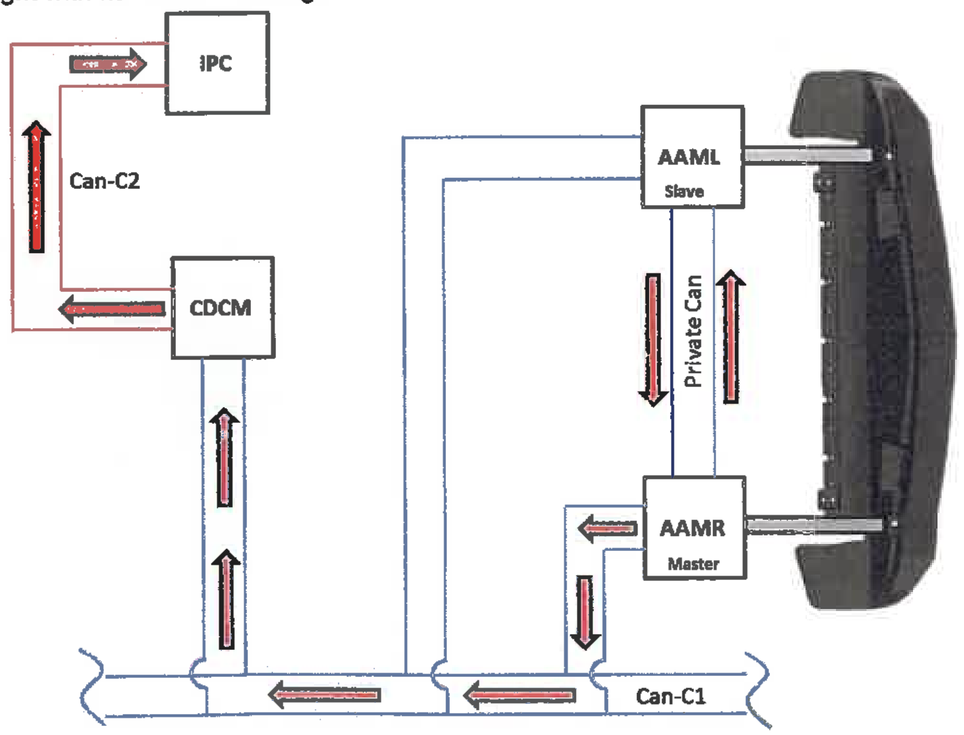
| Pin | Description |
|---|---|
| 1 | Power supply +30 by battery |
| 2 | Earth |
| 3 | Power supply +15 by battery |
| 4 | Power supply +30 by battery |
| 5 | CAN-H (private) |
| 6 | CAN-C2 (High) vehicle |
| 7 | Power supply +30 by battery |
| 8 | Earth |
| 9 | n.c. |
| 10 | Earth (Slave) |
| 11 | CAN-L (private) |
| 12 | CAN-C2 (Low) |

The two pin outs differ only for pins 9 and 10. The two actuators, AAML and AAMR, are identical. Both can be master or slave. The difference is in the wiring. If the actuator senses a ground at pin 9 and pin 10 is not connected, automatically it configures to run as Master. If the pin 9 is not connected and the pin 10 senses a ground, it is configured to operate in Slave mode.

During the movement of the Splitter, the two actuators, right and left (closing or opening), interact continuously through a private CAN line (which only connects the two actuators) in order to move the Splitter in a synchronized manner.




In the case where one of the two actuators should block, there is created between the two an asynchronism that could damage the Splitter. In order to avoid damage, the master actuator controls the interruption of the Splitter handling. The master actuator module communicates to the CDCM module the asynchronous condition that is created and then attempts, for a few tenths of a second, to resume handling. If the asynchronism still persists, the master actuator communicates to the CDCM module the condition of "Splitter blocked." In the "Splitter blocked" condition, the CDCM module communicates to the IPC instrument panel the command for switching on the specific damage indicator light with its related message.

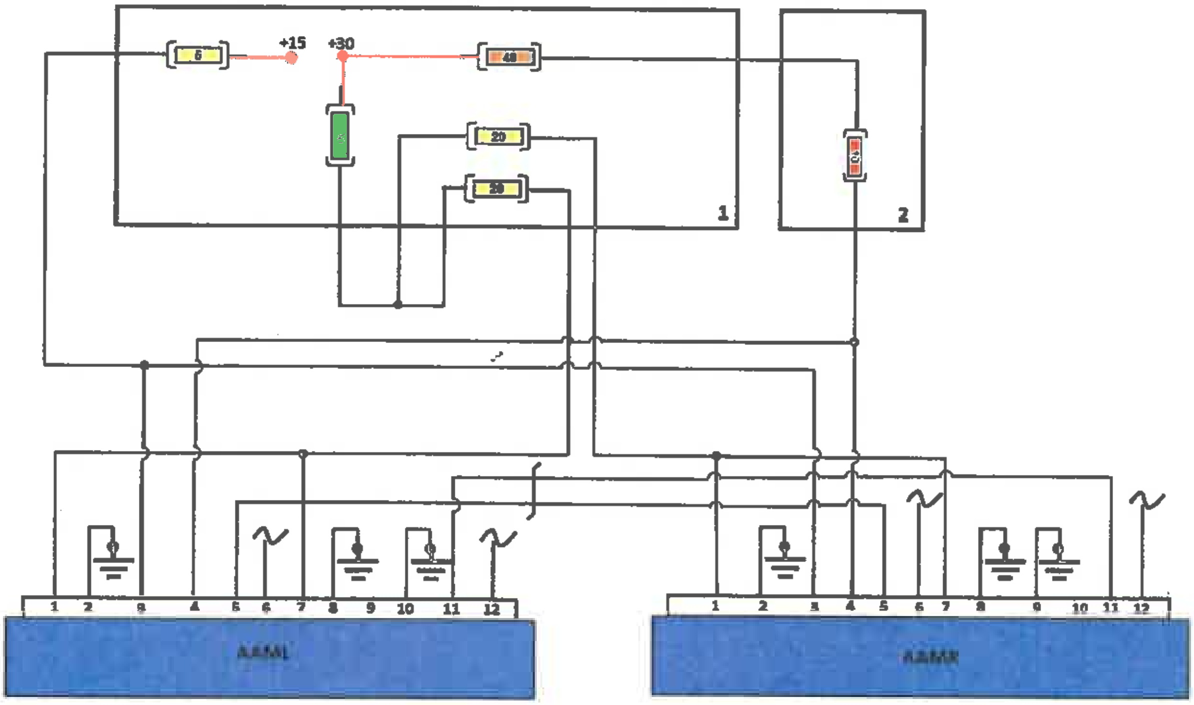


The Slave actuator receives commands exclusively from the Master actuator through the private Can line that connects them. The sole actuator to exchange data and messages with CDCM module is the master. The Slave actuator is also connected to the Can (Can-C1) network of the vehicle, only for needs related to software updating.

The master actuator communicates to the CDCM module the following messages:

- Splitter in movement
- Splitter in Target position
- Splitter Movement interrupted for asynchronism.
- Splitter blocked.

**Front Splitter electrical diagram.**




Key:

1 – Front PDC.

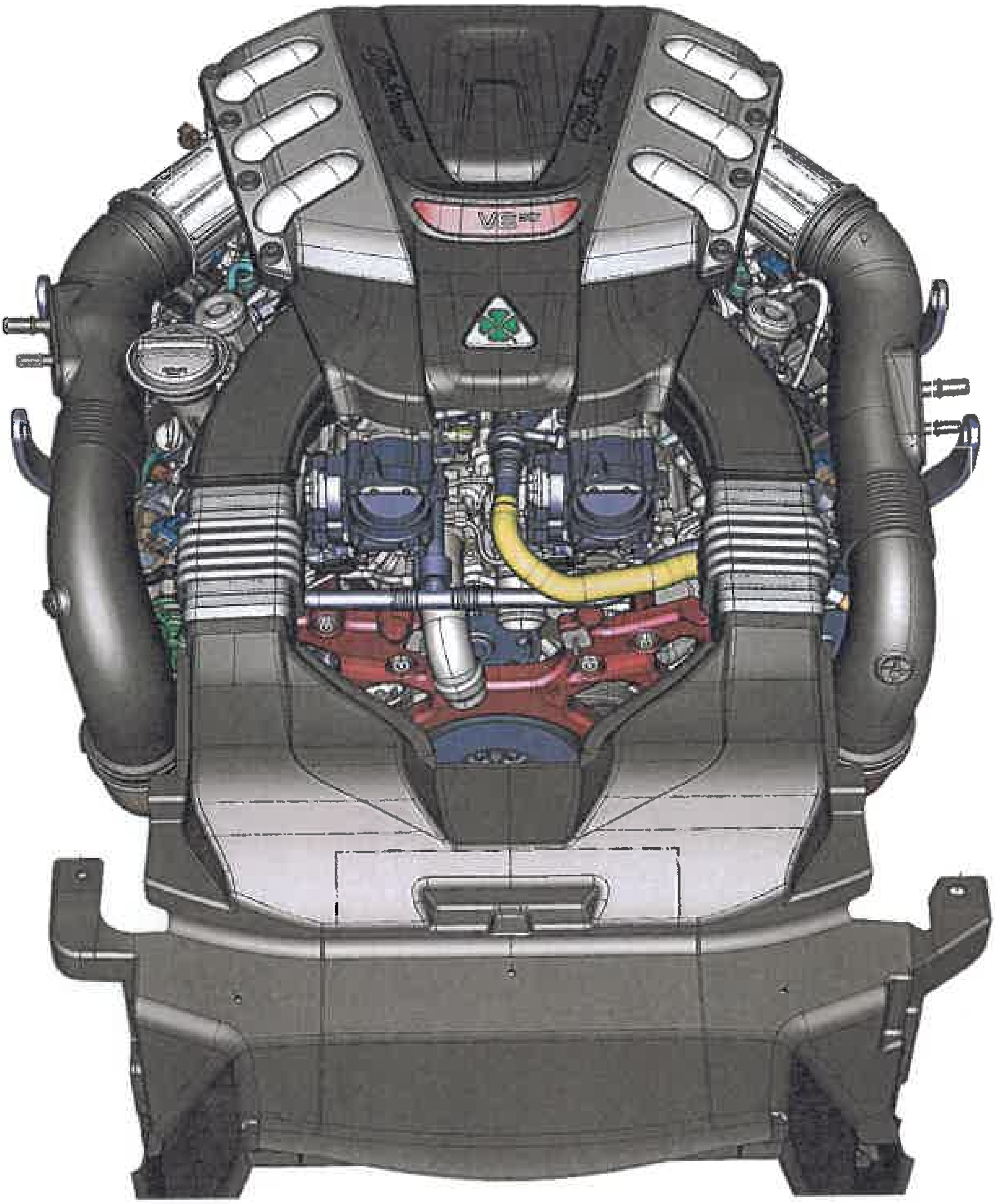
2 – Supplementary front fuse box door.

AAML – Actuator handling left Splitter.

AAMR – Actuator handling right Splitter.

# 2.9 V6 TURBO ENGINE.

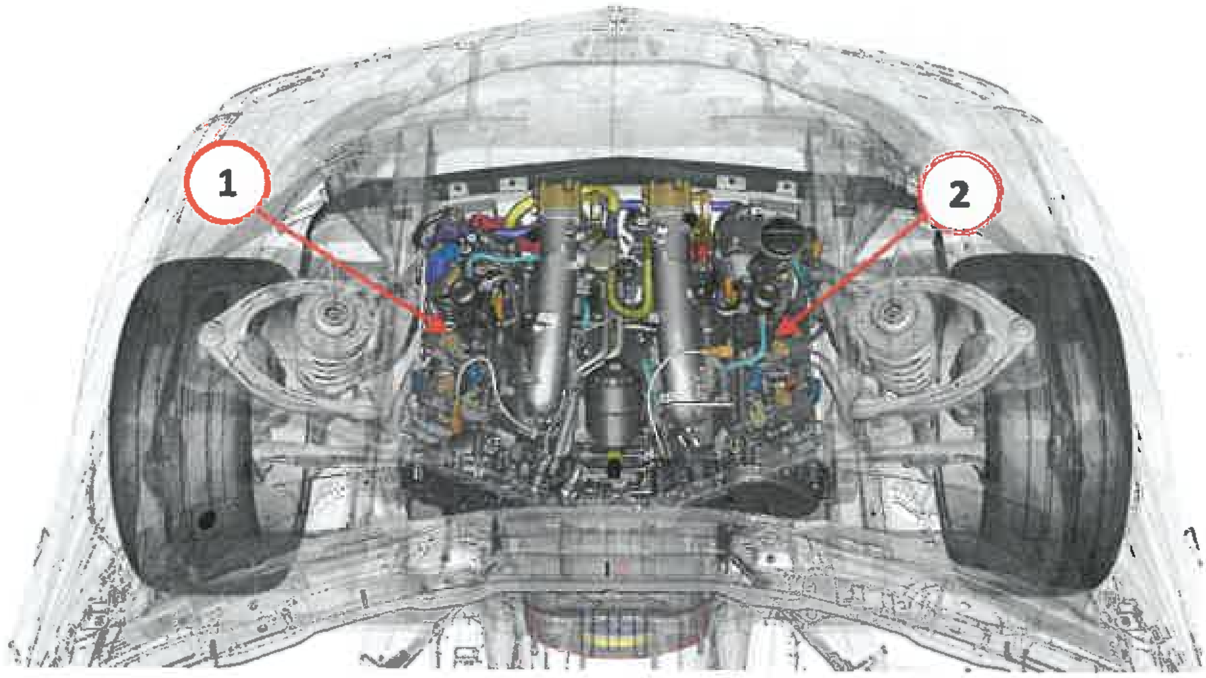
The 2.9 V6 turbo came into being from the Alfa Romeo and Ferrari engineers, and it represents the top in terms of performance (Torque and Power) in the new Alfa Romeo Giulia.



This engine is available only in the QV version.

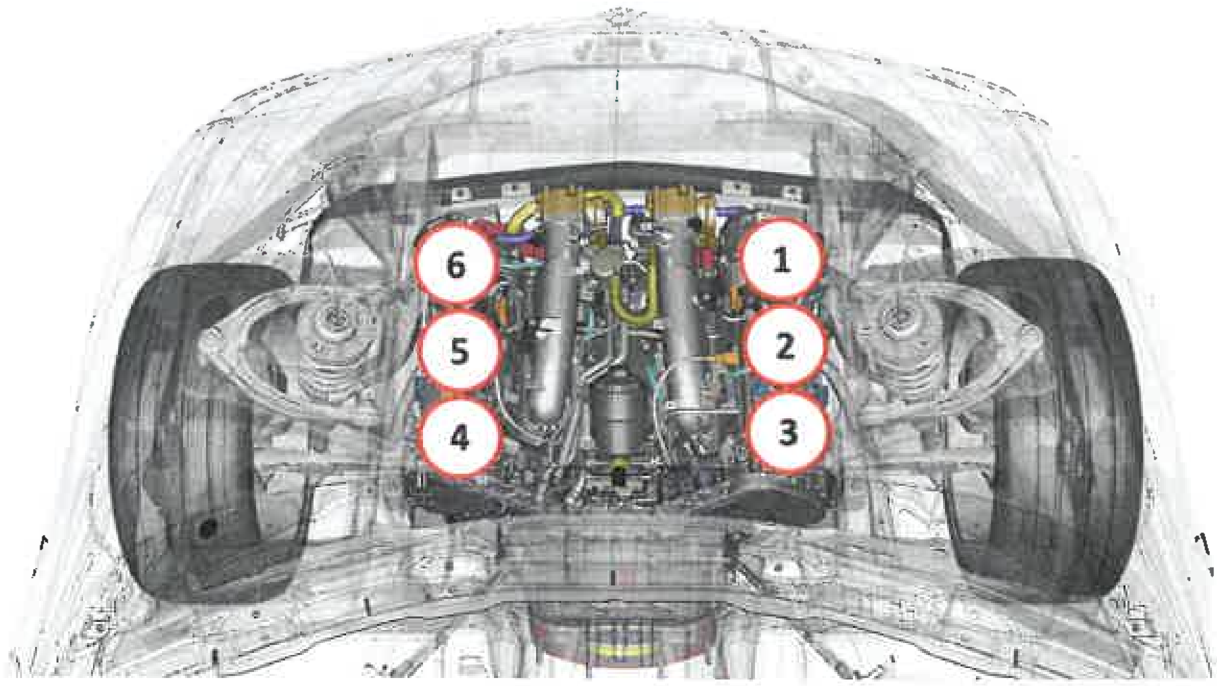
## BEARINGS INDICATION.

The engine has two bearings that form a 90° "V". As they are arranged in the car in a longitudinal manner, identifying the bearings is quite simple and intuitive.

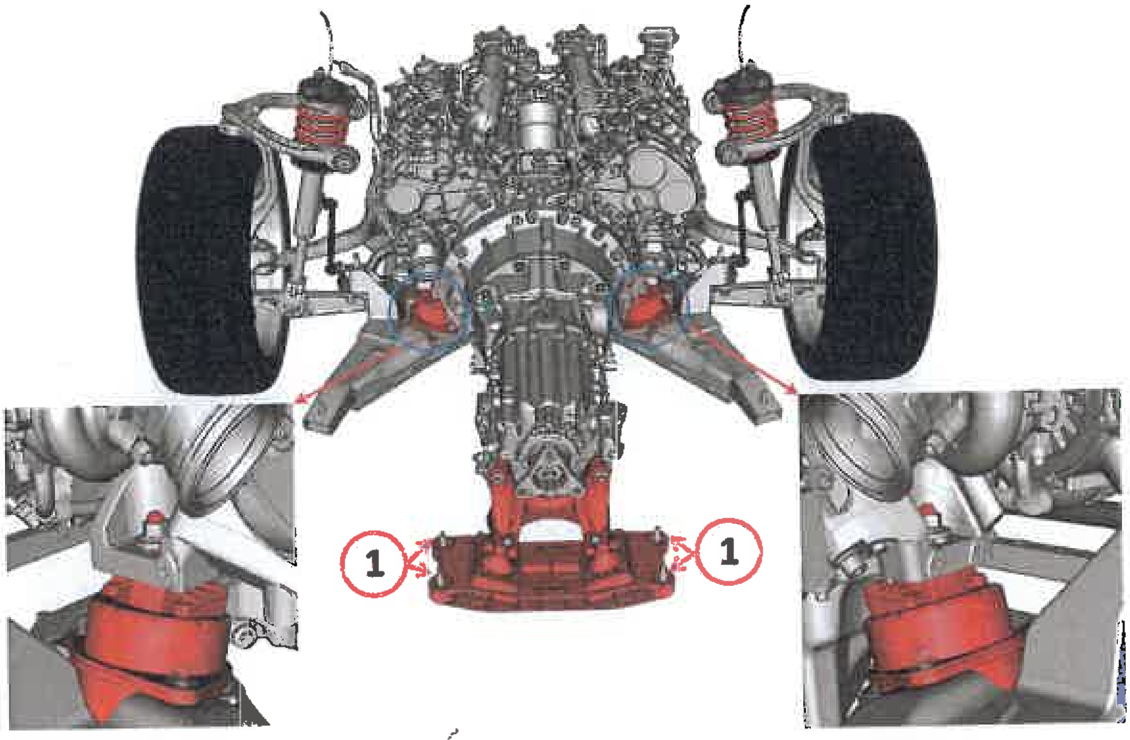



Key:
1 – Left bank.
2 – Right bank.

## CYLINDER NUMBER INDICATION.

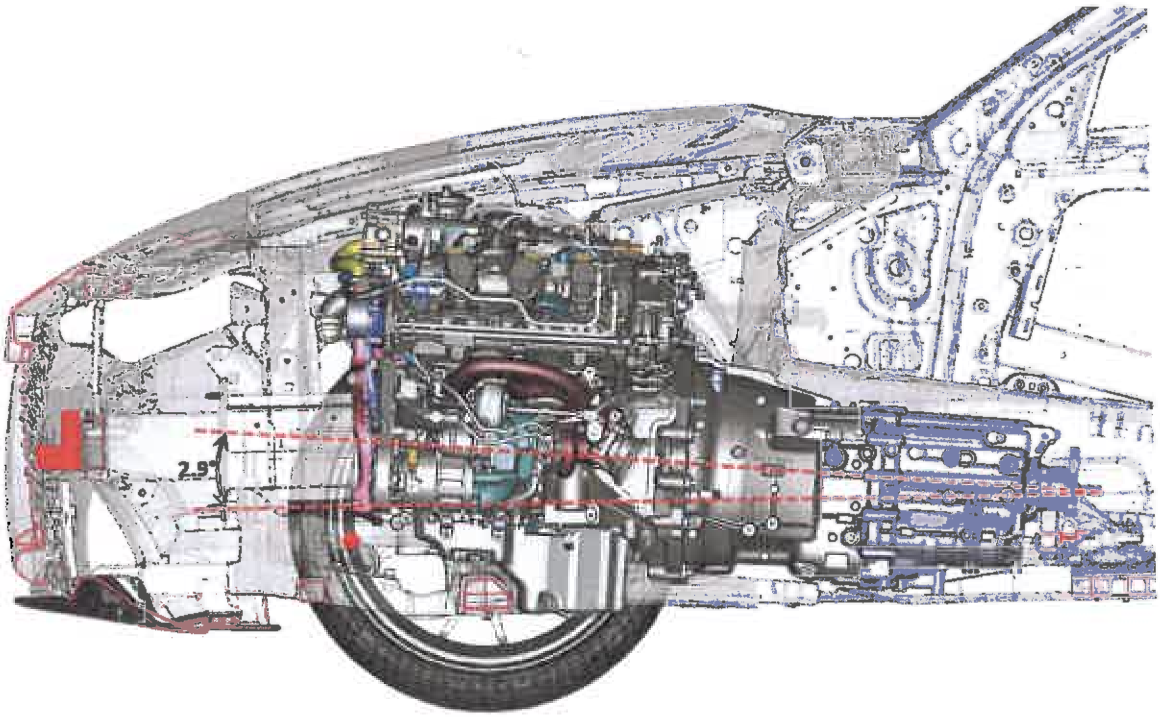


## ENGINE-TRANSMISSION SUPPORT GROUP.




Key
1 – Fixing points for vehicle floor transmission support.

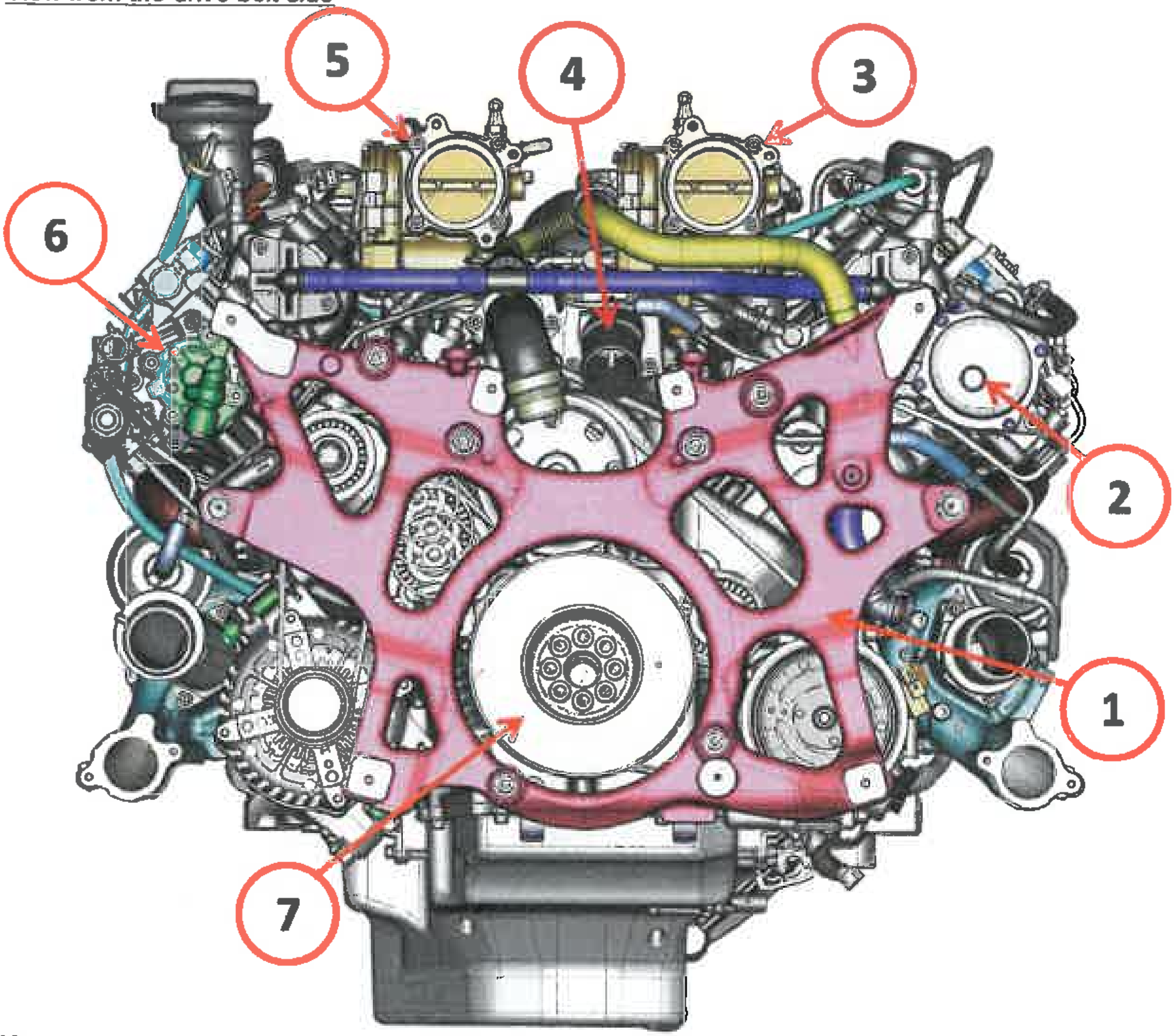
The engine-transmission group is held by three supports, two of which are placed along the front suspension to support the engine, placed longitudinally. The third supports the transmission near the flange attached to the transmission camshaft.




The engine-transmission group is tilted 2.9° with respect to the vehicle's horizontal line.

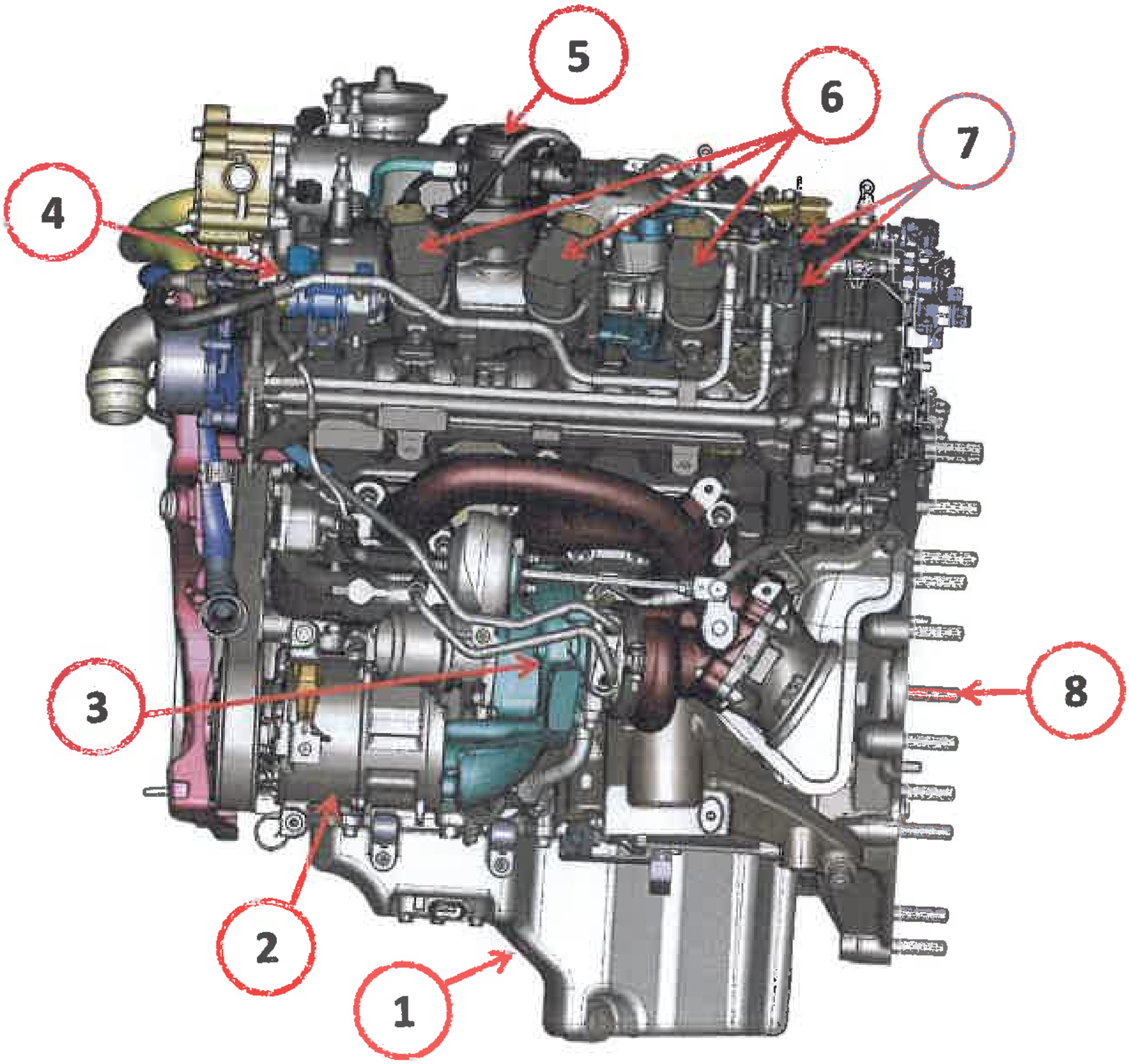
## Views of the engine.

*View from the drive belt side*




Key:
1 – Intercooler supports front plate.
2 – Vacuum pump.
3 – Left bank throttle body.
4 – Thermostat.
5 – Right bank throttle body.
6 – Additional oil pump.
7 – Damper.

*Left side view*

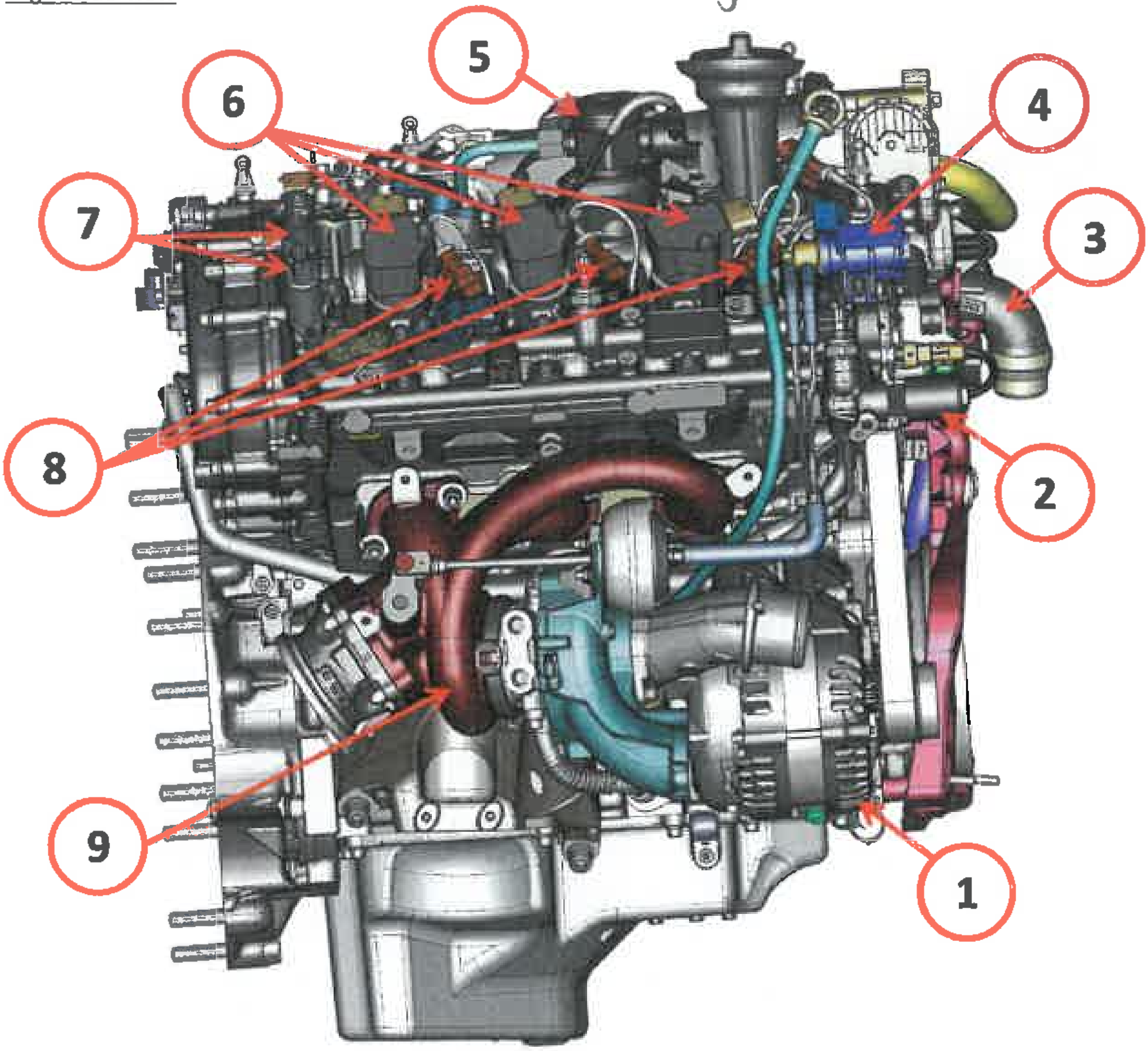



Key:
1 – Oil sump.
2 – Climate control system compressor.
3 – Left turbocharger
4 – Solenoid valve controlling waste gate.
5 – Left bank high pressure pump.
6 – Left bank ~~reel.~~ coils
7 – Solenoid valve controlling left bank phase transformer.
8 – Studs for connection to the gear box.

Close Type
waste gate
Naturally open

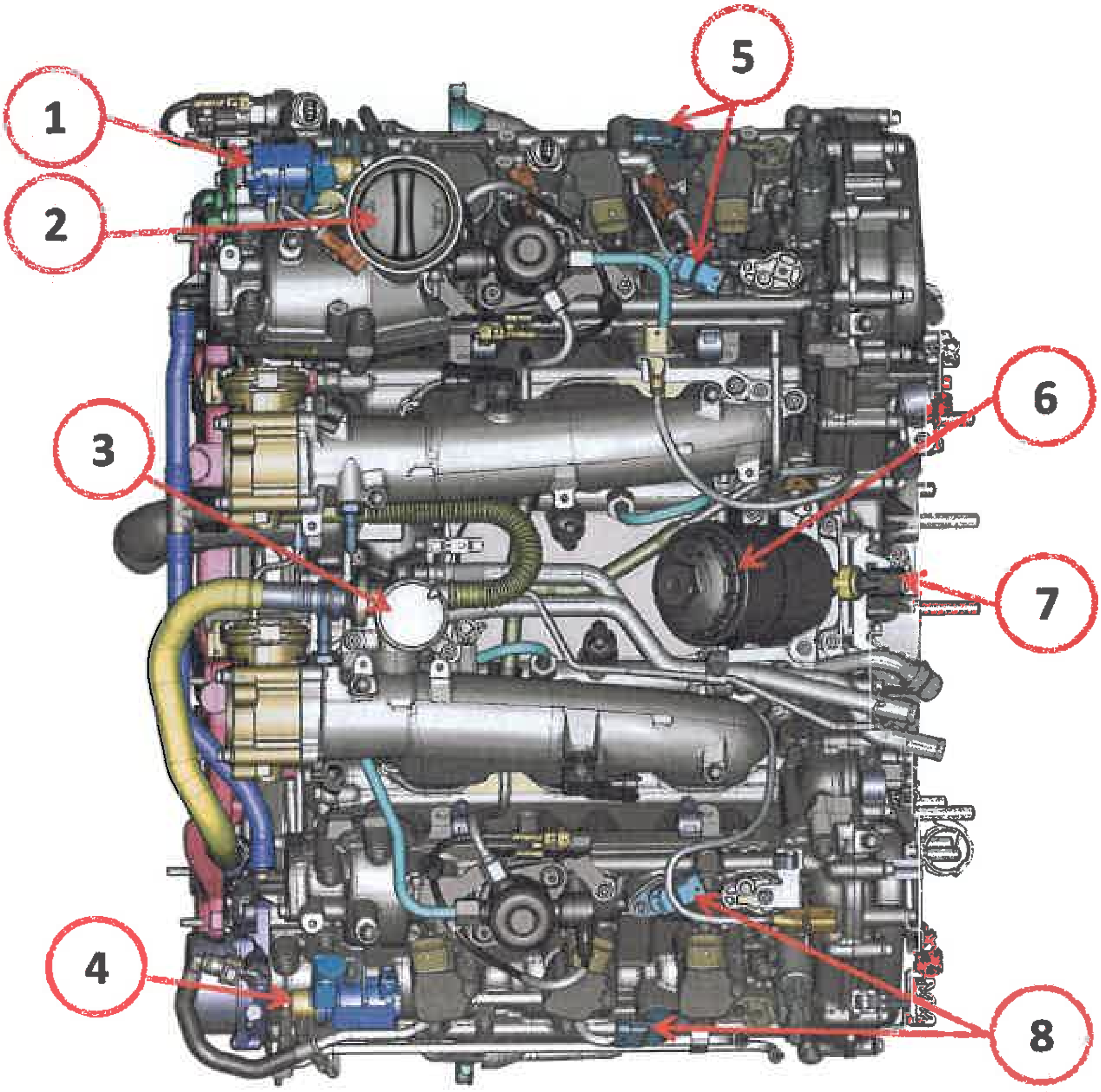
*Right side view*

Right Bank



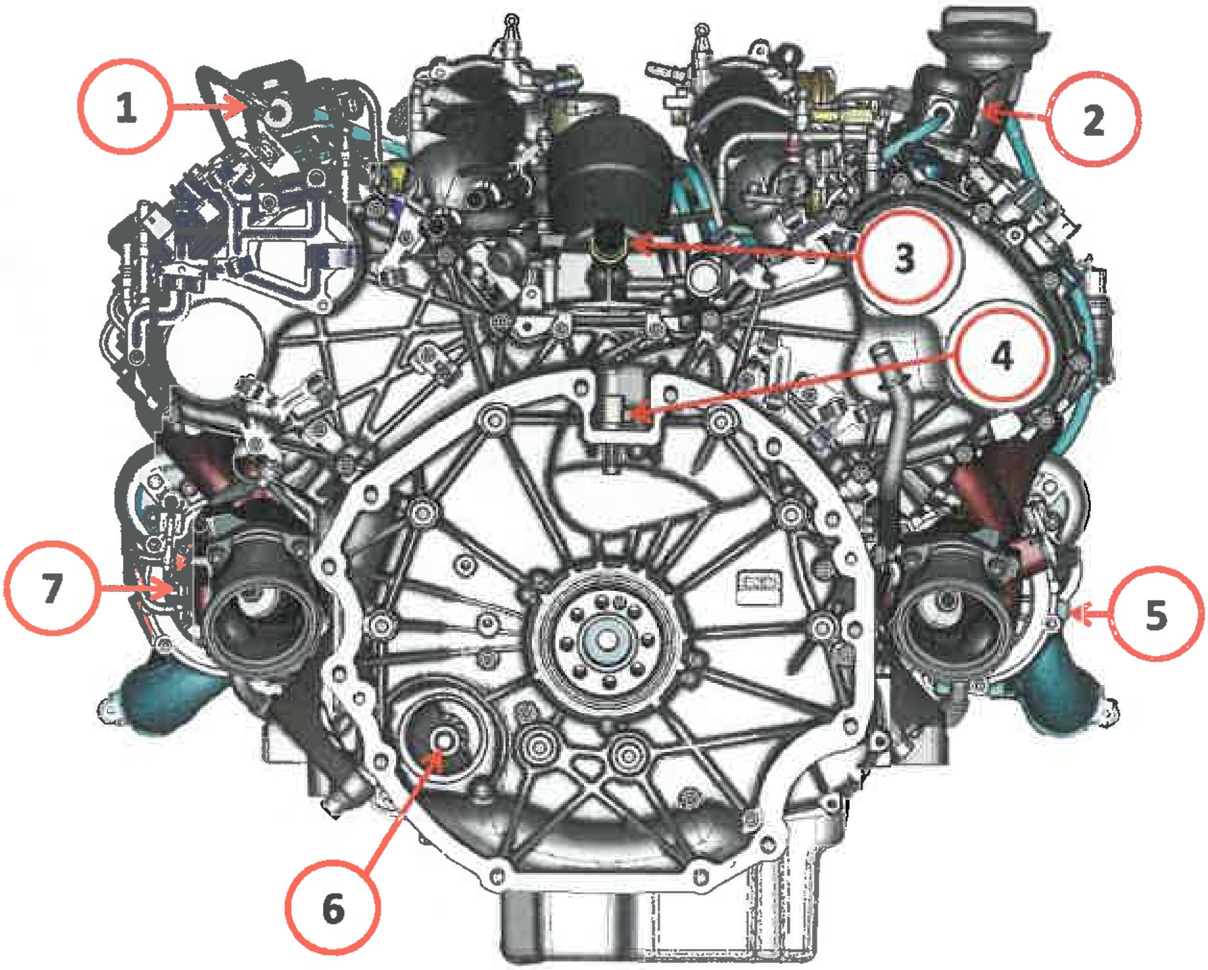

Key:
1 – Alternator
2 – Solenoid valve to lubricate right turbocharger.
3 – Water pump intake pipe connection.
4 – Solenoid valve controlling waste gate.
5 – Right bank high pressure petrol pump.
6 – Right bank coils.
7 – Solenoid valve controlling right bank phase ~~transformer.~~ Phasers
8 – Right bank solenoid valve to deactivate hydraulic tappet.
9 – Right turbocharger

*Top view*



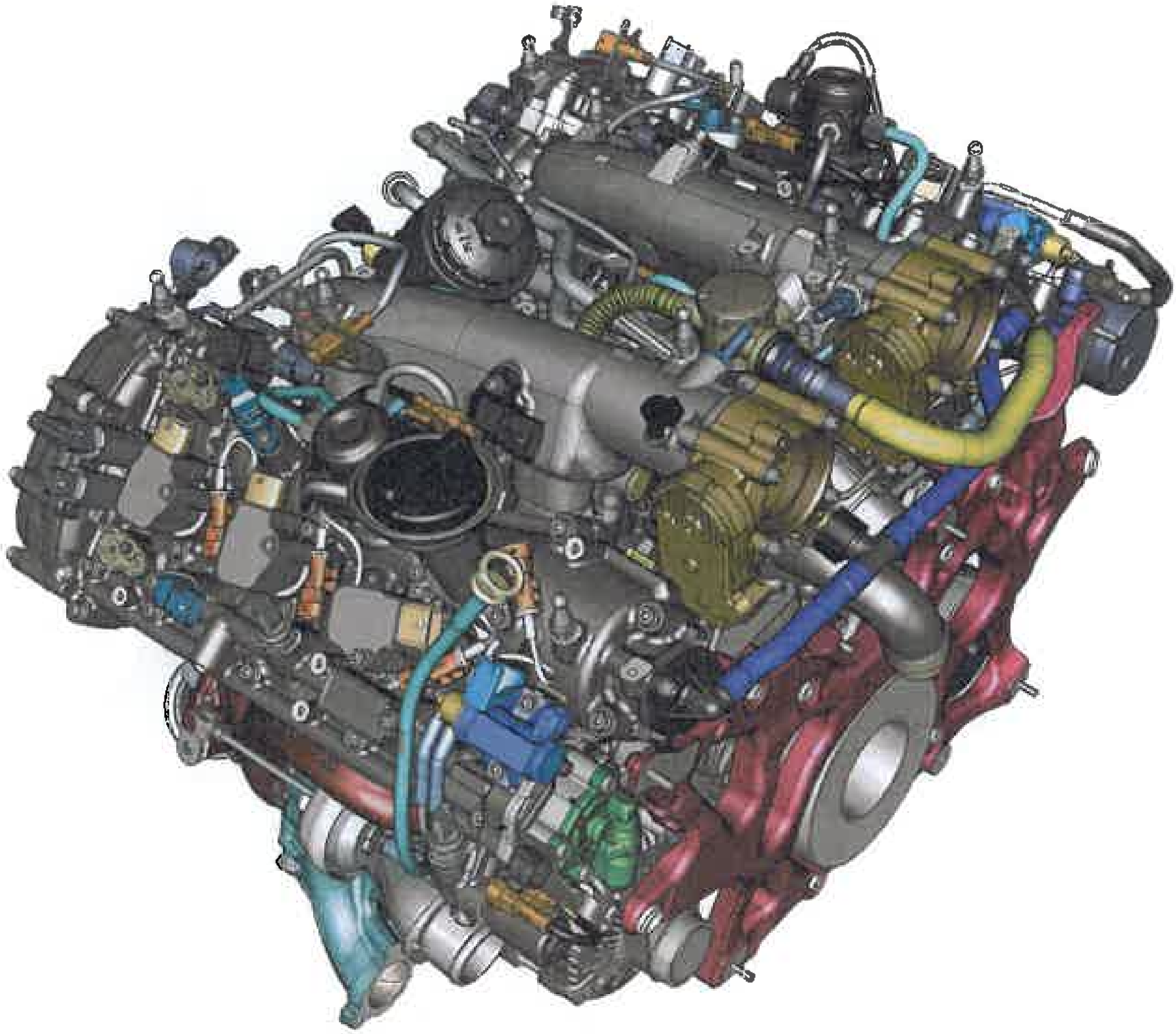

Key:
1 – Solenoid valve controlling right bank waste gate.
2 – Channel cap for engine oil entry.
3 – Oil vapour by-pass valve.
4 – Solenoid valve controlling left bank waste gate.
5 – Phase sensors (intake and exhaust) right bank.
6 – Oil filter.
7 – Oil pressure sensor.
8 – Phase sensors (intake and exhaust) left bank.

*Transmission side view (conciding with timing side).*




Key:
1 – Left bank high pressure pump.
2 – Right bank high pressure pump.
3 – Oil pressure sensor.
4 - Engine rpm sensor.
5 – Right side turbocharger
6 – Starter.
7 – Left side turbocharger

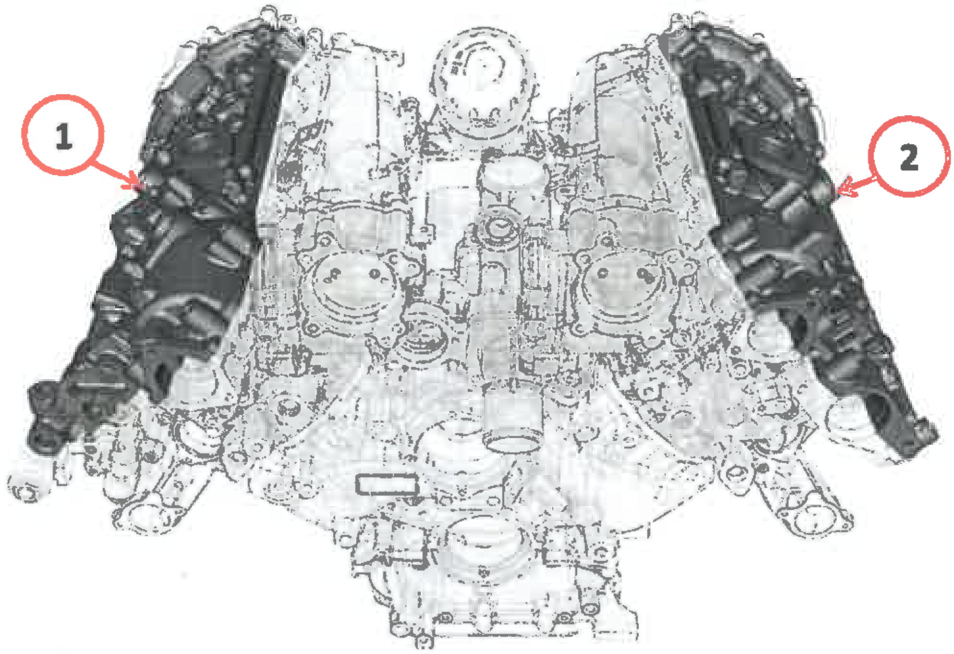
## MECHANICS OF THE ENGINE.



This chapter describes the characteristics of the following components:

- Tappet covers.
- Cylinder heads.
- Camshaft axles with timing reference.
- Intake and exhaust valve valve actioning.
- Engine bed.
- Under engine bed.
- Crankshaft.
- Pistons.
- Connecting rods.

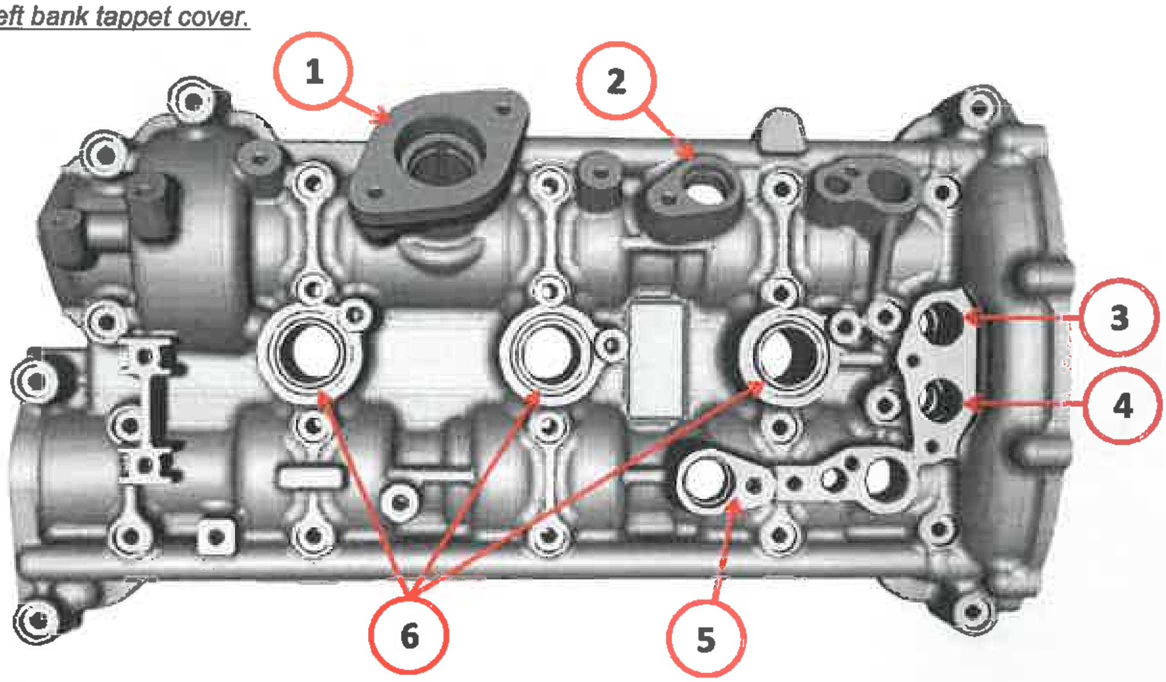
**Tappet covers.**




Key:
1 – Right tappet cover.
2 – Left tappet cover.

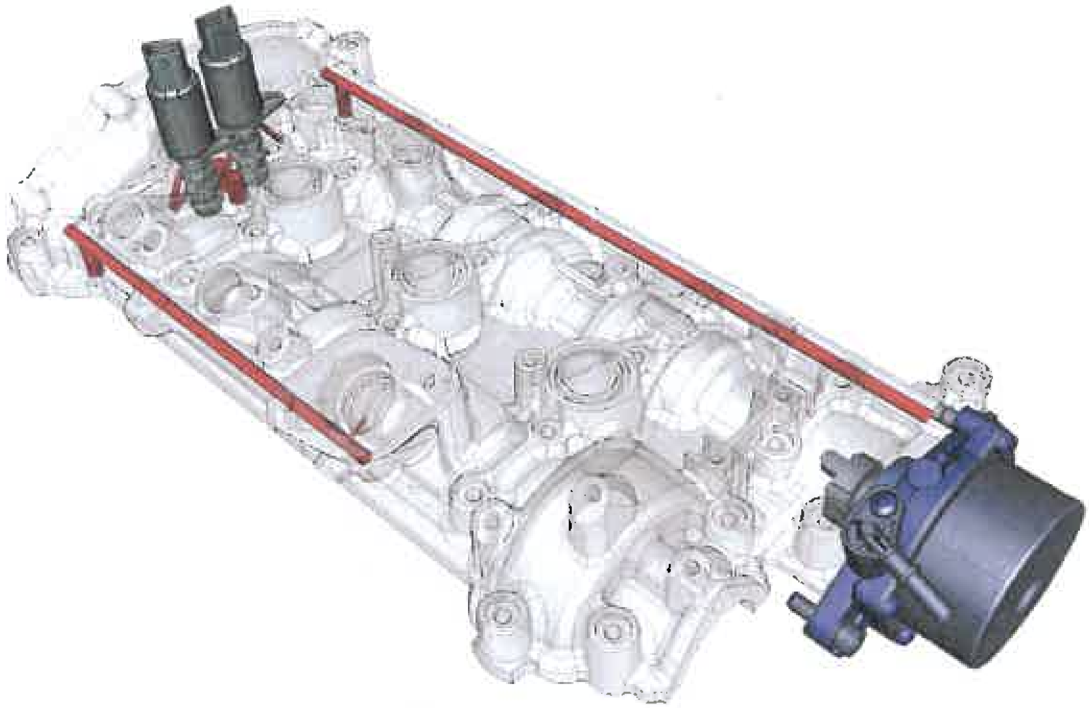
The tappet covers for the two bearings can be distinguished from each other by the shape of the interior engine oil channelisation. Both tappet covers are in aluminium. Along the lower surface of the cylinder head interface, there is a rubber gasket (sitting on the cylinder heads).

*Left bank tappet cover.*

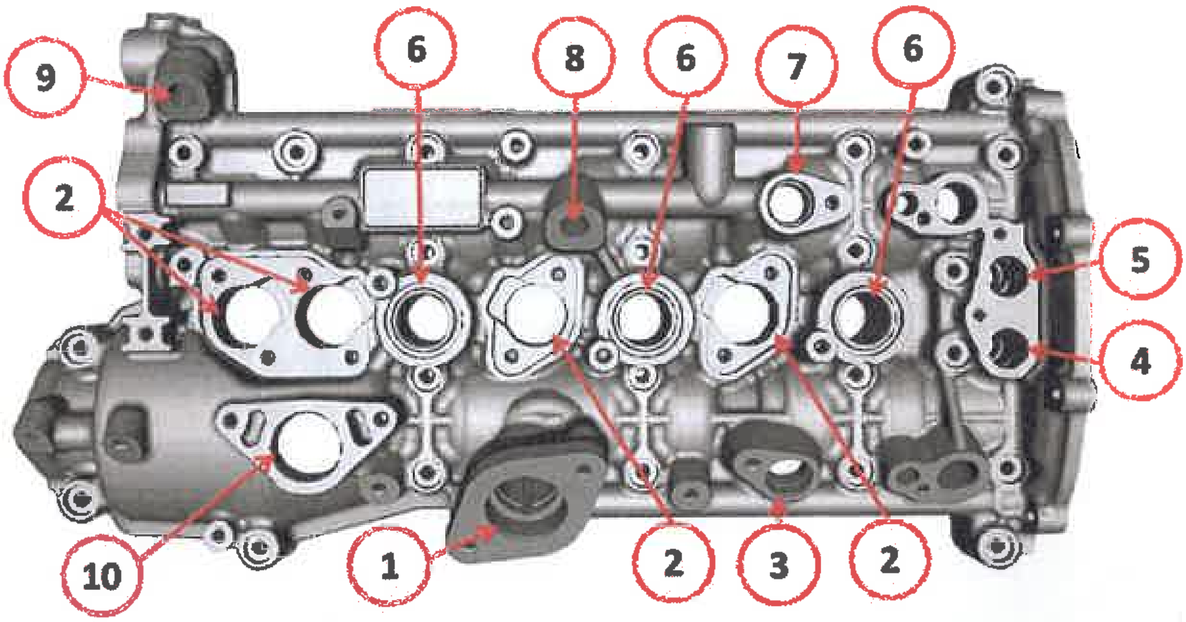



Key
1 – High pressure petrol pump housing.
2 – intake side phase sensor housing.
3 – solenoid valve transformer housing in exhaust phase.
4 – solenoid valve transformer housing in intake phase.
5 – exhaust side phase sensor housing.
6 – reel housings.

The tappet covers on the left side have oil channels inside needed to lubricate the vacuum pump, to supply the solenoid valve phase transformers and to lubricate the housing where the high pressure pump plunger runs.

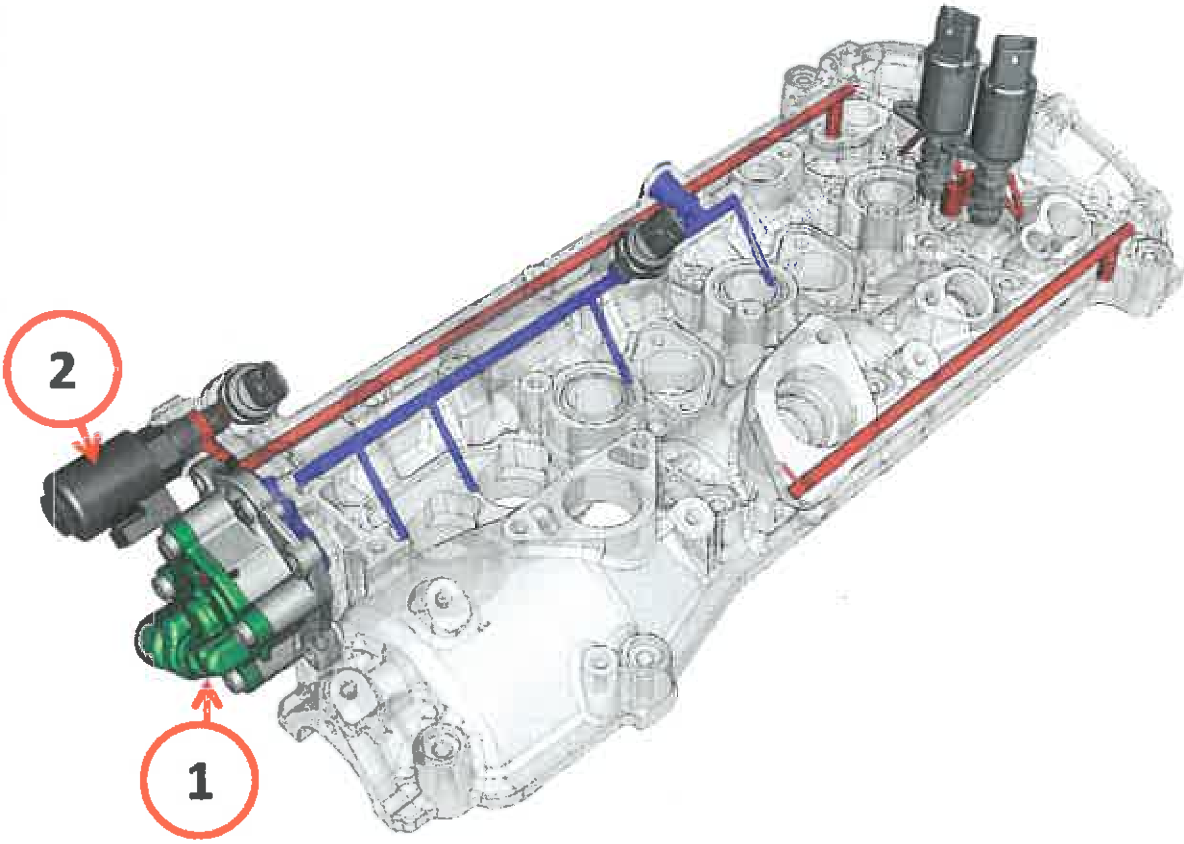


*Right bank tappet cover.*




Key:
1 – High pressure petrol pump housing.
2 – Hydraulic tappet deactivation solenoid valve housing.
3 – exhaust side phase sensor housing.
4 – Exhaust side solenoid valve transformer.
5 – Intake side solenoid valve transformer.
6 – Reel housings.
7 – intake side phase sensor housing.
8 – housing for oil pressure sensor of the hydraulic circuit to deactivate tappets.
9 – housing for oil pressure sensor of the hydraulic circuit to deactivate tappets.
10 – Engine oil entry cap support connection housing.

The left side tappet cover has the oil channels inside needed to lubricate the housing where the high pressure plunger runs, the oil channels that supply the solenoid valve phase transformer; the exit opening for turbocharger lubrication and the oil channels (in blue) of the hydraulic tappet deactivation circuit.

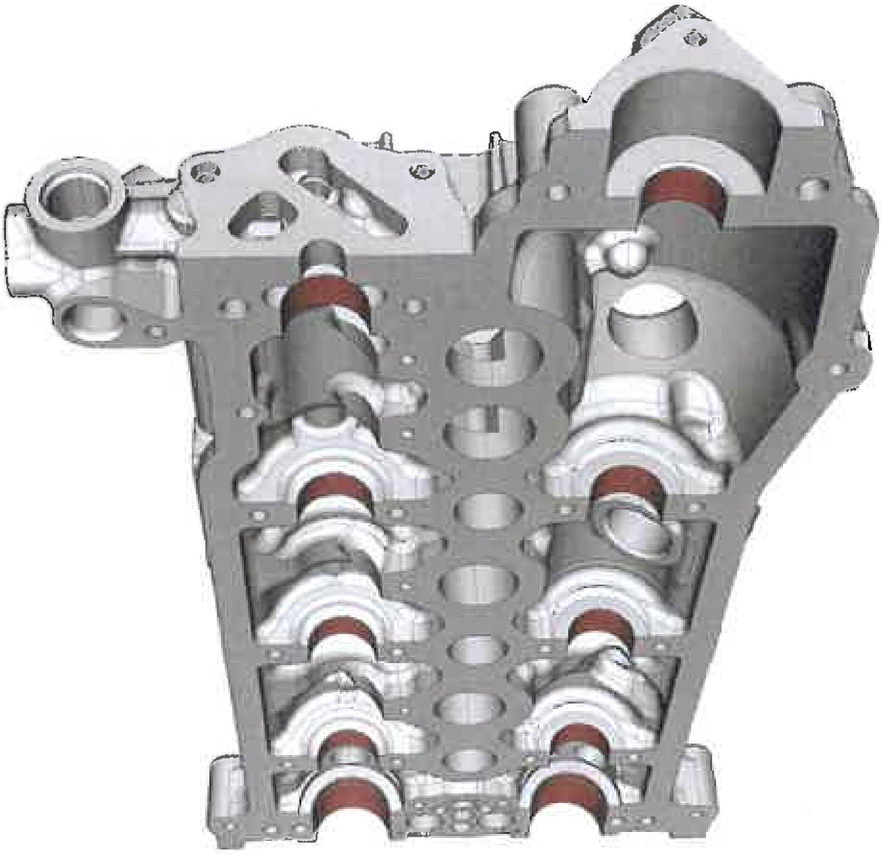



Key:
1 – Additional oil pump.
2 – Solenoid valve to lubricate right turbocharger.

The additional oil pump for the cylinder deactivation circuit is fastened in part to the tappet cover (the other fasteners are on the head) while the right turbocharger lubrication solenoid valve is seated in a housing obtained entirely in the tappet cover.

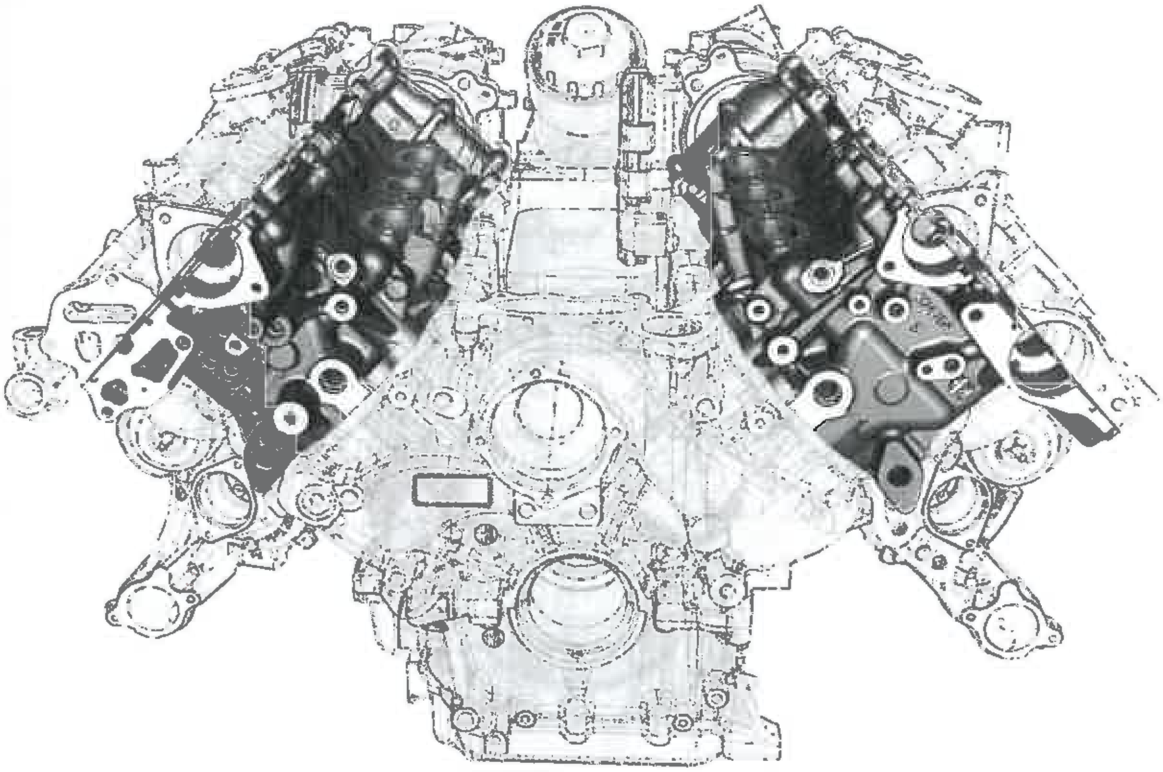
Both the tappet covers have the characteristic of integrating the cam shaft axle support caps in the lower part.

*Right tappet cover.*

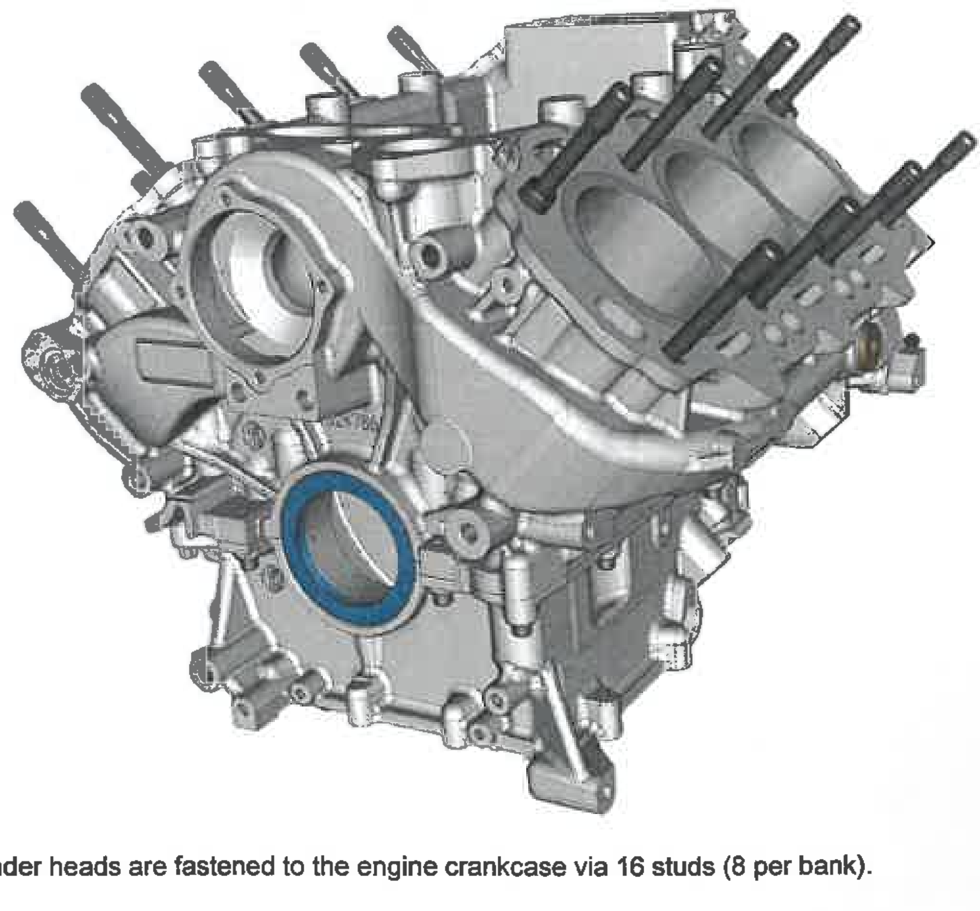


*Left tappet cover.*

**Cylinder heads.**

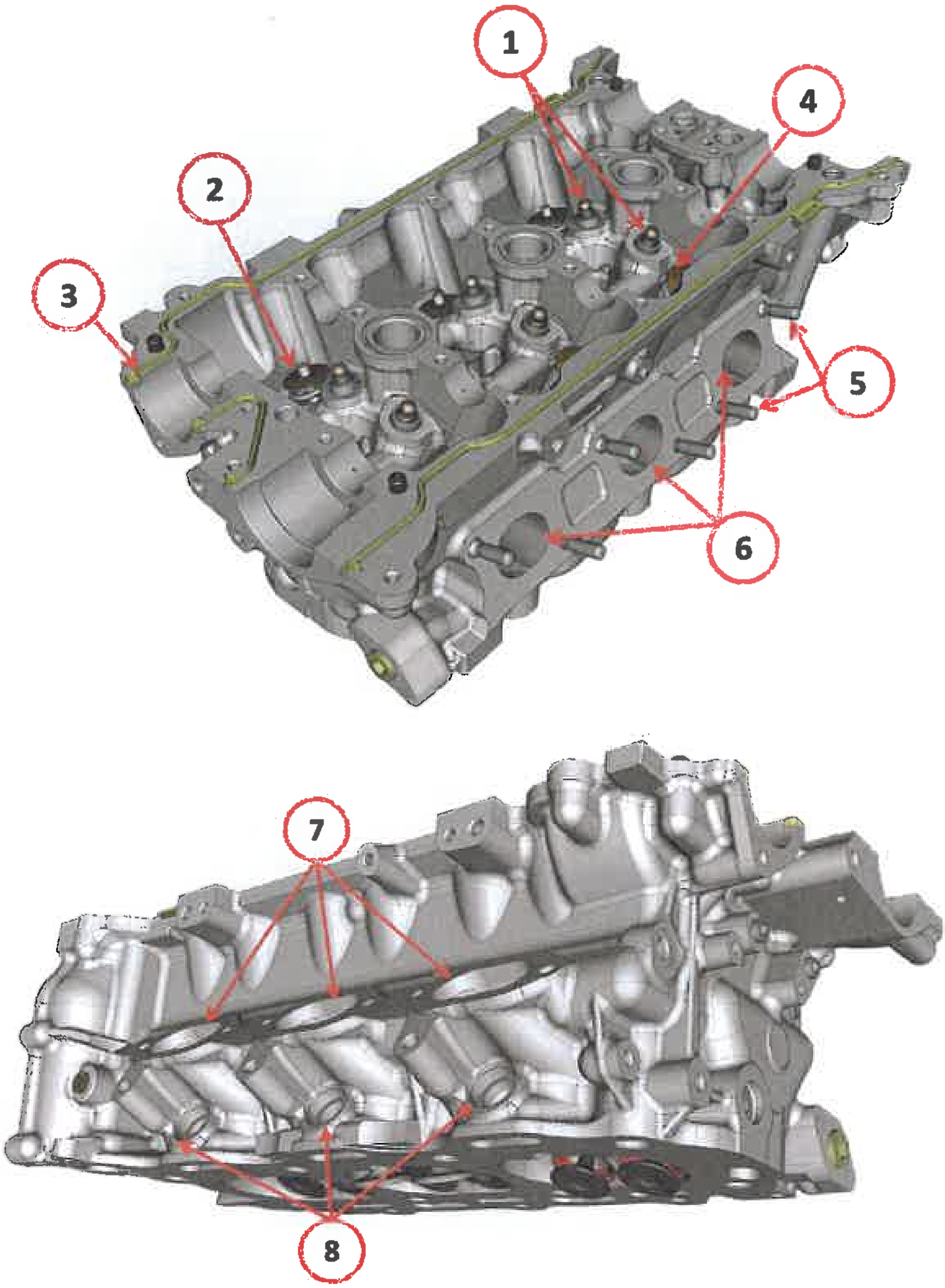


The two bank cylinder heads are in aluminium. They are different in shape, for the different internal lubrication channels and the different cooling circuit channels.



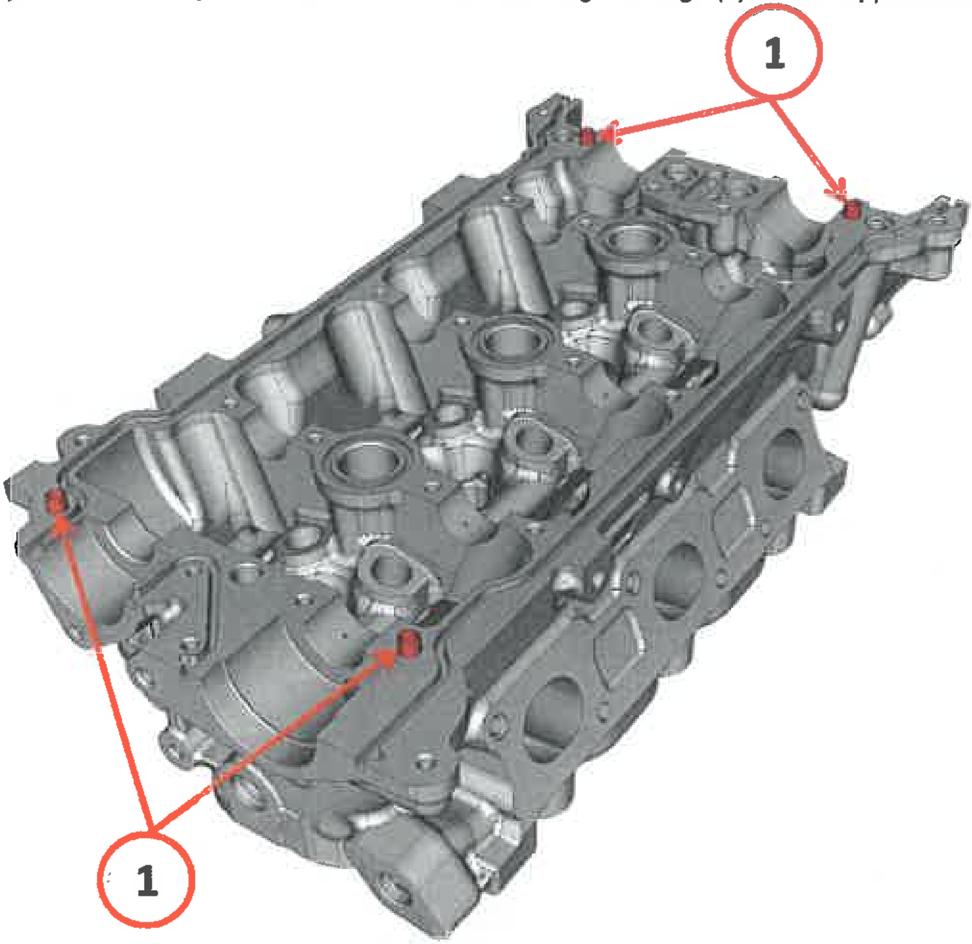
The cylinder heads are fastened to the engine crankcase via 16 studs (8 per bank).

<u>*Left bank cylinder head.*</u>

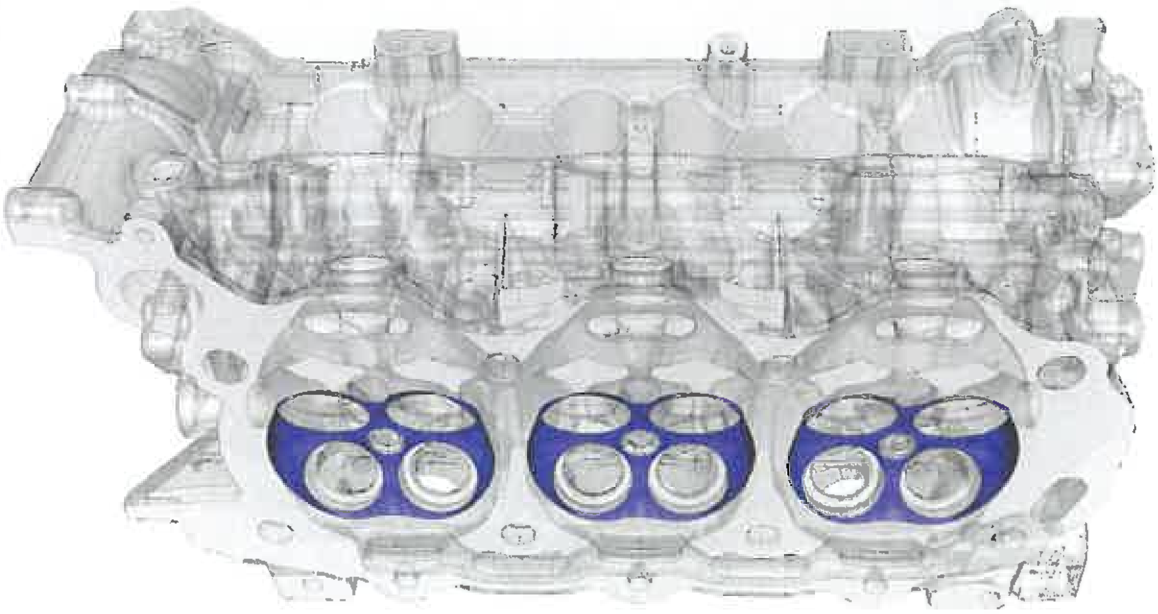


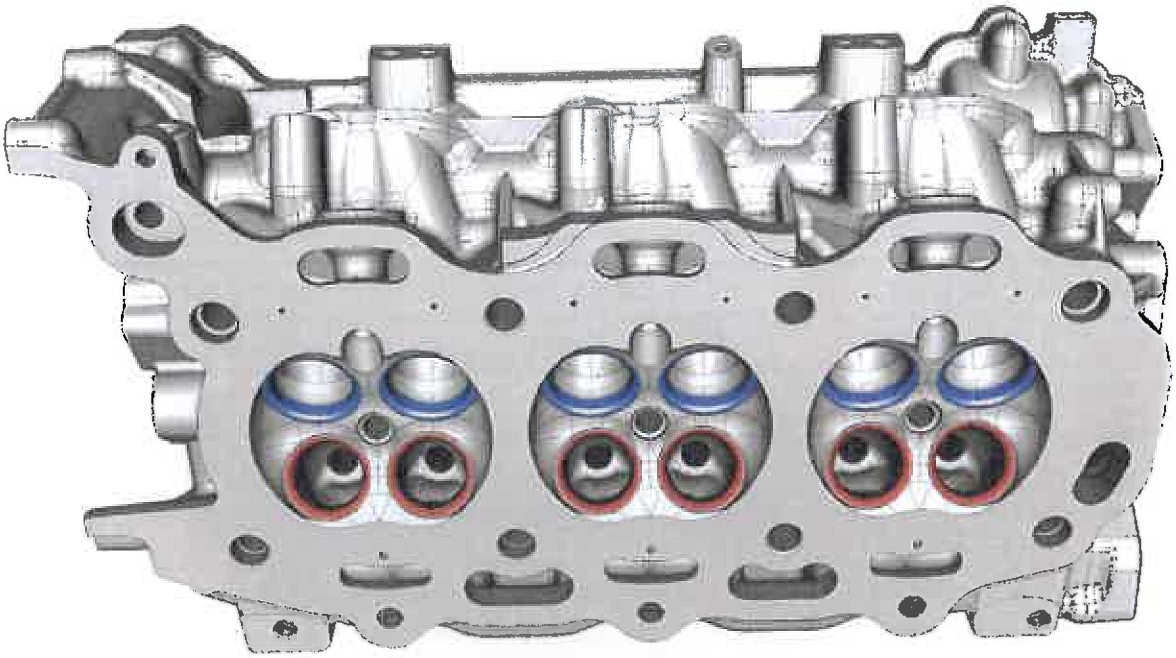

Key:
1 – Hydraulic tappets.
2 – Intake side valves.
3 – Cylinder head-tappet cover interface gasket.
4 – Exhaust side valve.
5 - Studs for exhaust manifold fastening.
6 – Exhaust duct.
7 – Intake duct.
8 – Injector housings.

On the upper side of the cylinder heads there are 4 centring bushings (1) for the tappet cover.

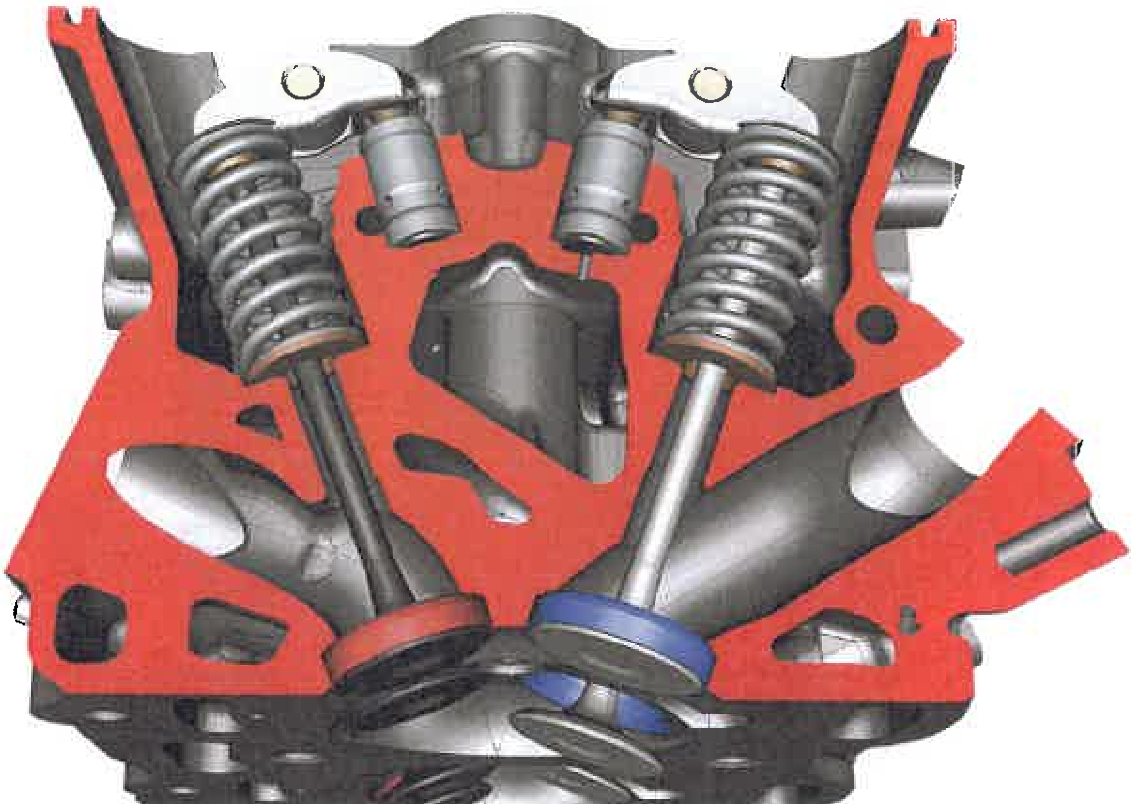



The cylinder head, along the interface surface with the crankcase, has three caps that constitute the combustion chamber. Inside them is where the air-petrol mixture burns, releasing thermal energy needed to increase the pressure from which the engine performance is obtained in terms of throttle and power.

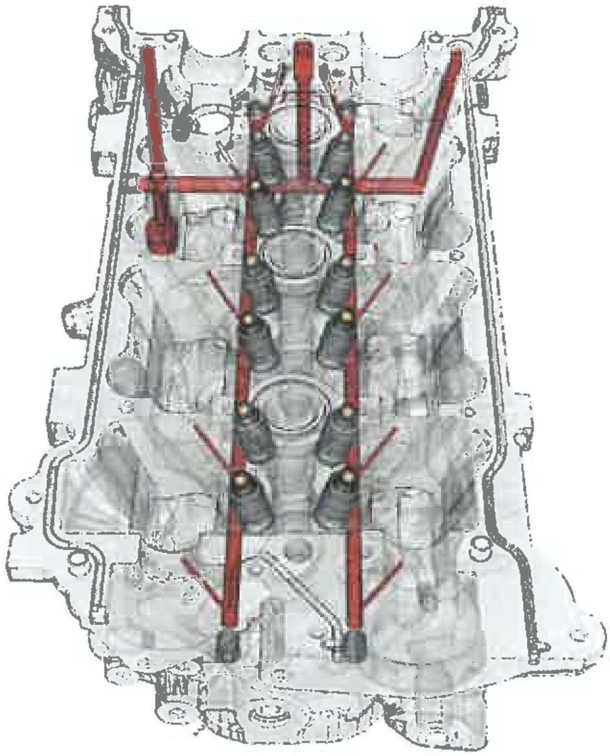




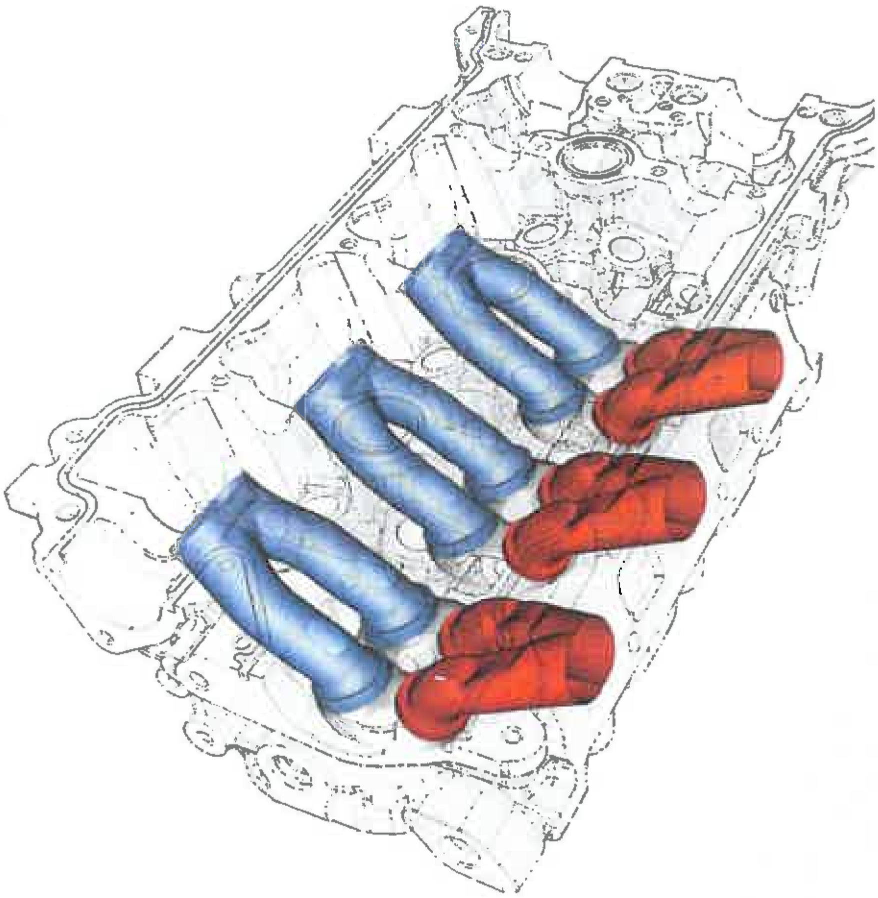
The inlet and exhaust valve housings are in steel.



Inside the cylinder heads are the lubrication and oil supply channels for the solenoid valve phase transformer.

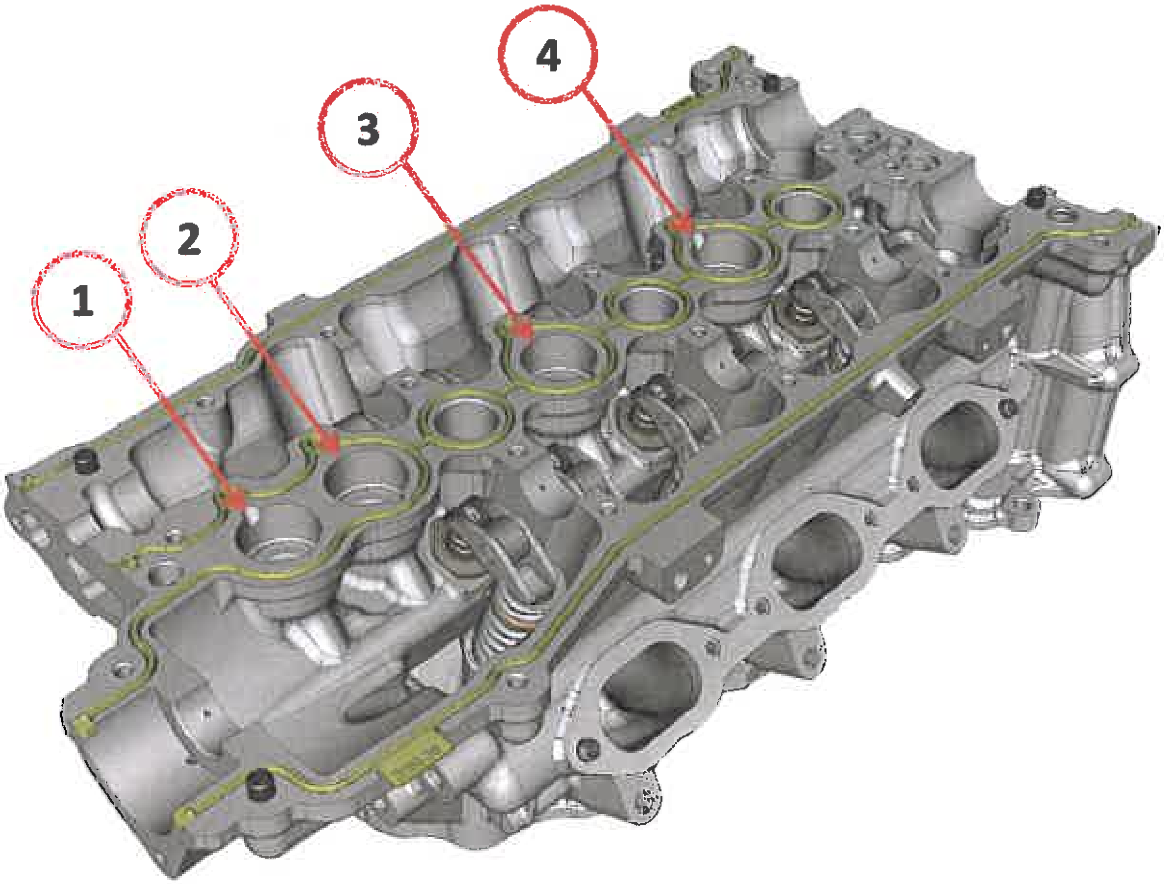


The geometry of the intake and exhaust conduits has been defined in order to optimise filling the cylinder and conferring the fresh charge entering the right level of turbulence to speed up the air-petrol mixture combustion.



*Right bank cylinder head.*

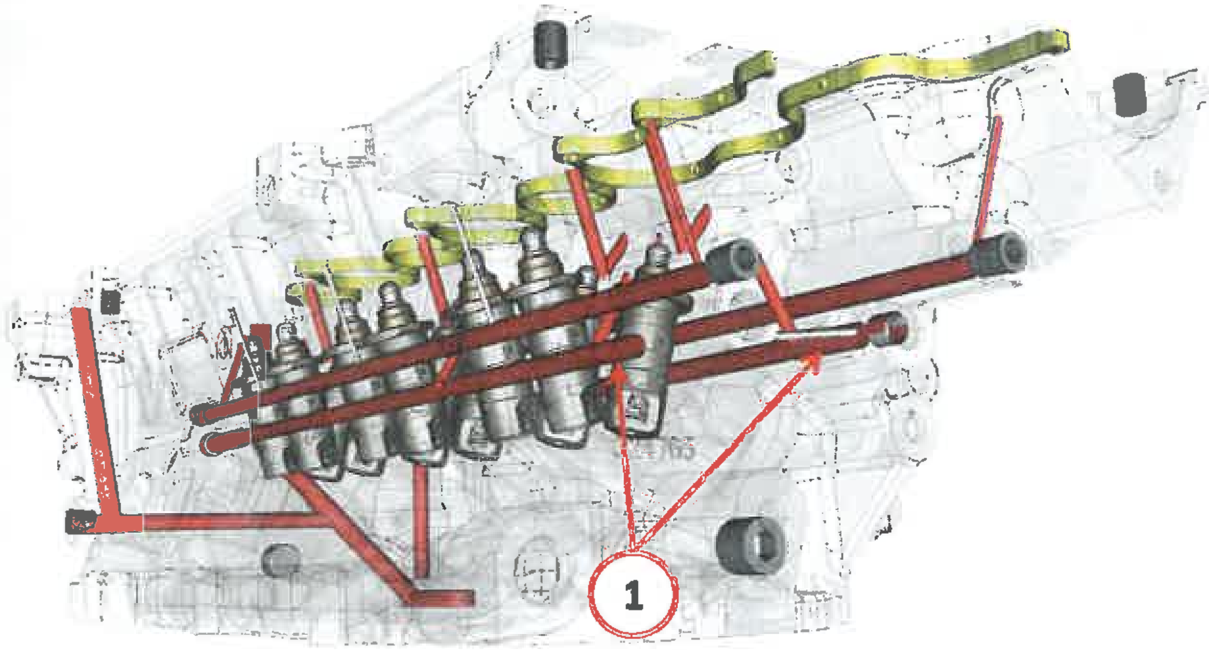
The right bank cylinder heads have the same characteristics as the left ones. The main difference is the different shape of the tappet housing, the internal oil passage channels and the solenoid valve housings to deactivate the tappets.




Key:

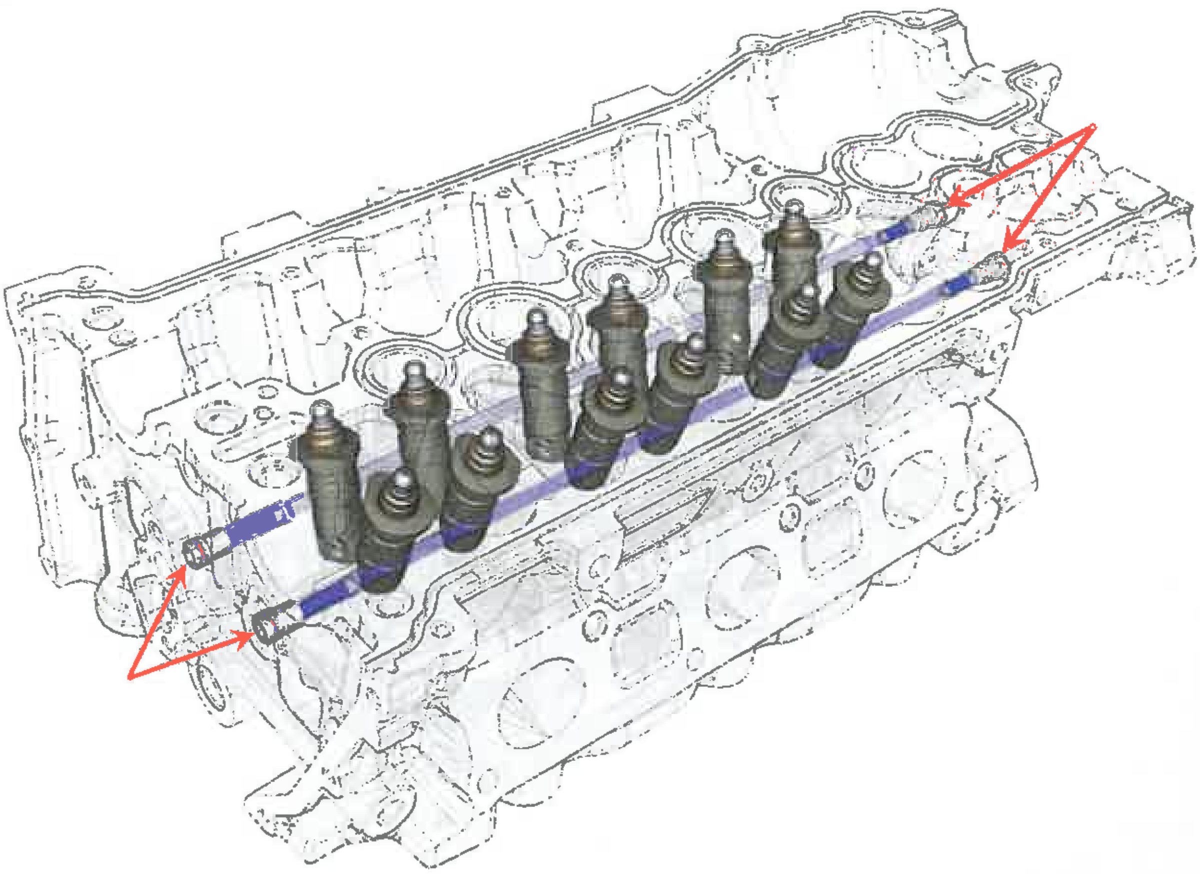
1 – Solenoid valve housing for deactivating the cylinder 1 tappet, intake side.
2 – Solenoid valve housing for deactivating the cylinder 1 tappet, exhaust side.
3 – Solenoid valve housing for deactivating the cylinder 2 and 3 tappet, exhaust side.
4 – Solenoid valve housing for deactivating the cylinder 2 and 3 tappet, intake side.

The presence of tappets that can be disabled implies that there is an additional oil passage channel in the right cylinder head needed for the tappets to operate.



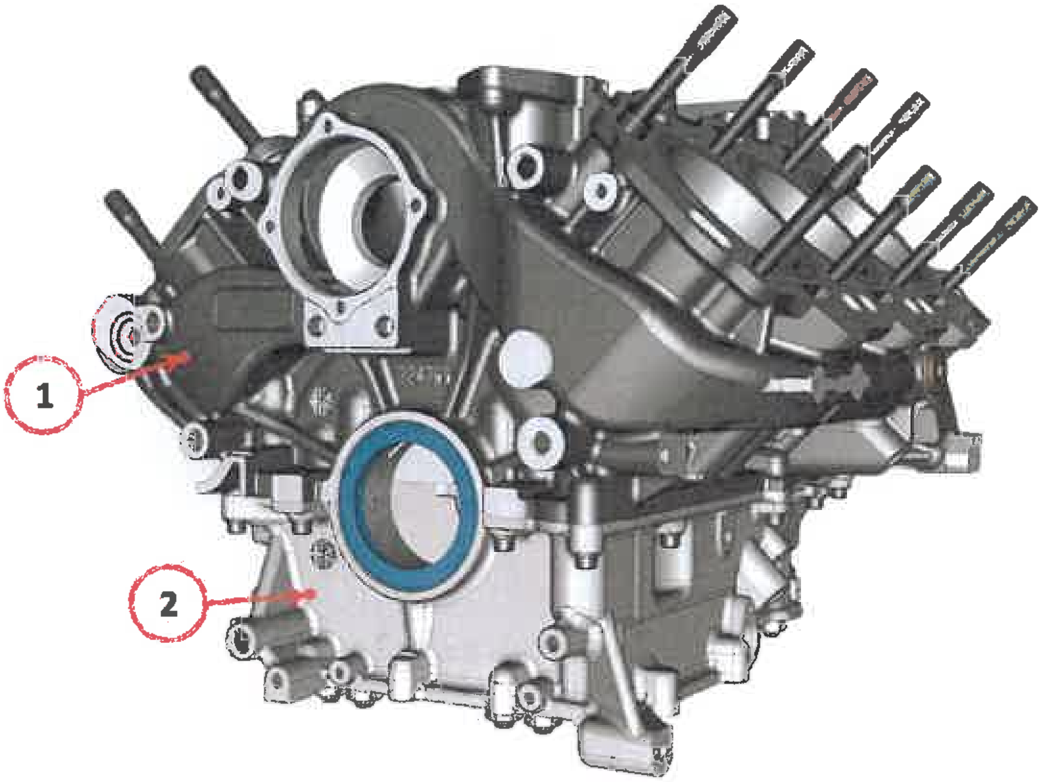

Key:
1 - Additional channel to disable tappets.

There are 4 filters (for life) for the additional channels, to ensure a further filtering step for the oil that operates the tappet deactivation mechanism.



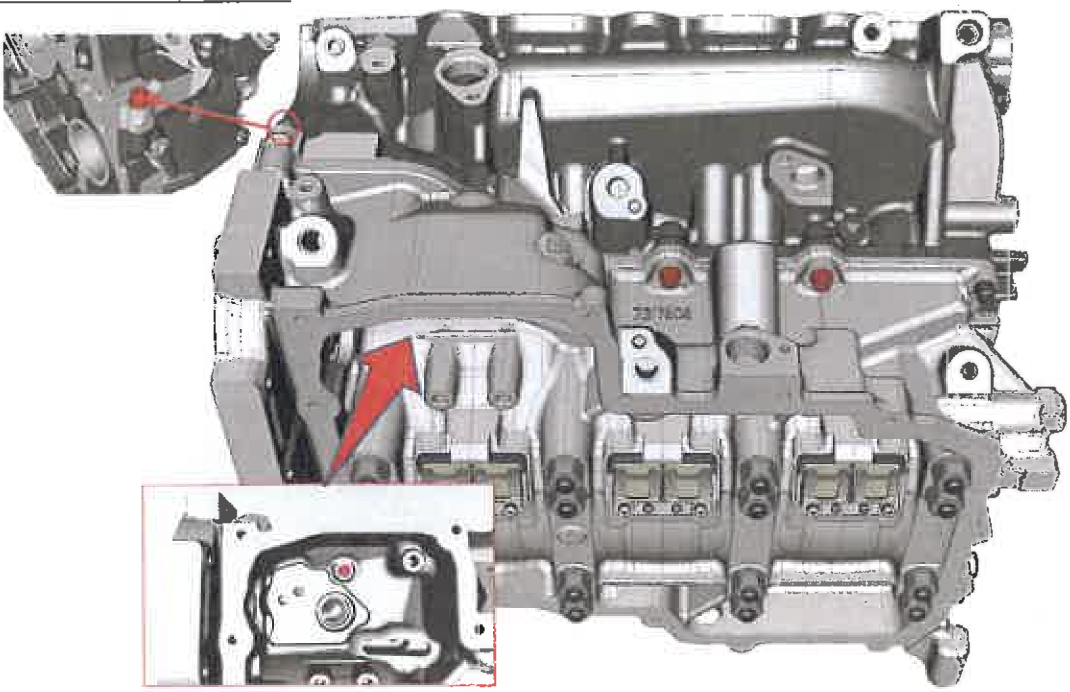
## Crankcase.

The engine monoblock consists of a crankcase and an under-crankcase. The two units are connected via screws arranged along the perimeter and studs placed on the lower part of the crankcase. The entire crankcase is in aluminium.



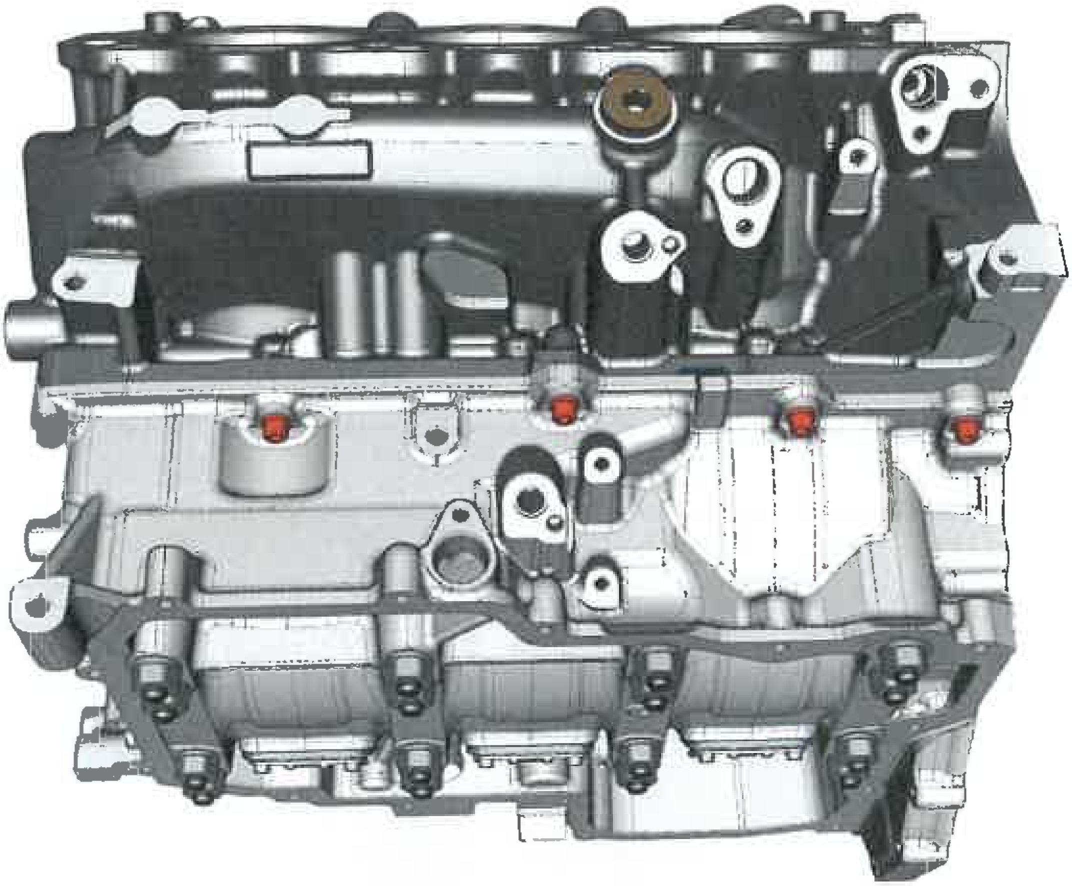

Key
1 - Crankcase.
2 – Under-block.

*Right side connection screws.*

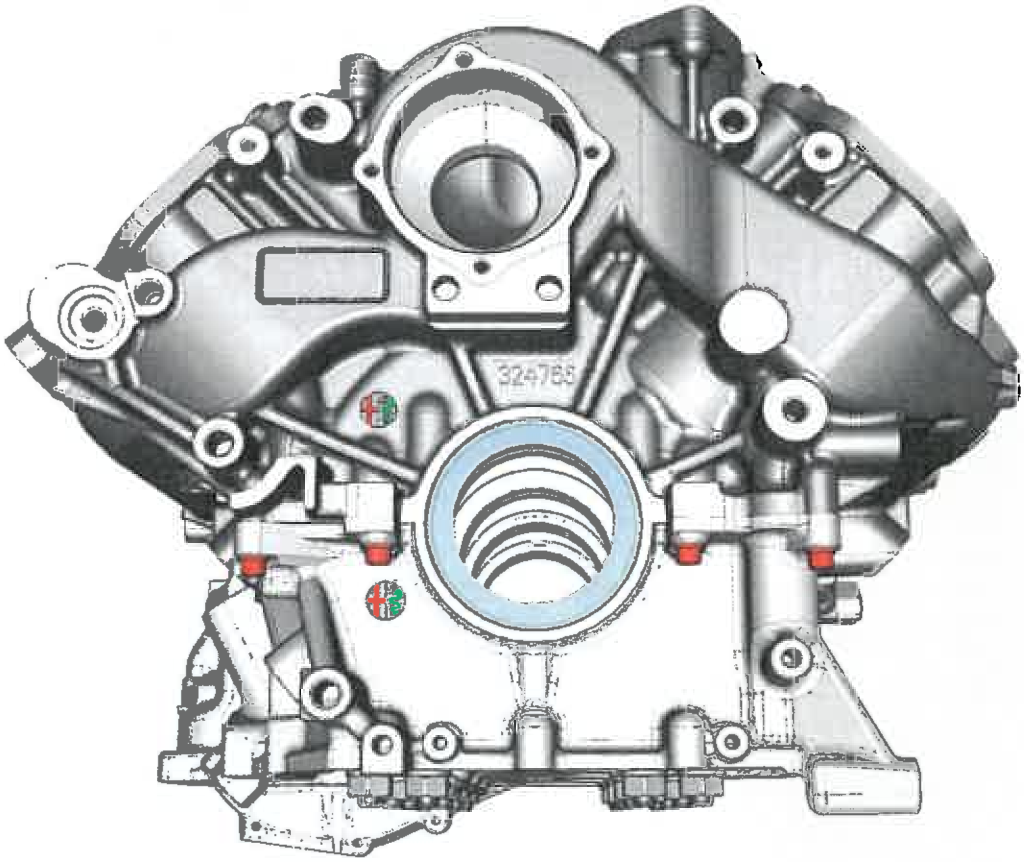


One screw is located inside the oil pump tank.

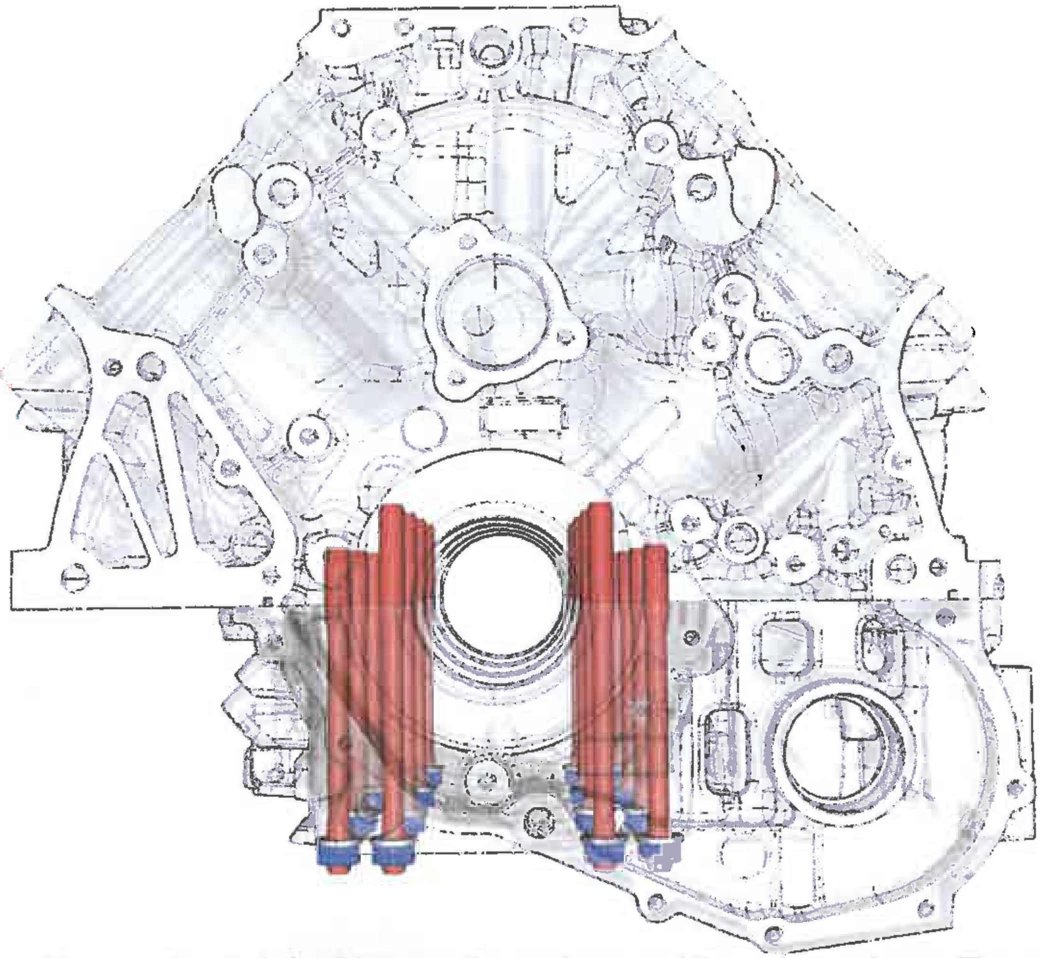
<u>*Left side screws.*</u>



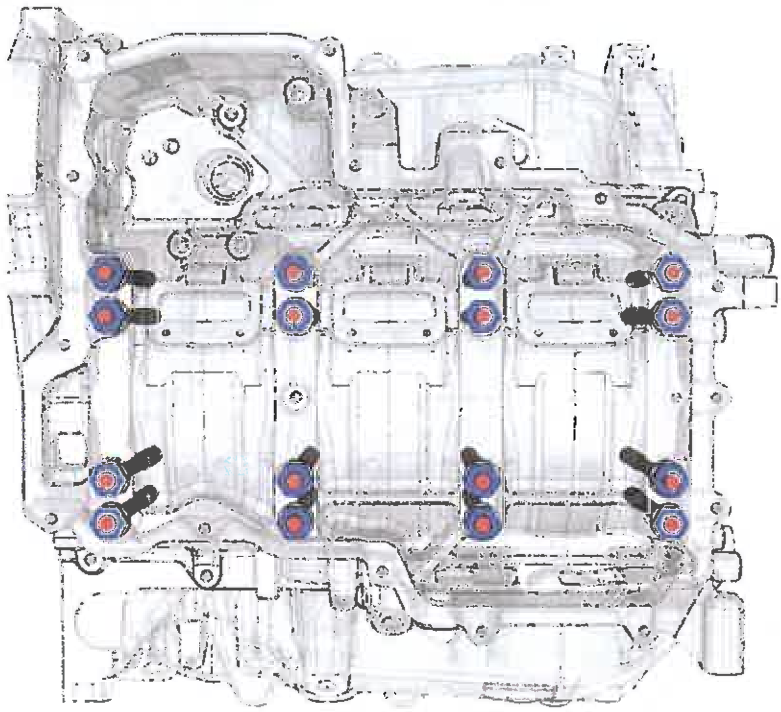
<u>*Front screws (drive belt side).*</u>



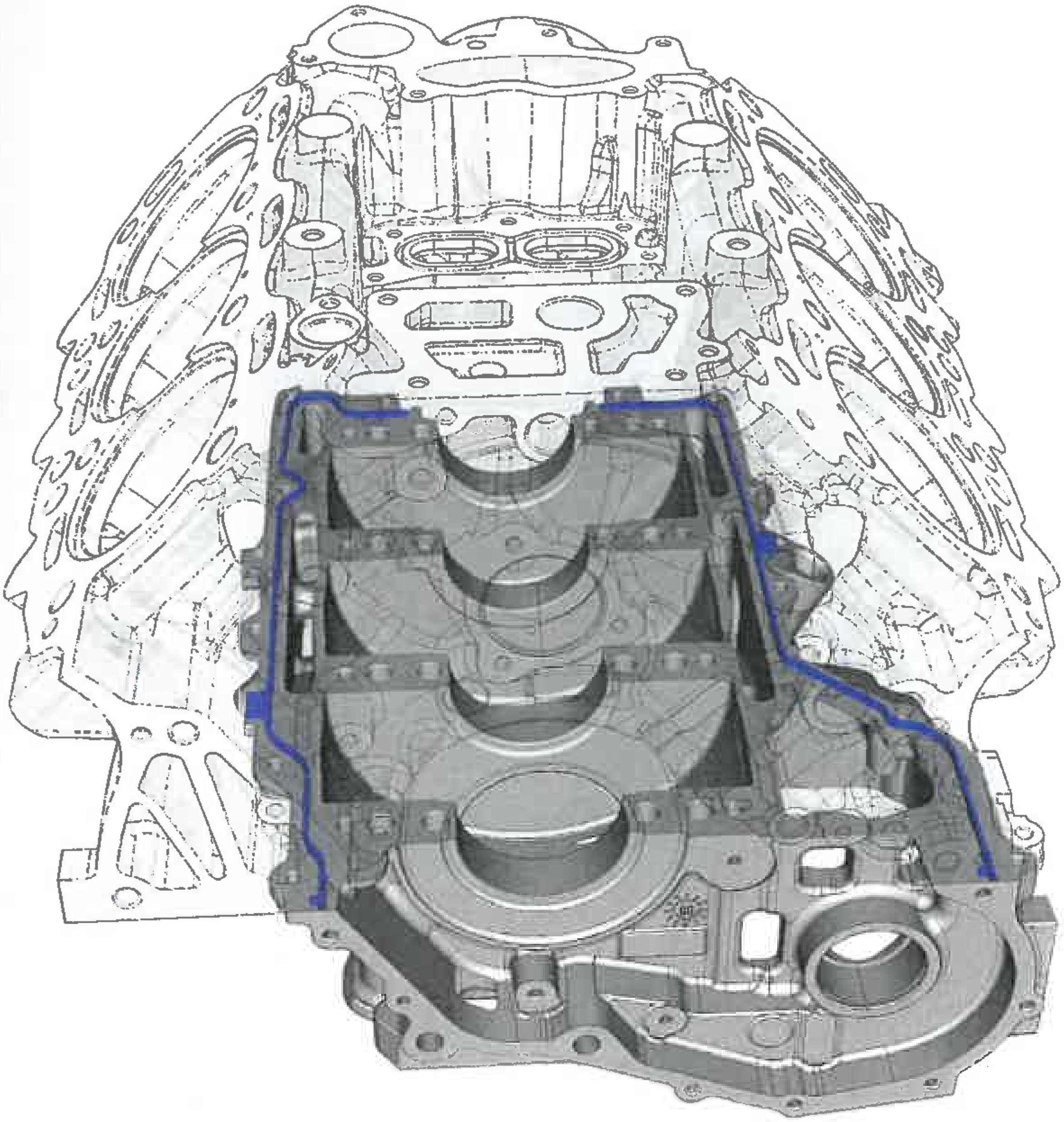
Lower area studs.



There are 16 connection studs in all between the crankcase and the under-crankcase. They are held in place by as many nuts.



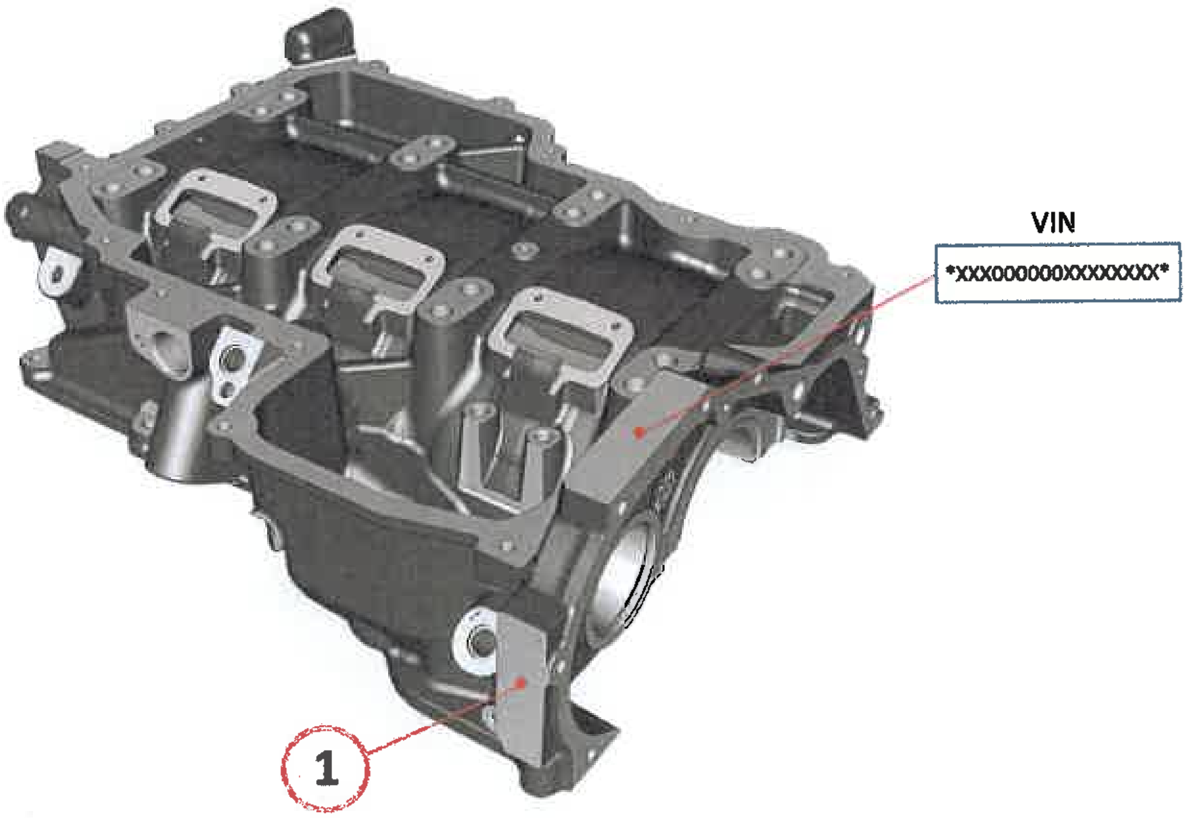
There are two rubber gasket sections between the crankcase and the under-crankcase.



The union of the crankcase and under-crankcase allows the engine camshaft to be supported by 4 main bearings.

*Engine marking and VIN (vehicle identification number).*

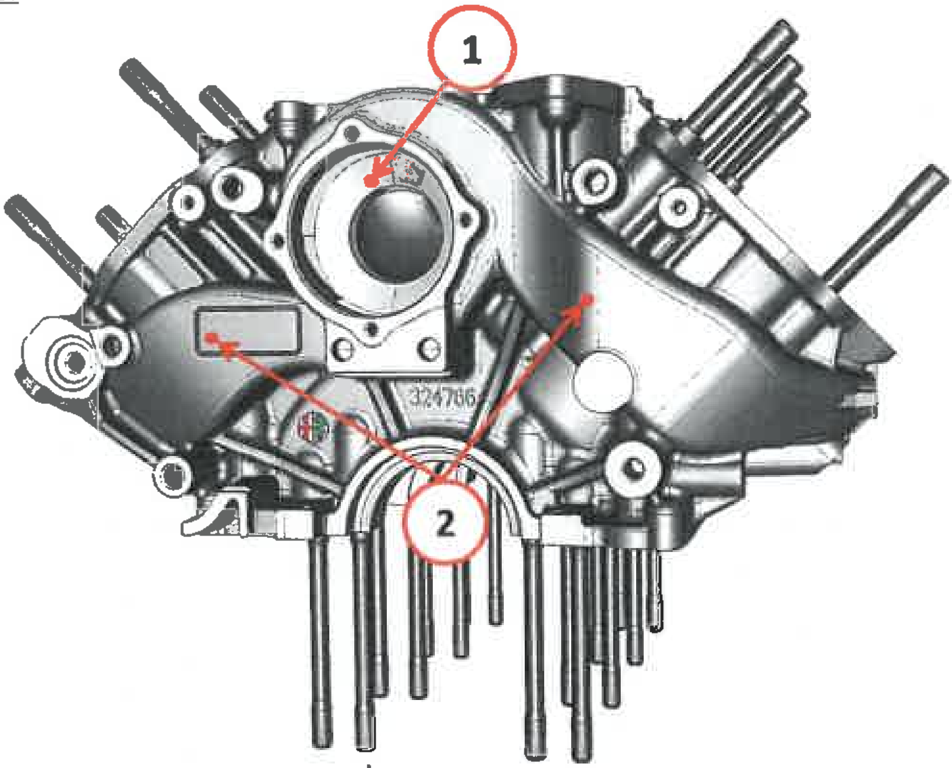
On the underside of the under-crankcase are the engine marking and VIN respectively in the points indicated in the image below.




Key

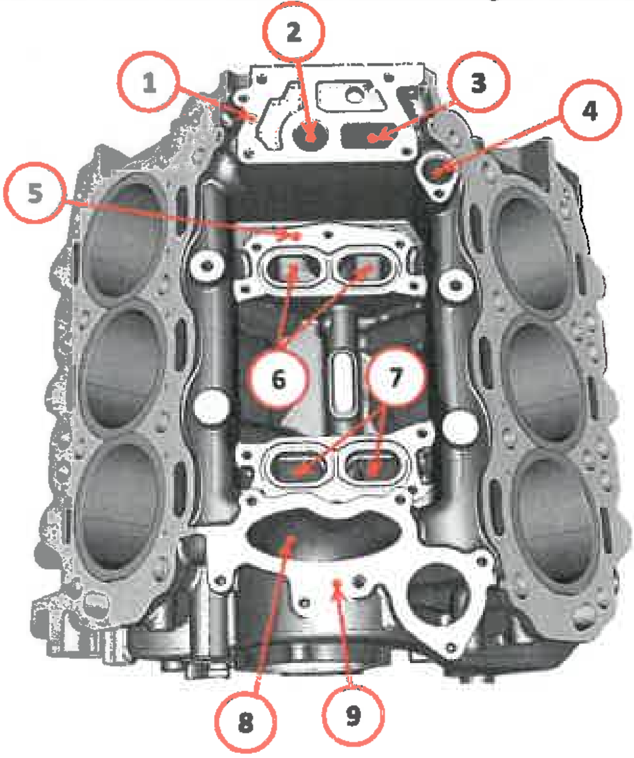
1 – Surface where the engine marking is.

<u>*Engine bed.*</u>




Key
1 – Water pump housing.
2 – Water pump main supply channels.

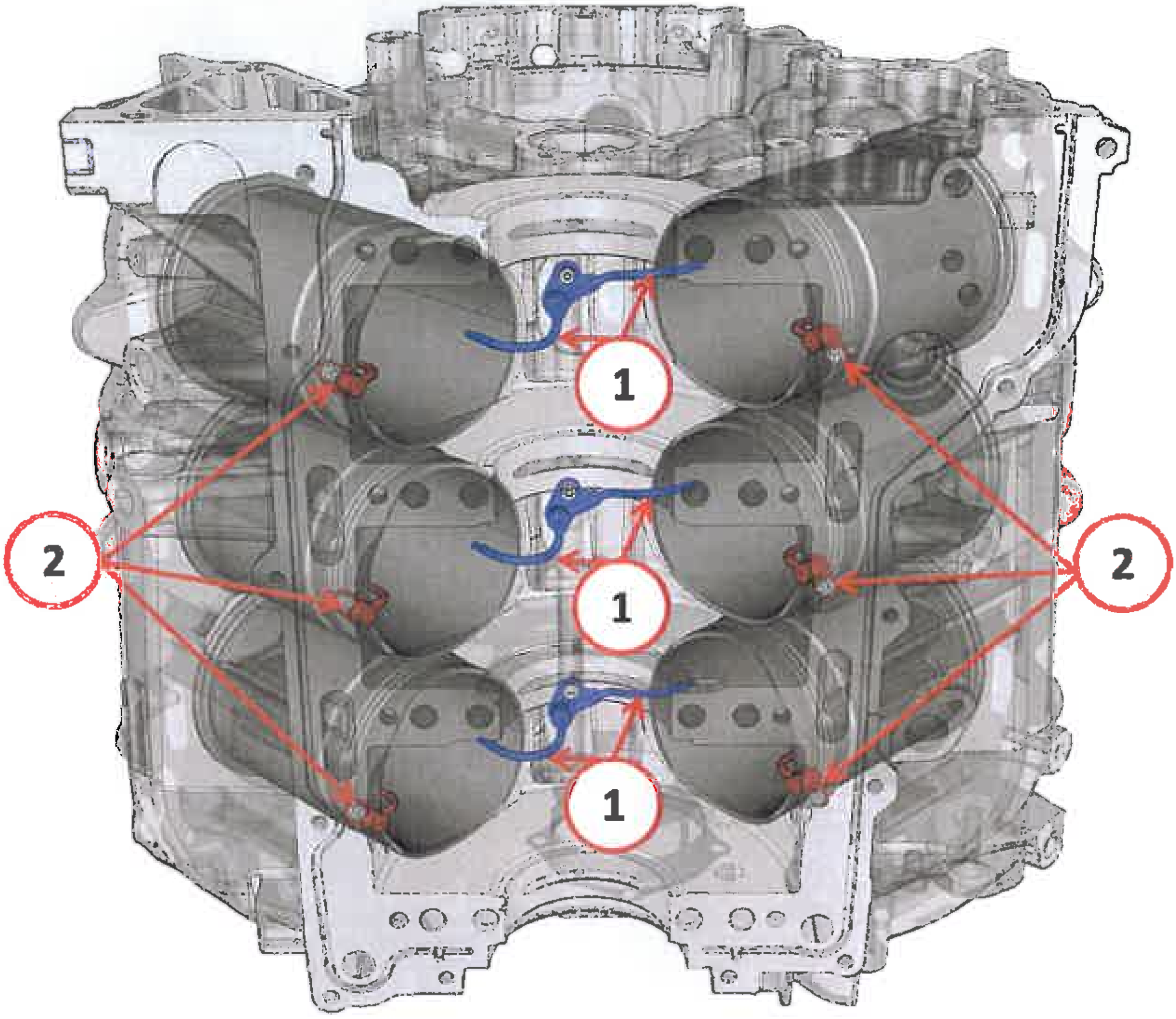
In its front part (drive belt side), the crankcase has its water pump housing, and you can also see on the outside two main pump supply channels in it. In the upper part of the crankcase, in the middle of the "V" are the holes for oil and water flow inside the heat exchanger, to cool the engine oil.




Key:
1 – Interface surface for oil filter support.

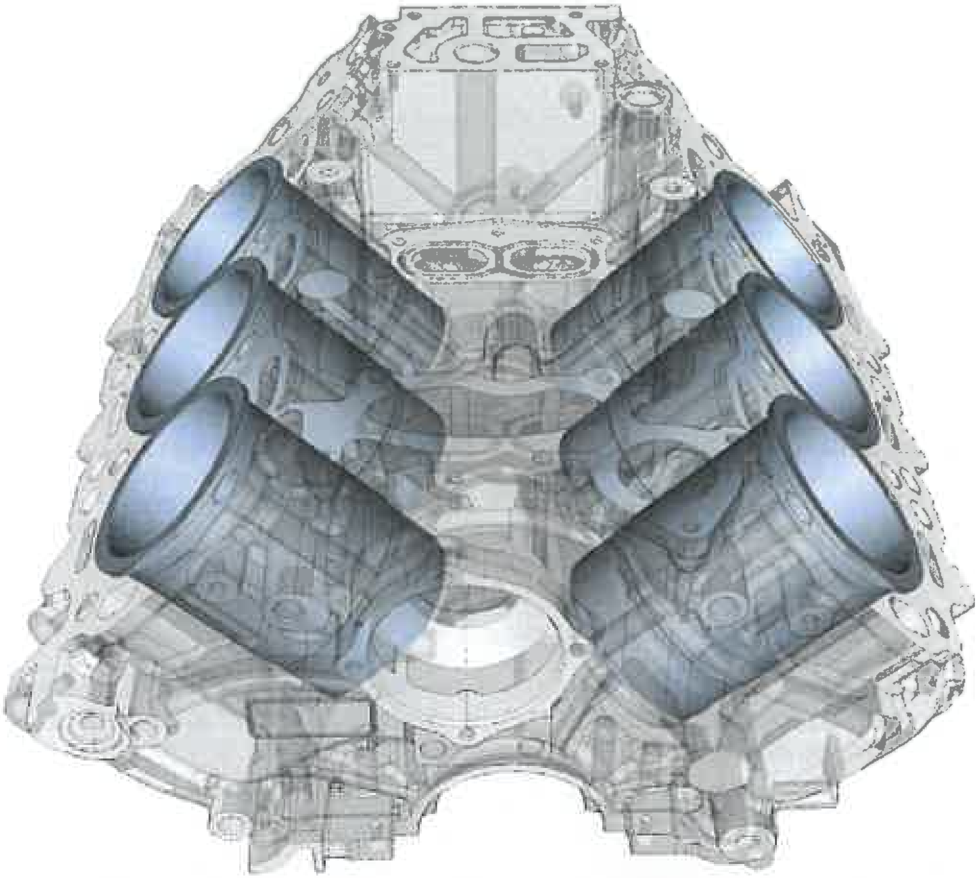
2 – exit channel for oil in the filter.
3 – Intake channel for oil in the filter (coming from the exchanger).
4 – Outlet opening for cooling liquid for the supply pipe towards the compartment heater.
5 – Interface surface for oil-cooling liquid heat exchange.
6 – inlet channel (left) and outlet (right) for oil flow in the exchanger.
7 – inlet channel (left) and outlet (right) for cooling liquid flow in the exchanger.
8 – Intake pump chamber for cooling liquid.
9 – Interface surface for the thermostat group.

In the lower crankcase part are the piston crown cooling nozzles.

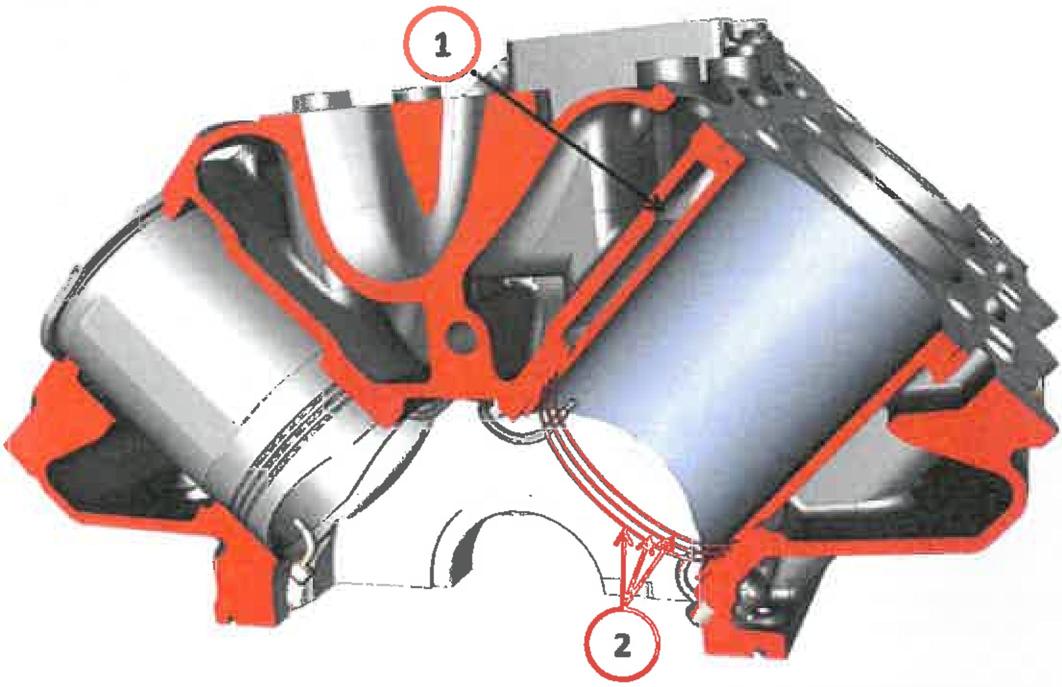



Key
1 – Piston crown cooling nozzles in the intake side.
2 – Piston crown cooling nozzles in the exhaust side.

The cylinders have steel barrels. They are inserted hot into the housings formed in the block. Together with the crankcase cylinder walls, the barrels form a hollow space that serves as a sort of water "shirt" whose objective is to cool the barrels themselves.

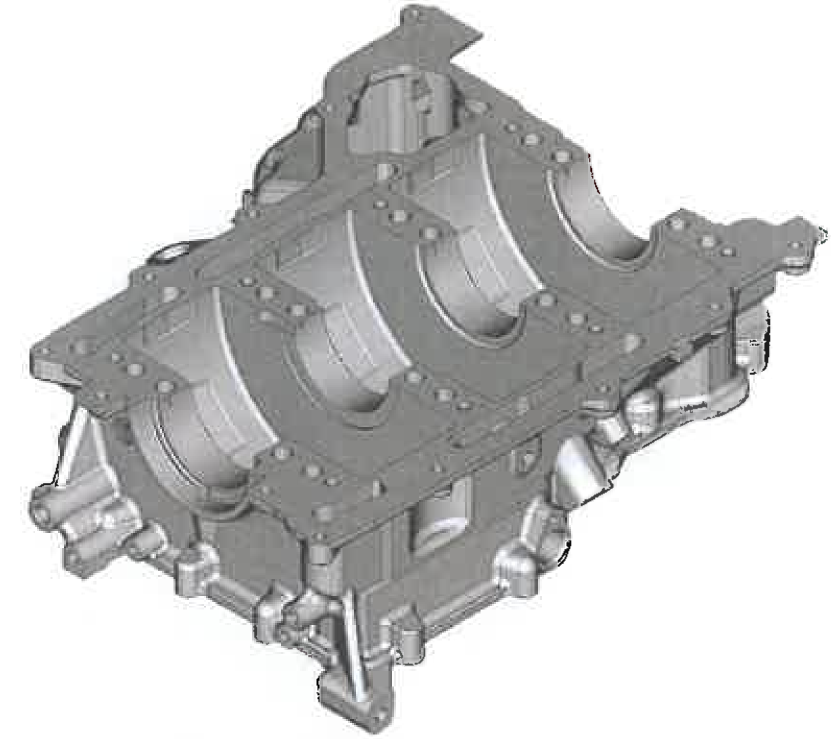


In the lower part of the barrel, there are three holding rings in PVC in order to contain any cooling liquid infiltration.

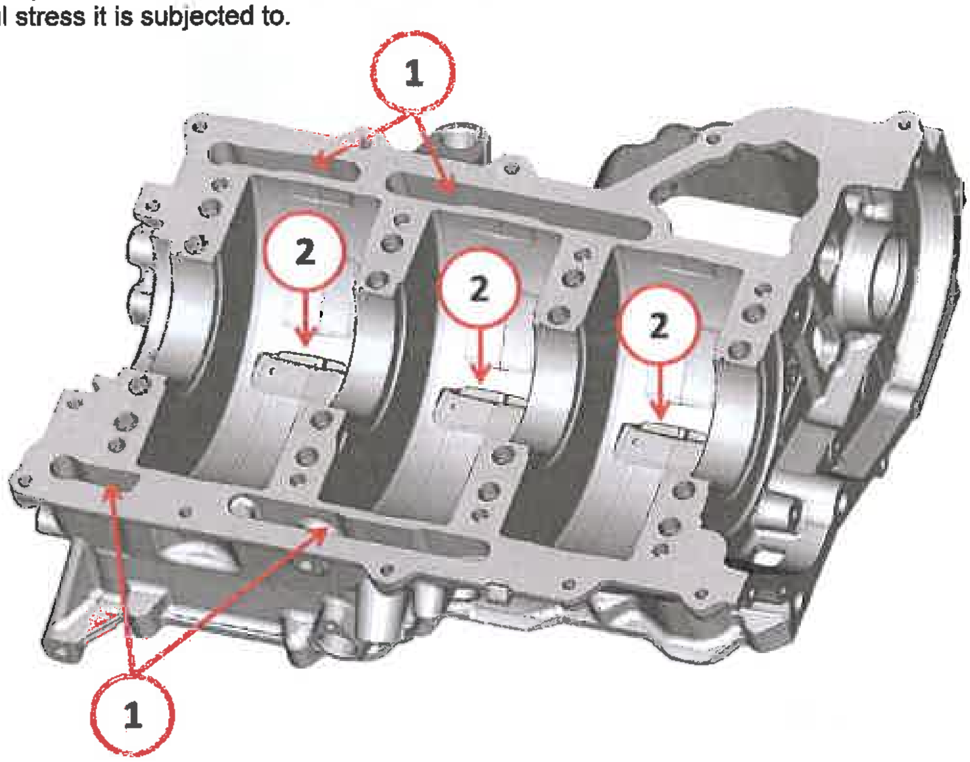



Key:
1 - Coolant temperature gap.
2 – Holding O-rings in PVC.

Under engine bed.

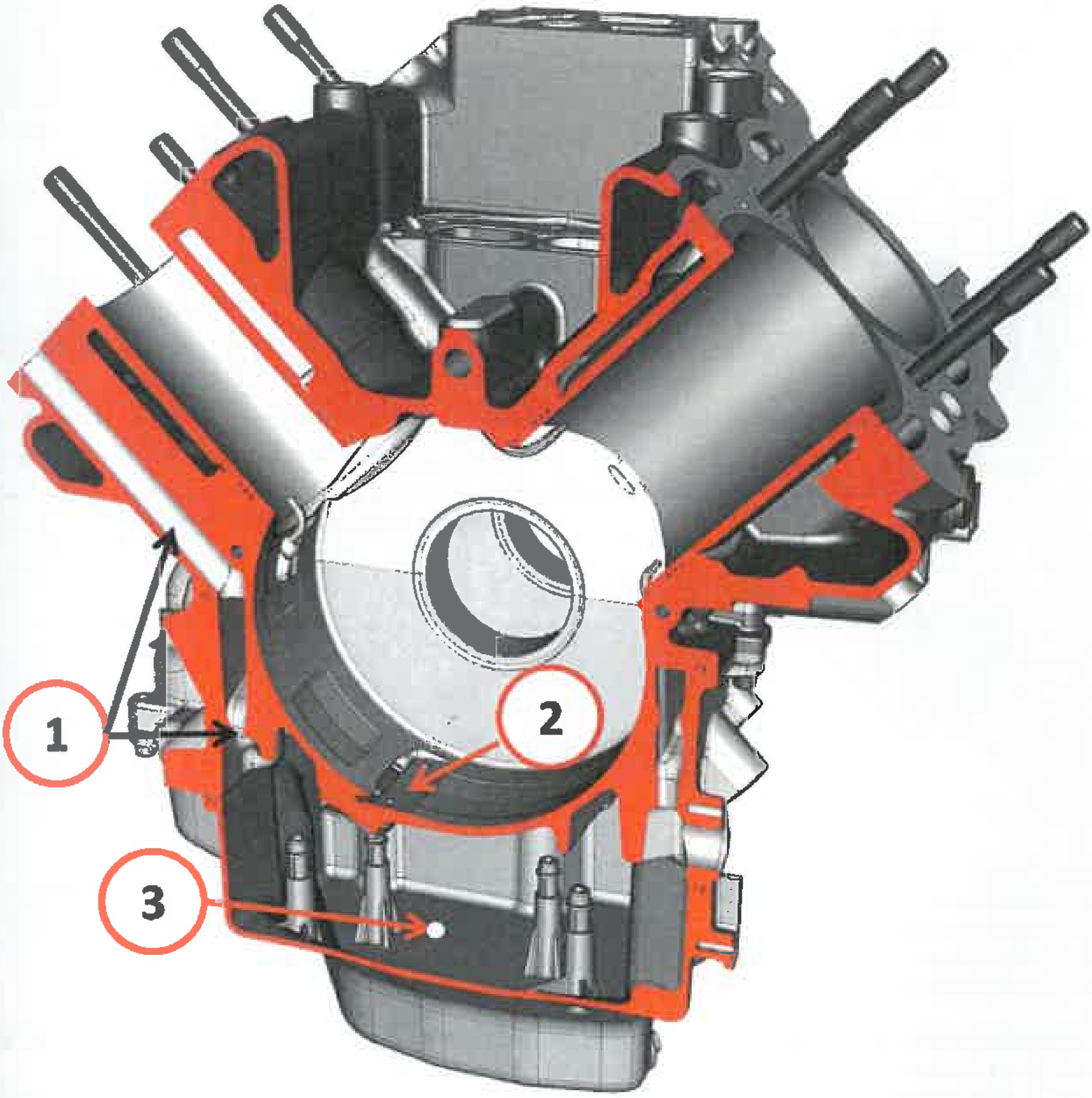


In addition to supplying support to the lower motor camshaft, the under-block also represents the structural part that allows limitation of the engine camshaft flexional deformation caused by the powerful stress it is subjected to.



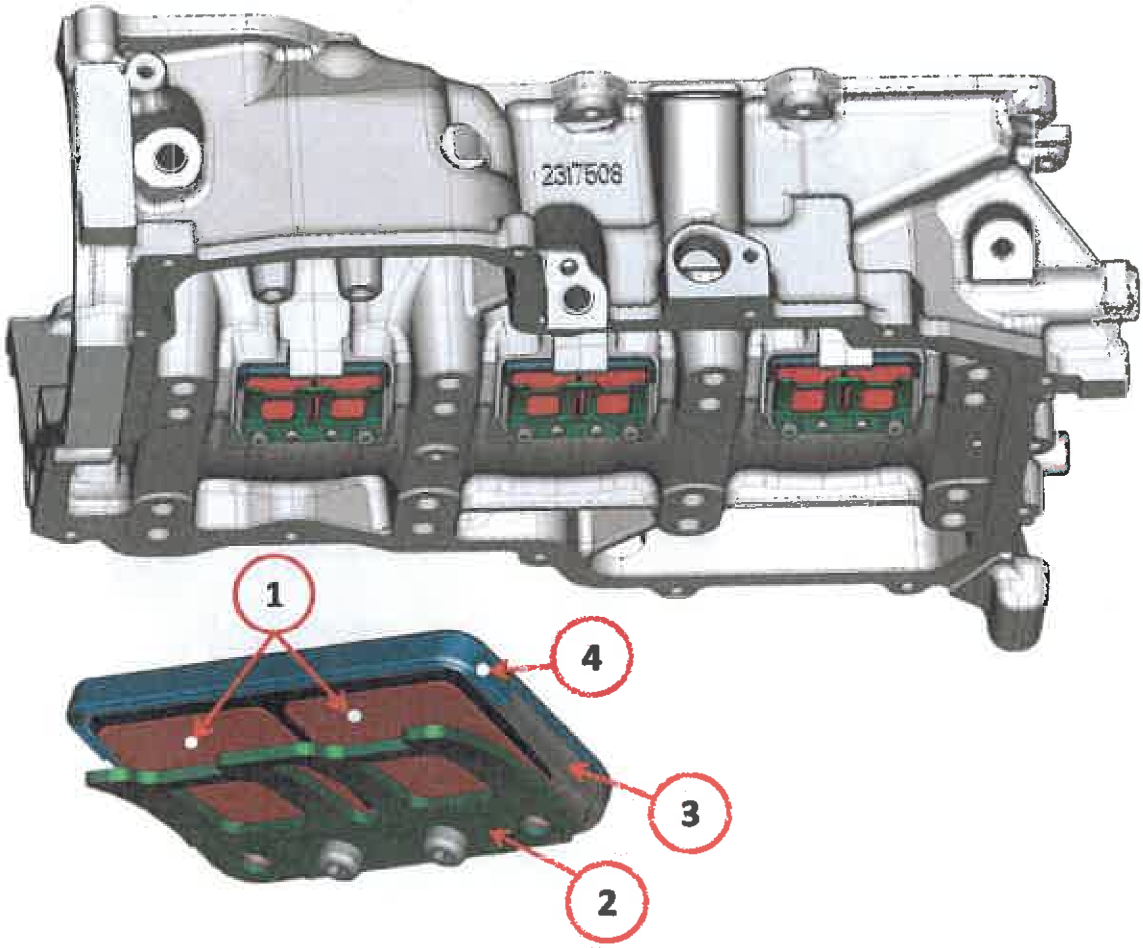

Key
1 – Oil vapour passage lights.
2 – Oil vapour vent windows.

The under-crankcase closes the lower part of the bank, creating the physical separation between the sump and the upper part where the thrust mechanism is (camshaft+rods+pistons+cylinders). This is how the "dry" carter is created. In a similar situation the oil vapour vent windows (2) allow the carter's vapours themselves to exit.




Key
1 – Oil vapour passage lights.
2 – Reed valve
3 – Sump.

We can see the clear separation between the thrust mechanism and cylinders ambient and the sump ambient in the image.



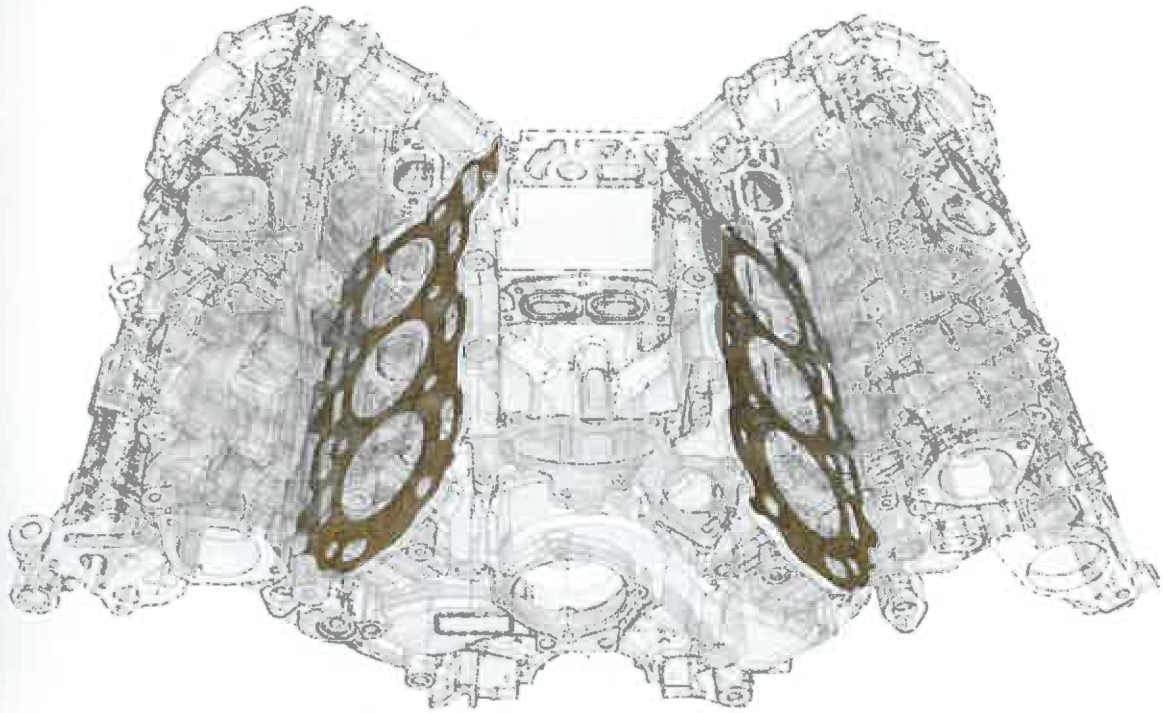

Key
1 – Reeds
2 – End of run "stopper"
3 – Valve support
4 – Rubber gaskets.

Regulation of the oil vapour flow exiting the carter is done through 3 reed valves placed in the lower part of the under-block corresponding to the vent windows.
The 3 reed valves in the lower part of the under-block constitute the solution that eliminates the pressure impulses in the area beneath the pistons during their expansion, which would have a negative effect, slowing down the camshaft's rotation. Since each pair of cylinders shares a connecting rod pin, when one of the two pistons starts to move in the cylinder from TDC to BDC, the other is completing its travel in the opposite bank, reaching its TDC. The latter piston reaches TDC after 90° with respect to the piston in the other bank. Once it has reached TDC, it starts its travel downwards. It therefore follows that both pistons travel downwards in their respective cylinders over a wide angular interval. This causes an increase in the pressure of the vapours in the under-block. The increased pressure opens the reeds allowing the vapours to vent. When the vent valves open, they allow the oil carried to the bank pins and connecting rod pins to return to the sump. This happens thanks to the light negative pressure created by the oil pump's intake. The first piston to reach BDC reverses its direction and after 90° the piston in the opposite bank will also reverse direction. Following this, both pistons will simultaneously rise towards TDC for a considerable angular interval. Their movement creates a slight pressure drop within the under-block, which causes the vent valve's reeds to close. With the reeds closed, the pistons move towards their relative TDC, opposed by the gasses in the under-block. The gasses works like elastic: the pistons rise, and the "elastic" (the gasses) stretches, opposing the piston's motion.
When the first piston reaches TDC and changes direction, the gasses that have expanded (stretched elastic) give all the elastic potential energy back to the piston.

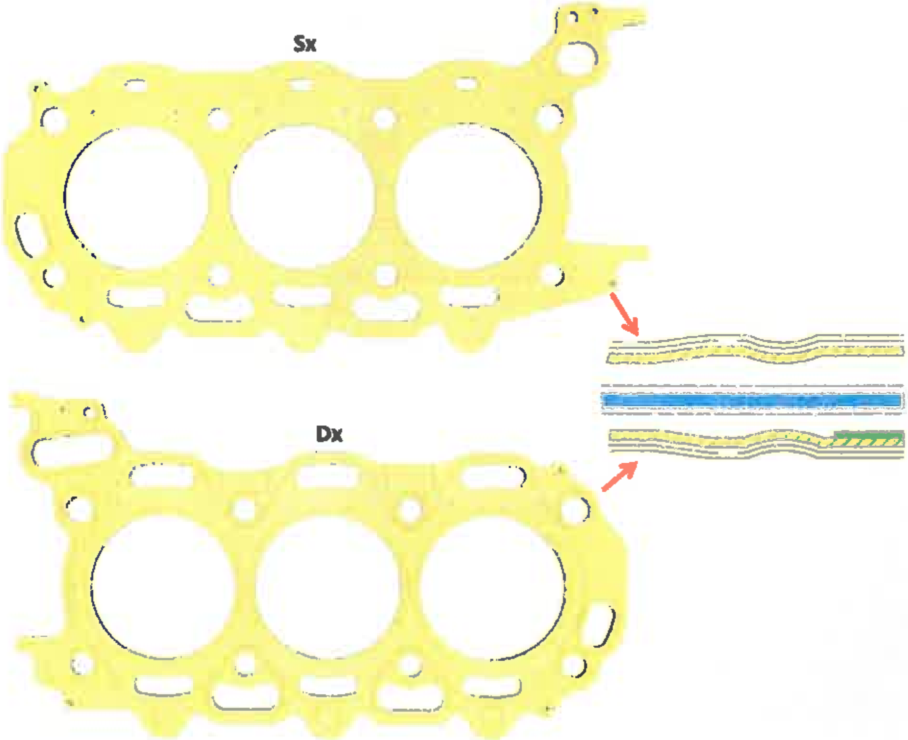
To give a better idea, we can imagine what happens when we block a bicycle pump's hole with our finger. If we block the hole and simultaneously pull the pump's plunger upwards, we feel a certain resistance due to the air under the plunger, which expands and drops in pressure. Releasing the plunger, we notice that the air behaves like elastic and pulls the plunger back in the opposite direction.

This effect allows the reeds to reduce the pumping losses, gaining about 30 HP.

**Cylinder head gaskets**



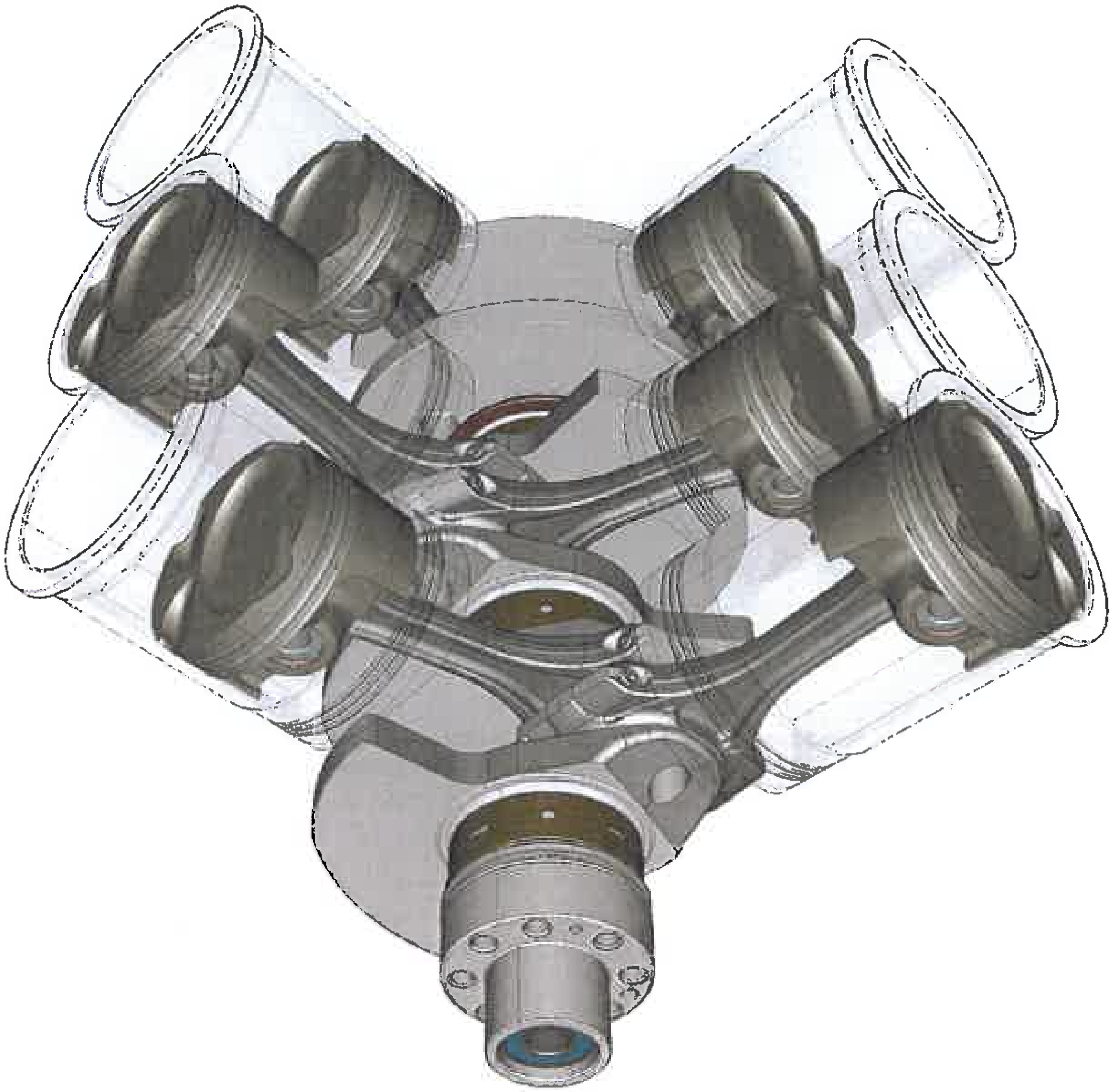
The cylinder head gaskets are three-layer metal type. It is available in one thickness only. The thickness value (in compressed conditions) is 0.87mm ±0.05mm.



## Thrust drive

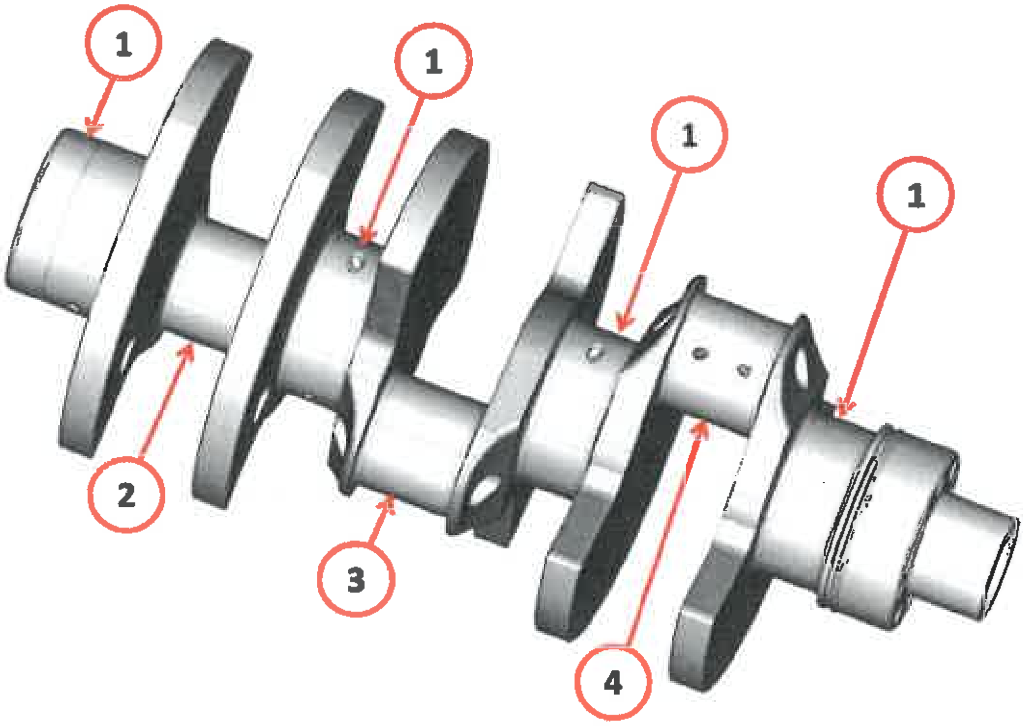
The thrust crank assembly consists of the following components:

- Crankshaft.
- Connecting rods.
- Pistons.



The drive components were designed with special attention to overall reduction in the forces of friction during the relative rotation among the various elements.

*Crankshaft.*



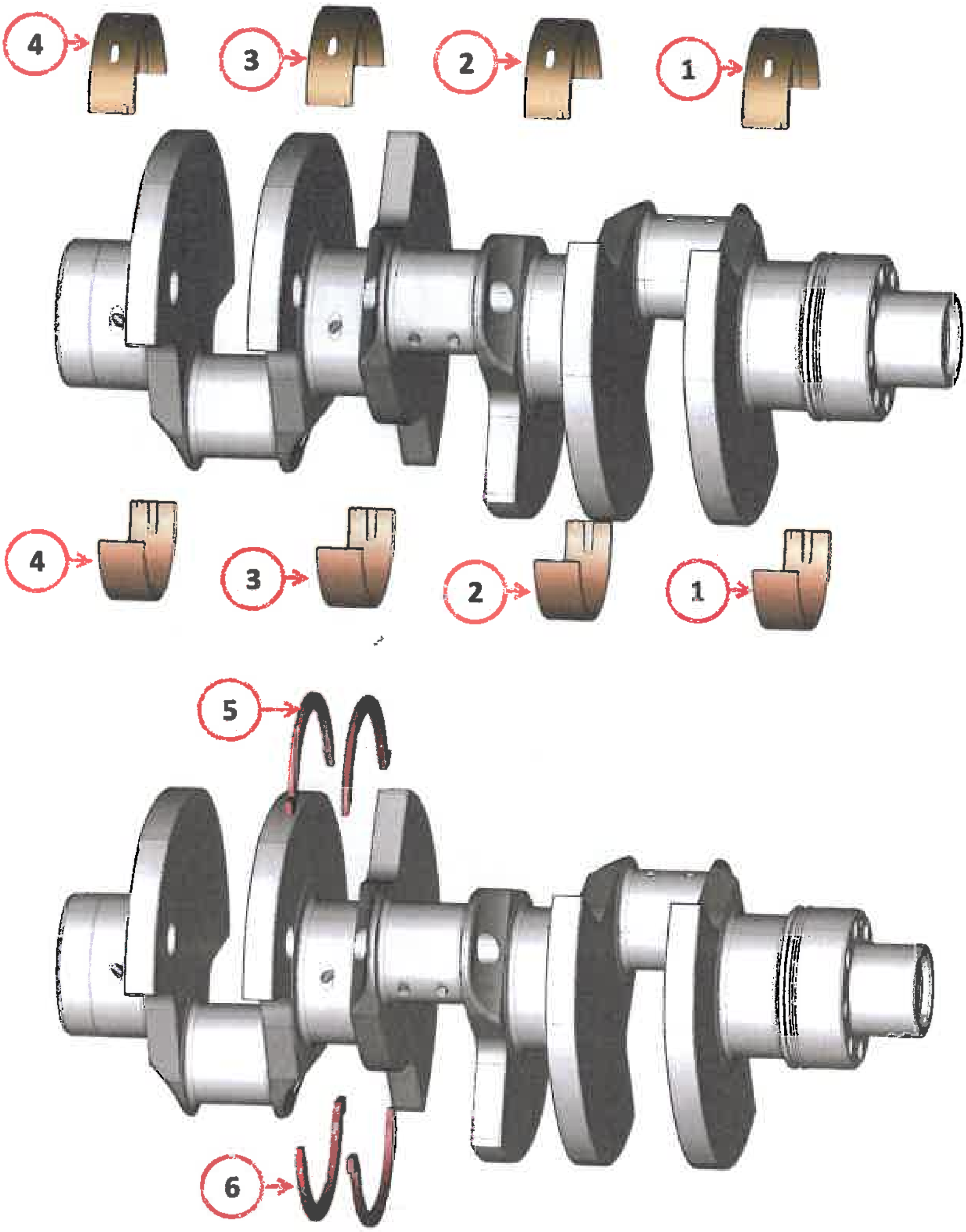

Key
1 – Bank pins.
2 – Pin for the 1st and 6th cylinder rods.
3 – Pin for the 2nd and 5th cylinder rods.
4 – Pin for the 3rd and 4th cylinder rods.

The camshaft is made of steel (initials 30CrMoV10) with nitriding surface treatment. The camshaft has 4 journals, 3 cylinder rod pins and 6 counterweights.

The nominal journal diameter is: ø=67mm. The cylinder rod pin diameter is: ø=47mm.

**NOTE:** For journal and rod pin tolerance classes, please refer to the technical assistance manual.

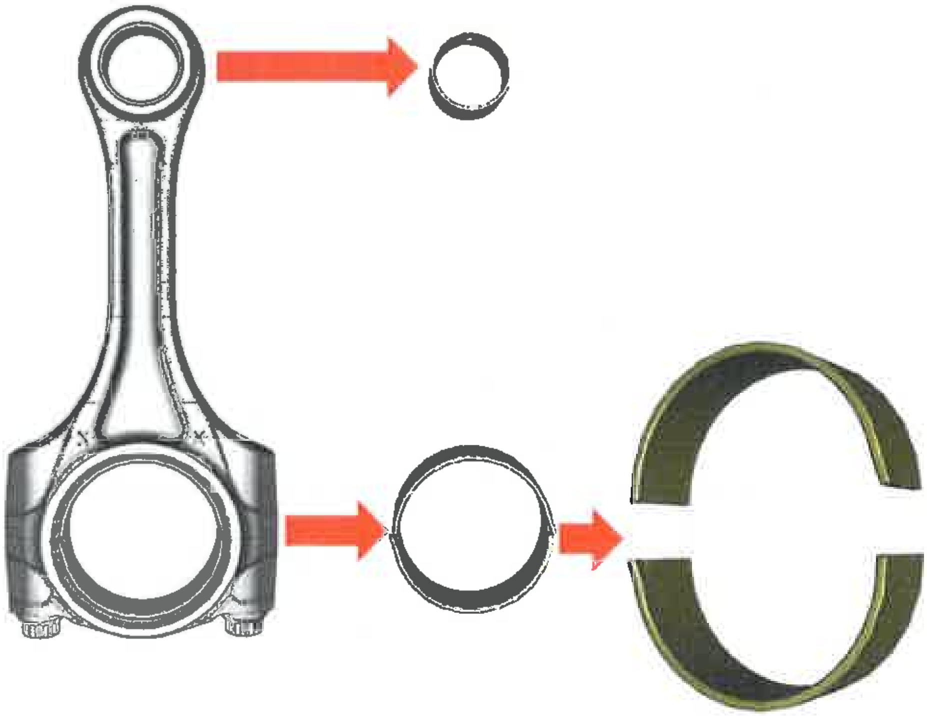

The journals rotate on housings formed by the bank supports and in order to reduce dragging friction, half-bearings are used (upper and lower). These are made of an alloy of bismuth+silver+aluminium. Along the exterior side surface of the upper half-bank, holes (1) were made for oil to enter. Along the interior surface there is the groove (2) that allows lubrication and oil inlet in the cylinder rod lubrication channels. On both the half-bearings there is the centring "tooth" (3).




Key
1 – Journal no.1 bank half-bearings (upper and lower).
2 – Journal no.2 bank half-bearings (upper and lower).
3 – Journal no.3 bank half-bearings (upper and lower).
4 – Journal no.4 bank half-bearings (upper and lower).
5 – Upper shoulder rings (inserted between the second and third counterweight).
6 – Lower shoulder rings (inserted between the second and third counterweight).

**NOTE:** For half-bearing tolerance classes, please refer to the technical assistance manual.

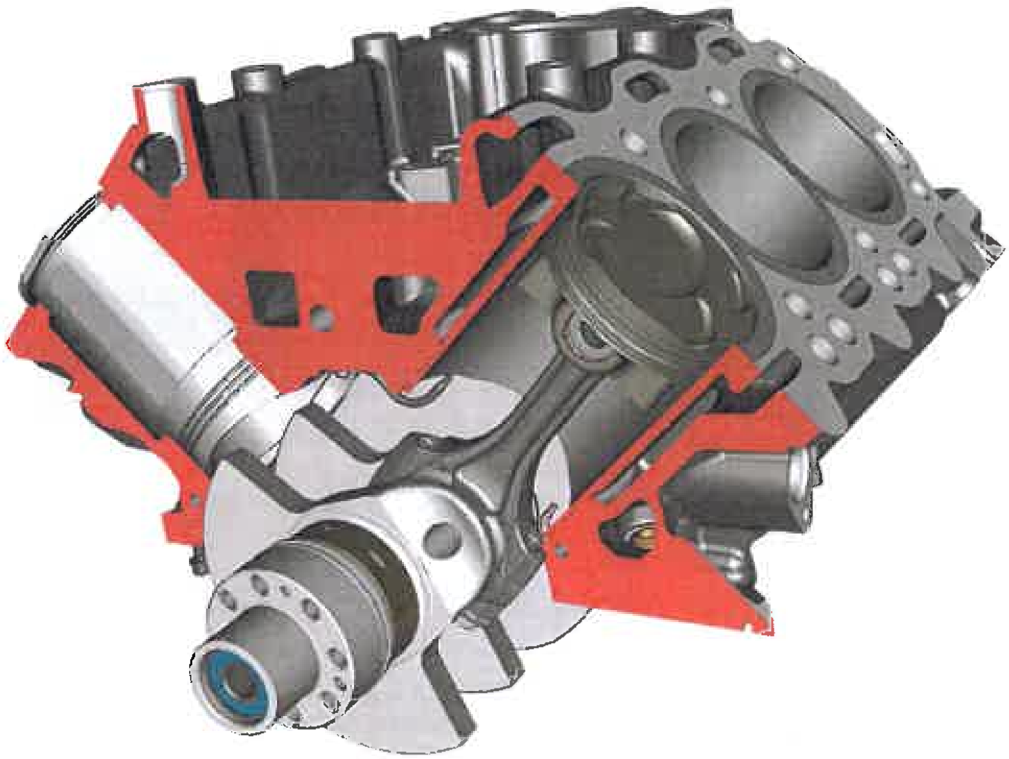
*Connecting rods.*



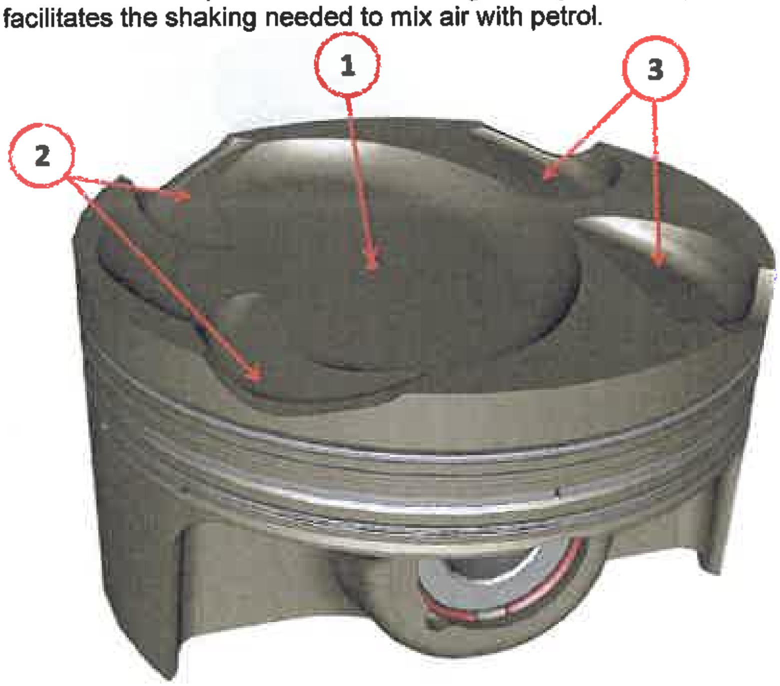
The connecting rods are in forged steel. There is a piston pin centring bushing corresponding to the connecting rod foot that facilitates the motor relating to between the rod foot and the pin itself and limits friction generated during its relative movement.
The connecting rods on the other side (1st and 6th for example) divide the rod pin itself from the camshaft.

## *Pistons*

The 2.9 V6 engine pistons are made of cast aluminium alloy with graphite coating.

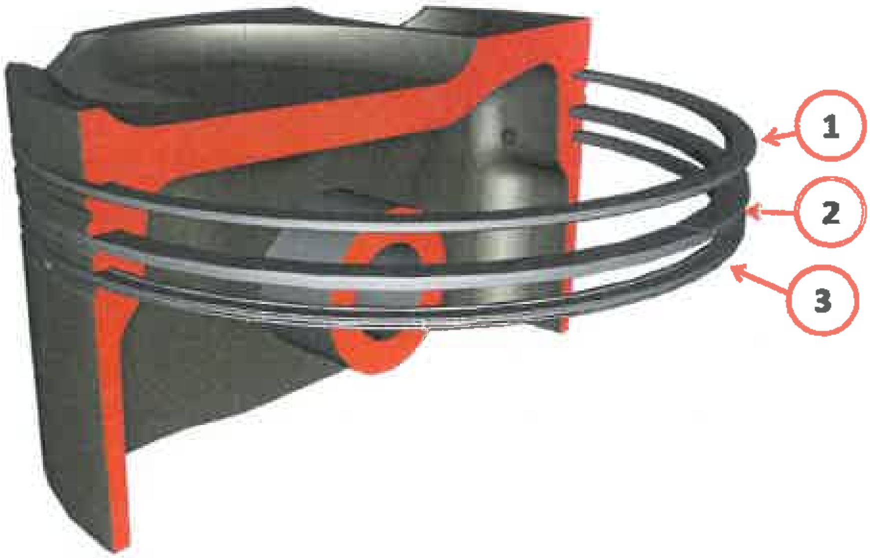


On the piston crown you can distinguish the marks for juxtaposing the intake and exhaust valves. Moreover, there is a hollow area (with indentation facing the injector side) in the central part of the piston crown that facilitates the shaking needed to mix air with petrol.

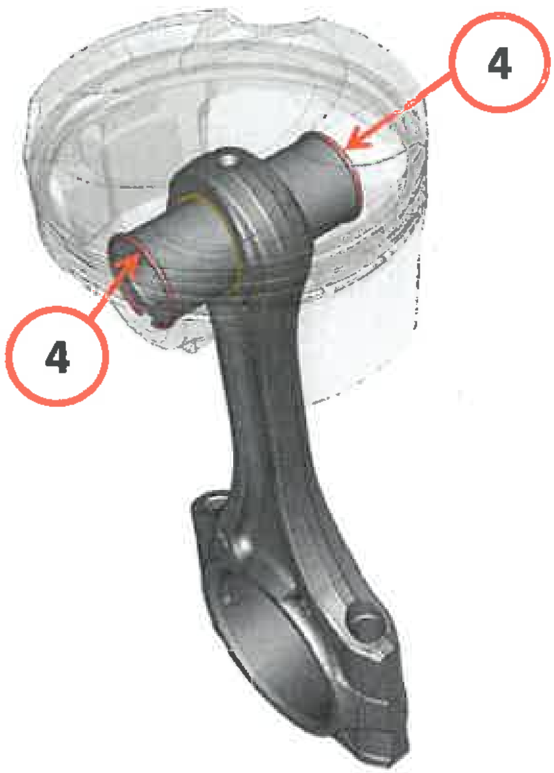



Key:
1 – Piston crown hollow area.
2 – marks for intake valves.
3 – marks for exhaust valves.

The pressure held in the combustion chamber is ensured by two holding rings placed in the first two circumferential piston grooves. The ring that scrapes the oil from the cylinder walls is in the third groove.

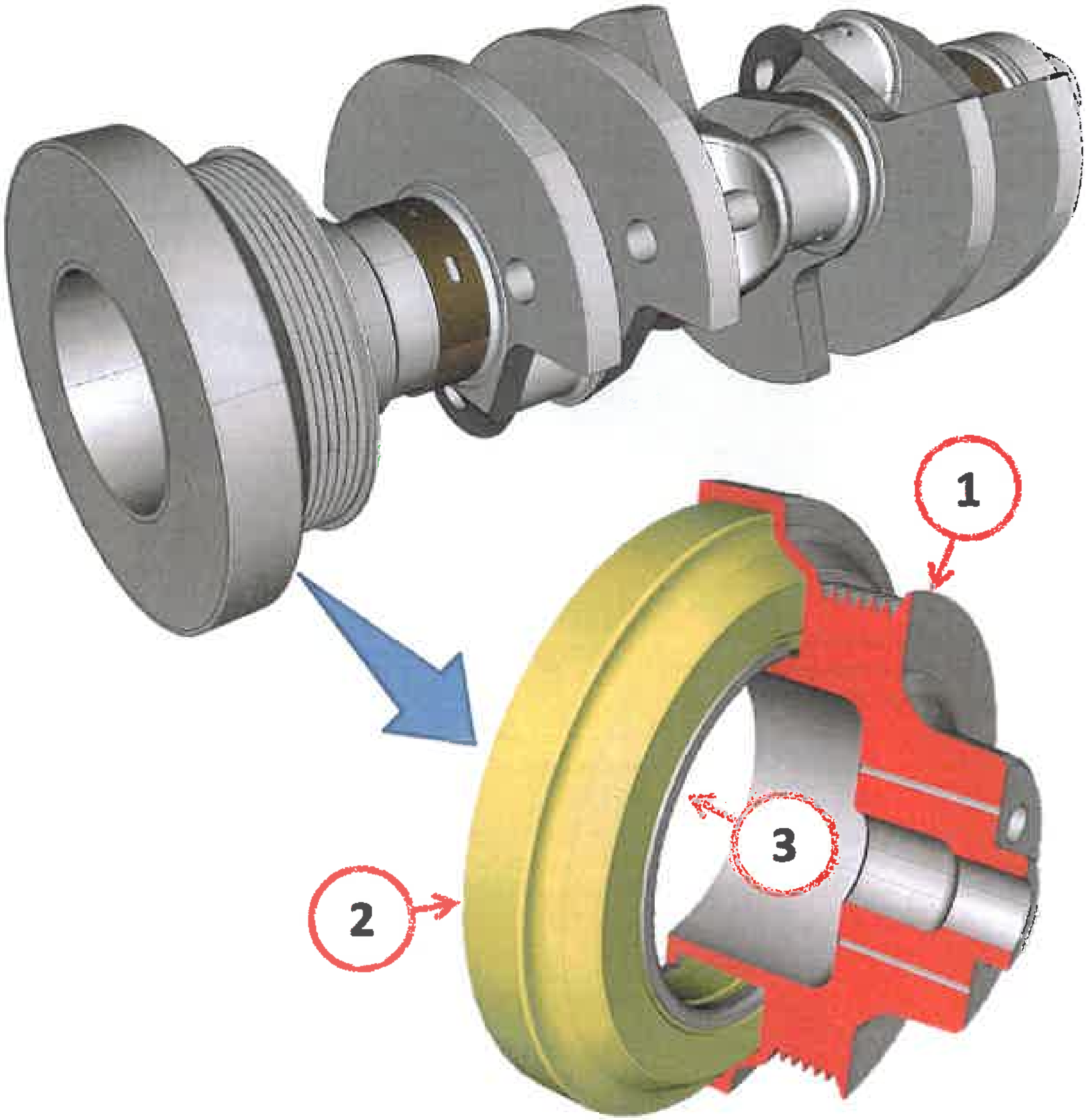



Key
1 – First groove holding ring.
2 – Second groove holding ring.
3 – Third groove holding ring.




The bushing that allows mechanical connection between the rod foot and the piston is held in its place by two stopping rings (4).

## Viscous damper

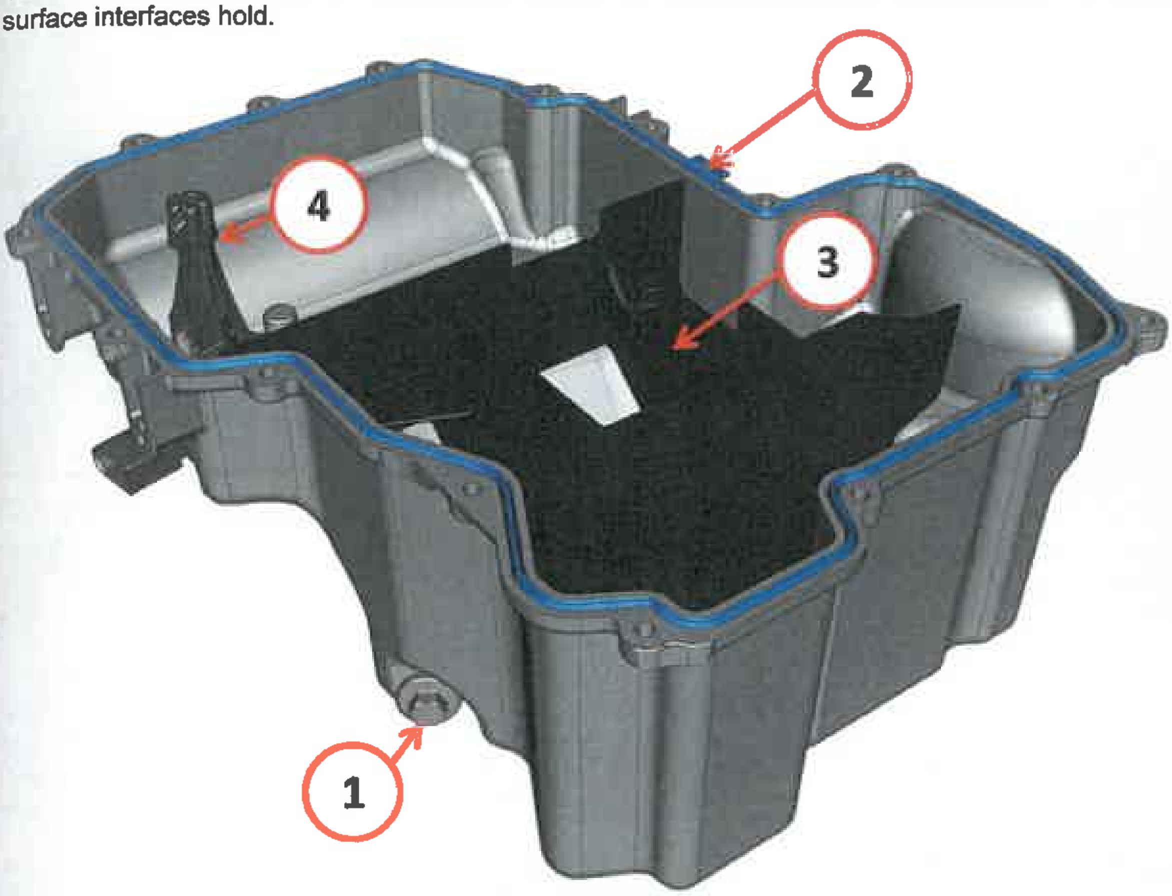



Key:
1 – External damper housing that integrates the pulley for engine's auxiliary parts.
2 – Inertia ring
3 – sliding bearing.

The auxiliary parts pulley includes a viscous damper. This performs the important function of reducing the torsional vibrations of the crankshaft and the camshafts. The torsional vibrations are damped thanks to the combined elastic action (damping) of the oscillating inertia ring and the main mass (external housing).

### Oil sump.

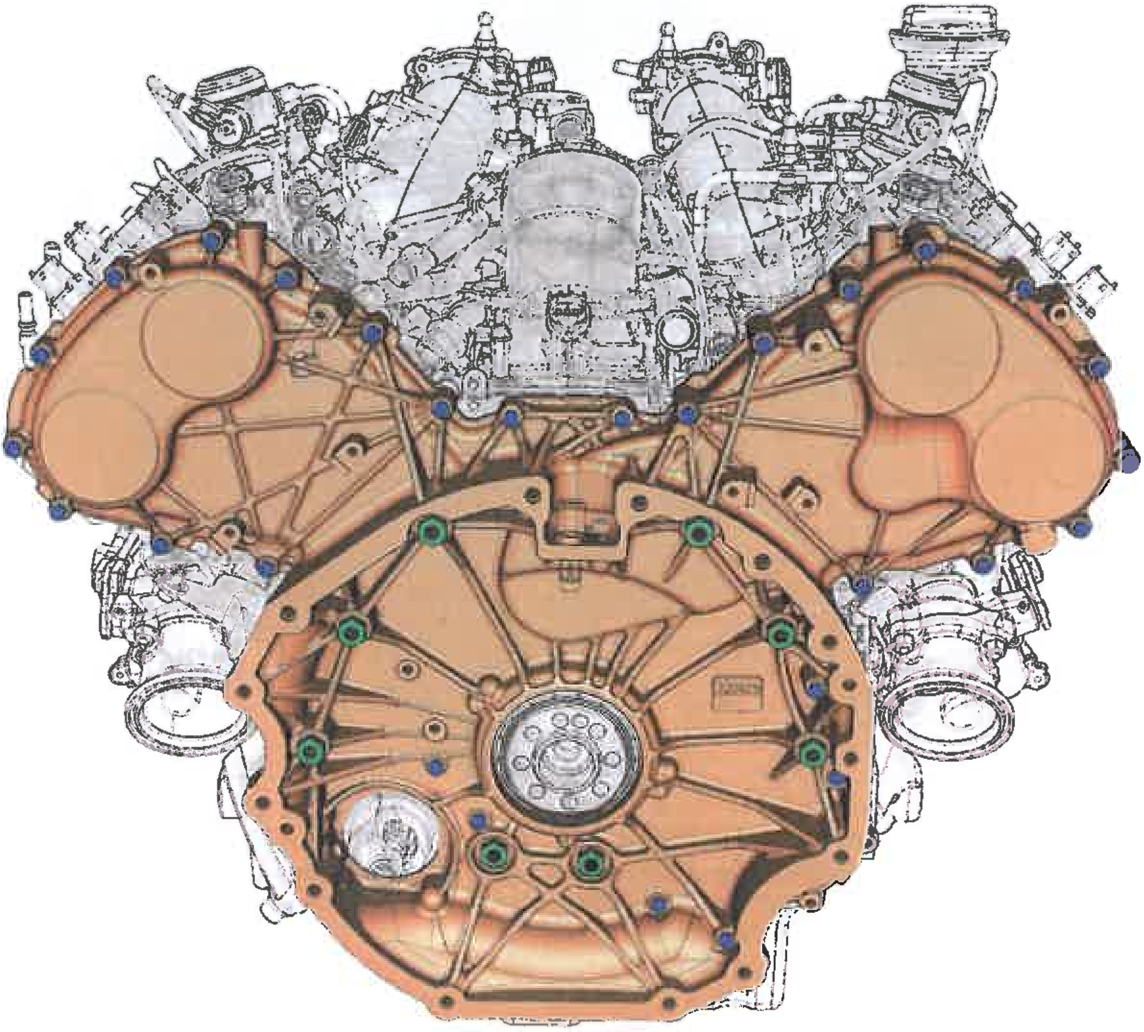
15 screws fasten the oil sump to the under-crankcase. There is a rubber gasket that ensures the two surface interfaces hold.




Key:
1 – Threaded cap to close the oil outlet.
2 – Rubber gasket in the under-crankcase and sump interface area.
3 – Plastic wall to prevent the oil from sloshing.
4 – Oil level and temperature sensors

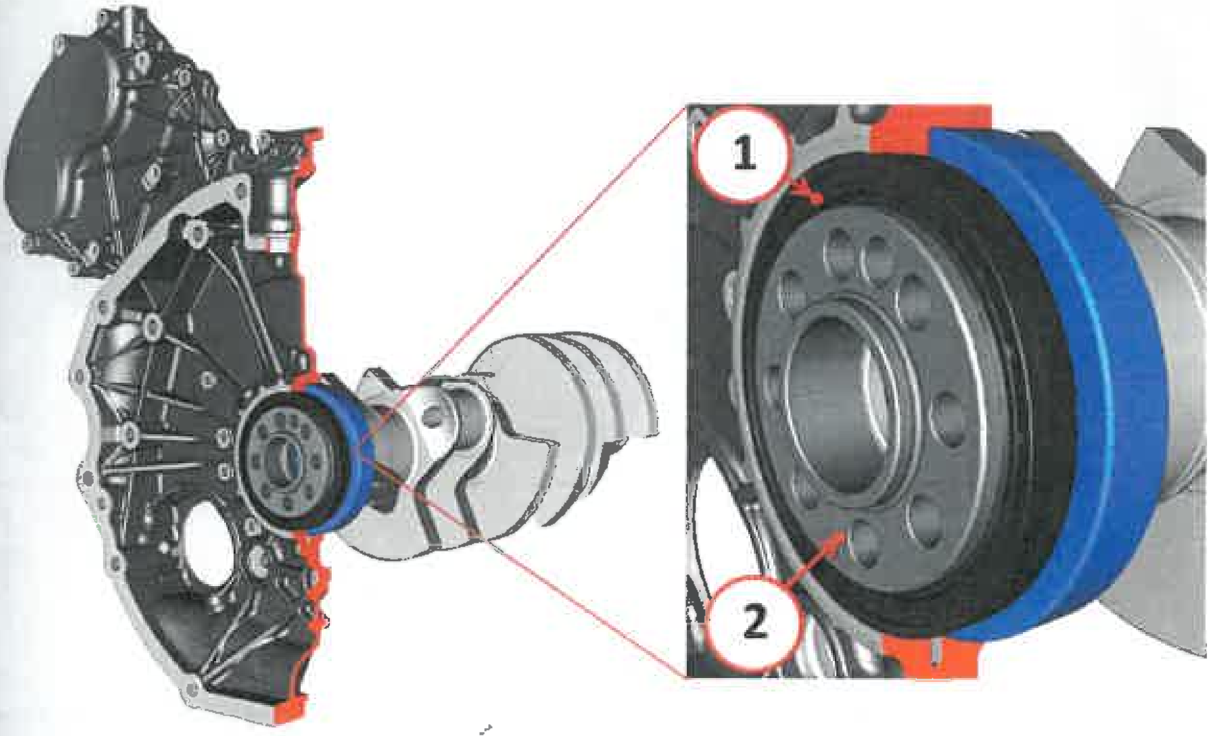
**Timing.**

The engine camshaft sends the movement to the intake and exhaust axle cams between the banks via chains. The timing chains are in the side of the engine that interfaces with the transmission.
The cover over the timing is highlighted in the picture below.



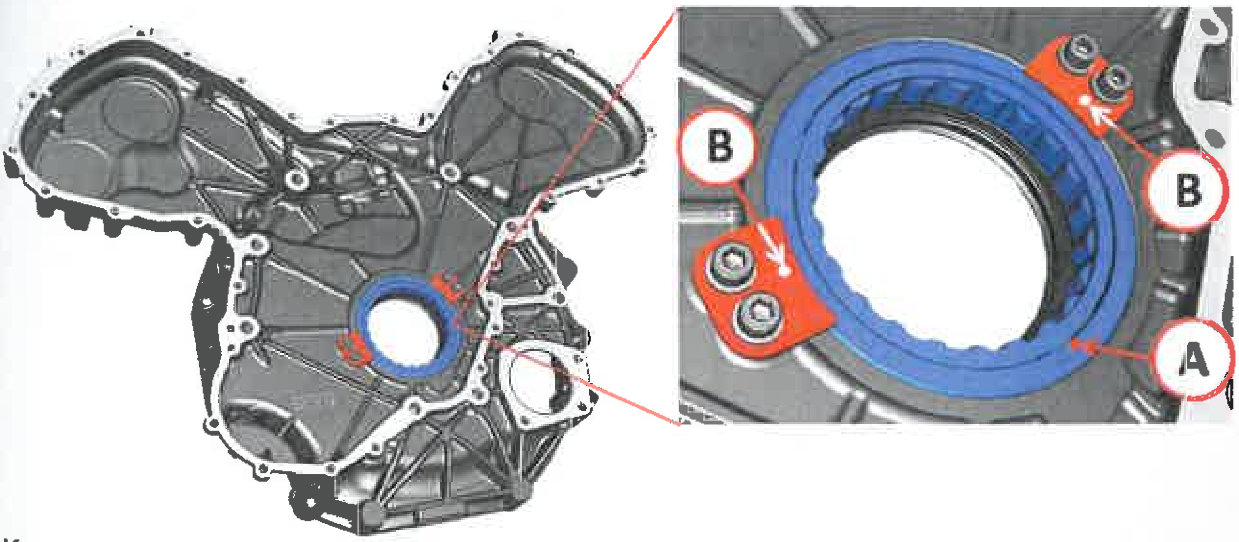
The timing cover is attached to the crankcase, to the cylinder heads and tappet heads via screws (in blue in the picture) and studs (green in the picture).

There is an opening in the central part of the timing cover where the spacer mounted on the camshaft is housed.



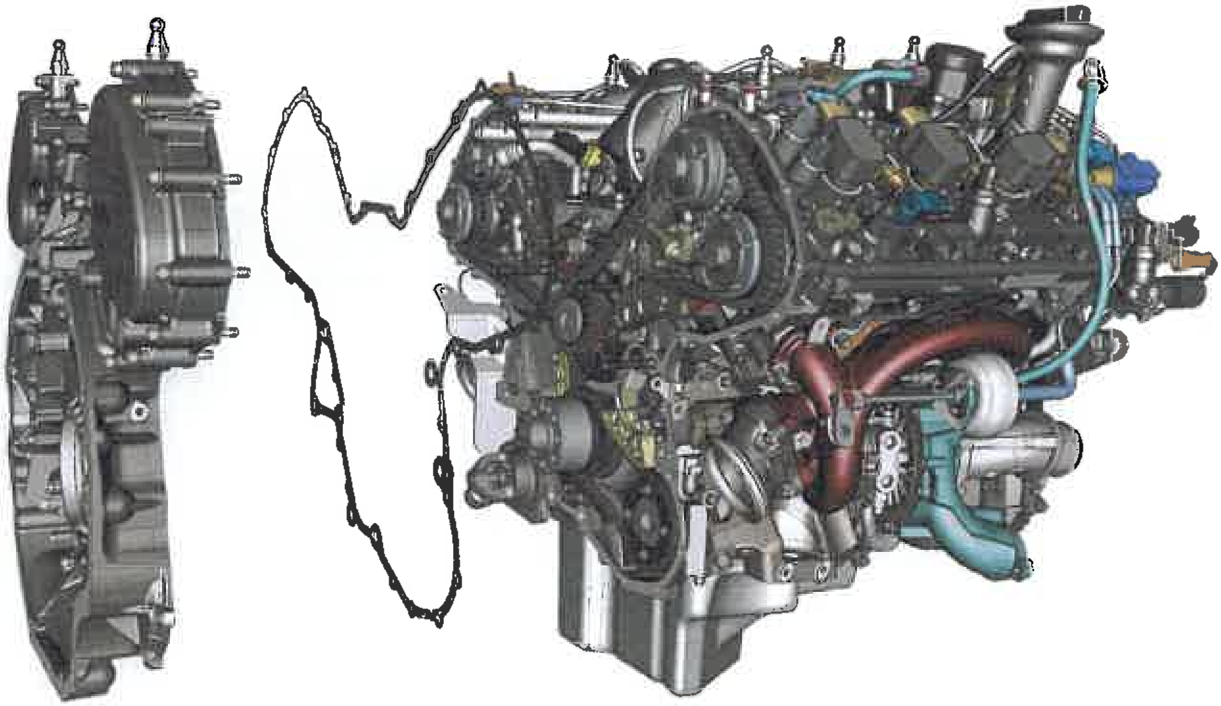

Key
1 – Oil seal
2 – Crankshaft spacer

As noted in the image, there is an oil seal between the timing cover and the spacer. There is also a roller bearing between the cover and the spacer.




Key
A - Roller bearing.
B - Retaining brackets.

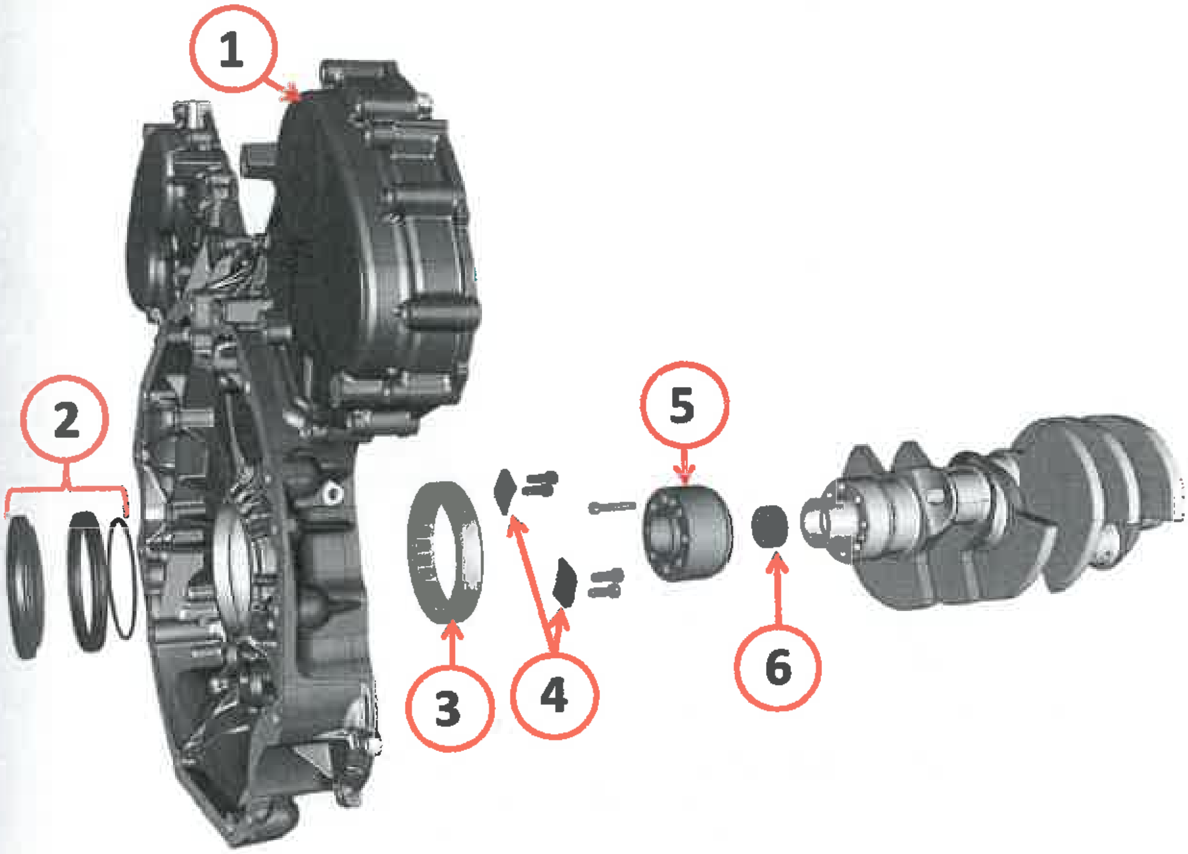
The ball bearing is held in its place in the tappet cover by two small containment plates (shoulder plates).



There is a metal gasket between the timing cover and the engine. The gasket is not reusable.

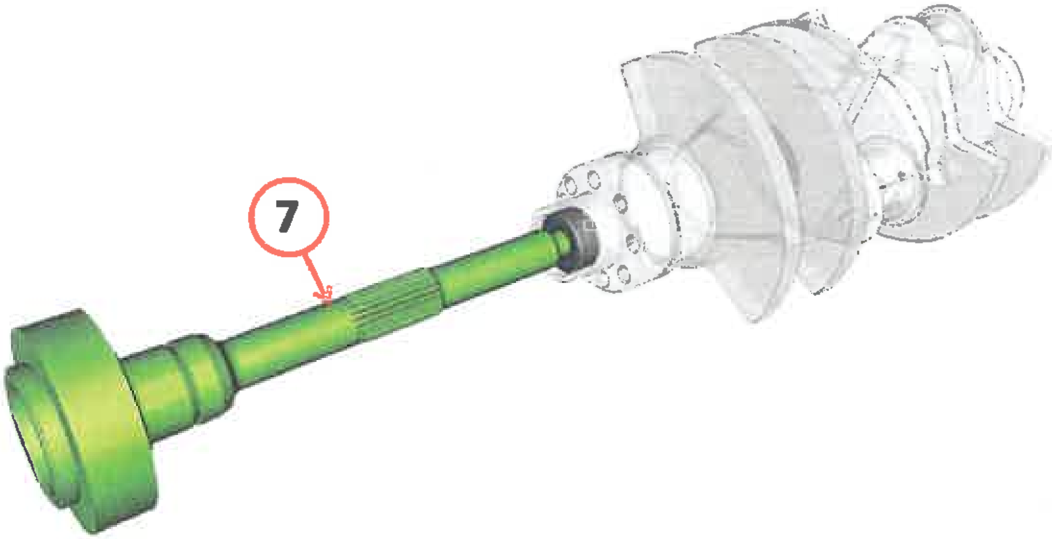
The screws holding the cover to the engine must be tightened in a precise order. Failure to follow the correct tightening order could create a non-uniform load on the roller bearing, creating noise during engine operation.

In the picture below, a breakdown shows all the components in the interface area between the camshaft and the timing cover.

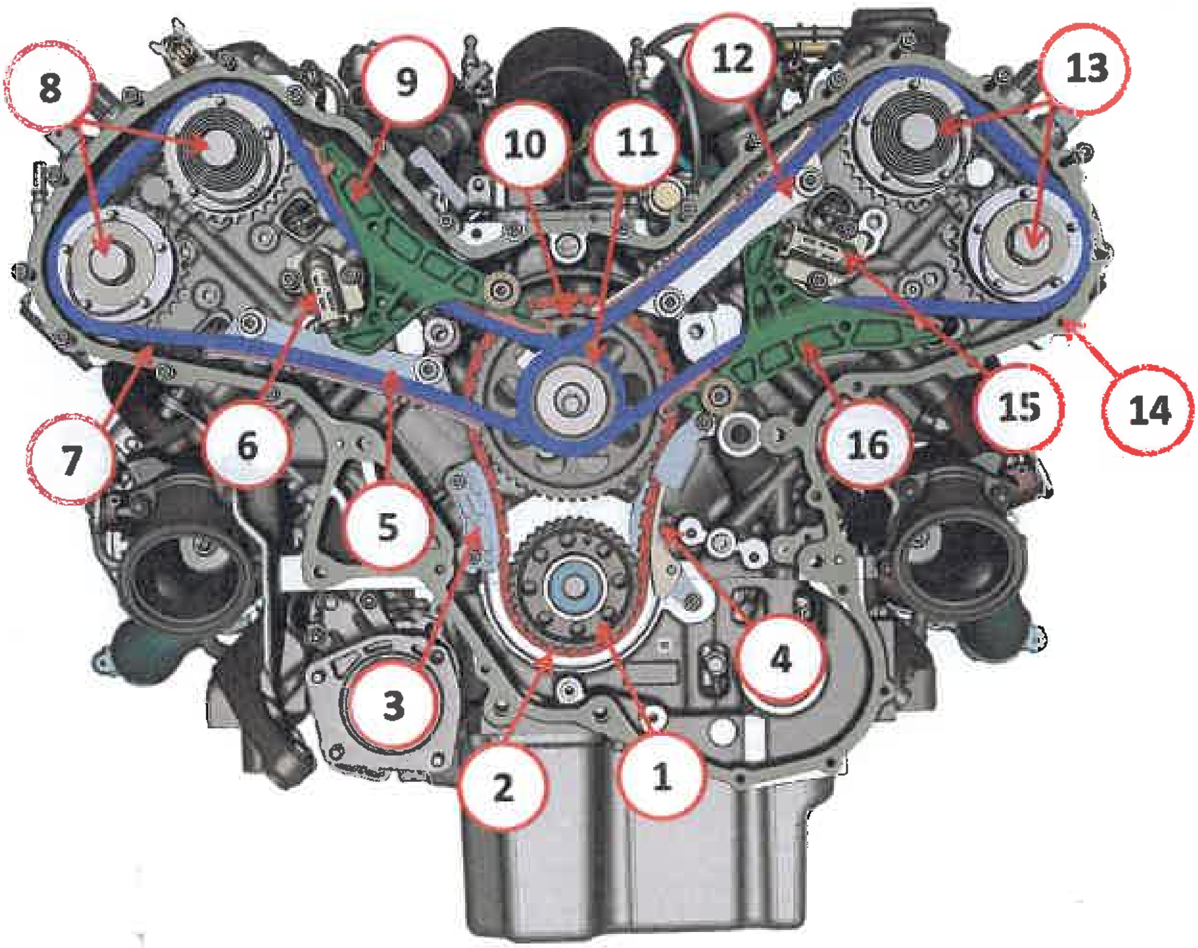



Key
1 – Timing cover.
2 - Oil seal assembly.
3 - Roller bearing.
4 – Roller bearing retaining bracket.
5 - Spacer
6 - Ball bearing.
7 - Gearbox input shaft.

The ball bearing (6) is inserted inside the camshaft and supports the transmission input shaft (7).

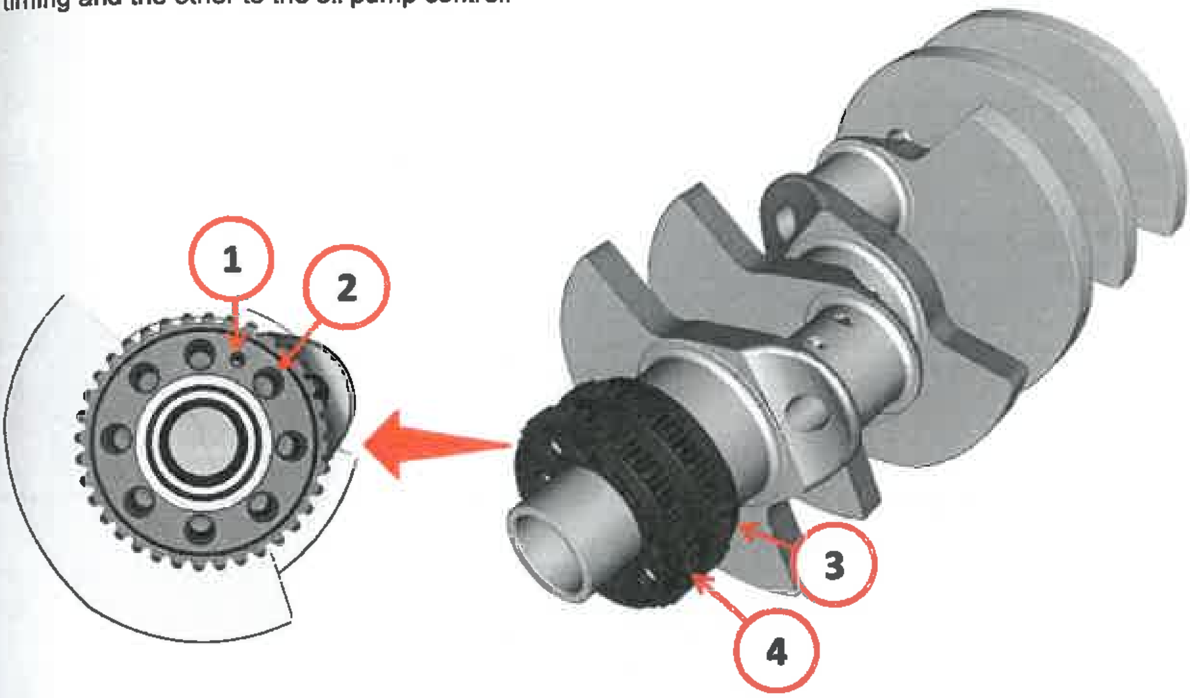


## *Timing components*



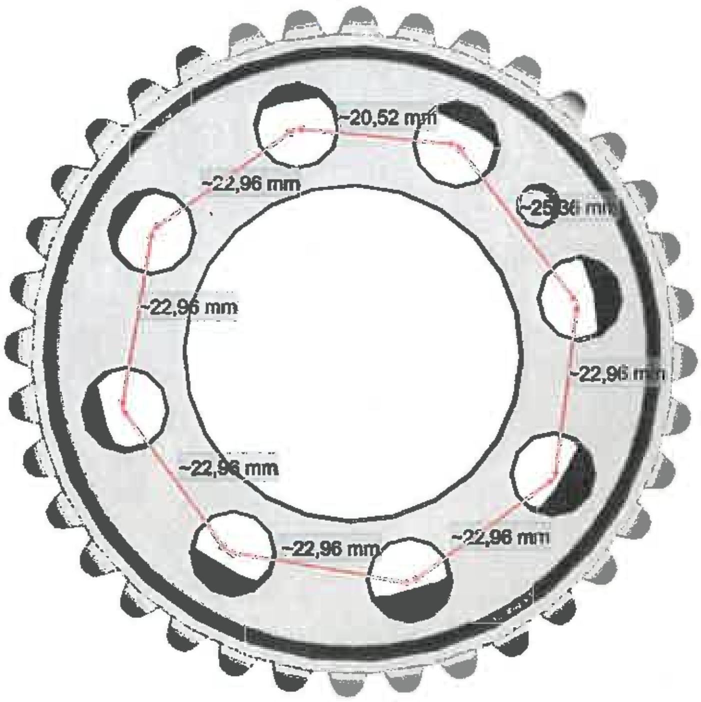

Key:
1 – Toothed gear secured to crankshaft.
2 – Reverse gear chain of command.
3 – Stationary pad for chain at point 2
4 – Stationary pad for chain at point 2
5 – Stationary pad for chain at point 7
6 – Hydraulic tensioner throttle body.
7 – Left bank camshaft chain of command.
8 – Transformer in left bank phase (intake and exhaust)
9 – Left bank mobile pad.
10 – Centre bank reverse gear engagement.
11 –Co-axial gear of left and right timing chain of command.
12 – Stationary pad for chain at point 14
13 – Transformer in right bank phase (intake and exhaust).
14 – Right bank timing chain.
15 – Right bank hydraulic tensioner.
16 – Mobile pad.

A gear is clamped onto the camshaft that integrates the two gears, one of which is dedicated to the timing and the other to the oil pump control.

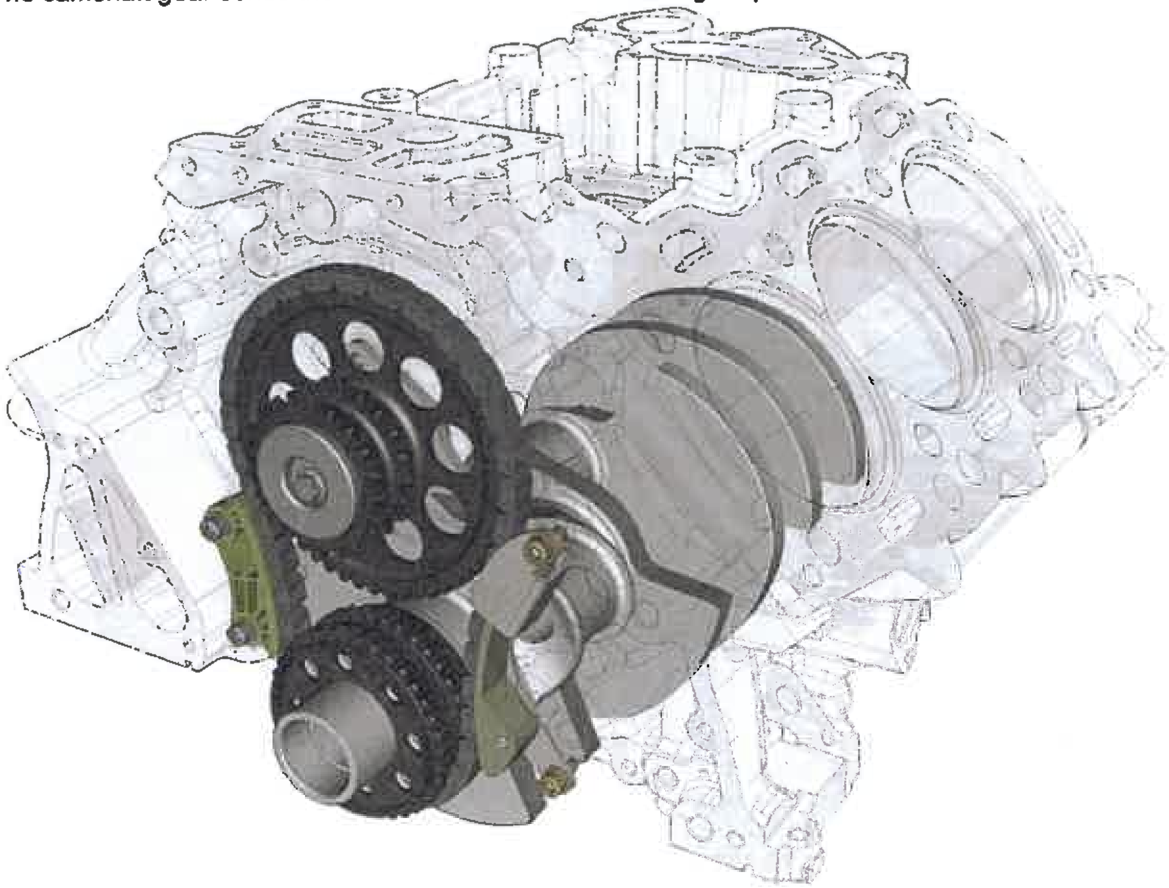



Key
1 – Hole for the spacer fixing screw.
2 – Opening for gear to be connected to the camshaft.
3 – Toothing for timing control.
4 – Toothing for oil pump control.

The screws that fasten the gear to the camshaft are the same as those that fasten the flywheel. The gear can be fastened to the camshaft in one position only. This is because the fastening is at a different distance from the screw holes.

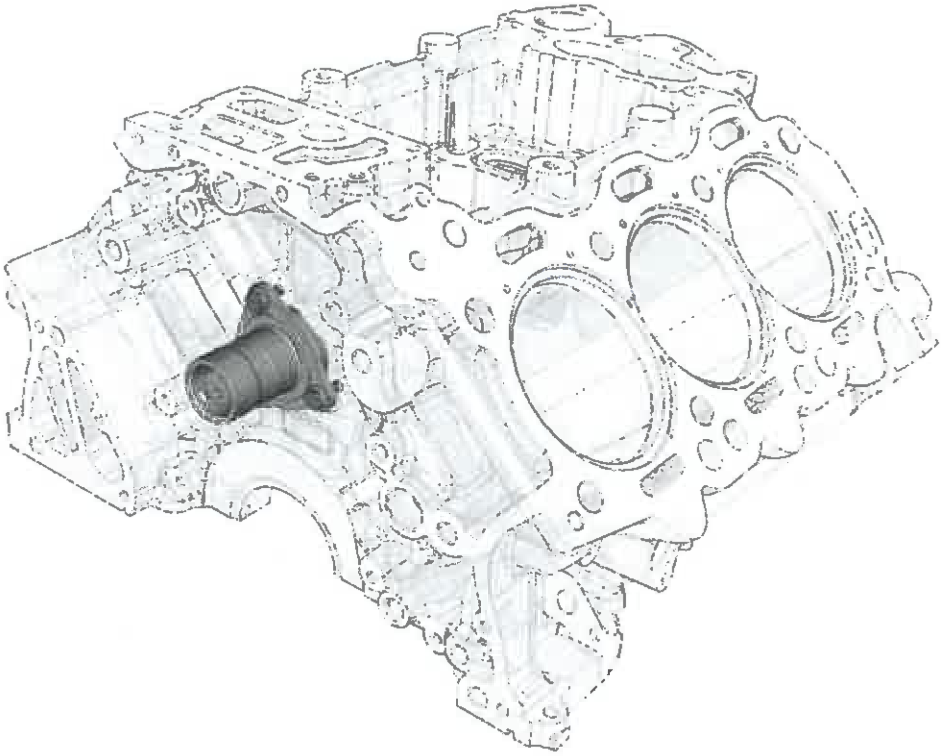


The camshaft gear sends the motion via a chain to a return gear placed in the centre of the crankcase.

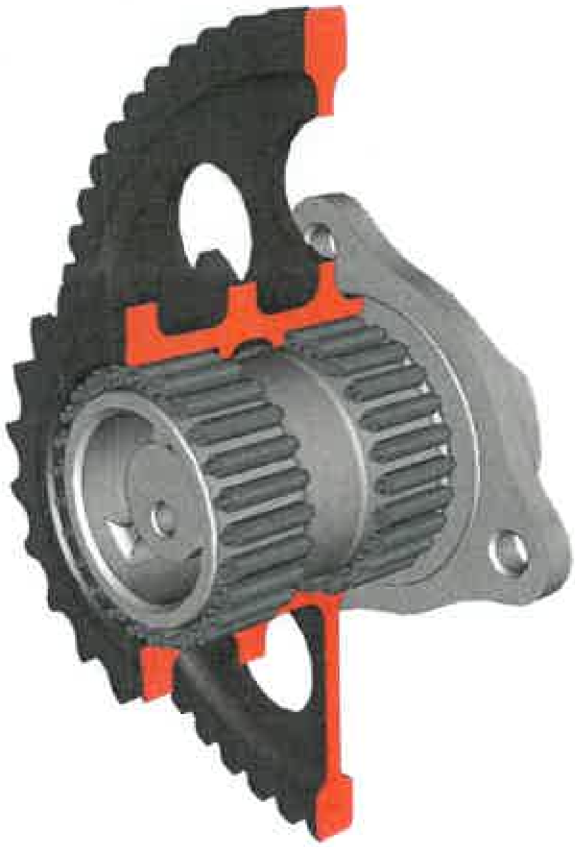


The return gear integrated two other smaller gears through which the motion is sent to the two bearings' cams via the timing chain.

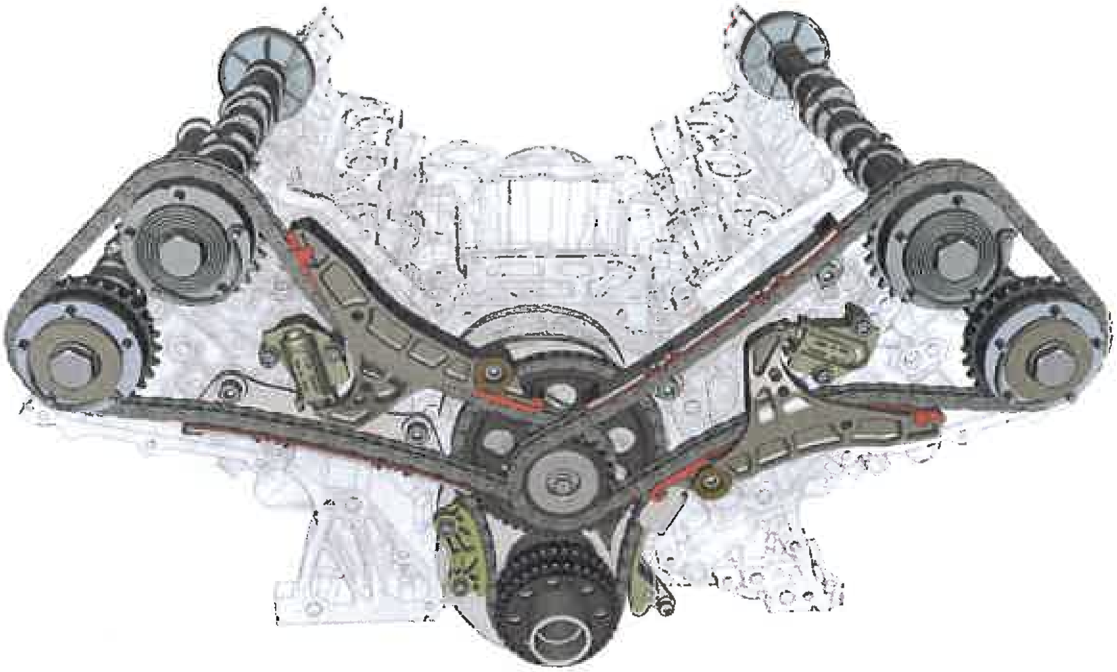

Key
1 – chain of command gear for left bank timing.
2 – chain of command gear for right bank timing.



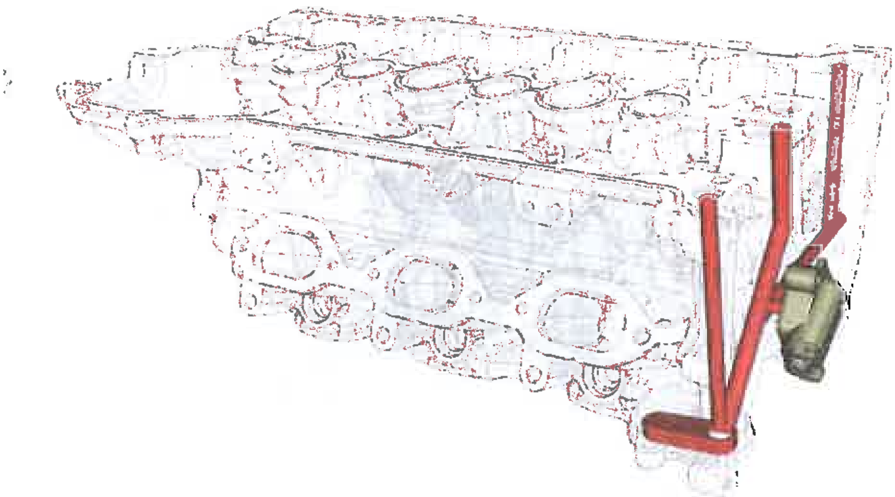
The return gear is clamped onto a pin fastened to the crankcase centre. The pin also acts as a cap to an engine* oil timing chamber for the cylinder heads. The gear's rotation on the pin is guaranteed by two roller bearings along the side surface of the pin itself.

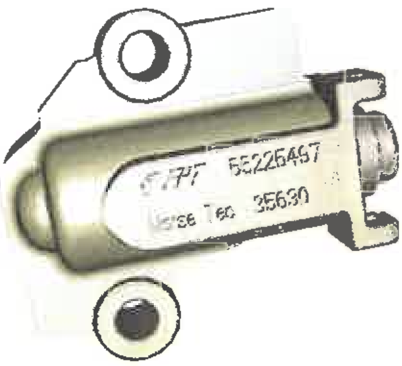


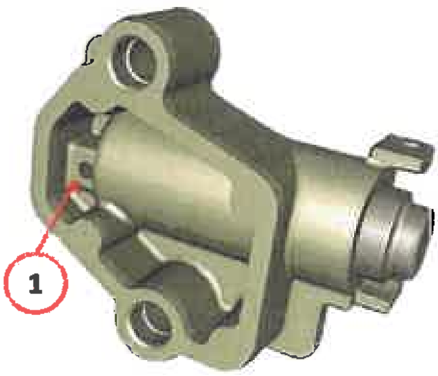
*** NOTE:** Please refer to the chapter on the engine lubrication system to get a view of the shape and characteristics of the oil timing chamber.



The timing chains for the two bearings are kept under tension by their hydraulic turnbuckles. They are fastened by two screws on the cylinder heads and get the indispensable engine oil to be able to function from the interior channels in the heads. The turnbuckles hold the chain tension via two mobile pads on which these last run.



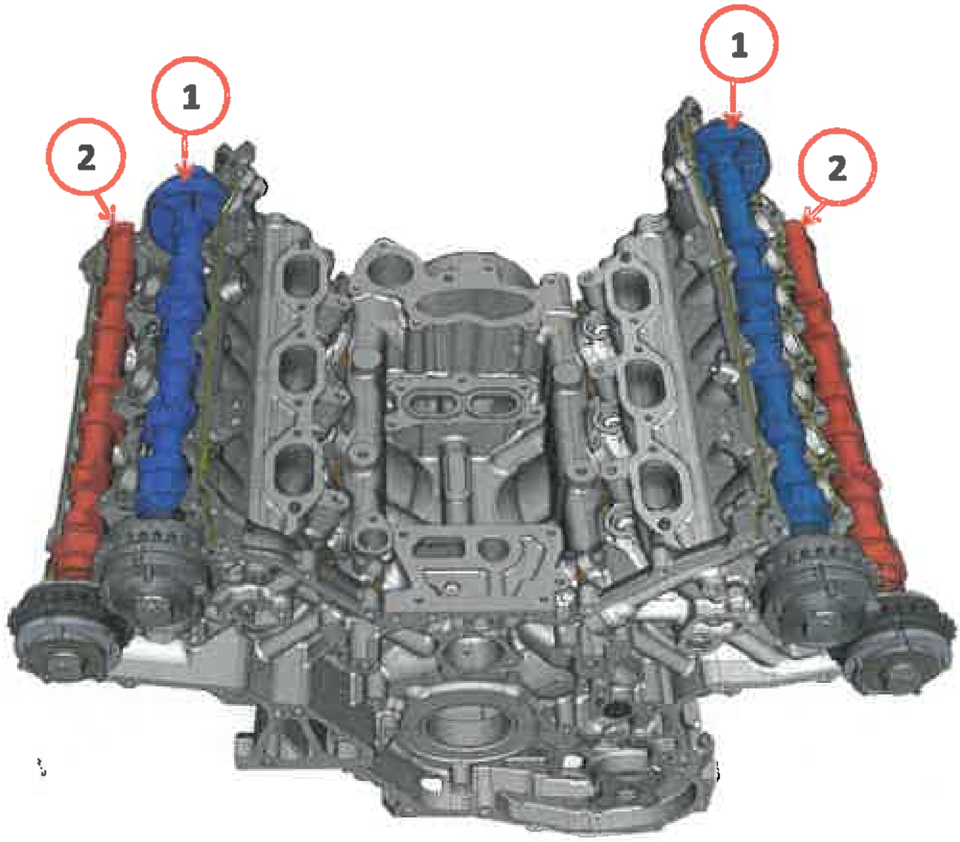





Key
1 – Oil inlet opening.

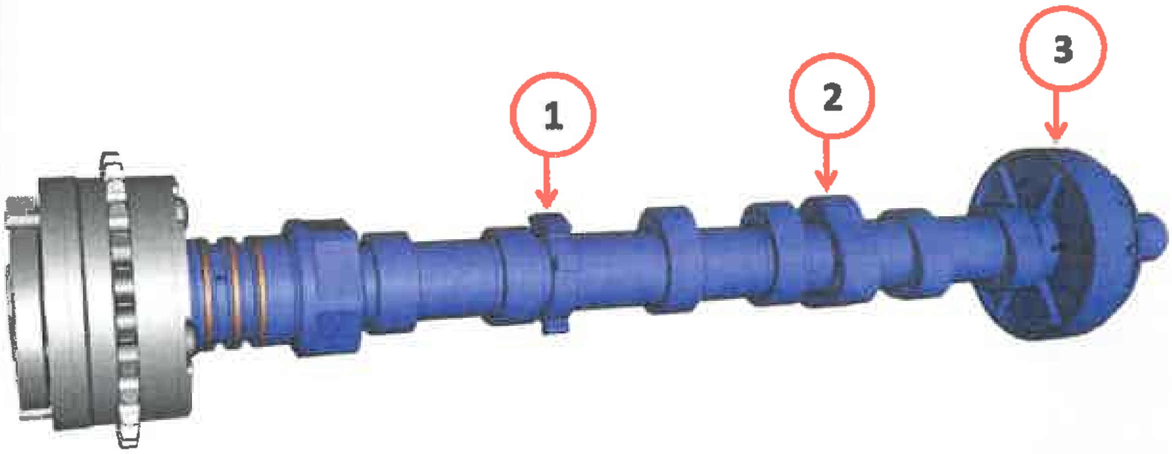
*Camshafts.*

The intake and exhaust camshafts for both bearings are made of steel. The cams are shown. The intake and exhaust camshafts, apart from their different placement in the cam and their shape, are different because of the different devices that activate them.



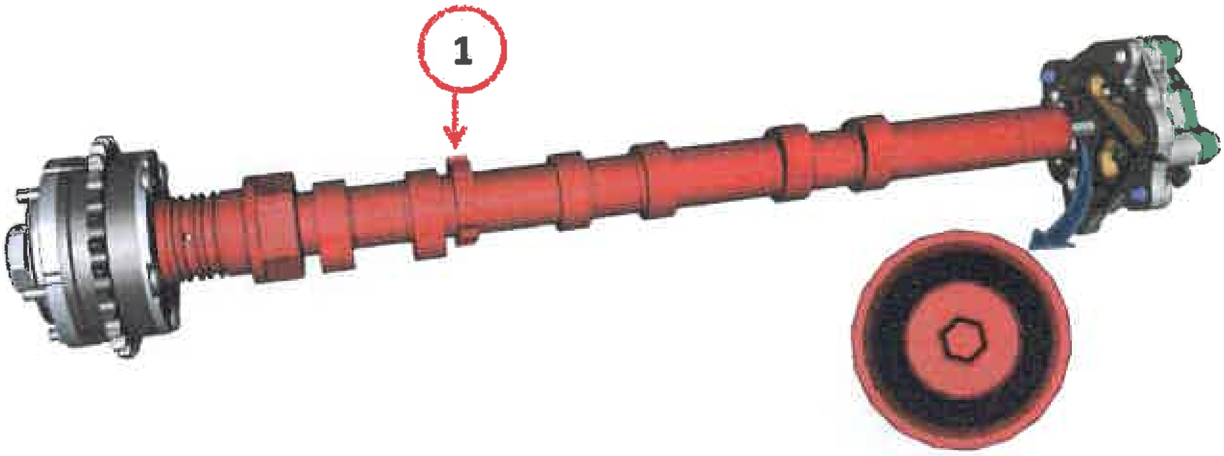

Key:
1 – Intake camshaft.
2 – Exhaust camshaft.

*Intake camshafts.*



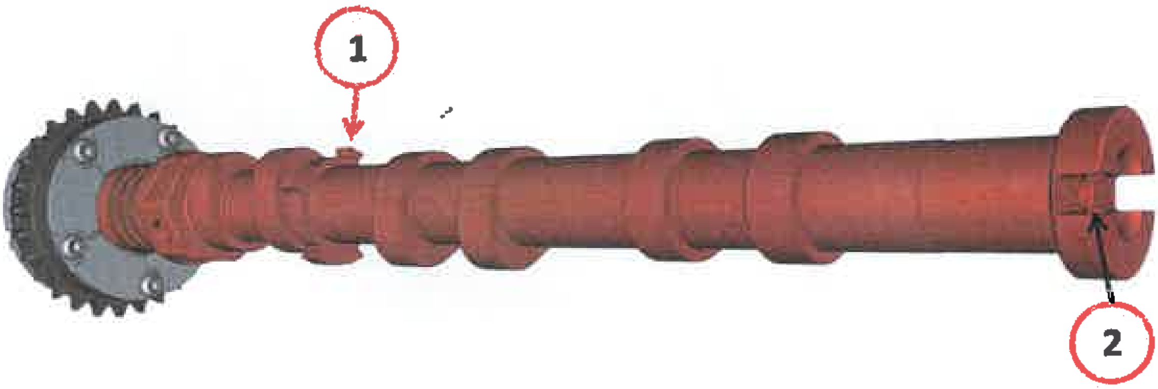

Both intake camshafts have a phonic wheel (1) for the phase sensor, the specific cam (2) to activate the high pressure pump and at the end the oil vapour separator (3).

*Right bank exhaust camshaft.*




The right bank exhaust cam also has a phonic wheel (1) for the phase sensor. In addition, the end of the cam (drive pulley side) has a hexagonal marking to connect it to the additional oil pump.

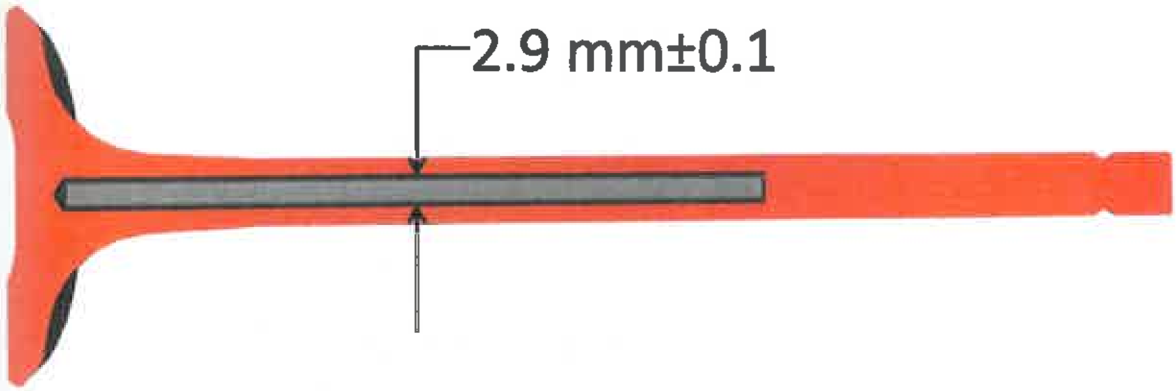
*Left bank exhaust camshaft.*




In the left bank exhaust cam, in addition to the phonic wheel (1) for the phase sensor, there is the housing for the vacuum pump placed at the end of the cam itself (drive belt side).

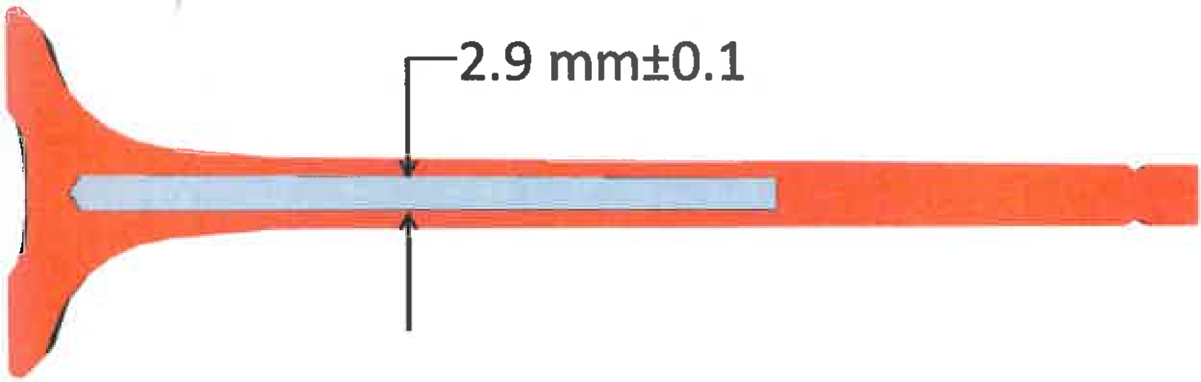
Replacing the internal charge for the combustion chamber happens via 4 valves per cylinder (2 intake and 2 exhaust). The individual valve is activated via a cam push on a rocker (arm) which rests at one end on the hydraulic tappet and the other end on the valve.

The intake valves are in steel and have been subjected to a hardening heat treatment and then to a tempering to increase its hardness.




Because of the high mechanical and thermal stresses owing to the high value of specific power, the central part of the valve stem has been made in hollow sections with an internal diameter of about 2.9mm. The hollow section allows improved efficiency in dispersing the heat, allowing the maximum reachable temperatures to be limited.

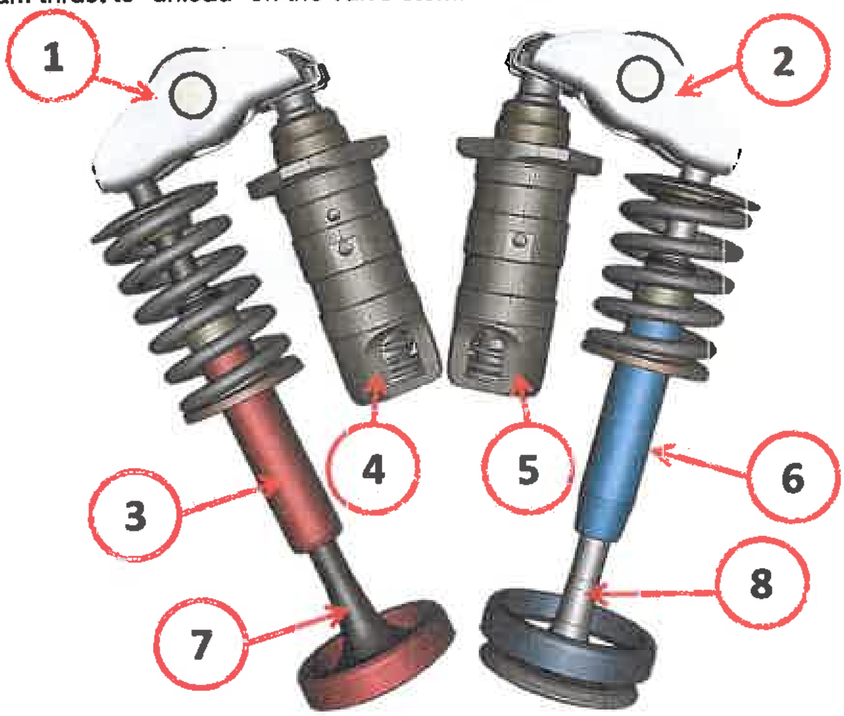
Differentiating from the intake valve, the exhaust valves have to resist higher temperatures and are also subjected to the corrosive effect of exhaust gases. For this reason, the valve head has been made in a different steel alloy from the stem. The exhaust valve head is produced in a special alloy, high in nickel and chrome, called Nimonic.




The exhaust valves' internal stem cavity is filled with 60% sodium. This last in metallic form becomes liquid at around 100°C; the liquid sodium allows the heat to be dispersed more efficiently. Sodium in liquid stage moves inside the valve cavity during high alternating motion, transferring part of the high heat from the valve head to the stem (and from there to the cylinder head via the guide valve). This way, the valve temperature goes down to about 70÷100°C.

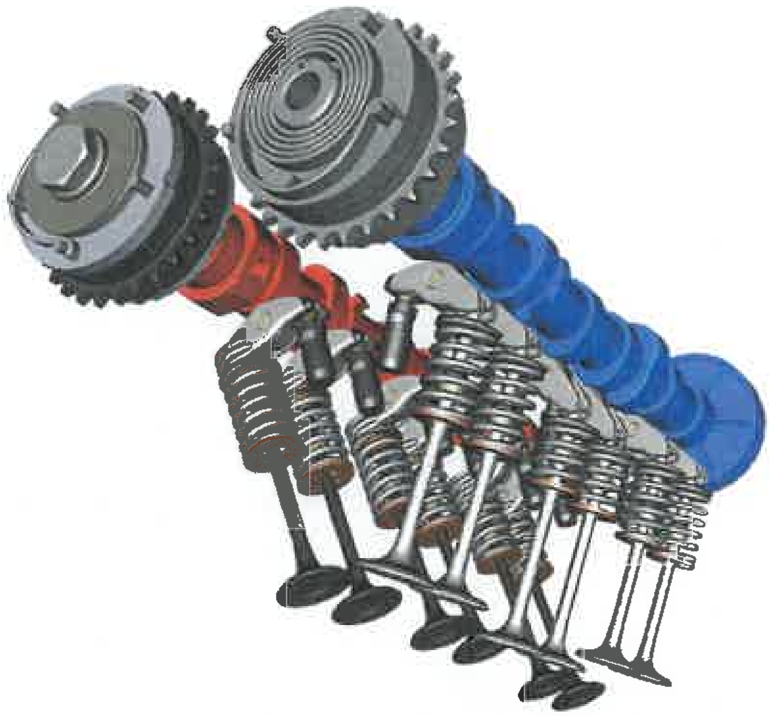
*Valve activation - Right Bank.*

The opening and closing of the intake and exhaust valves happens thanks to the hydraulic tappets that allow the cam thrust to "unload" on the valve stem.




Key
1 – Exhaust valve rocker
2 – Intake valve rocker.
3 – Exhaust guide valve.
4 – Collapsible hydraulic tappet (exhaust side)
5 – Collapsible hydraulic tappet (intake side)
6 – Intake guide valve.
7 – Exhaust valve.
8 – Intake valve.

*Valve activation - Left Bank.*

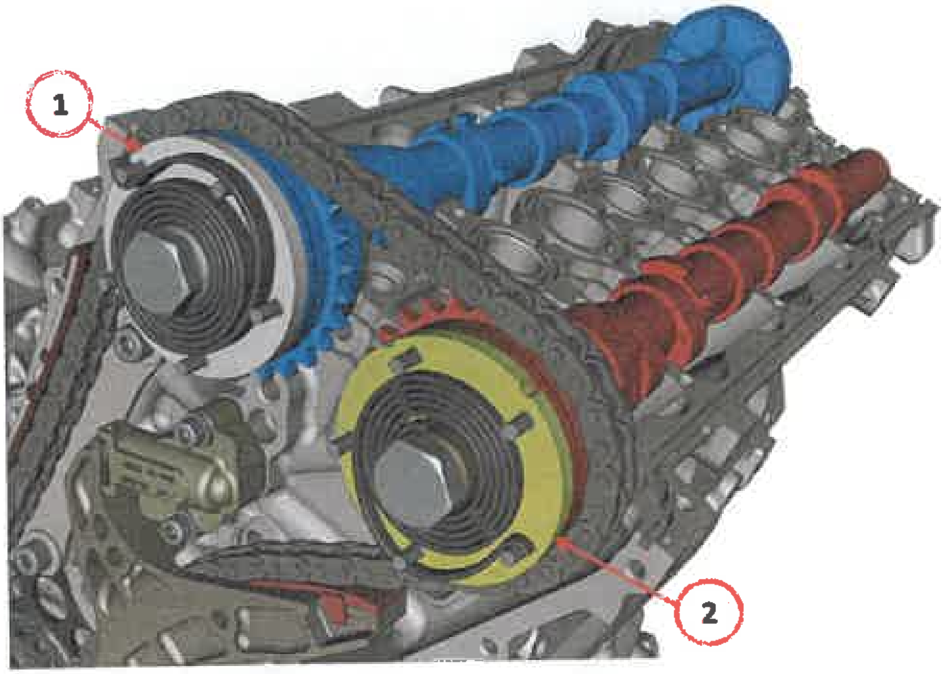


The opening and closing of the intake and exhaust valves happens thanks to the hydraulic tappets that allow the cam thrust to "unload" on the valve stem. The left bank tappets cannot be deactivated because the cylinder deactivation system is only on the right bank.

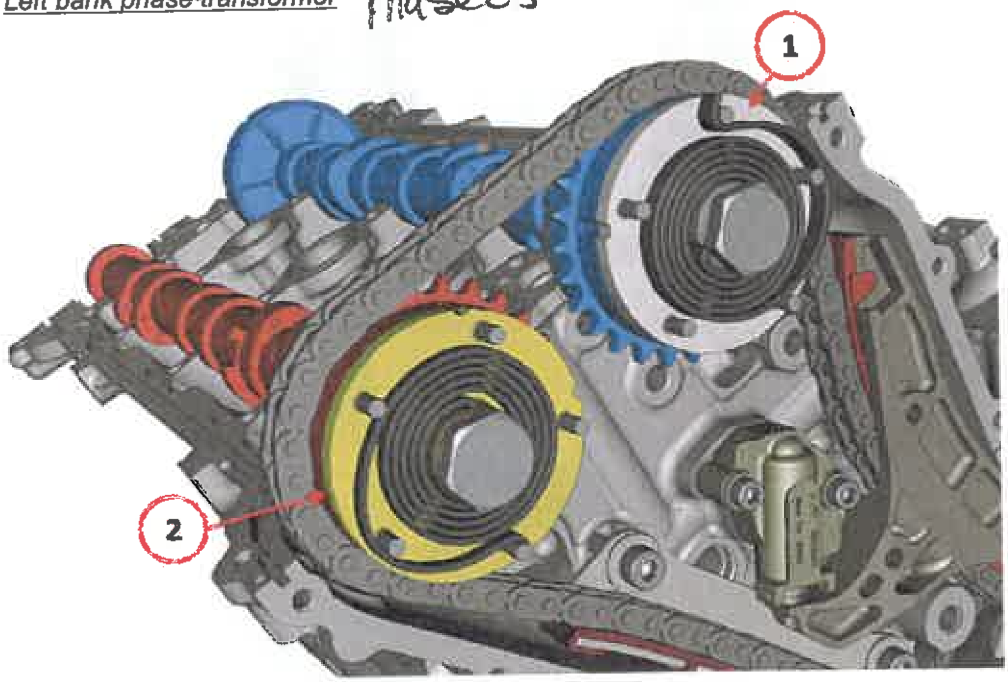

Key
1 – Exhaust valve rocker
2 – Intake valve rocker.
3 – Exhaust guide valve.
4 – Hydraulic tappet (exhaust side)
5 – Hydraulic tappet (intake side)
6 – Intake guide valve.
7 – Exhaust valve.
8 – Intake valve.

An important technological content that characterises the 2.9 V6 engine timing is the variable phasing. Variable phasing allows for optimising cylinder filling by adapting the opening and closing angles of the valves according to the engine's operating point. Optimising the filling coefficient allows benefits in terms of performance, consumption and emissions. There are phase transformers on the intake and exhaust cams on both bearings that allow both ECM control modules to adopt the best phasing.

*Right bank phase transformer*



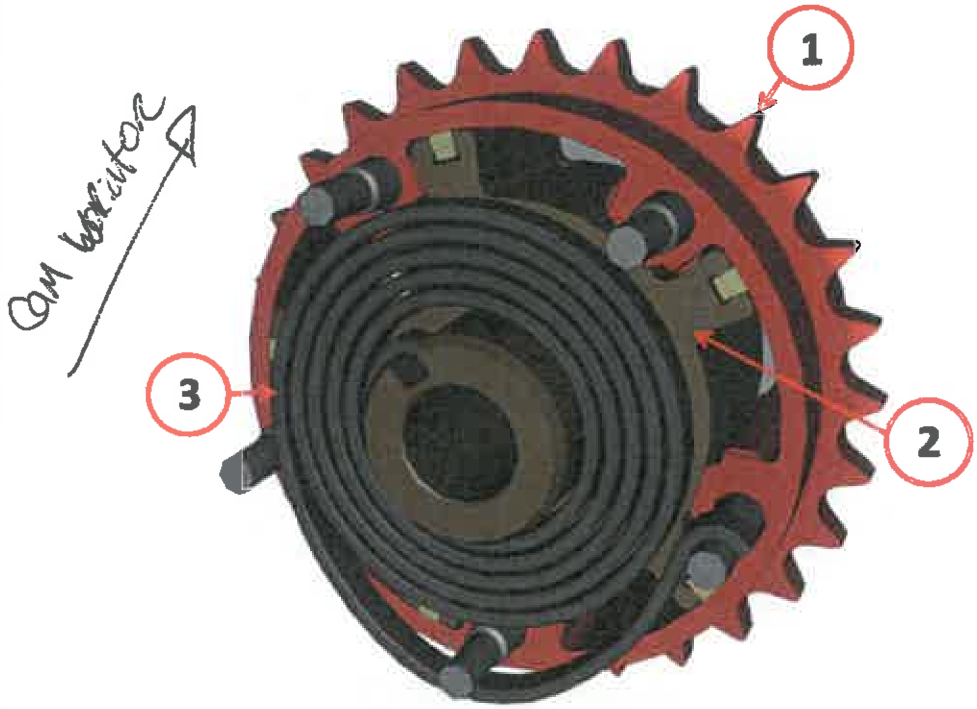

*Left bank phase-~~transformer~~* Phasees



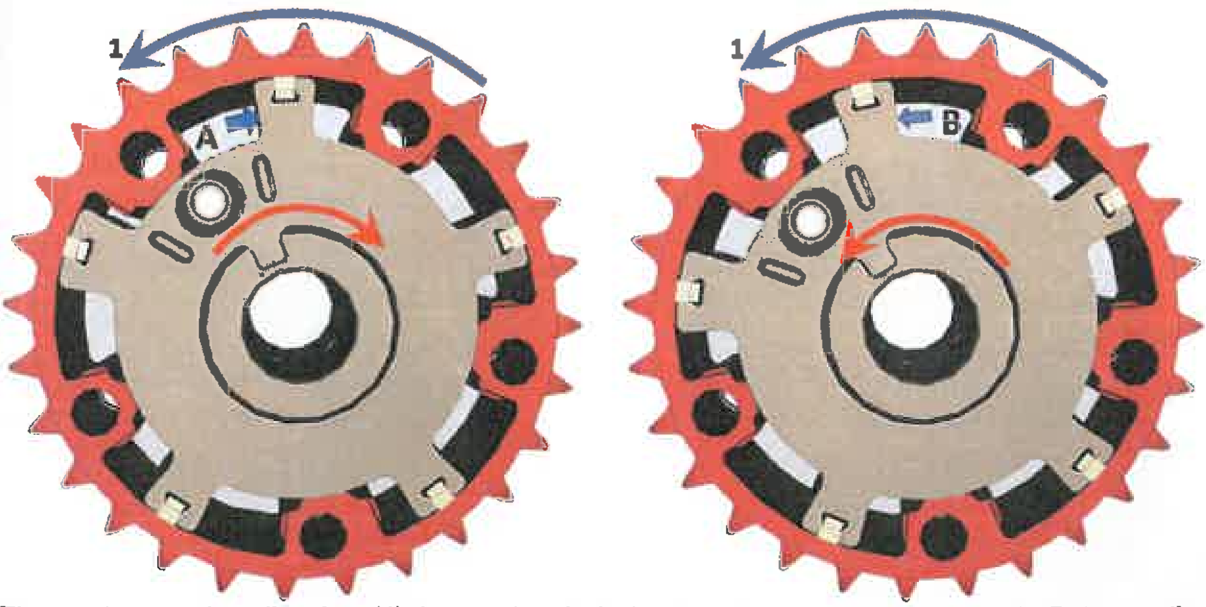

Key
1 – Intake side phase ~~transformer~~
2 – Exhaust side phase ~~transformer.~~

**NOTE:** The screws that fasten the phase transformers to their relative camshafts are of the left-hand type.

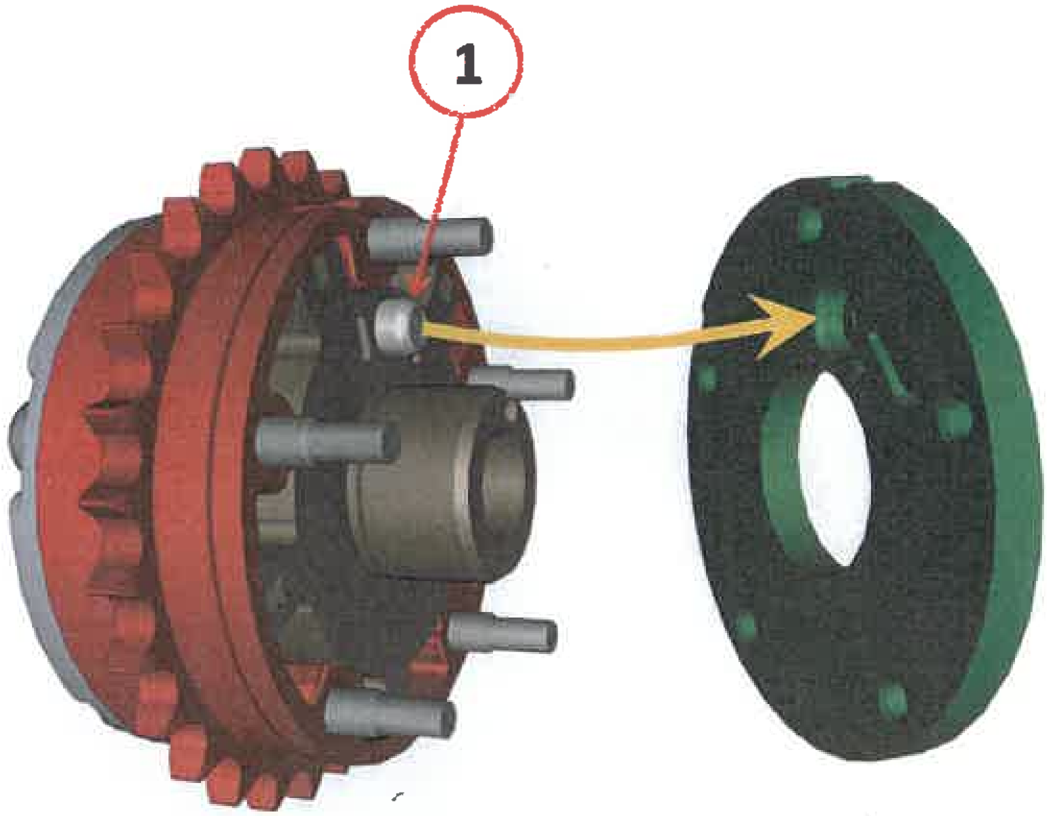
The phase transformers (intake and exhaust) are hydraulically activated and have the feature of having an exterior part joined to the camshaft via the timing chain. Furthermore, they are equipped with a spring that allows the part joined to the camshaft to turn in the neutral position when the oil thrust diminishes.



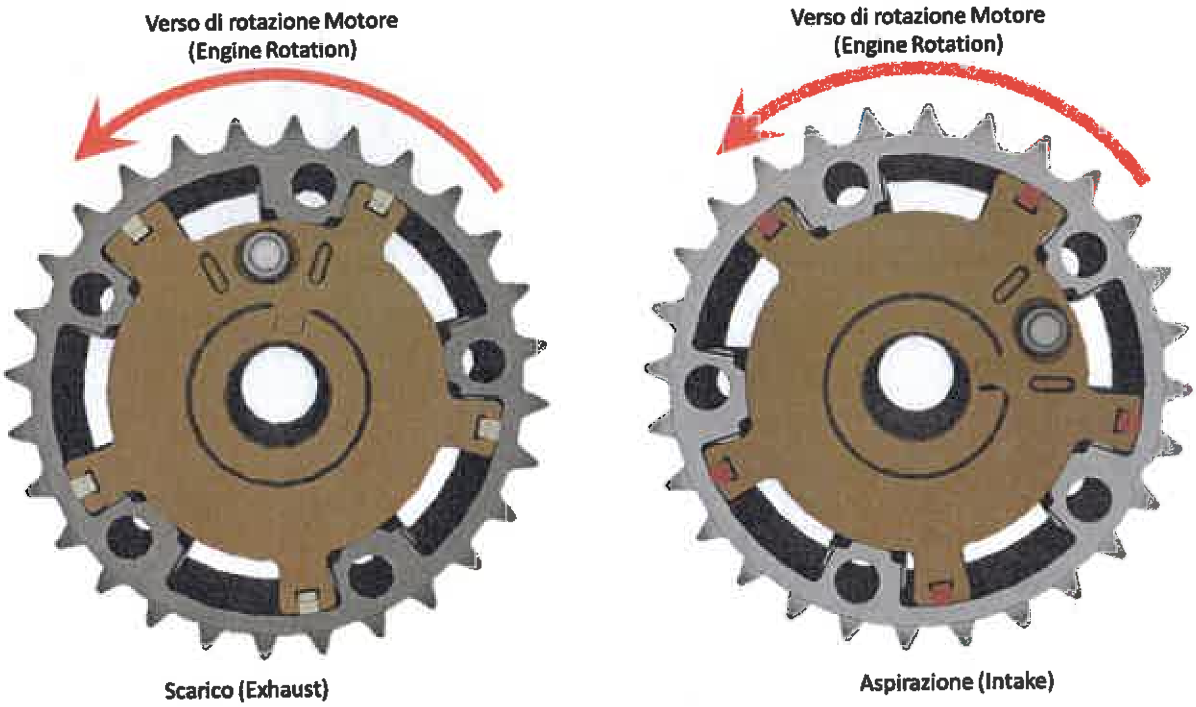

Key
1 – Exernal part of the transformer joined to the camshaft via chain.
2 – Internal part of the transformer joined to the camshaft via fastening screws.
3 – Recovery spring.




The engine rotation direction (1) is counter-clockwise (leaning on the timing side). Between the internal part joined to the camshaft there are chambers that fill with oil depending on the transformer's anticipating or postponing the phase. If oil fills chamber A, the internal part joined to the camshaft turns contrarily to the engine rotation direction and consequently the phase is delayed. If instead oil fills chamber b, the internal part joined to the camshaft turns in the same direction as the engine rotation and consequently the phase is anticipated.

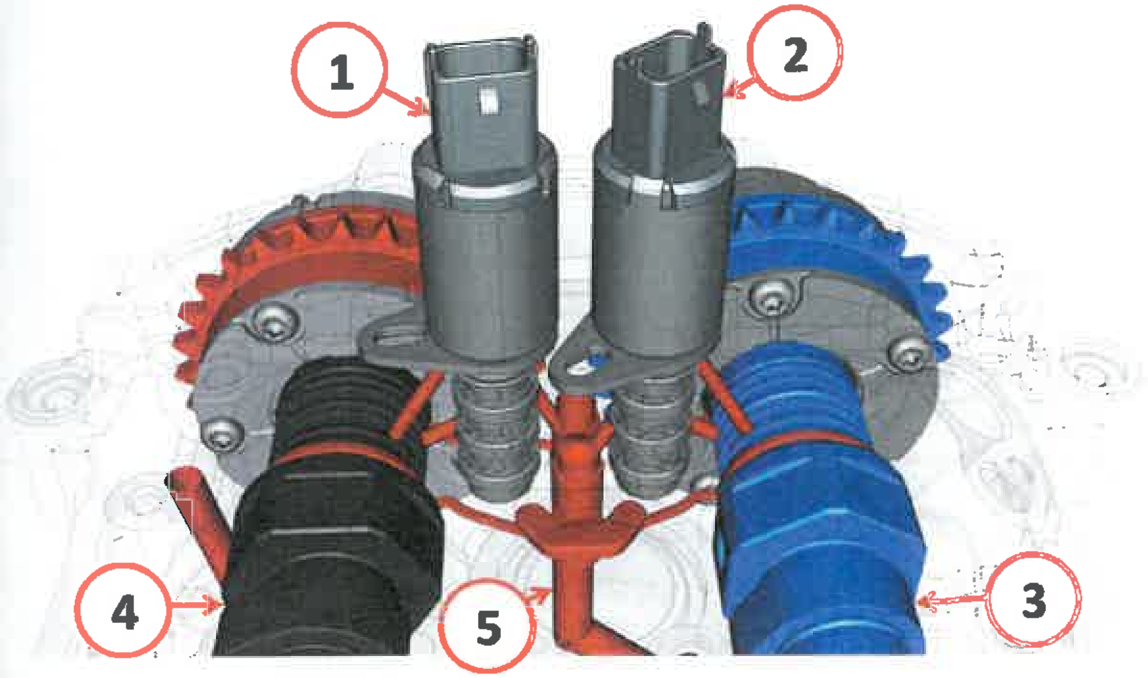



In neutral conditions, the phase transformers have a mechanical block that consists of a pin inserted in a housing created on the transformer's front cover. The front cover is joined to the external part that receives camshaft motion. The pin instead is on the part joined to the camshaft. A spring pushes the pin into the housing on the cover. When the engine starts up, the oil under pressure enters the housing and pushes the pin backwards, overcoming the spring load and consequently the mechanical block is removed.



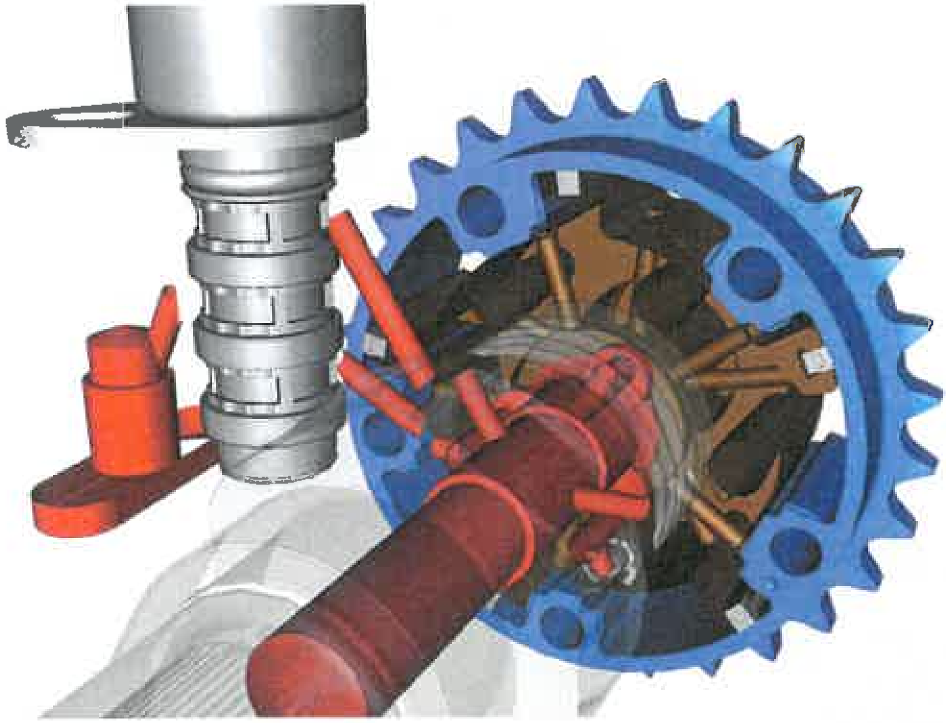

When the transformers are in neutral (mechanical block) the intake camshafts are in maximum delay. The exhaust camshafts are in maximum anticipation instead.

The transformer movement in anticipation or delay is created through two solenoid valves (two per bank) that distribute the oil appropriately in the transformers' internal chambers.

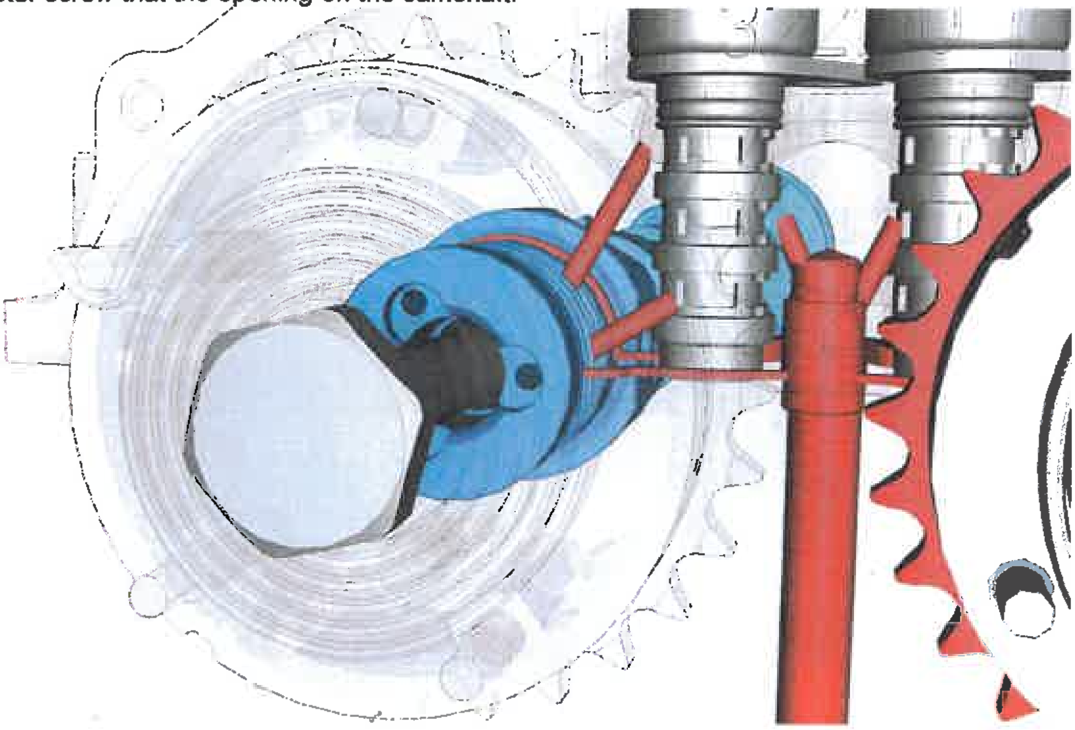



Key
1 – Solenoid valve transformer oil distribution in exhaust phase.
2 – Solenoid valve transformer oil distribution in intake phase.
3 – Intake side camshaft.
4 – Exhaust side camshaft.
5 – Intake oil channel coming from cylinder head.

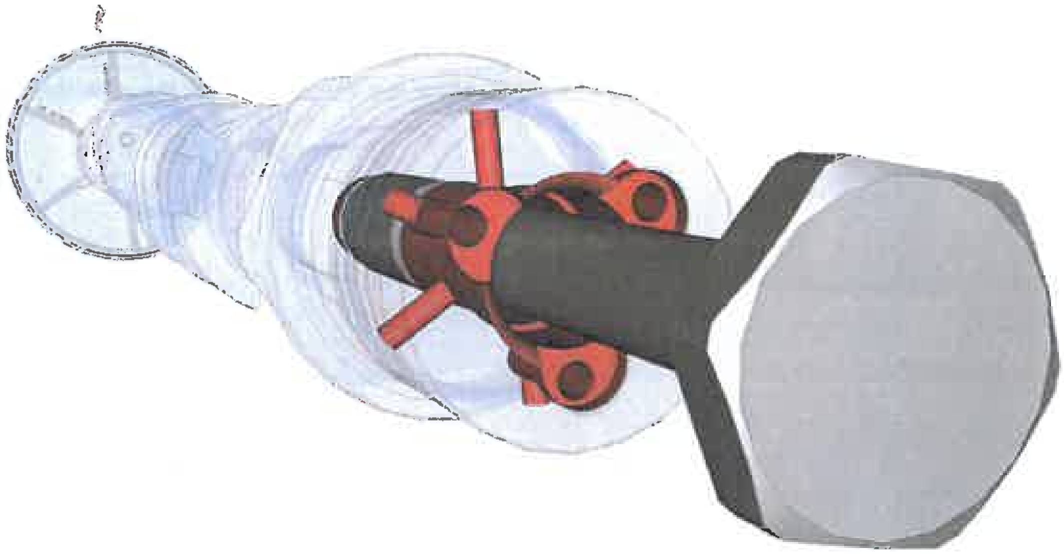
Special channels connect the solenoid valves with grooves made in the side surface of the camshafts' ends. There are openings along the groove that allow the exiting oil from the solenoid valve to reach the phase transformer chambers.



The phase transformers are connected to the respective camshafts by full shaft fastening screws, not hollow. The oil flow to the phase transformer camshaft and vice versa is possible because of a smaller diameter screw that the opening on the camshaft.

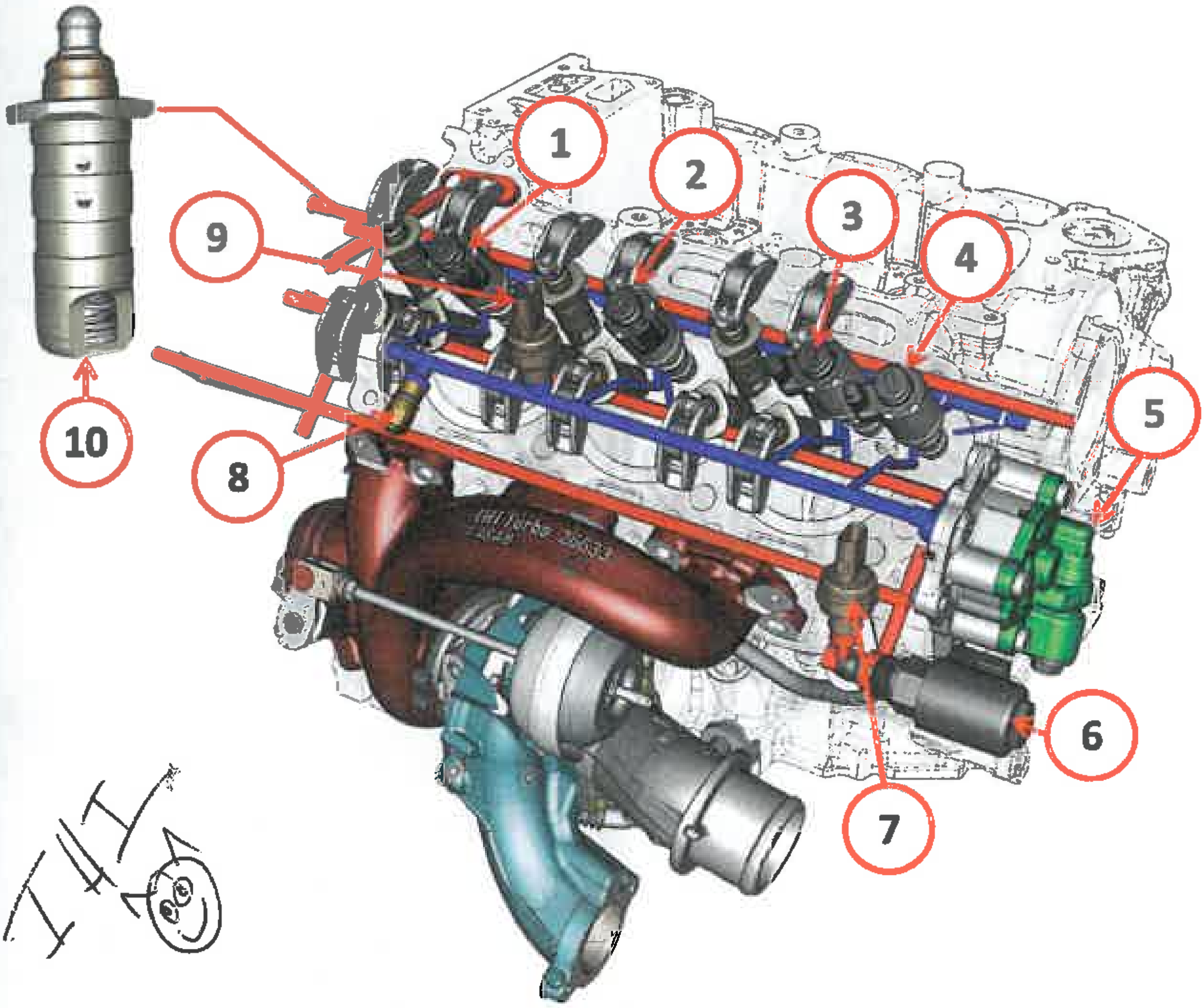


The fastening screw is centred inside the camshaft opening; the smaller screw diameter works so that there is a space between the opening on the camshaft and the screw shaft surface allowing oil from the solenoid valve to reach the internal parts of the phase transformer.



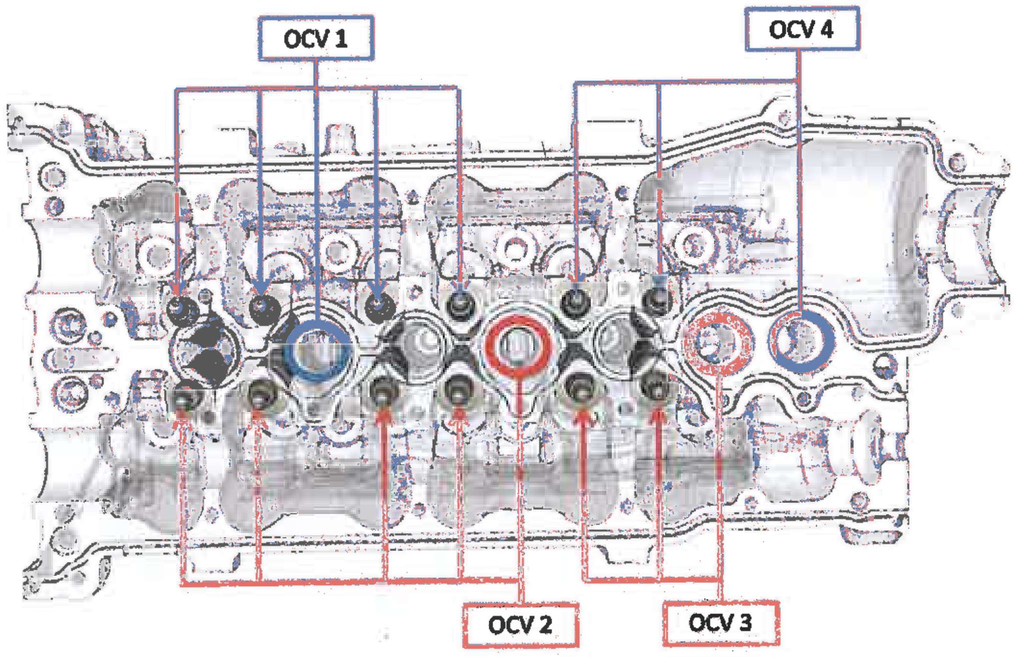
### Deactivation system for right bank cylinders

In the right bank cylinders there is a cylinder deactivation system. This system acts in a way that the intake and exhaust valves for all the bank cylinders remain closed for the entire deactivation time.
The components forming the system are:

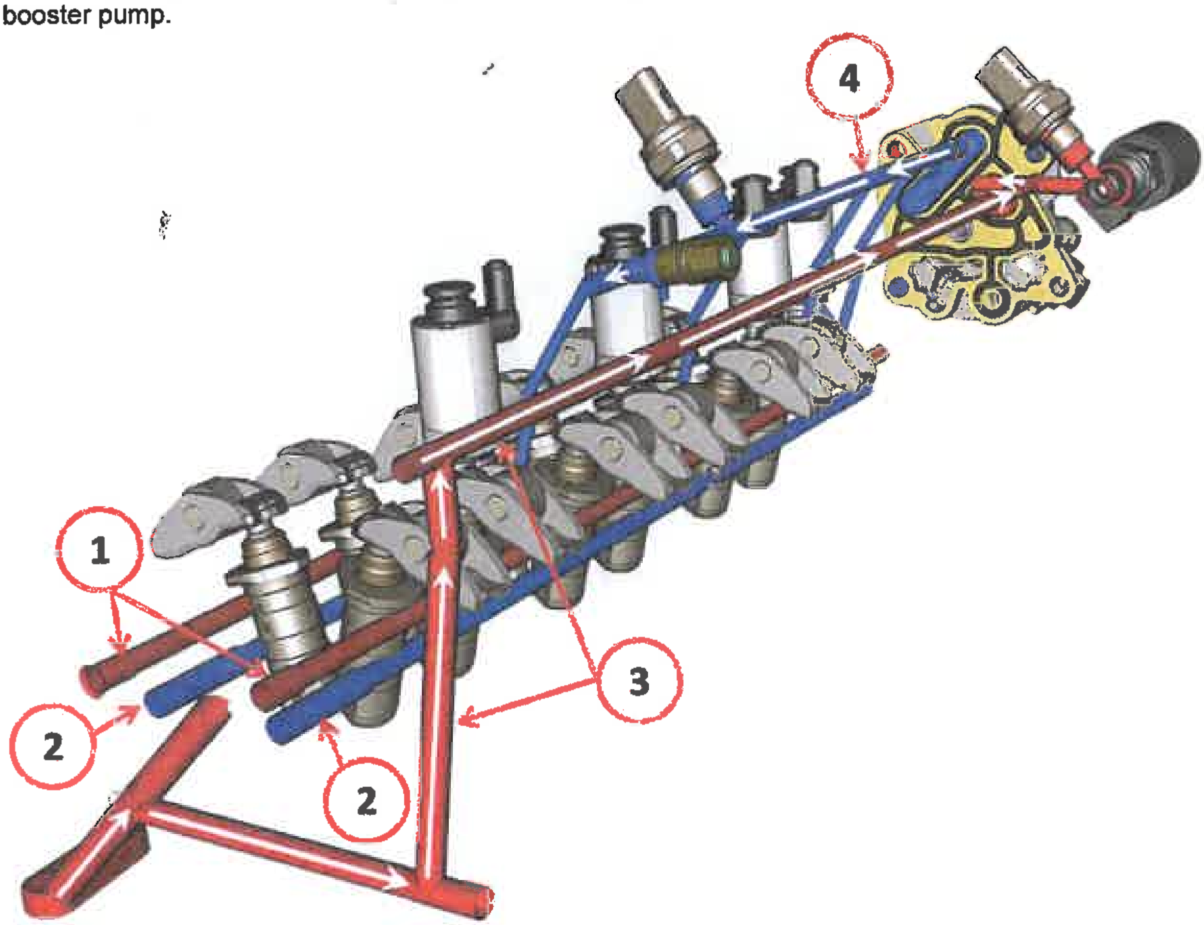



Key
1 – OCV solenoid valve no.1 to deactivate the hydraulic tappets on the nos.2 and 3 cylinders' intake side.
2 – OCV solenoid valve no.2 to deactivate the hydraulic tappets on the nos.2 and 3 cylinders' exhaust side.
3 – OCV solenoid valve no.3 to deactivate the hydraulic tappets on the no.1 cylinder's exhaust side.
4 – OCV solenoid valve no.4 to deactivate the hydraulic tappets on the no.1 cylinder's intake side.
5 – Oil pump for the hydraulic cylinder deactivation circuits (booster pump).
6 – Solenoid valve to control the oil flow for lubricating the turbocharger.
7 – Turbocharger lubrication circuit pressure sensor.
8 – Maximum pressure valve.
9 – Cylinder deactivation circuit pressure sensor.
10 – Collapsible hydraulic tappets.

The oil channels in blue represent the hydraulic circuit that lets the "thrust" oil from the booster pump (5) reach the hydraulic tappets in order to make them collapse. The tappets in their "collapsed" state do not let the valves open.

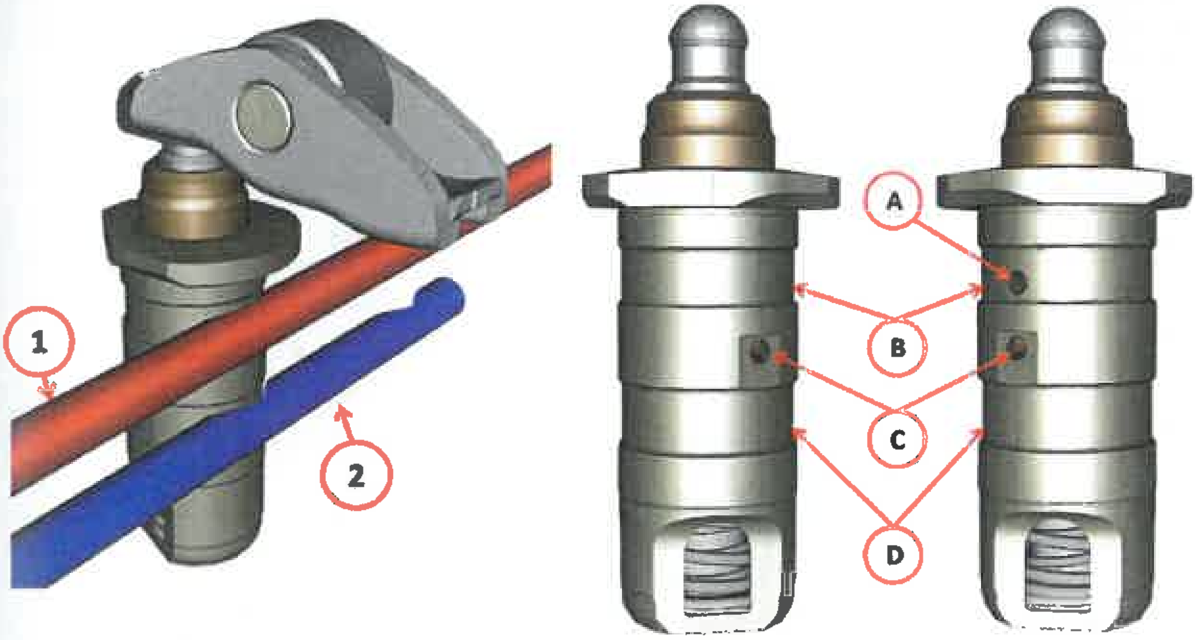



The image shows the right bank cylinder heads from above and the collapsible hydraulic tappets controlled by each OCV solenoid valve. Below shows the entry oil channels and in delivery to the booster pump.

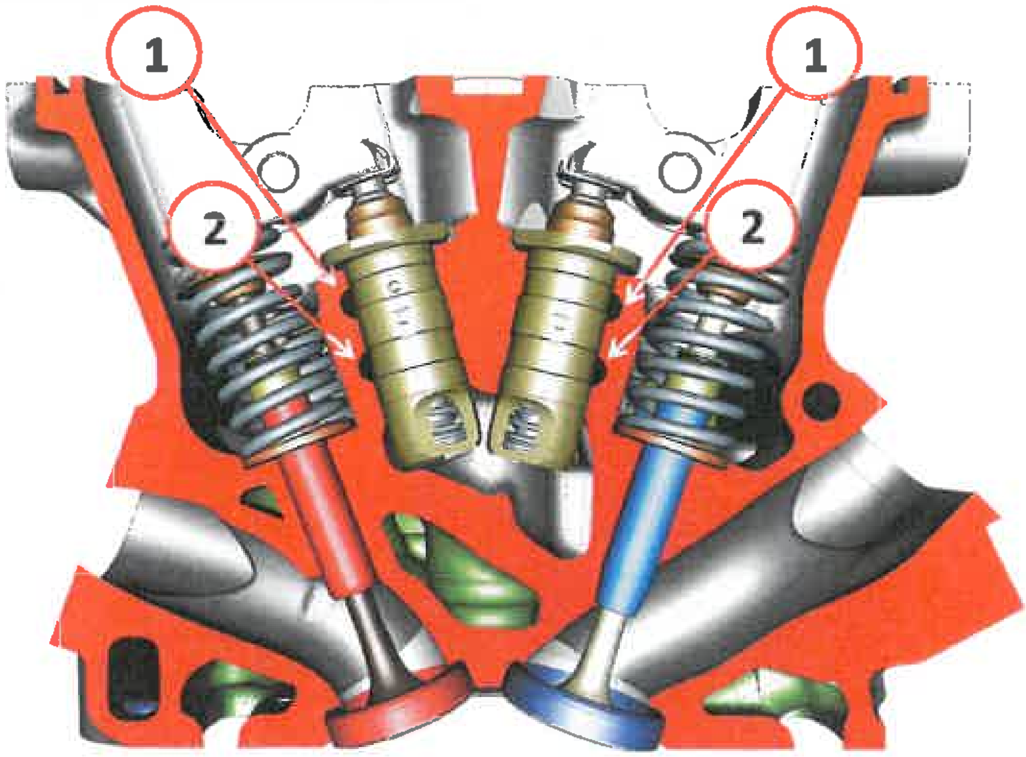



Key
1 – Tappet lubrication oil channels (standard)
2 – Cylinder deactivation circuit oil channels.
3 – Oil channels (from the engine block) entering the booster pump to deactivate the cylinders.
4 – Cylinder deactivation circuit oil supply channel.

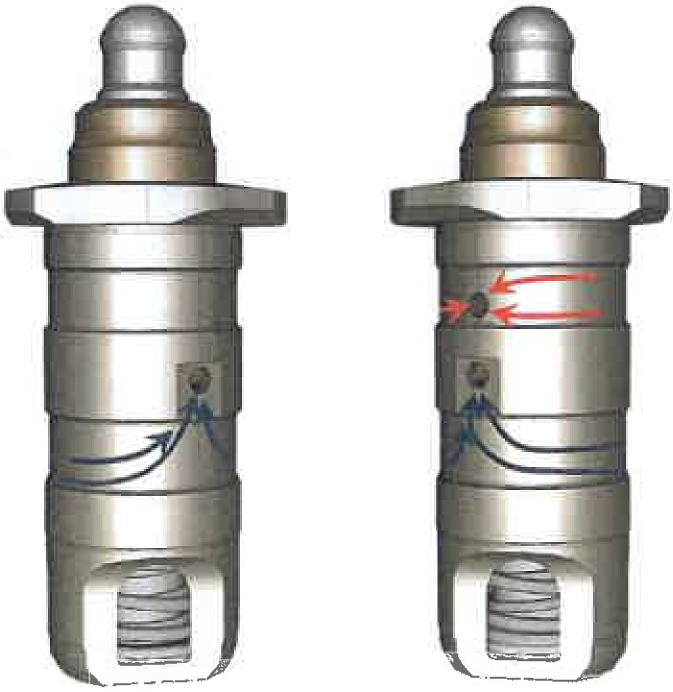
The collapsible tappets get their normal oil flow for lubrication and their correct operation from the oil channel in red (1). The lower part of the tappet contains the collapse mechanism. When the channel in blue (2) fills with oil, the collapse mechanism becomes active and the tappet (upper part) collapses.



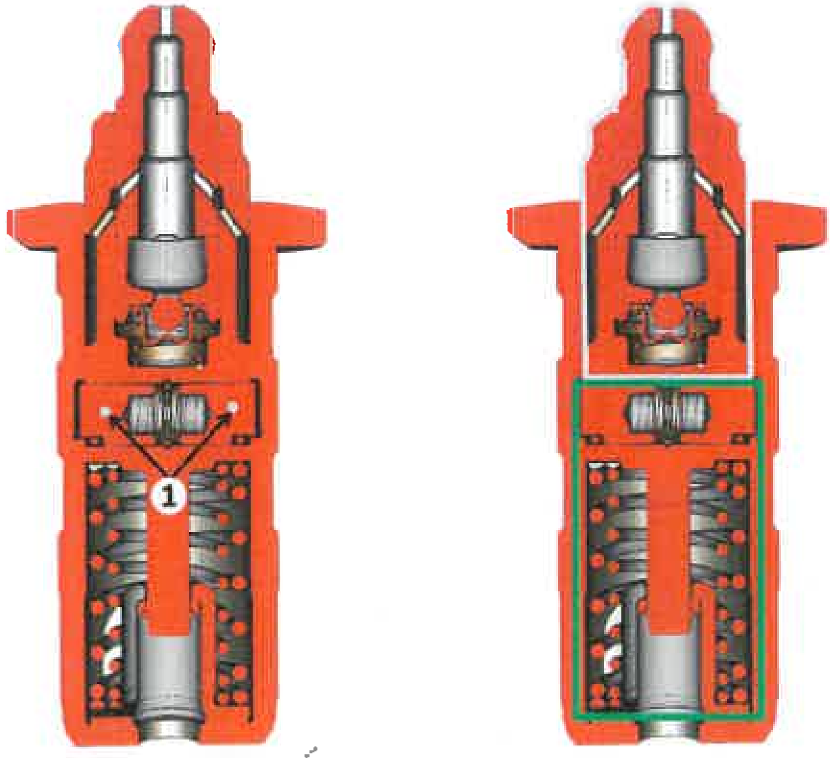

Key
1 – Standard tappet lubrication channel
2 – Tappet deactivation mechanism supply channel.
A – Tappet lubrication entry opening
B – Tappet oil supply groove
C – The oil entry opening for tappet deactivation.
D – Deactivation mechanism oil supply groove.



There are grooves and 3 openings (two on one side and one on the other side) along the external side surface of the tappets that can be disabled. Oil fills groove B, inserting itself in opening A to lubricate the upper part of the tappet, guaranteeing its proper operation. When the ECM (master) control motor decides to deactivate the cylinders, it sends oil through the OCV solenoid valves into the blue channel (2). The oil fills groove D and from there it goes into openings C to activate the mechanism that will make the tappets collapse.

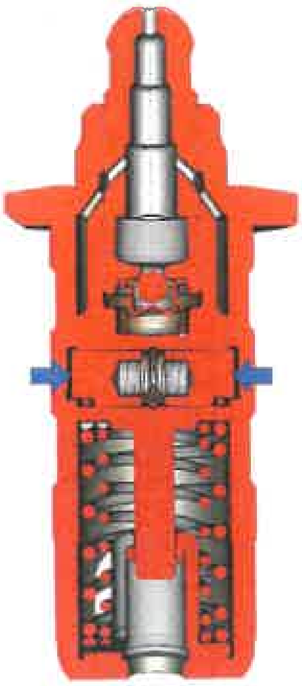


The picture below shows the section of a deactivated tappet.




The real tappet is in the upper part (light edge). This last falls onto a base that is none other than the deactivation mechanism (green edge). The mechanism consists of two small pistons (1) that fall onto a lateral housing made along the internal surface of the tappet's exterior shell. The two pistons in this configuration support the entire upper tappet.

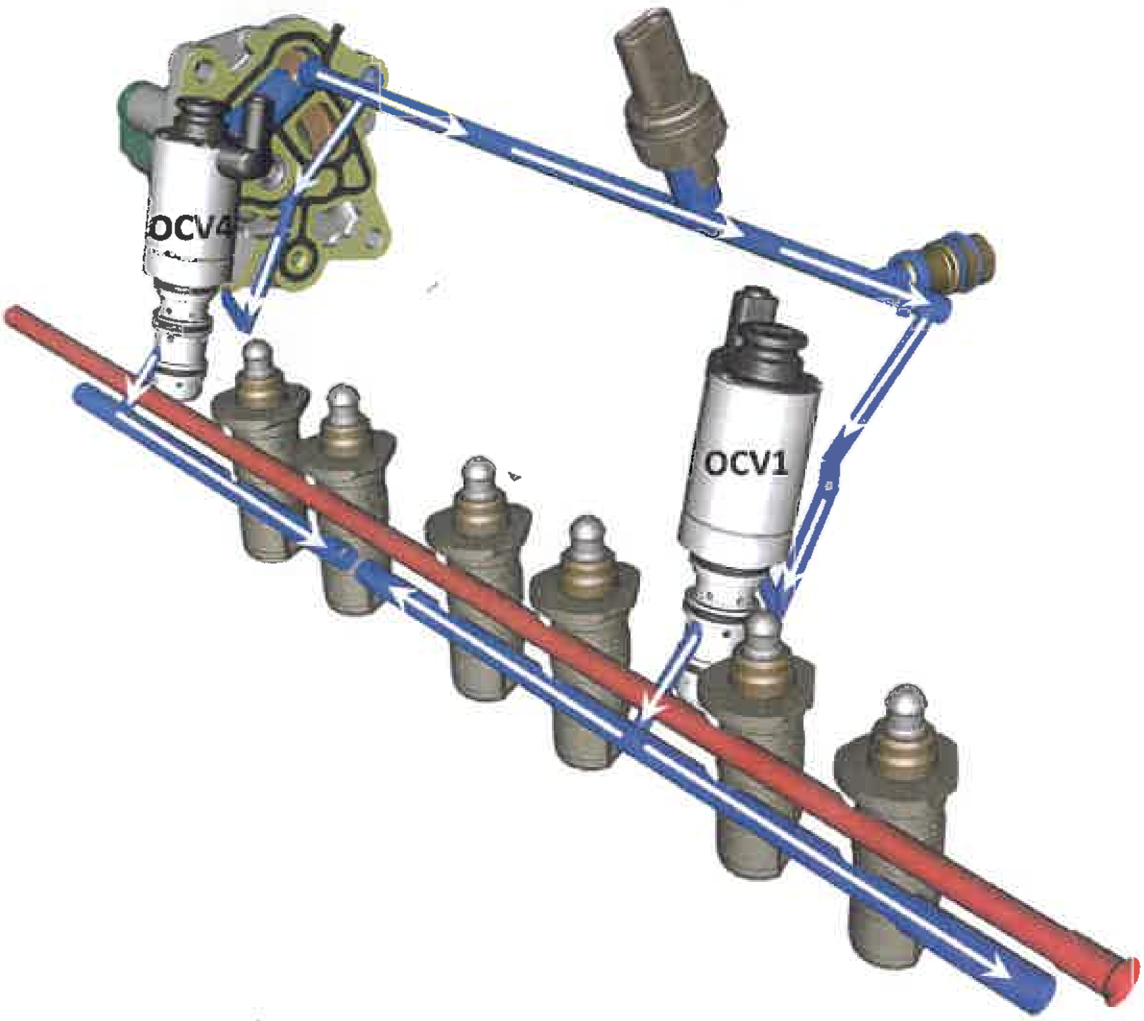
When the ECM (master) activates the cylinder deactivation strategy, the chamber between the pistons and the external shell body fills with oil. Oil pressure pushes the pistons, compressing the spring located in the space in between them. When the pistons pull back, they leave the support housing and consequently cannot offer support to the tappet. The result is the tappet collapses downwards; the pistons start moving when the relative pressure is about 0.8 bar and they are completely at the bottom of their track when the pressure is 1.2bar.



When the OCV solenoid valves receive power from the $ECM_1$ Master, they allow oil supply from the booster pump to reach the oil channels to deactivate the tappets. The pressure of the oil supplied by the booster pump is about 3-3.5 bar in nominal conditions (T-oil≈95°C). When the Master $ECM_1$ decides to deactivate the cylinders, the engine is running at a speed of no more than 3000 rpm. In these operating conditions, the oil pump operates at low pressure (LP). Oil supplied by the pump in LP mode reaches a nominal value of about 1.5 bar. The booster pump receives the oil at 1.5 bar and increases the supply pressure about 1.2 bar (relative pressure) reaching to 3-3.5 bar. If it were not for the boost pump, the whole cylinder deactivation hydraulic circuit would have to operate at a limit pressure of (1.5 bar), just enough to make the collapsible tappets work. The boost pump creates that safety over-pressure for the system's operation.

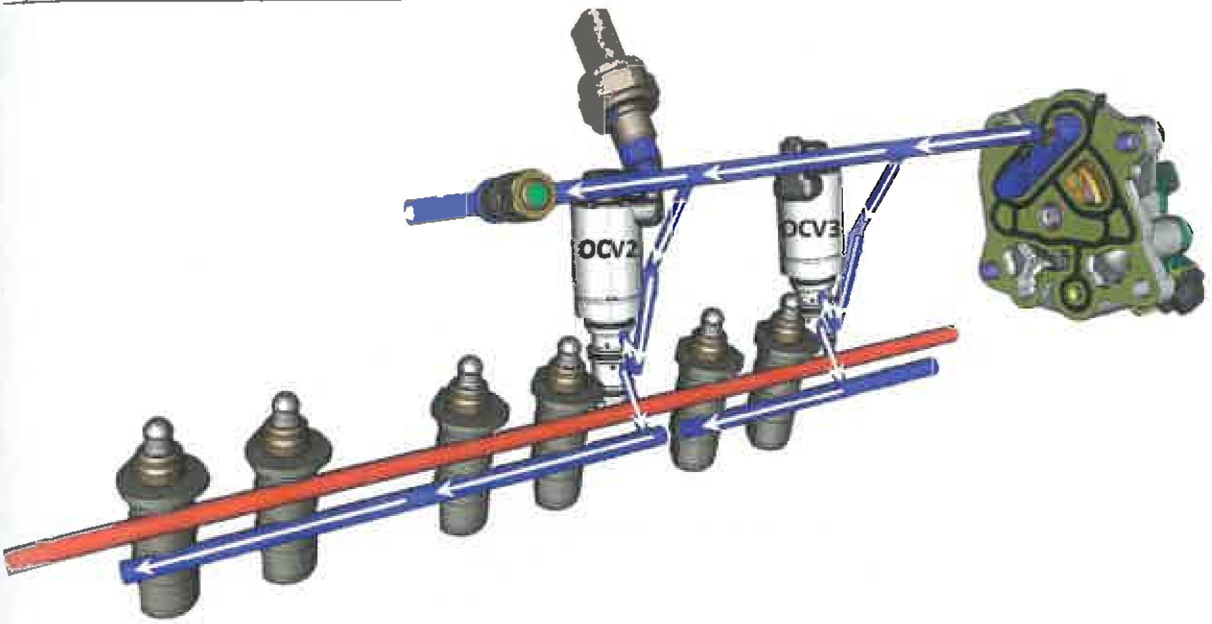
To keep the pressure on the supply conduit from the booster pump to the tappets from getting too high (low temperature or malfunction) there is a maximum pressure valve that maintains the pressure below 6 bar.

*Hydraulic tappets on intake side*

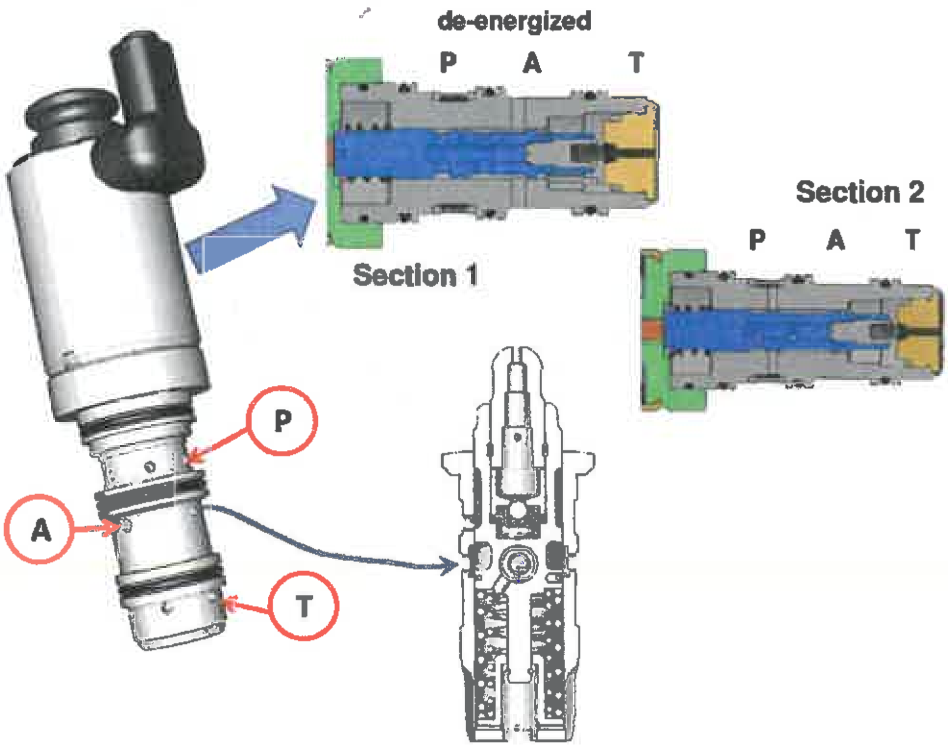



The picture above shows the oil flow that the pump sends to the oil channels, making the tappets that regulate the intake valve opening collapse. The OCV1 and OCV4 solenoid valves open up the "path" towards the channels concerned.

*Hydraulic tappets on exhaust side*




Like the intake side hydraulic tappets, the OCV2 and OCV3 solenoid valves allow the supplied oil to reach their respective channels to deactivate the tappets on the exhaust side.



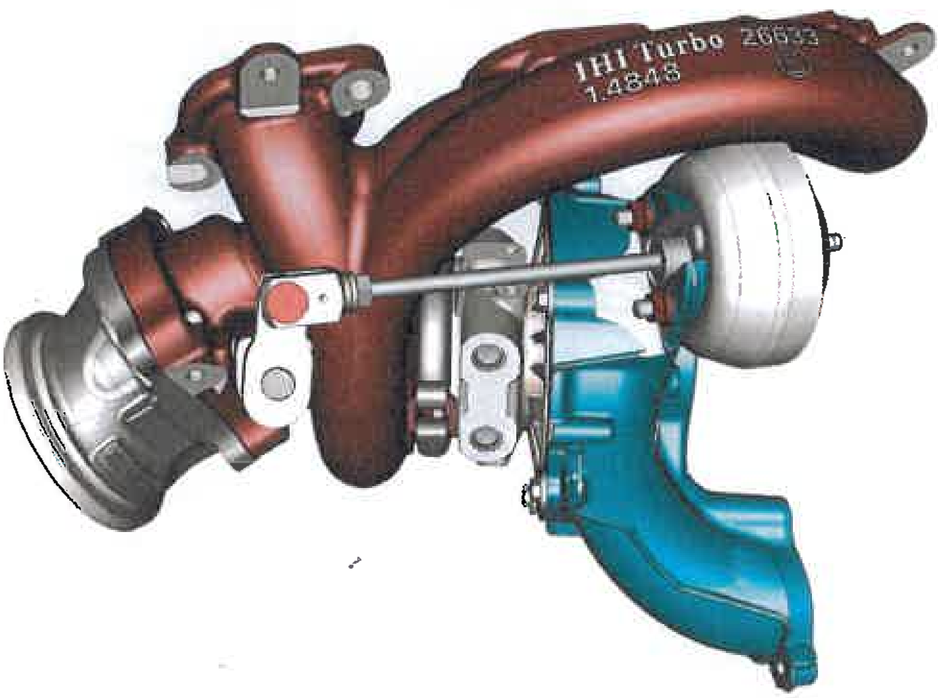

The OCV solenoid valves have openings along the stalk's lateral surface. The P openings receive supply channel oil from the booster pump. When the OCVs are not order to, the oil enters from the P openings and goes back out the T openings to return via the head and engine block channels in the sump. When the OCVs are ordered to by the $ECM_1$ Master, the cylinder inside the OCV moves to the right, so the oil entering from the hydraulic tappet's A openings to enter into C openings, where the deactivation mechanism will be enabled.

**NOTE:** For information about the engine conditions on which the $ECM_1$ Master actuates the cylinder strategy, please see the chapter "Motor Management".

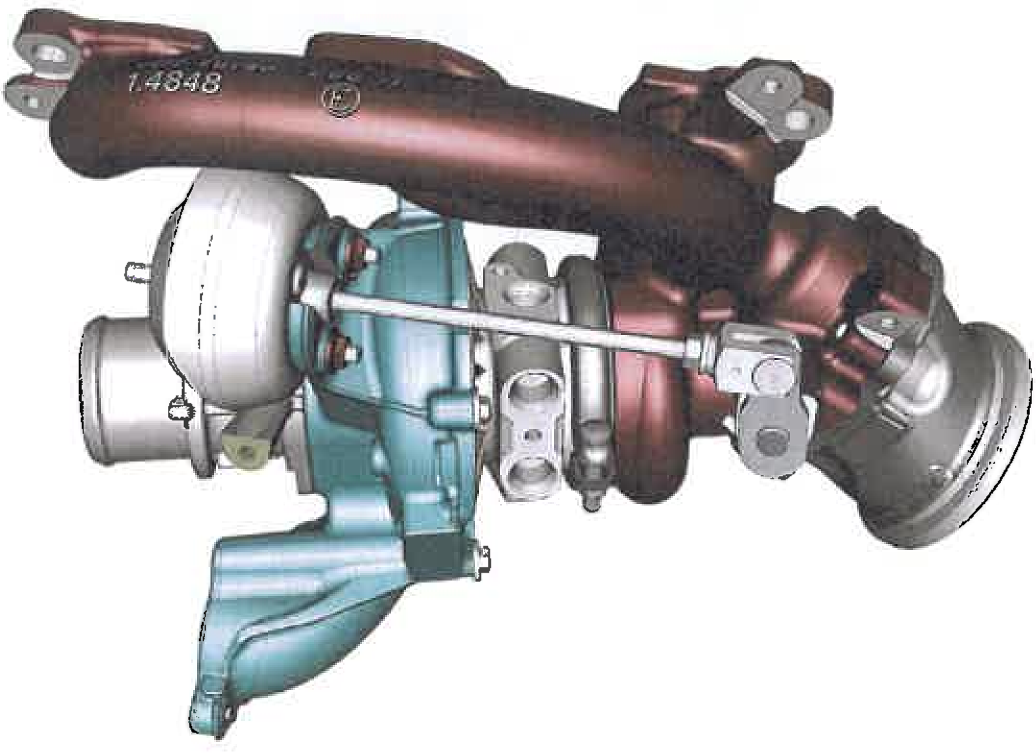
## Turbochargers.

The engine has two turbochargers with an exhaust gas by-pass waste gate valve. The two turbochargers "supercharge" the right and left bearings respectively. Both turbochargers are IHI products.

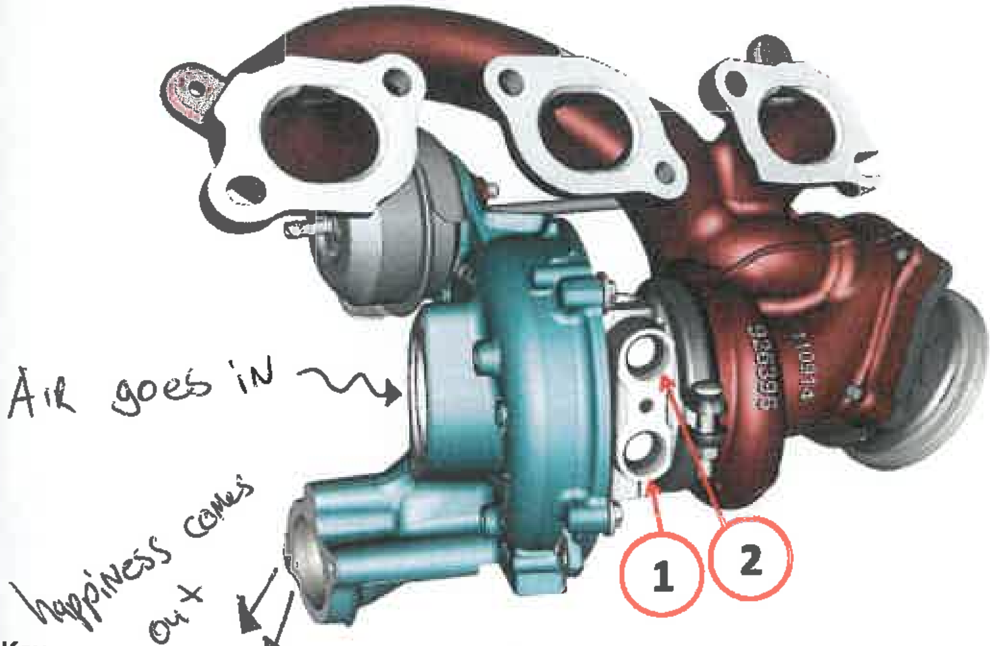
*Right turbocharger.*




*Left turbocharger*

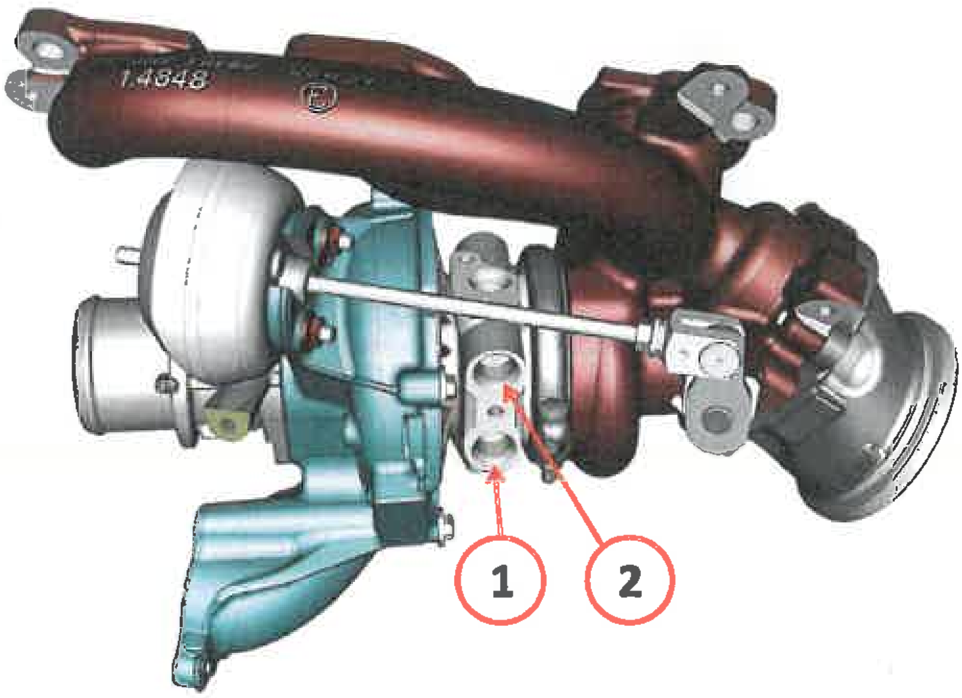


A feature that differentiates the two turbochargers is shown by where the cooling pipes are attached to them. The right turbocharger's cooling pipes are attached in the rear, beneath the exhaust collector.



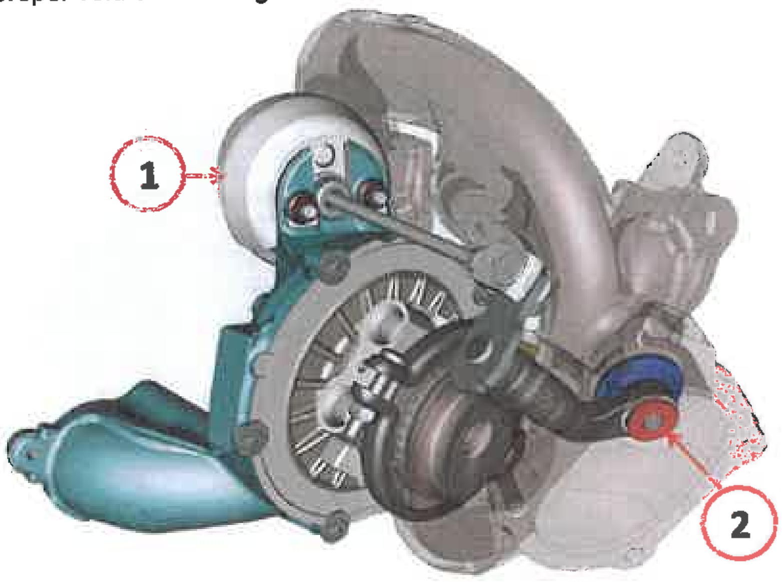

Key
1 – Cooling liquid entry.
2 – Cooling liquid exit.

The left turbocharger receives the cooling liquid in its front area.



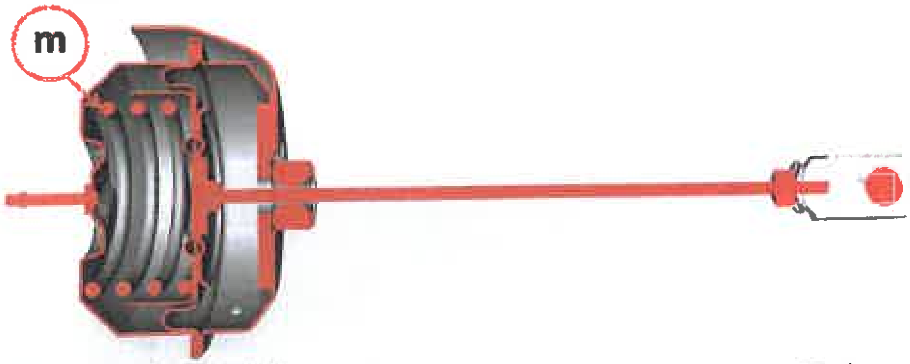

Key
1 – Cooling liquid entry.
2 – Cooling liquid exit.

The actuators that move the by-pass waste gate valve are pneumatic. The waste gate valve is normally open. To be able to close the valve, the pneumatic actuator that moves it has to get a vacuum from the proper void channelling.

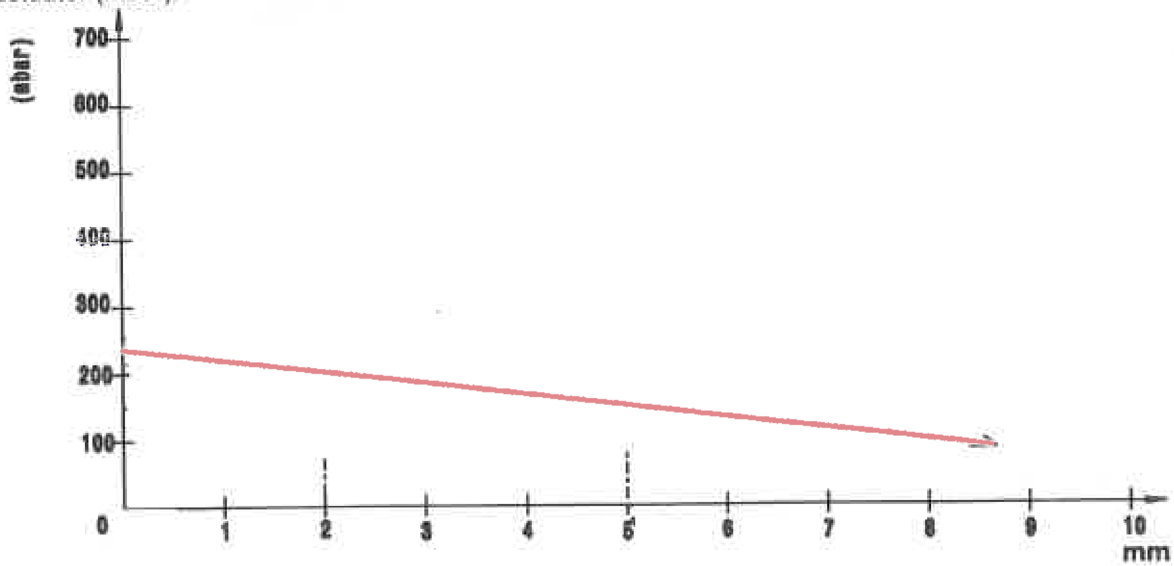



Key
1 – Pneumatic actuator.
2 – Waste gate valve.

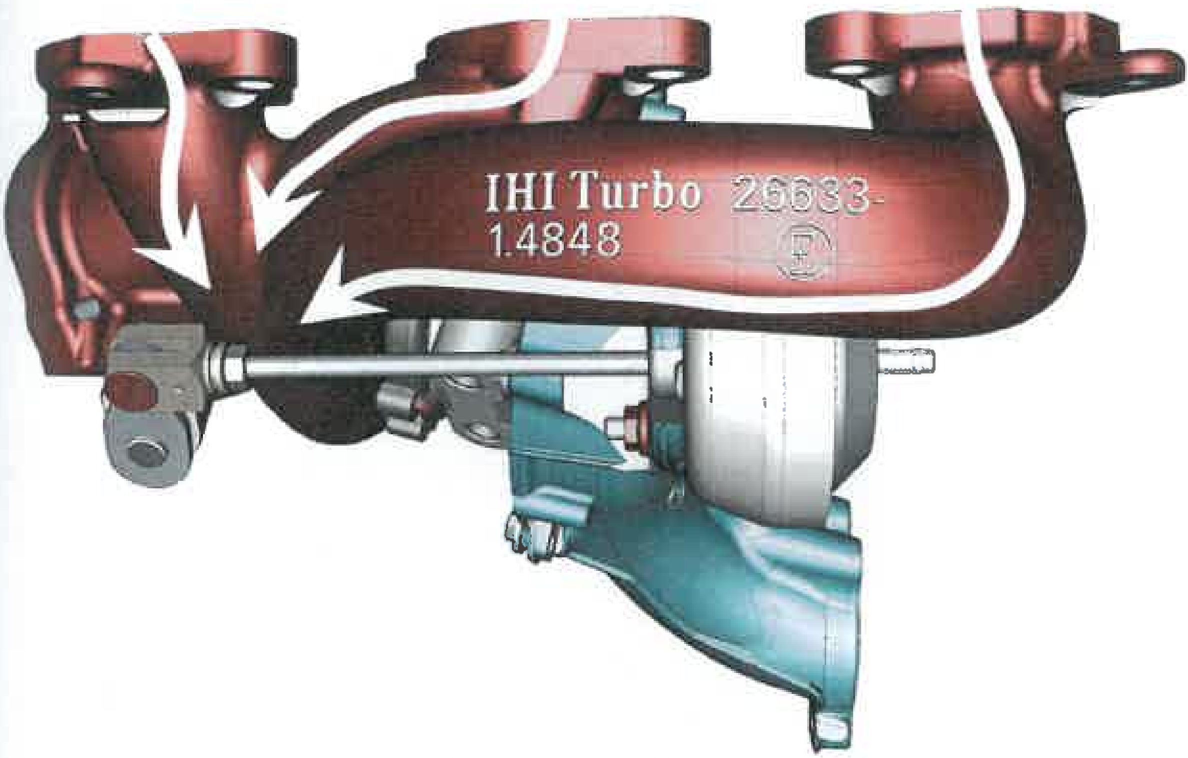
The pneumatic actuator has an internal reaction spring (m) that lets the waste gate valve open when the vacuum in the actuator diminishes.




The graph shows the characteristic actuator movement (in mm) depending on the vacuum in the actuator (mbar).



A further feature of the two turbochargers is the direct connection between each cylinder's exhaust and the turbine turning. In engines with low specific power, the cylinder exhausts collect in a single volume which is in turn connected to the turbine entrance. This last solution is defined as "supercharging at constant pressure". The gases entering the same volume are subjected to a little expansion, reducing the pressure impulses that characterise them, allowing the turbine to work in more stationary conditions even at lower pressure levels. With this system, turbine efficiency is favoured at the expense of pure performance, and obviously it is the system adopted in road use. When each cylinder's exhaust is sent directly to the turbine, the supercharging is the "pressure impulse" type. This way the pressure impulses make the turbine work in improved stationary conditions but at the same time with higher pressure levels. Supercharging to pressure impulses is typical of racing cars where pure performance represents the more important parameter.




The exhaust collector is a single part with the turbine. It is made of steel. The maximum temperature of the gas in it is 980°C.

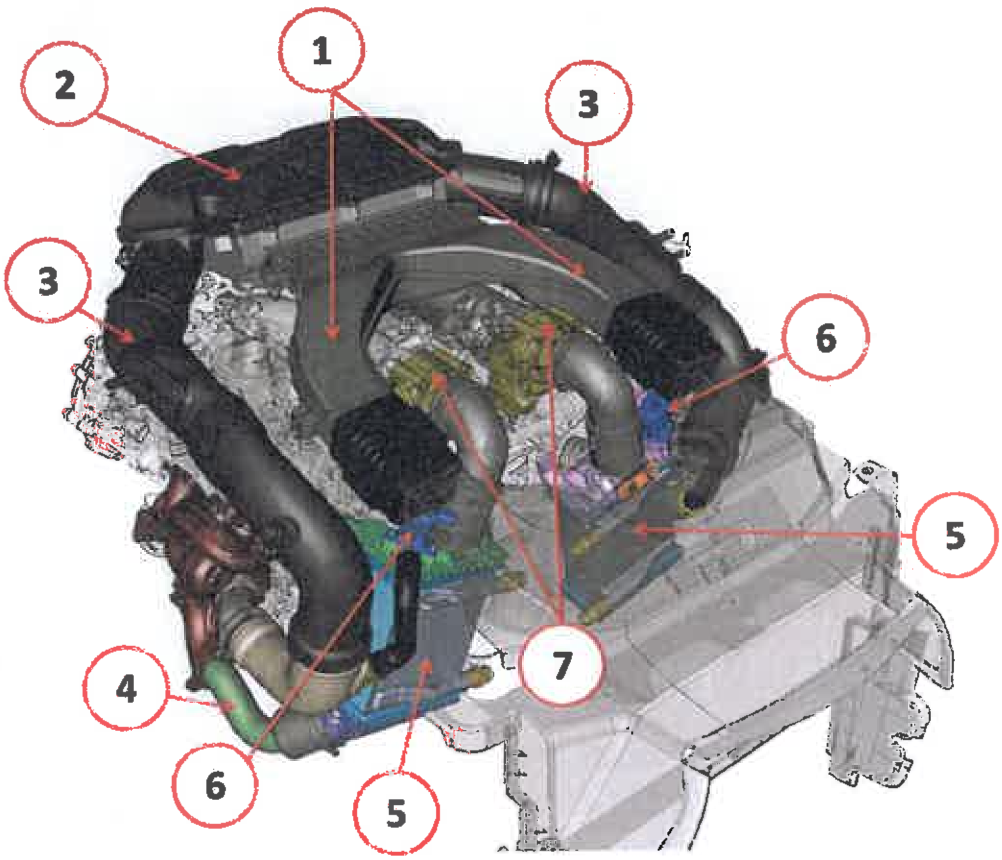
## ENGINE SYSTEMS.

In this chapter the technical characteristics of engine systems are described. Specifically:

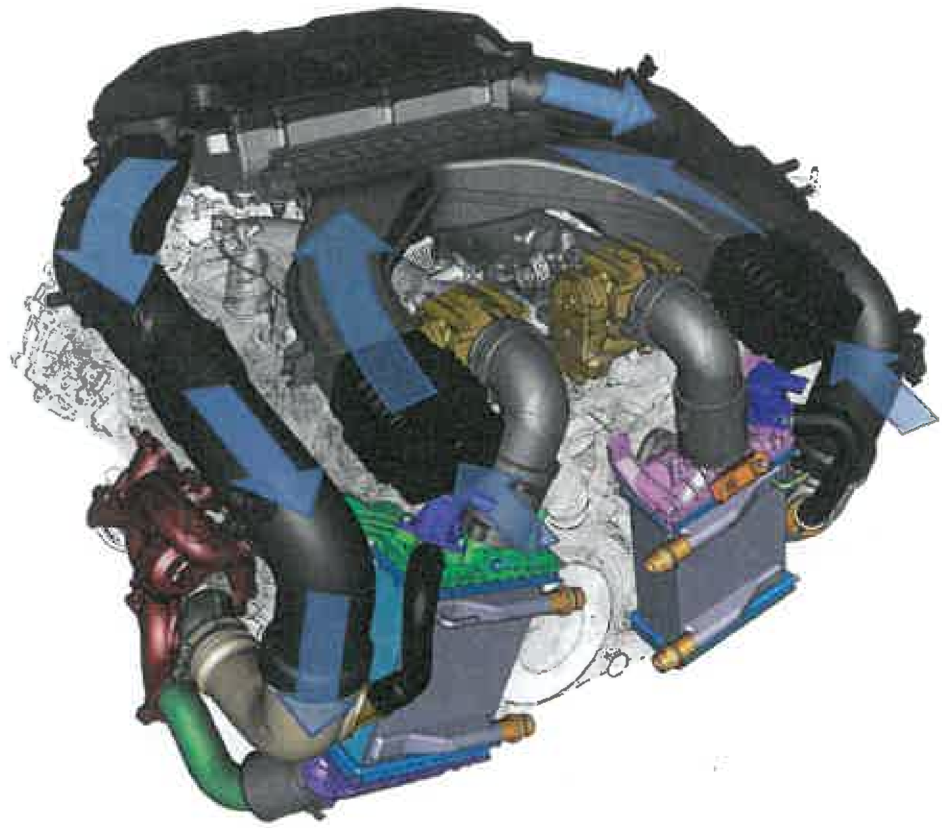
- Air supply to engine system.
- Fuel supply system.
- Petrol vapour recirculation system.
- Oil vapour recirculation system (blow-by).
- Cooling system.
- Lubrication system.
- Exhaust system.
- Vacuum system.

**Air delivery system.**

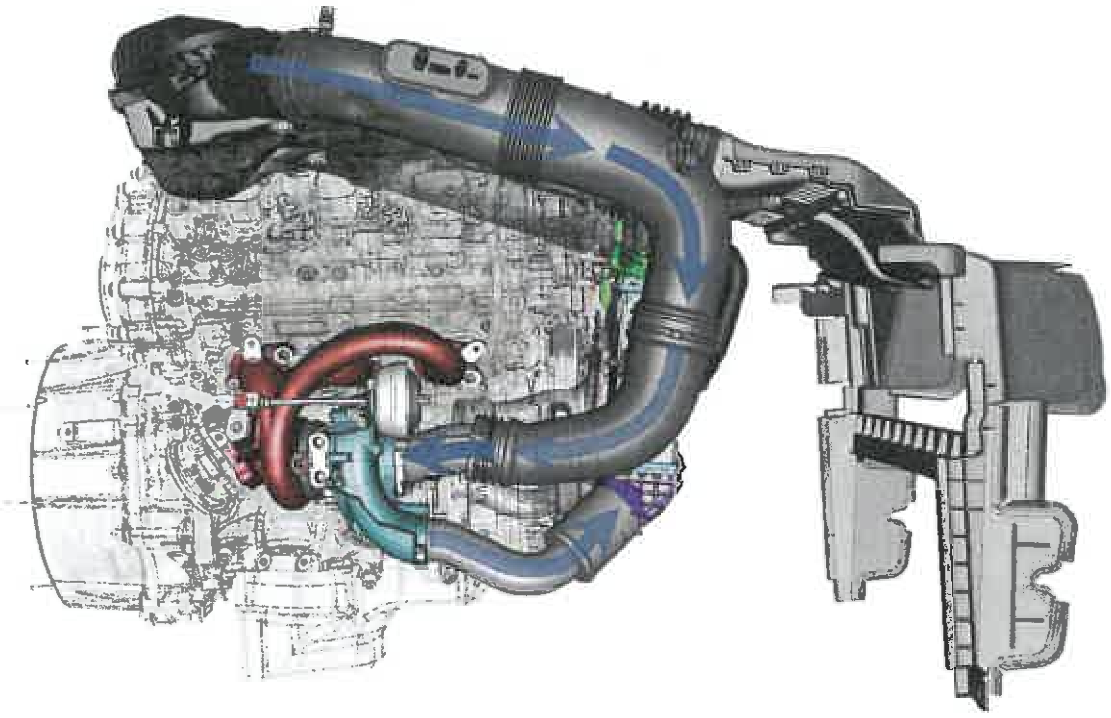
The air inlet system consists of the following components:



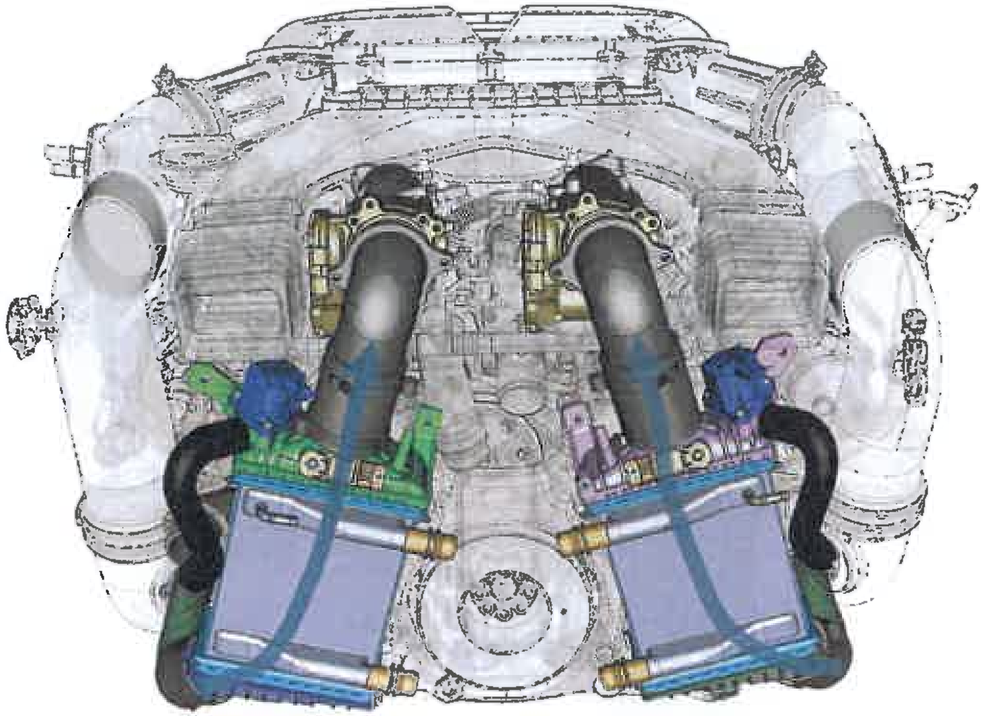

Key:
1 - Inlet sleeve for "dirty" air
2 – Air filter.
3 – Turbocharger inlet "clean" air sleeve.
4 – Sleeve for air delivery to turbocharger.
5 – Intercooler.
6 – Dump solenoid valve.
7 – Throttle body.



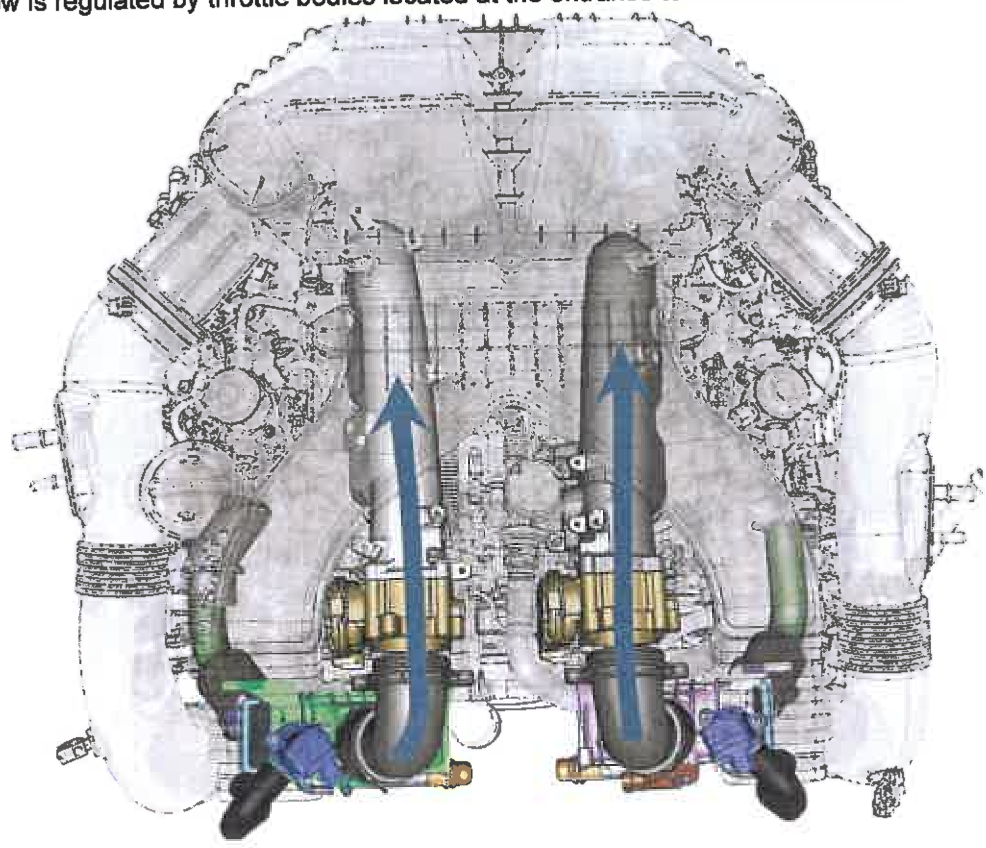
The air taken from the engine is carried towards the air filter located underneath the engine cover. At the filter's outlet, the air goes in two directions to supply the two banks. The air enters into the inlet to the twin turbo compressors via the inlet sleeve. The compressors squeeze the air and send it under higher pressure to the intercooler via the appropriate sleeves.



The intercoolers are water cooled: the heat is removed from the air when entering the intercooler by lower temperature water that circulates in the intercooler through a specific system.

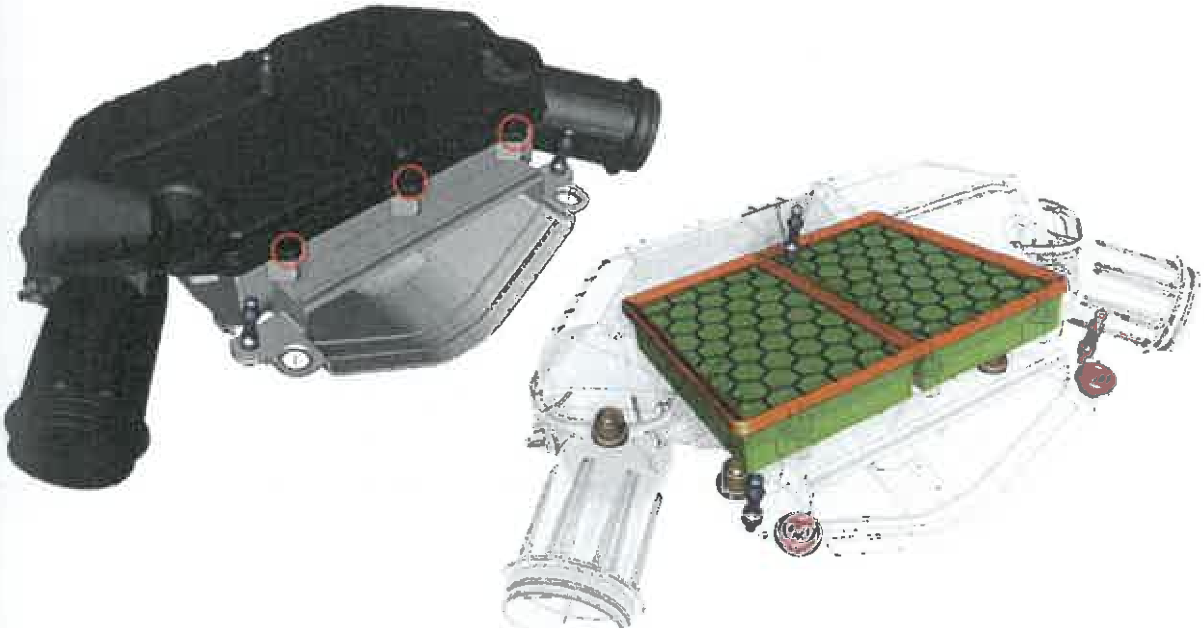


The air, appropriately cooled by the intercoolers, enters the inlet collector inlet via the rigid sleeves. The air flow is regulated by throttle bodies located at the entrance to the inlet collectors.

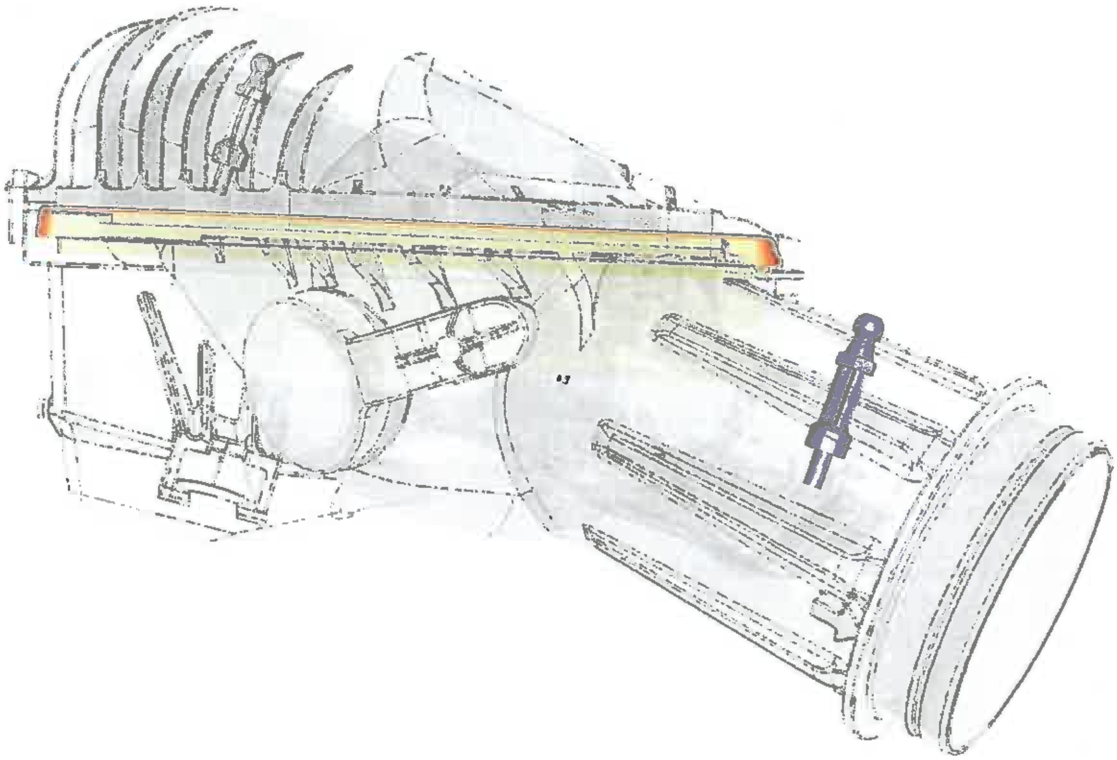


**Air filter.**

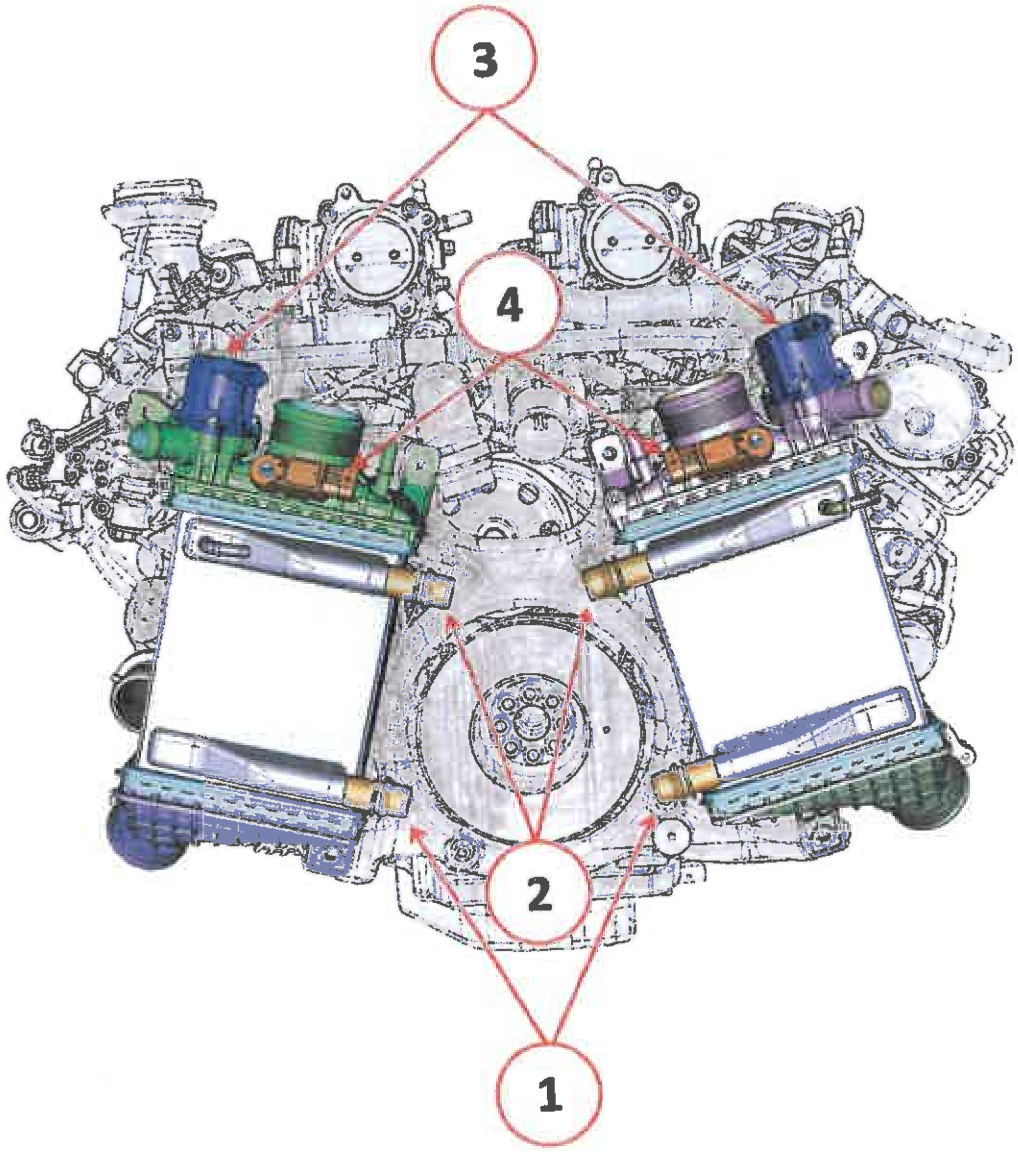
The air filter is located at the entrance to a plastic shell and closed on the upper part by a cover, also plastic.



The plastic cover is solidified by the inner shell by indentations and three screws on the front.



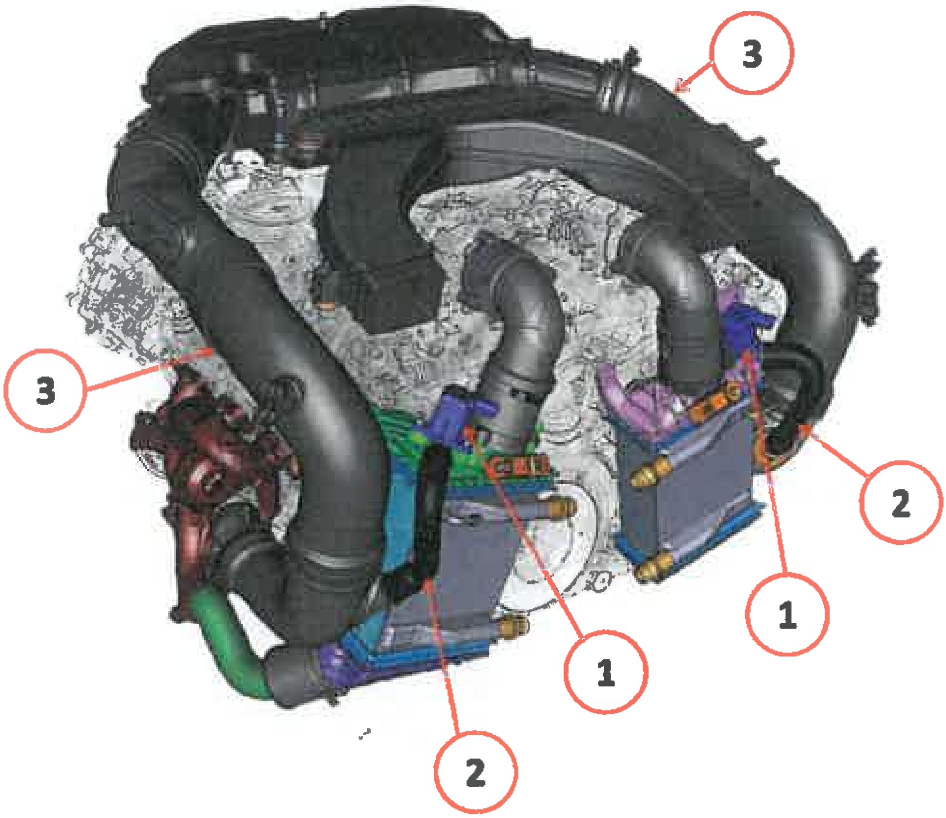
## Intercooler



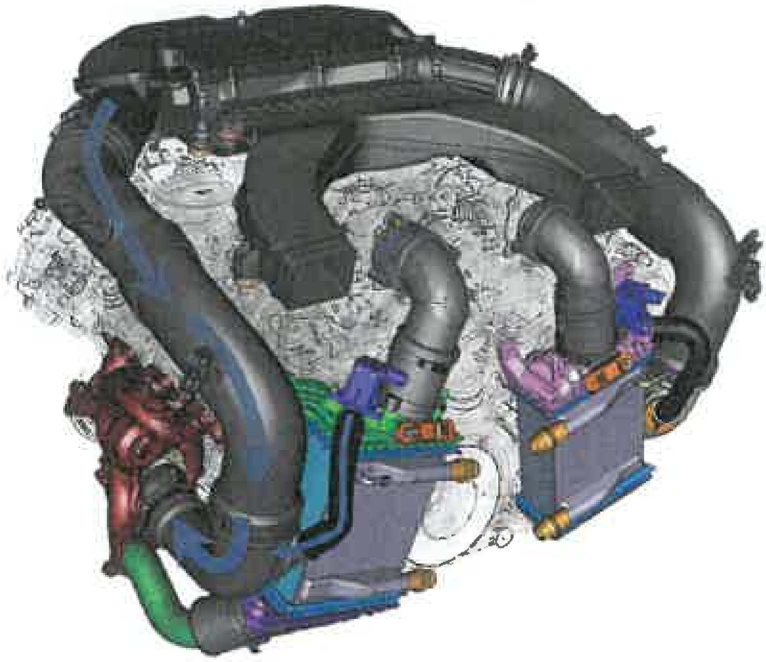

Key
1 – Water drainage pipe to cool compressed air.
2 – Water intake pipe to cool compressed air.
3 – Dump solenoid valve.
4 – Pressure and over supply sensor.

The intercoolers are water-cooled. Via a specific cooling system. On the intercooler's body there are sensors that measure the over supply pressure generated by the turbochargers and the Dum solenoid valve.

## The Dump solenoid valve recycling circuit.




Key:
1 – Dump solenoid valve.
2 – Air recirculation pipe.
3 – Sleeve for air entry to turbocharger.



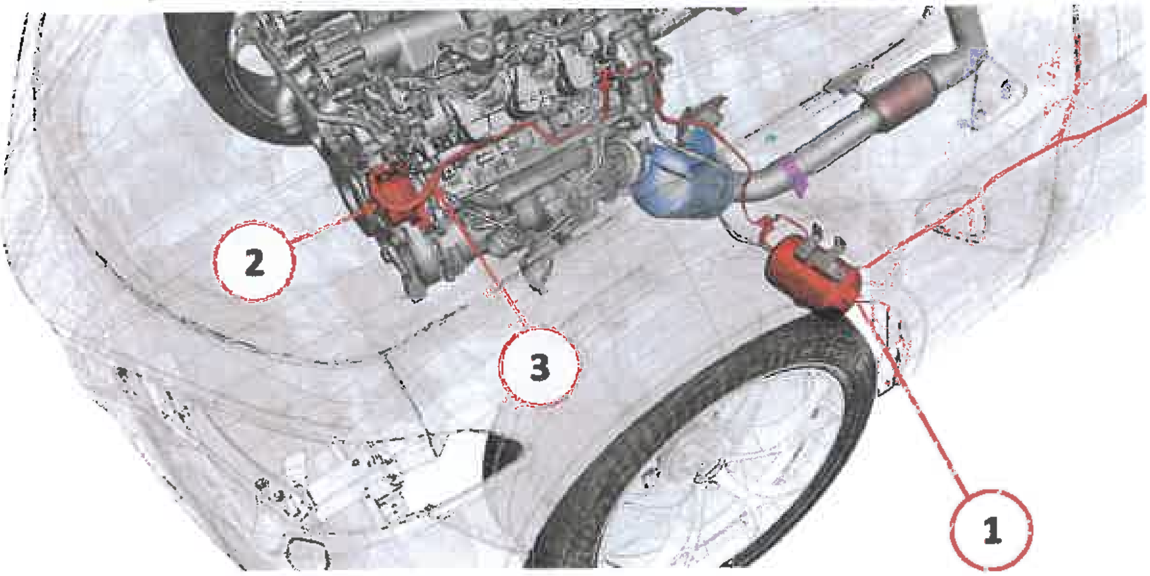
The Dump solenoid valves are commanded by ECM control modules and engine management. In cut-off conditions, the ECMs command the solenoid valves, allowing recirculating of air pushed by the turbocharger. The air recirculating pipes (2) connect the intercooler's recirculation with an air intake sleeve in the turbocharger.

**Vacuum system.**

The vacuum system has to create a special reservoir inside, an environment in constant depression.
The vacuum reservoir has to guarantee depression for the following components to function:

- The turbochargers' Waste-gate tyre actuators.
- Exhaust by-pass tyre actuators.

The system consists of the following components:



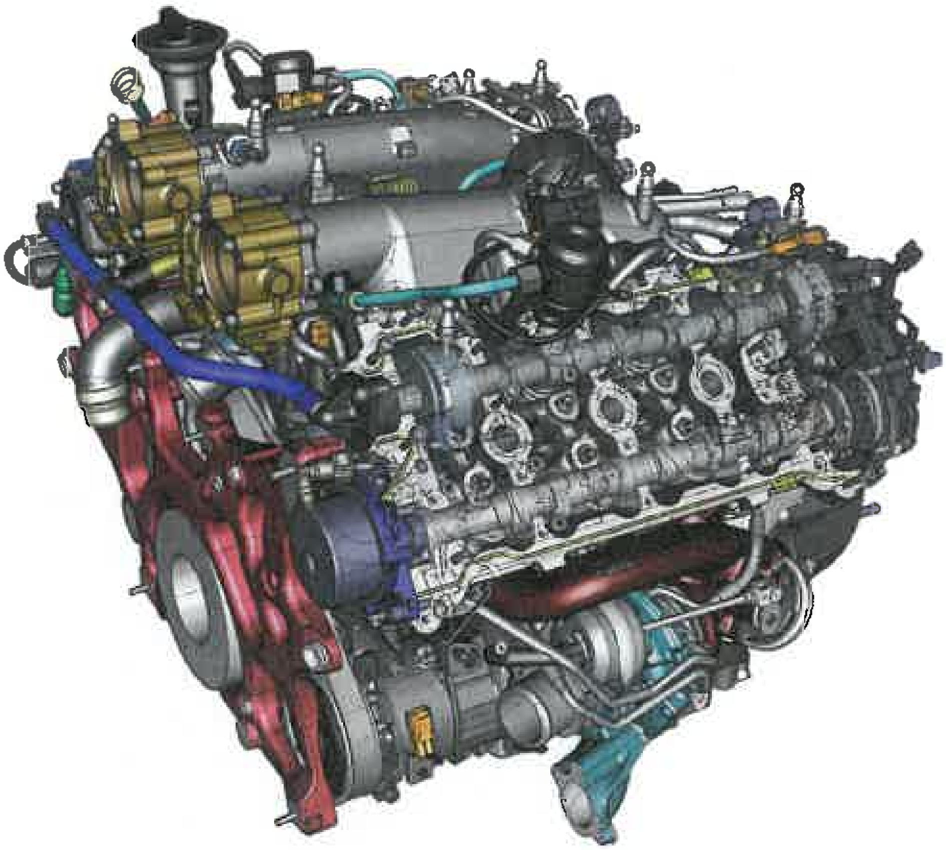

Key:
1 – Vacuum reservoir
2 – Vacuum pump connected to the exhaust camshaft on the left bank.
3 – Vacuum pump reservoir connecting pipe.

**Accumulation reservoir.**

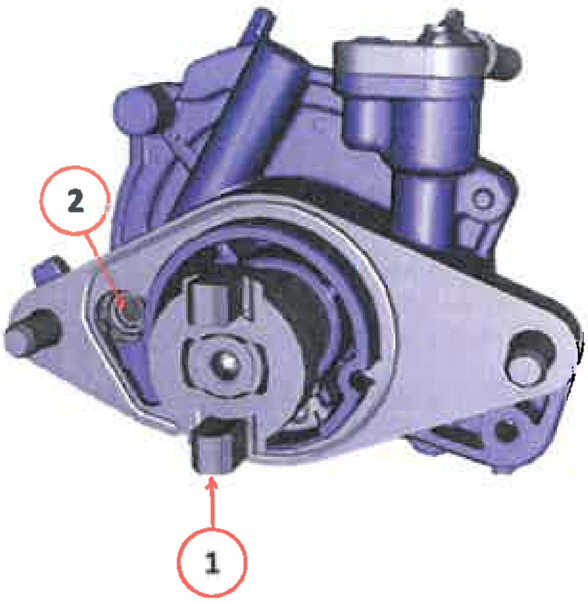

Key:
1 – Pipe connection fitting to the vacuum pump.
2 – Pipe connection fitting to the Waste-gate solenoid valve.

The vacuum's accumulation reservoir is plastic and has an internal volume of about 1280 $cm^3$. Its thickness is 2.5 mm. Its weight is 280g. Before installing it in the vehicle, it is subjected to holding tests with 500 mbar depression. It is placed under the left front wheel arch.

**Vacuum pump.**



The vacuum pump moved by the exhaust camshaft on the left bank. Connection is ensured by an Oldham type joint.

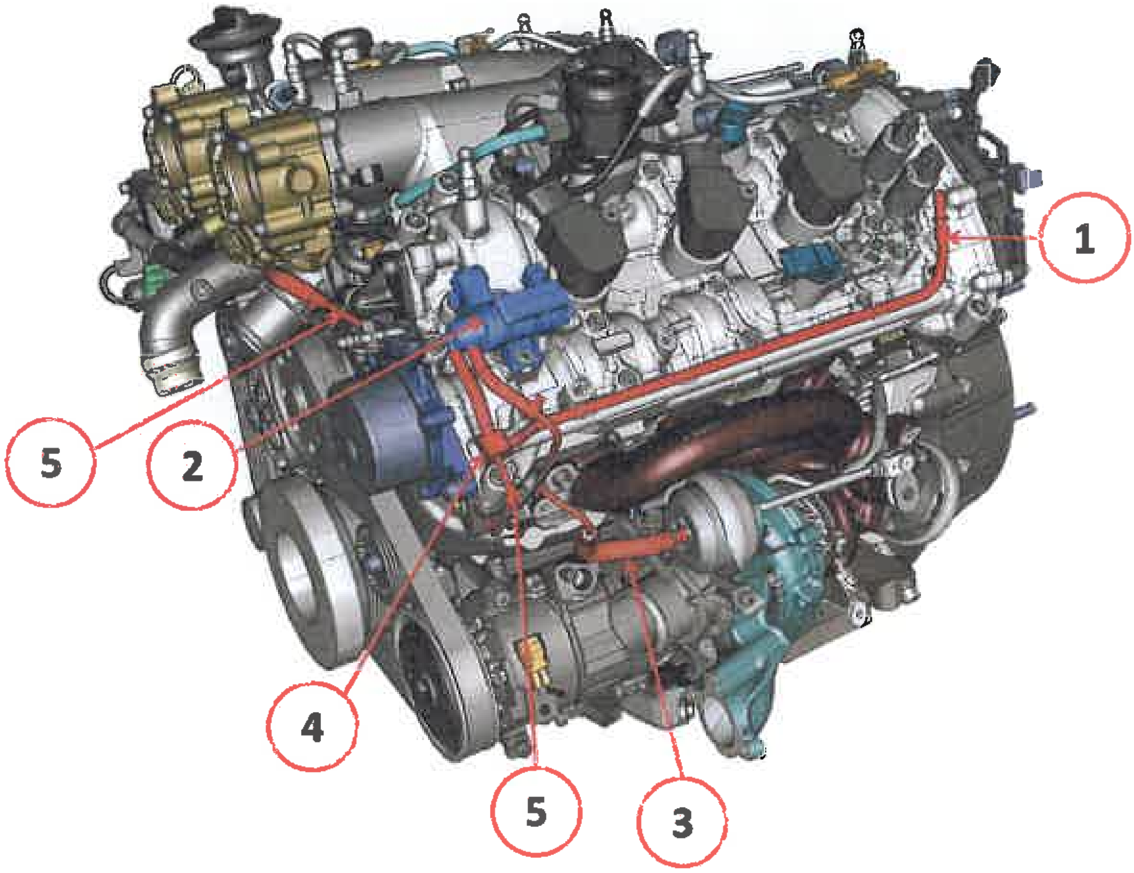



Key:
1 - Link connection.
2 – The oil entry hole for lubrication with filter.

The vacuum pump creates a depression of about 300 mbar (absolute pressure 700 mbar).

**The Waste-gate actuator control system.**

The waste-gate actuators receive the necessary depression to move the vacuum system's waste-gate door to precisely between the two solenoid valves (one for each bank). The solenoid valves are connected to the vacuum system via two inlets (exactly one inlet per exit).



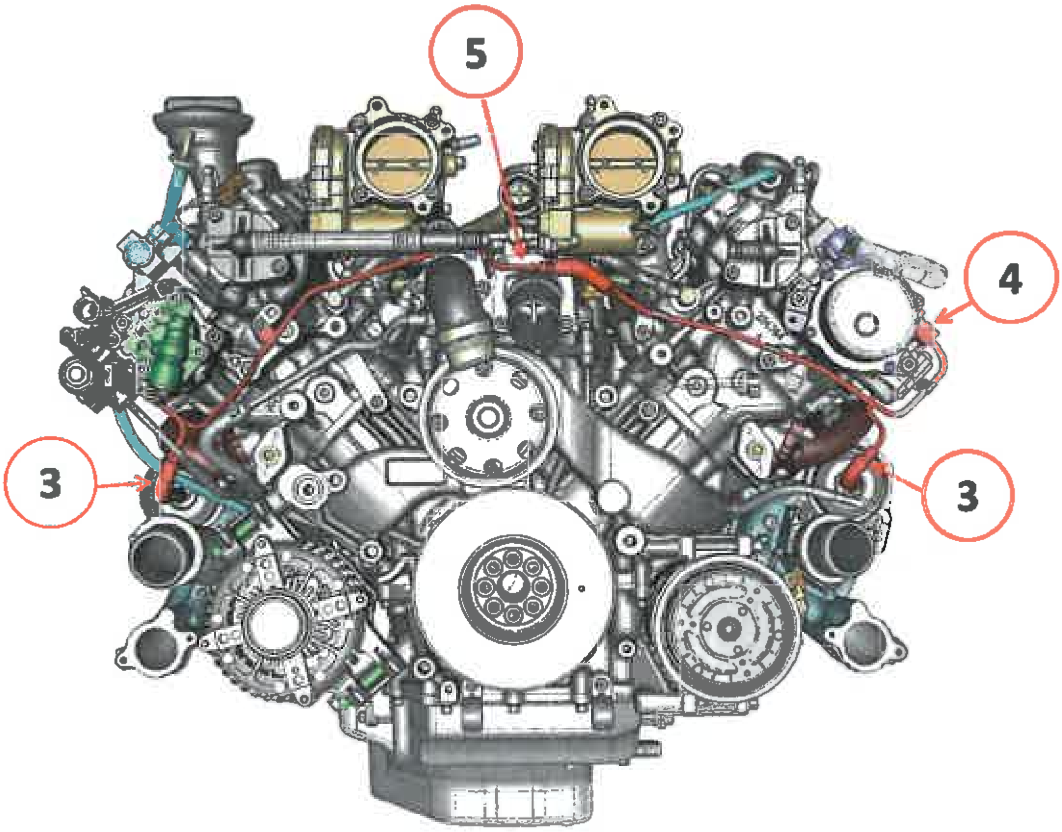

Key:
1 – Vacuum reservoir with connection pipe.
2 – Left bank solenoid valve waste-gate.
3 – Solenoid valve connection pipe – waste-gate actuator.
4 – T joint.
5 – Vacuum reservoir connection pipe - right bank solenoid valve.

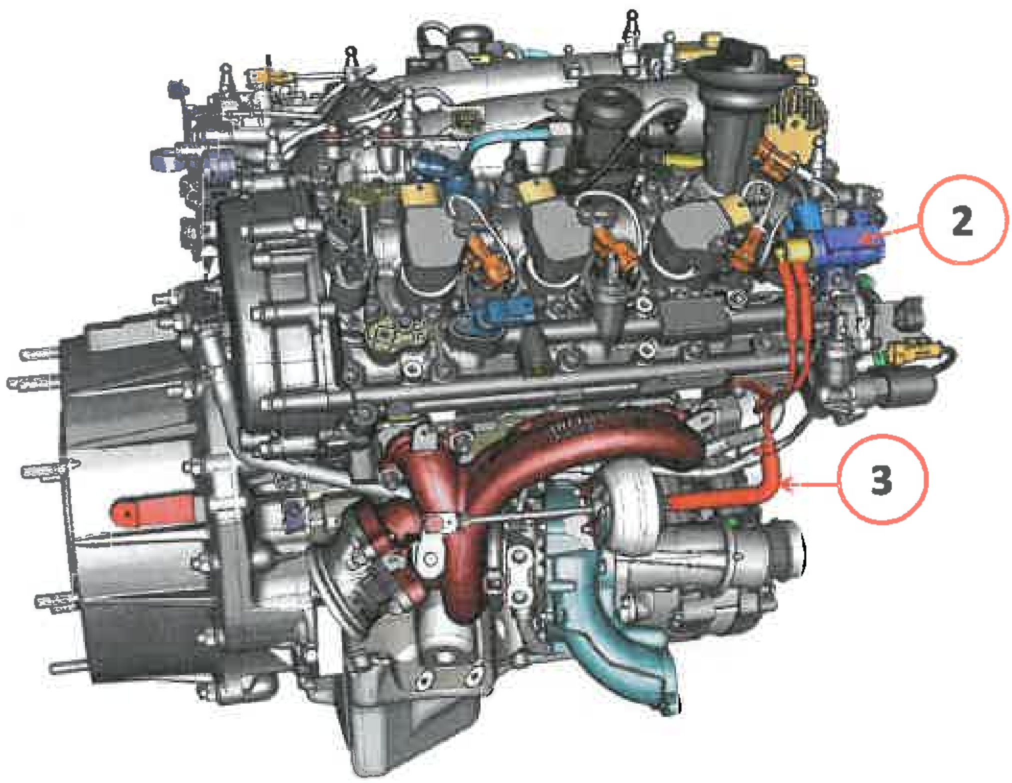
At the minimum motor in the connection pipe (3) a depression is sent by the solenoid valve to keep the waste-gate door closed (normally it is open). The depression value that lets the actuator to completely close the waste-gate door is around 700 mbar (absolute pressure).

The connection pipe (1) to the vacuum reservoir is sent via a T joint (4) in two connecting pipes, one of which is connected to the left bank solenoid valve (2) and the other to the right bank solenoid valve (5).

The solenoid valve receives the vacuum from the pipe coming from the T joint, to then send it to the left waste-gate actuator through the pipe (3).

The same connection logic is repeated for the right bank solenoid valve and waste-gate actuator (as shown in the following images).

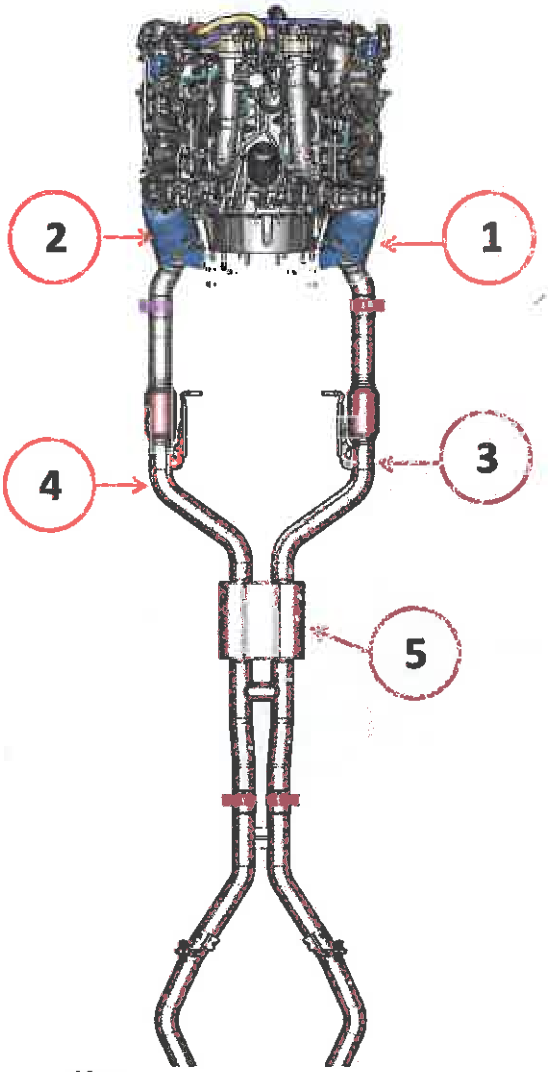



Key:
2 – Right bank solenoid valve waste-gate.
3 – Solenoid valve – wastegate actuator connection pipe.
4 – T joint.
5 – Vacuum reservoir connection pipe - right bank solenoid valve.

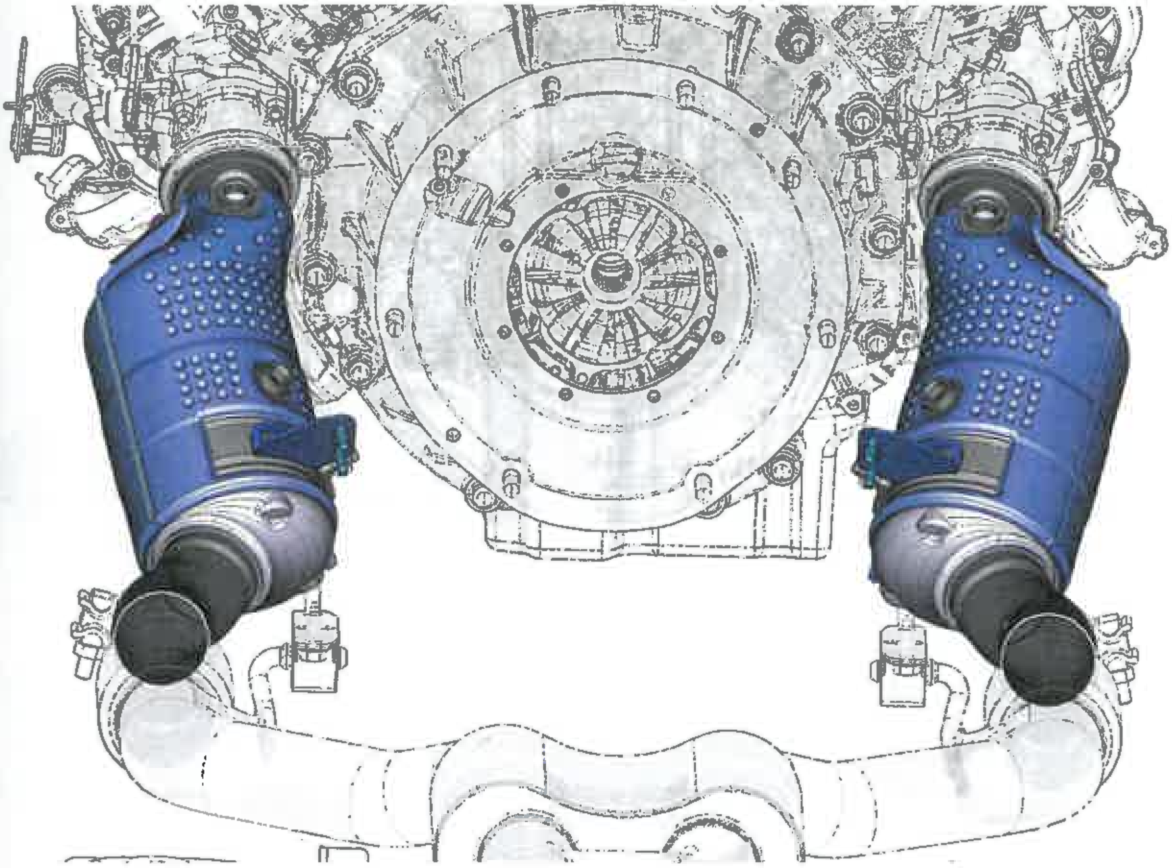
**Exhaust system.**

The exhaust system consists of two exhaust lines, each one pertaining to its respective engine bank.

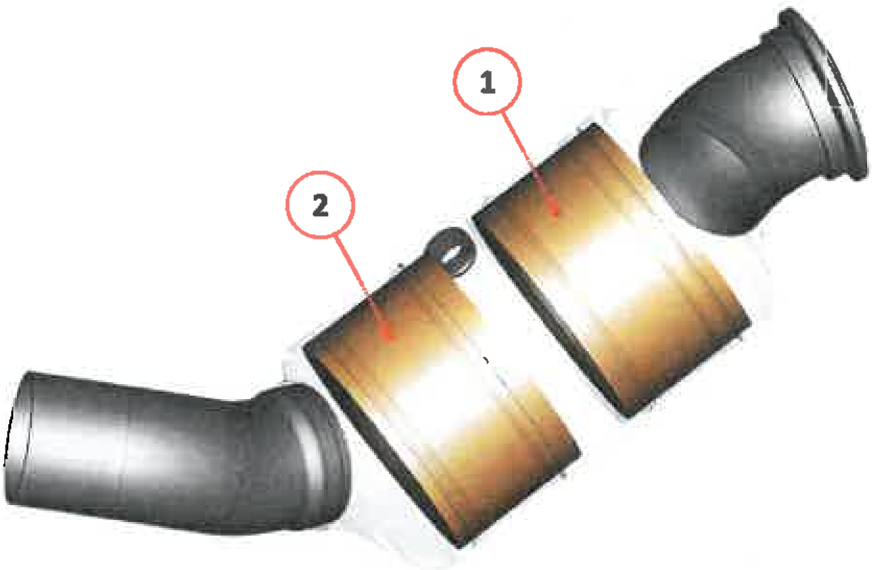



Key:
1 – Right bank catalytic converter.
2 – Left bank catalytic converter.
3 - Right drainage pipe
4 - Left drainage pipe
5 – Pre-silencer
6 - Right by-pass exhaust pipe
7 - Left by-pass exhaust pipe.
8 – Silencer.

**Catalysts.**



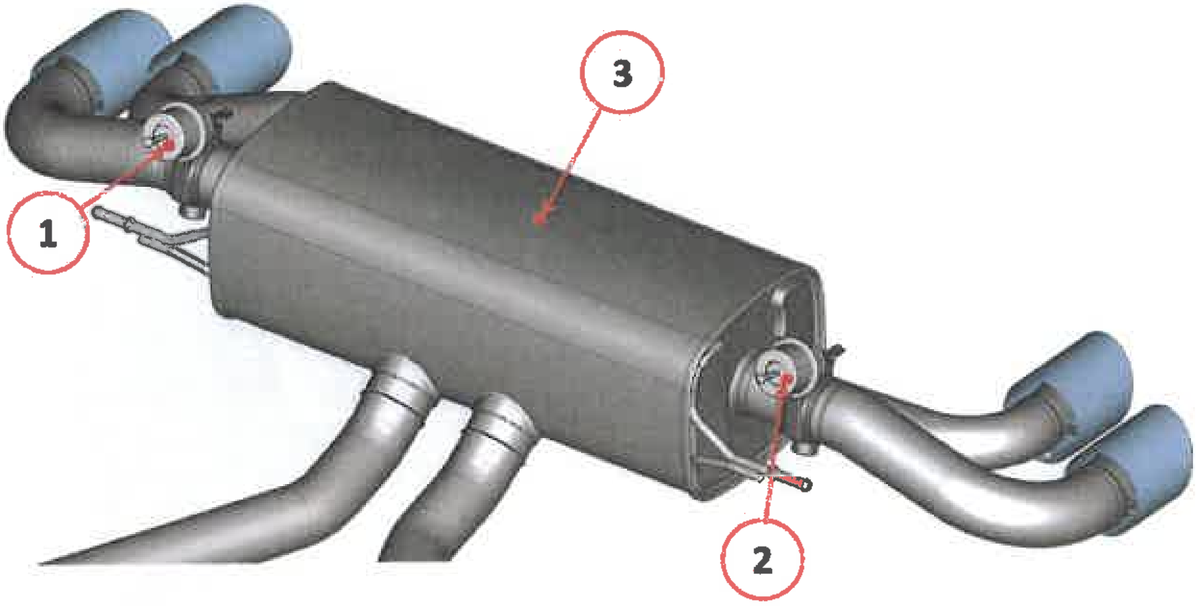
The catalysts used to combat polluting agents are monolithic beehive type.




Key:
1 – Pre-catalytic converter
2 – Catalytic converter.

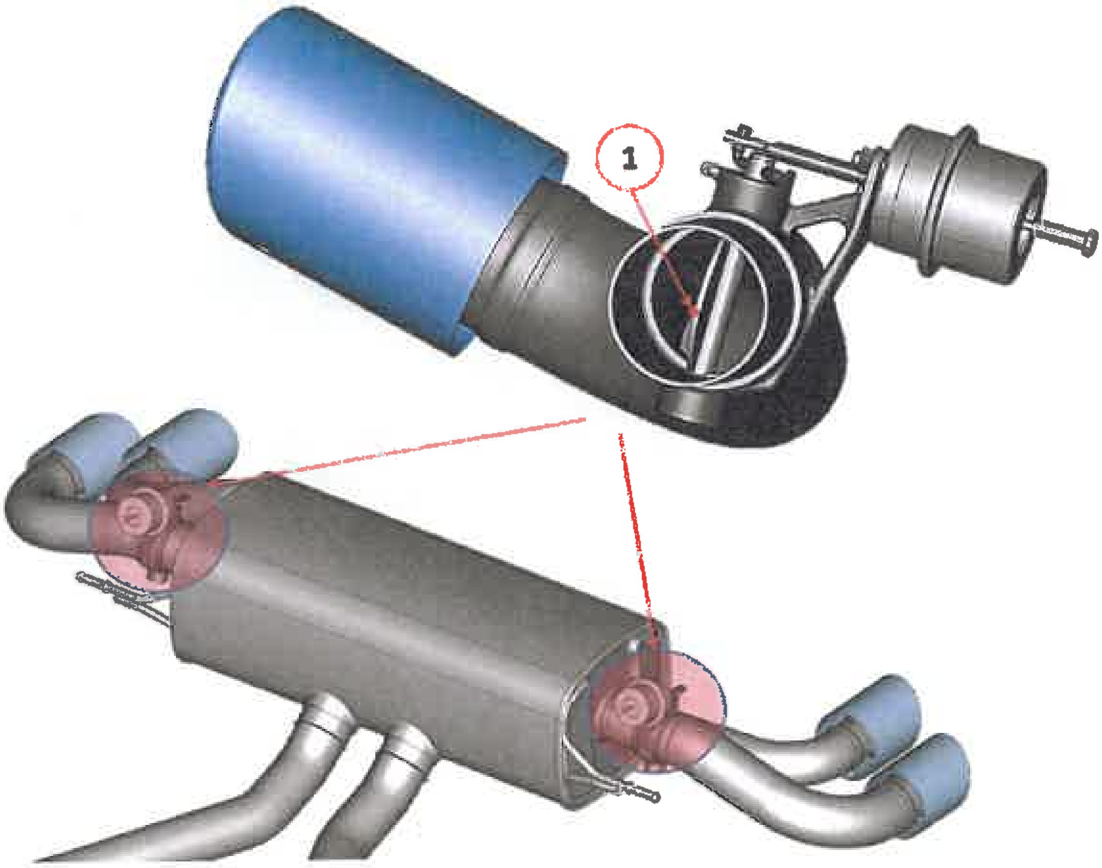
The pre-catalytic converter and catalytic converter are encased in a single metal shell. The downstream oxygen sensor is located after the pre-catalytic converter.

**Exhaust by-pass system.**

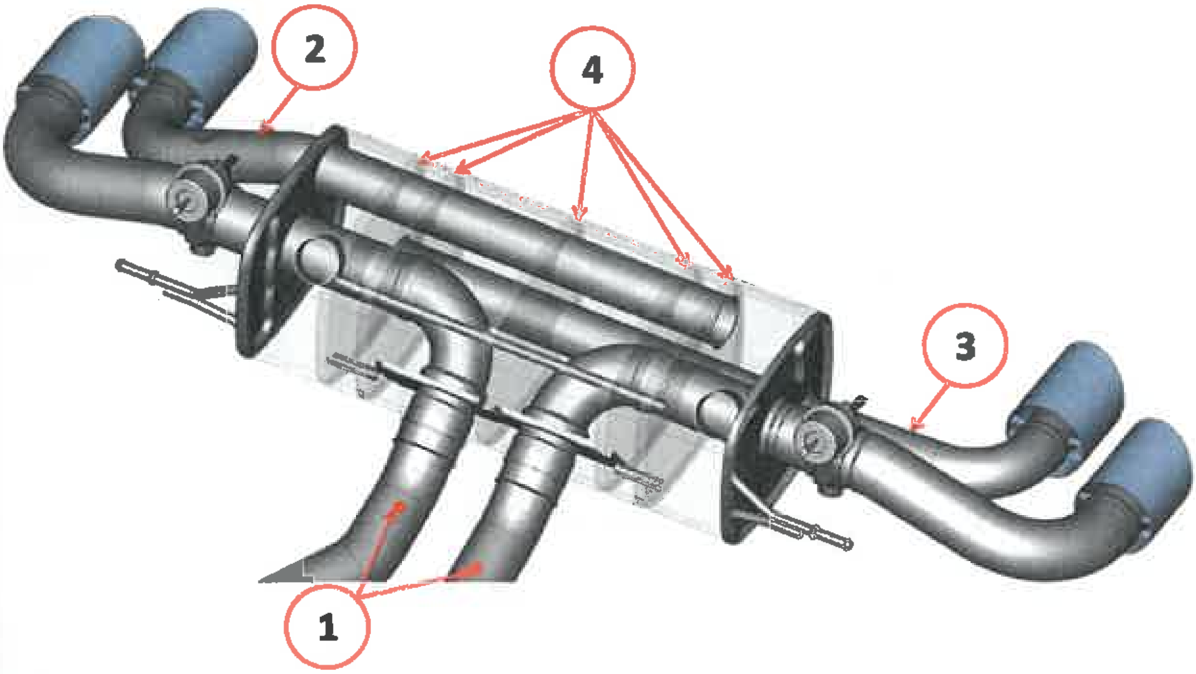



Key:
1 – Right pneumatic actuator
2 – Left pneumatic actuator
3 – Silencer.

In the end part of the exhaust, there is a by-pass system that lets the exhaust gas be sent directly to the outlet, reducing the effect of the silencer.



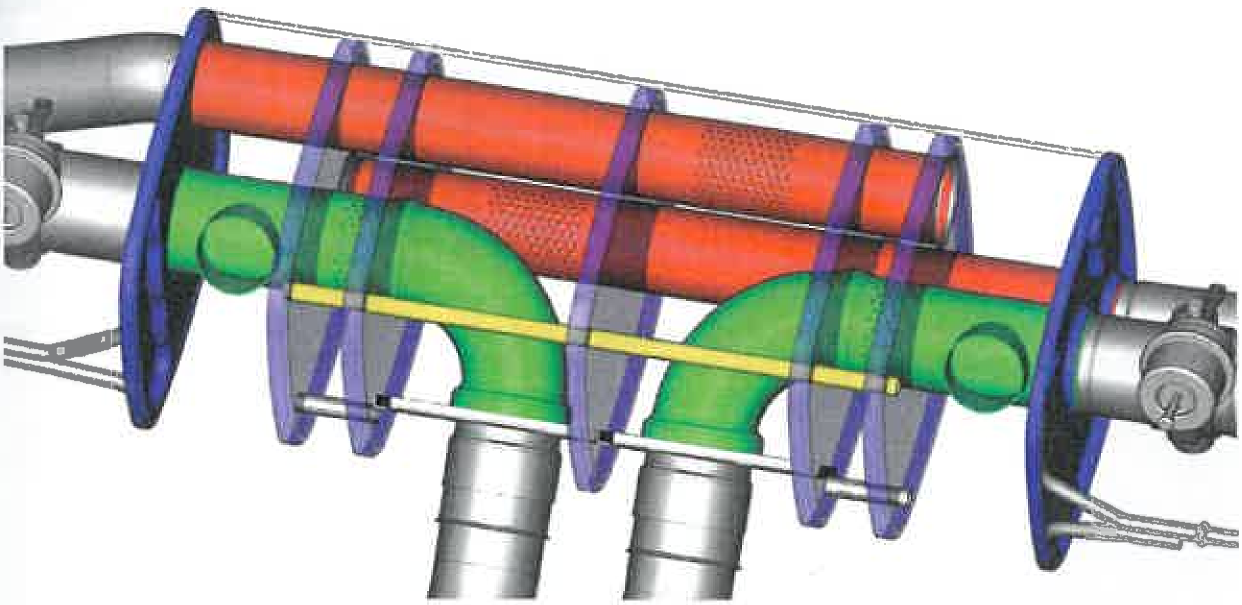

Key:
1 – By-pass throttle valve.



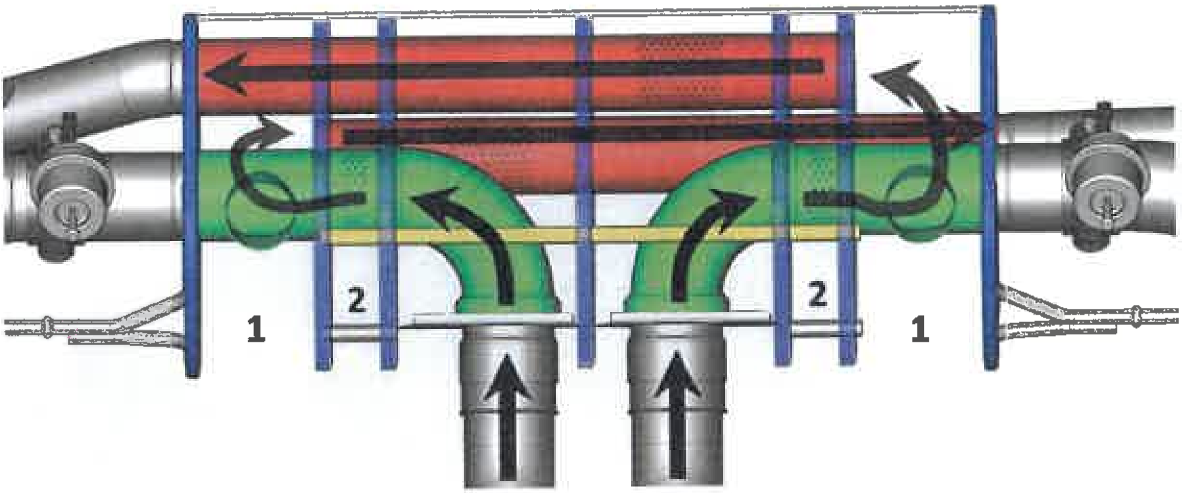

Key:
1 – Exhaust pipe coming from the engine.
2 – Right exhaust pipe coming out of the silencer.
3 – Left exhaust pipe coming out of the silencer.
4 – Inner bulkhead delimiting the silencer chambers.

The exhaust pipes coming from the engine enter the silencer, they cross is and join the exit pipes on which the by-pass throttle valves are placed, actioned by the tyre actuators. In normal conditions the by-pass throttle valves are closed.
At the silencer's exit, there are two other exhaust pipes (one for each side) that "hide" inside the silencer itself. There is no by-pass system on these last.

The picture shows that the silencer is sub.divided internally into 6 chambers delimited by 7 bulkheads.

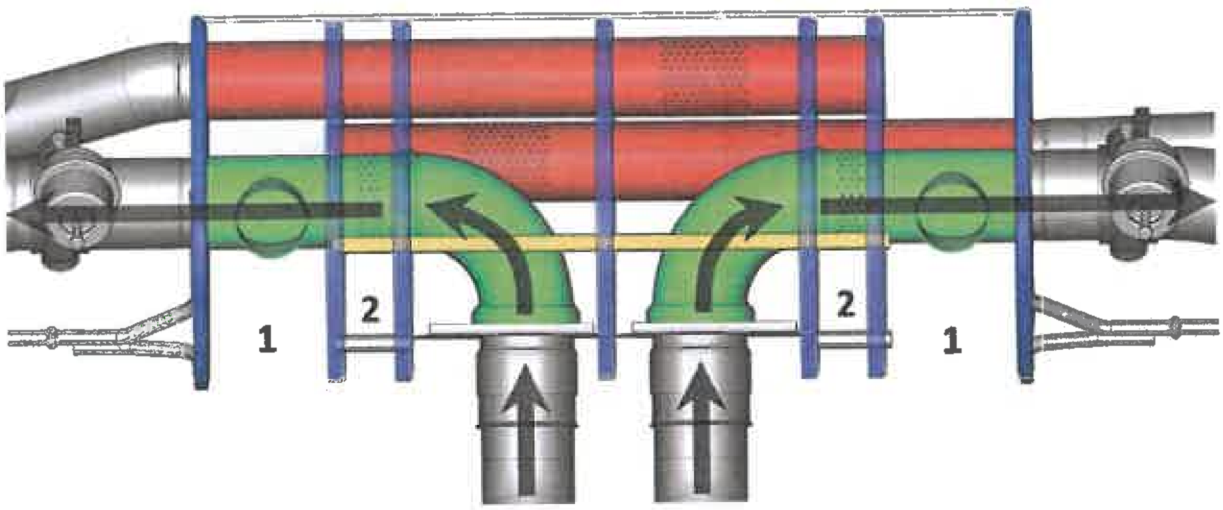


When the throttle valves are closed, the exhaust gases follow the flow shown in the picture.




The gases from the engine bump against the throttle valves and, unable to flow towards the exit, find an outlet through the hole in the last part of the pipe connected to the side chamber (1) and through the small holes in the part of the preceding chamber pipe (2). The exhaust gases coming from the next to last part's small holes expand inside the chamber (2) dampening the pressure impulses. The gases that fill the chamber (1), recalled by the lower pressure on the outside, come out through the exhaust pipe (in red), which carry them from inside the silencer to the outside. This way the pressure impulses are dampened in chambers (1) and (2) at the same time.

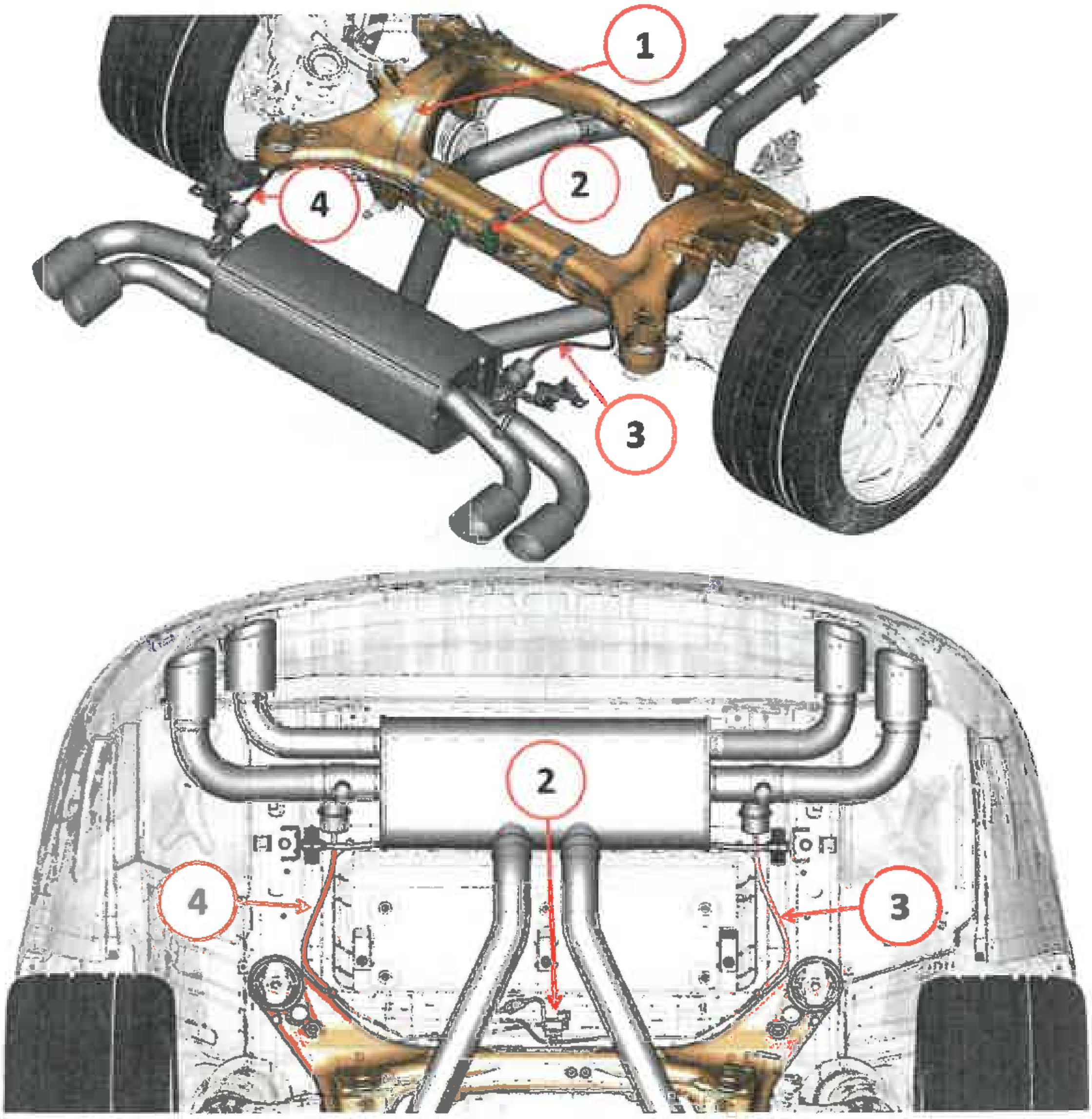
When the throttle valves are open, the exhaust gases follow the flow shown in the picture below:




With the throttle valves open, the exhaust gases from the engine find no barrier along the way and can flow towards the outside without having to expand inside the silencer chambers (1) and (2). It follows that the undampened pressure impulses generate more noise.

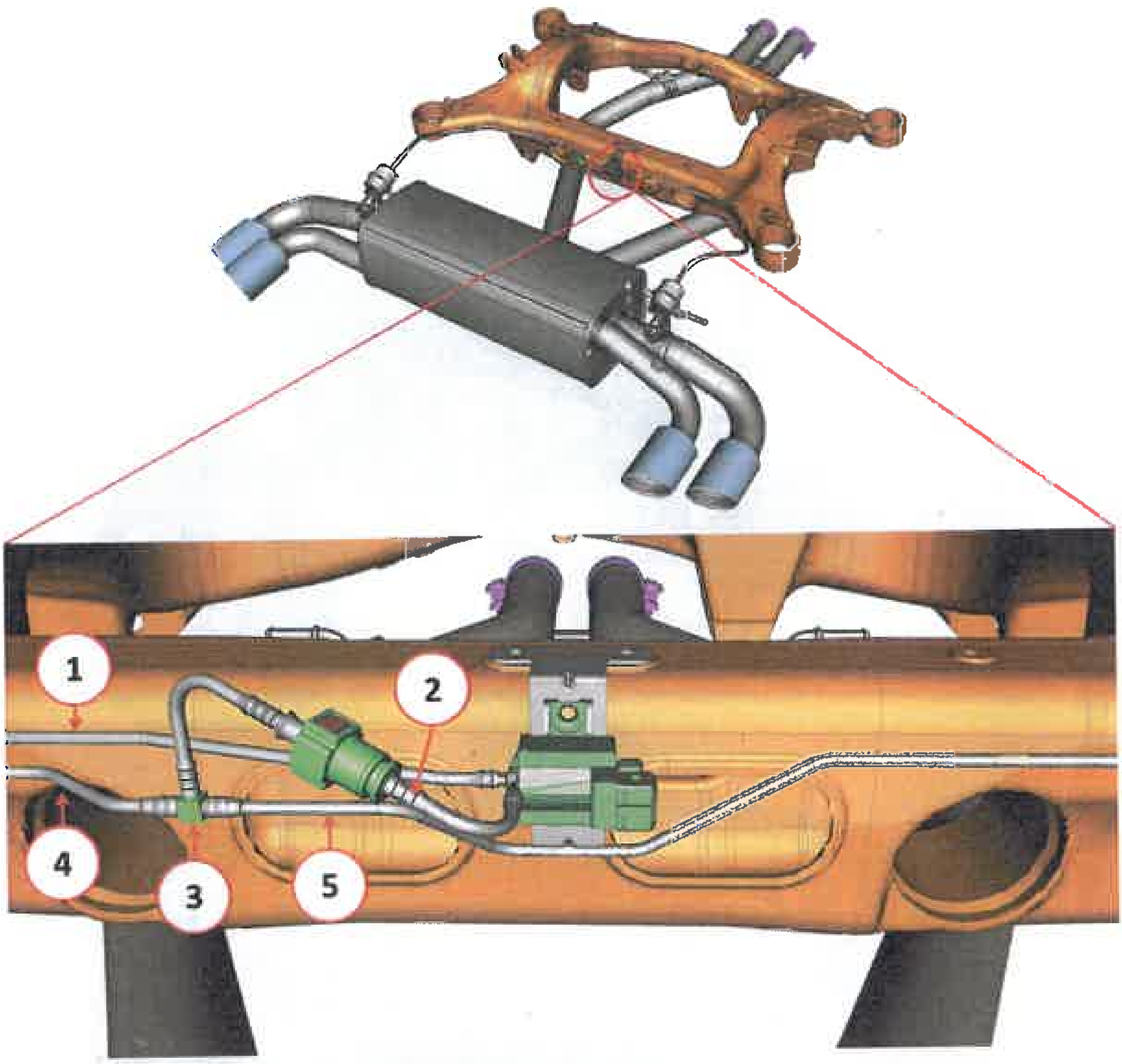
The by-pass valve actuators have to receive depression when the ECM (Slave) decides to close them. Normally the by-pass valves are open. To keep them closed, the ECM has to send depression to the actuators.

The pneumatic actuators receive the depression from the vacuum system. To open or close the actuator connection towards the vacuum system, the ECM uses a two-way solenoid valve.



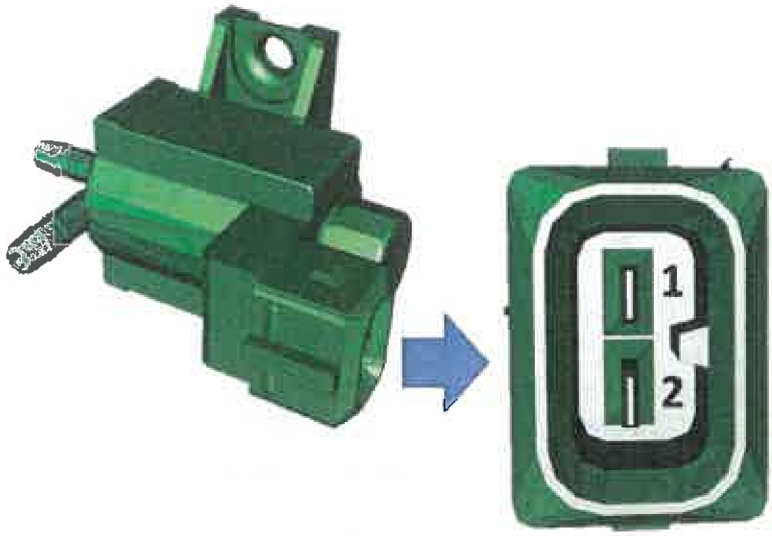

Key:
1 – Vacuum pipe coming from the vacuum/reservoir depression accumulator.
2 – By-pass solenoid valve
3 – Solenoid valve connection pipe – pneumatic actuators.

The solenoid valve is held by a support bracket which is in turn mounted on the rear suspension crossbar.

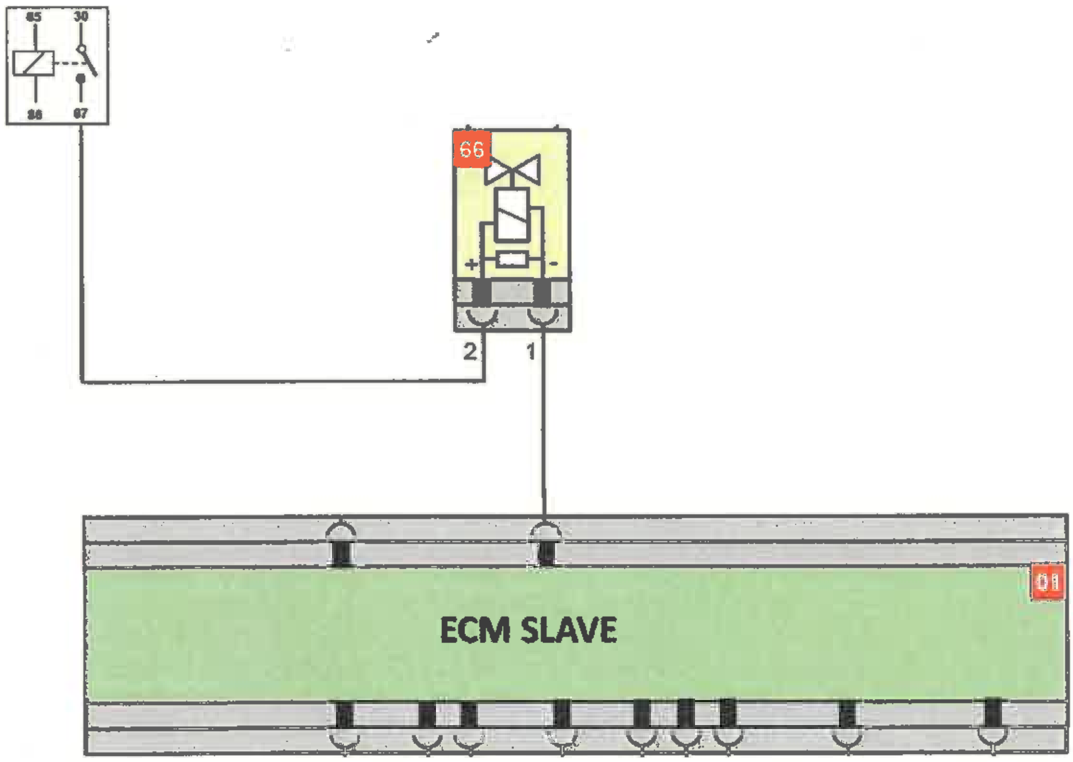


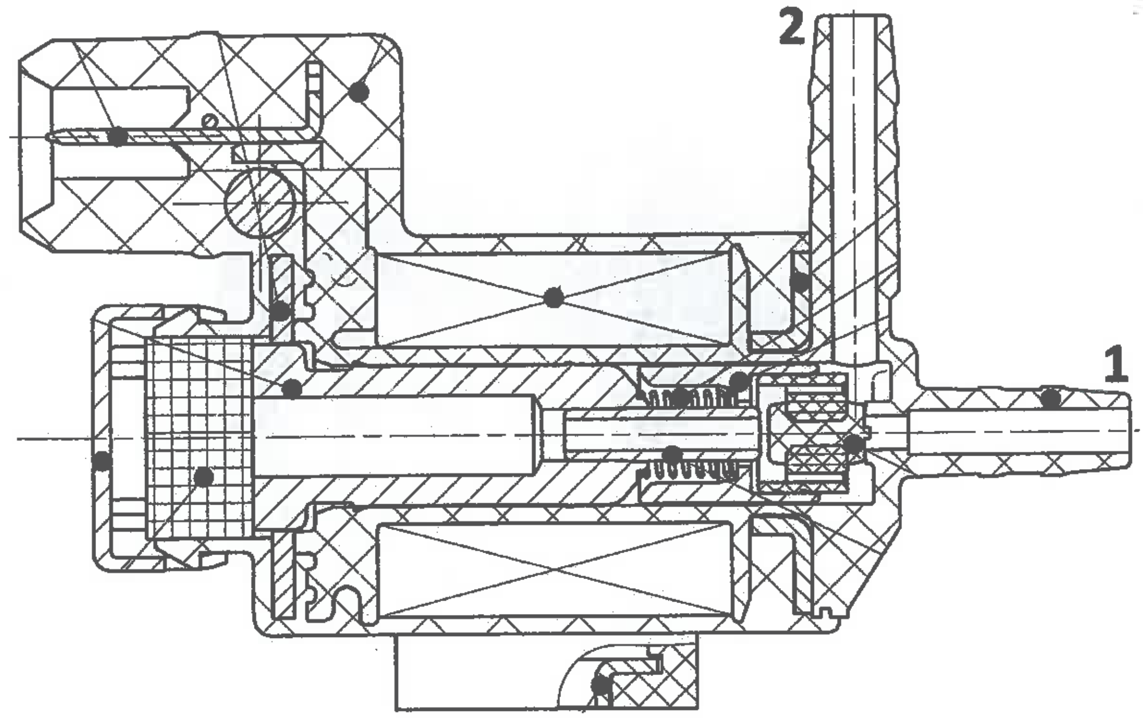

Key:
1 – Vacuum pipe coming from the vacuum/reservoir depression accumulator.
2 – Solenoid valve connection pipe – pneumatic actuators.
3 – T joint.
4 – Offshoot of pipe towards the left dynamic exhaust actuator.
5 – Offshoot of pipe towards the right dynamic exhaust actuator.

**Exhaust by-pass solenoid valve.**




Pinout
1 – Earthing order from $ECM_2$ Slave.
2 – Power supply from main relay.



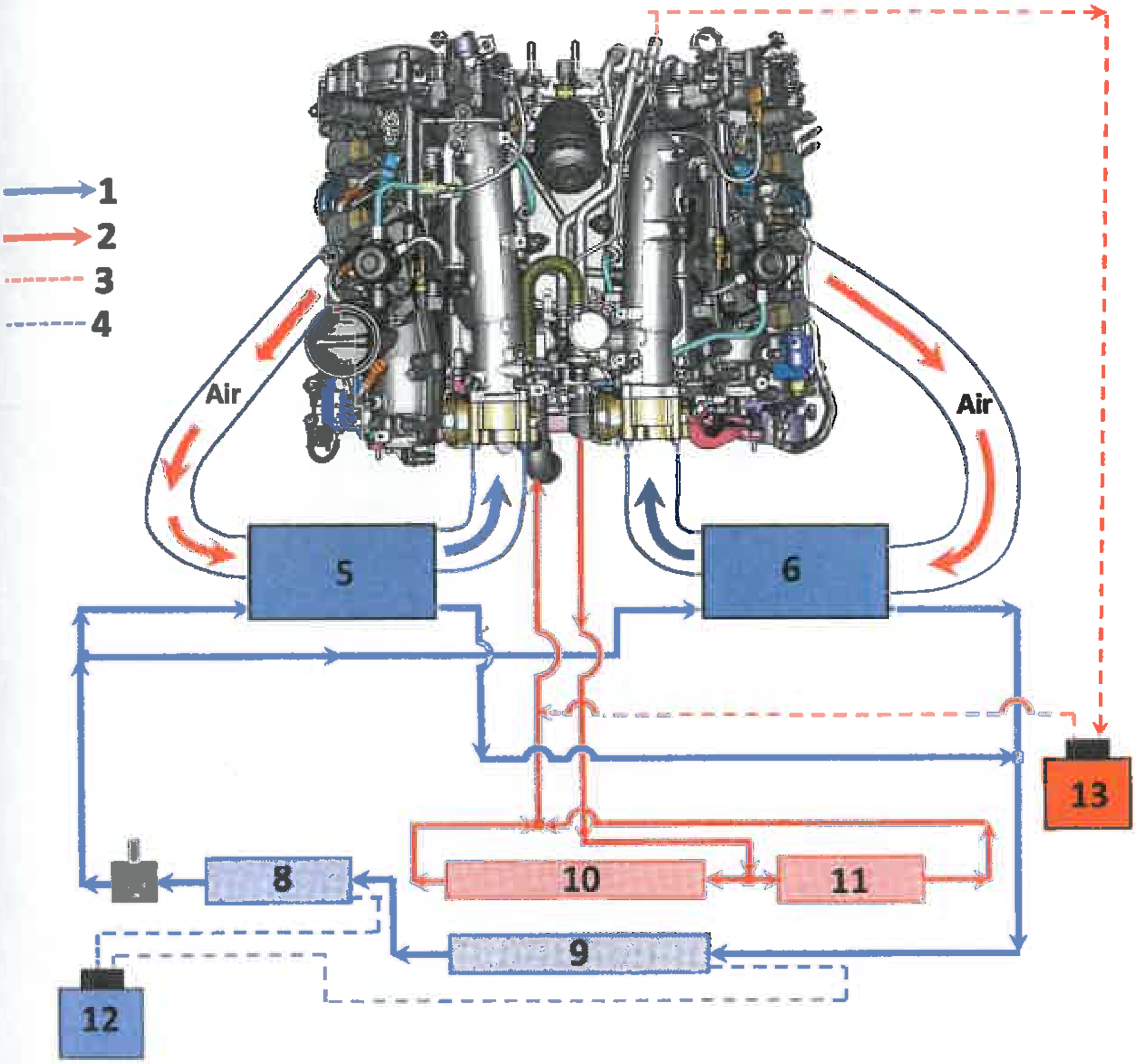



The solenoid is an ON/OFF type switch. When the solenoid valve is not ordered by the $ECM_2$ Slave to bypass the silencer, the vacuum system inlet (1) is not in communication with the outlets (2) towards the pneumatic actuators. The $ECM_2$ Slave sends a 12V order.

Instead, when the $ECM_2$ Slave orders the solenoid valve to bypass the silencer, the inlet (1) is placed in communication with the outlet (2). In this condition, the $ECM_2$ Slave sends an earthing order to the solenoid valve.

**Cooling system.**
The general engine cooling system is subdivided into two sub-systems:

- A high temperature HT cooling system
- A low temperature LT cooling system.



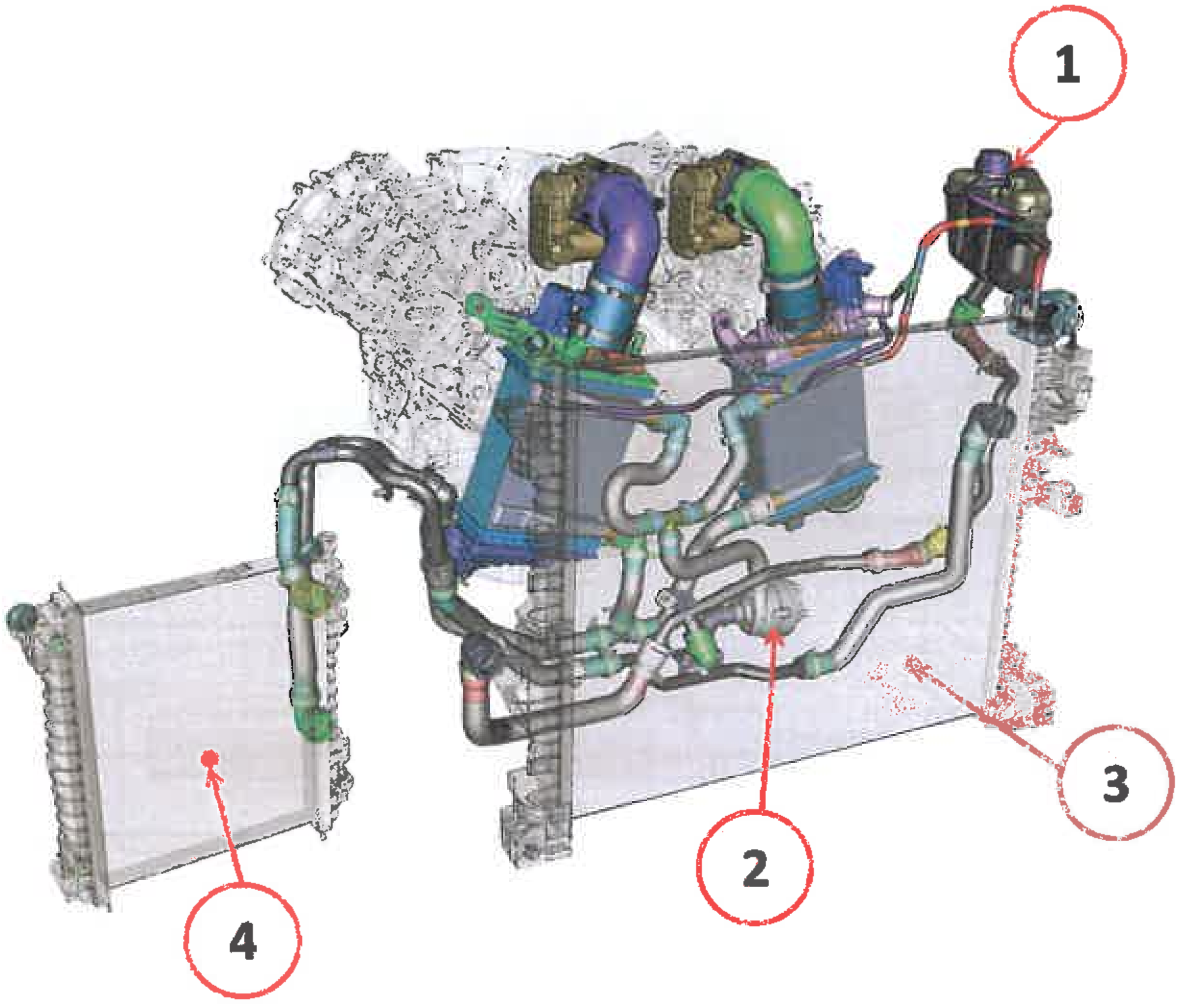

Key:
1 – a low temperature cooling system (LT system).
2 – a high temperature cooling system (HT system).
3 – Tank connections from expansion HT system to HT system
4 – Tank connections from expansion LT system to LT system
5 – Right bank intercooler.
6 – Left bank intercooler.
7 - Electric pump
8 – Additional radiator for LT system water cooling
9 – Radiator for LT system water cooling
10 – Radiator for HT system water cooling
11 – Additional radiator for HT system water cooling.
12 – Expansion tank for LT system.
13 – Expansion tank for HT system.

The two systems, HT and LT, are separate and do not communicate. That is shown by the presence of two specific expansion tanks: one for the HT system and the other for the LT system.

The low temperature system has to cool only the water used to cool the air circulating in the intercooler.

The high temperature system has to col the water used to cool the engine.

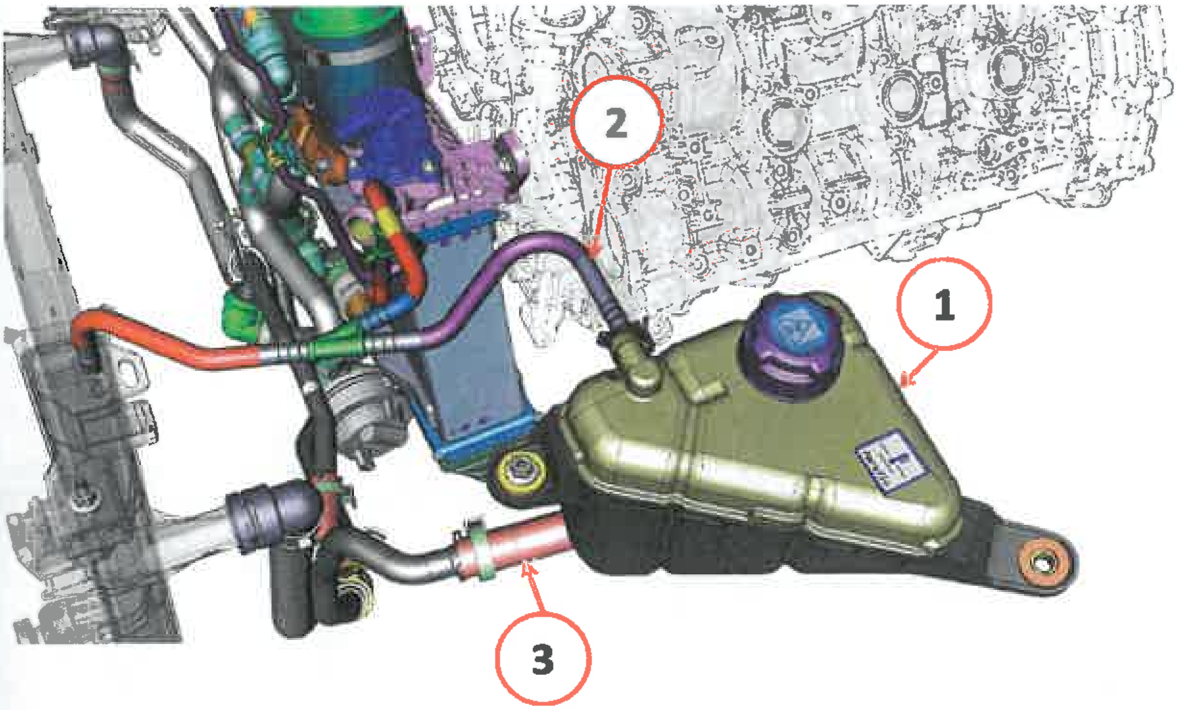
**A low temperature LT cooling system.**

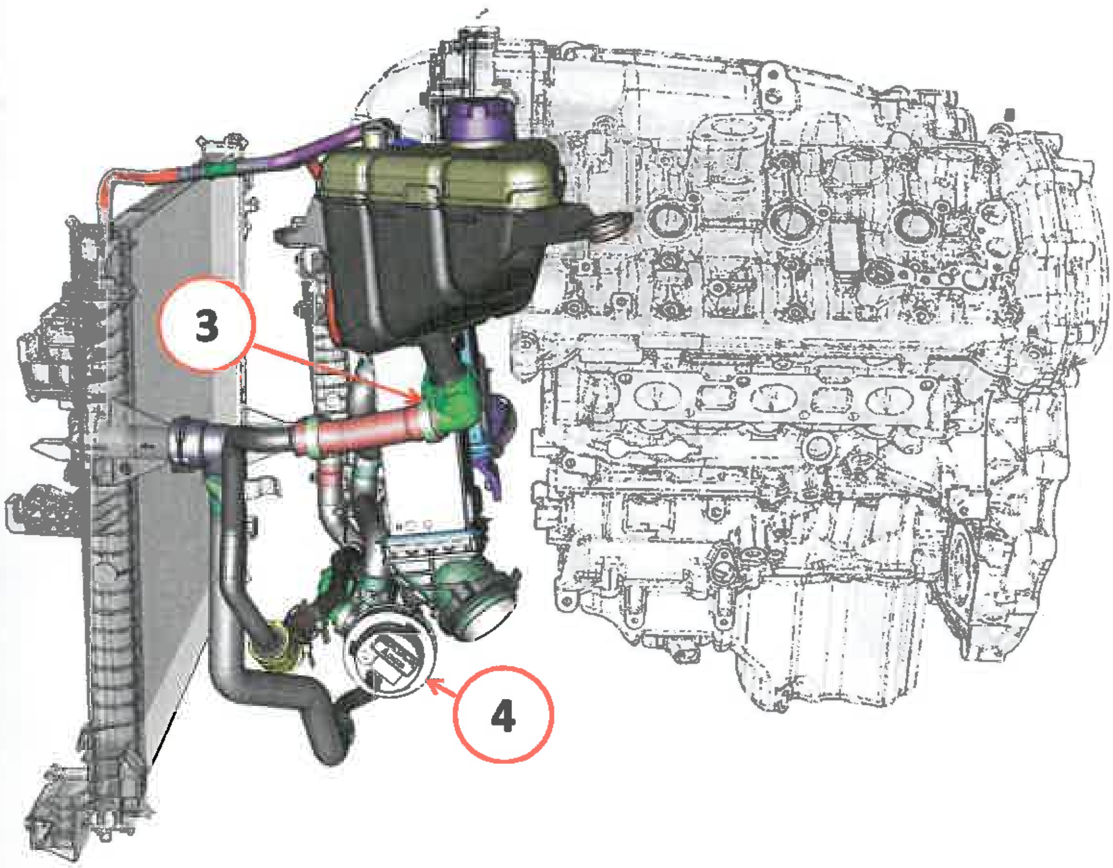



Key:
1 – Expansion tank for LT cooling system.
2 - Electric pump
3 – Radiator for LT system water cooling.
4 – Additional radiator for LT system water cooling.

As the LT system is separate from the HT engine cooling system, it cannot rely on pressure from the engine's water pump. The consequences are that water circulation within the LT system is ensured by an electric pump. This last is controlled by the ECM$_1$ Master.

**LT system expansion tank.**



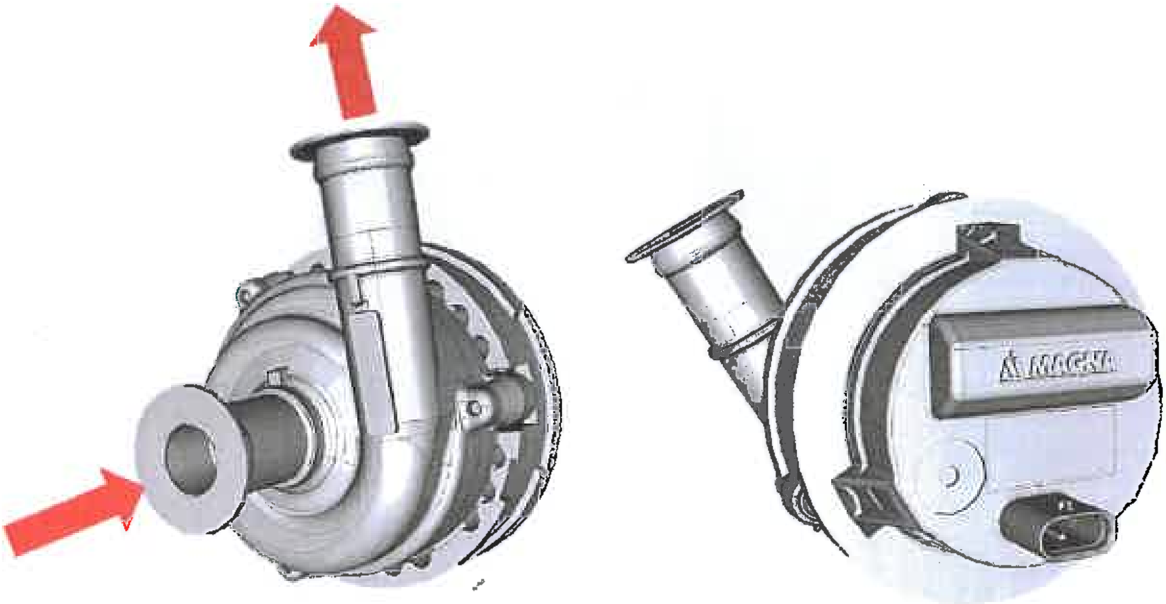




Key:
1 – Expansion tank for LT system.
2 – Radiator gas vent collection pipe.
3 – Intake piping for electric pump.
4 - Electric pump.

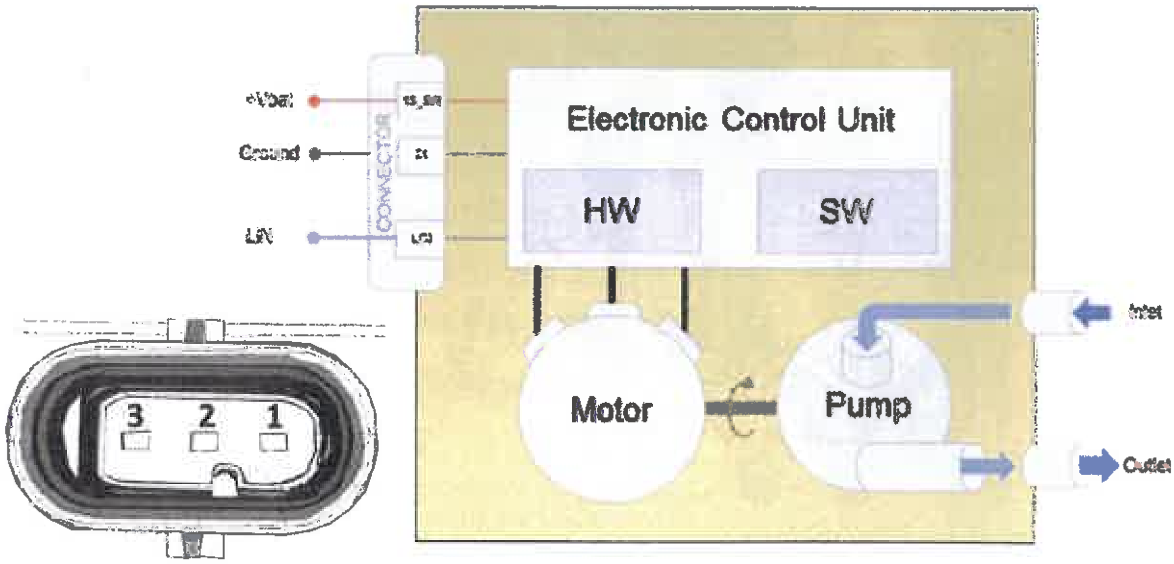
The inlet for the pipe that collects the gas venting that comes from the radiator and the two intercoolers is in the upper part of the expansion tank.

The LT cooling system is pressurised to 1.4 bar.

**LT Electric pump.**



The LT electric pump effects water circulation in the cooling circuit of the two intercoolers. There is a LIN type electronics inside the electric pump. The $ECM_1$ Master module sends the orders to the electric pump's electronics through a LIN line. The electric pump's electronics, depending on the orders received from the ECM, activates the electric motor to make the pump impeller turn at the desired speed.

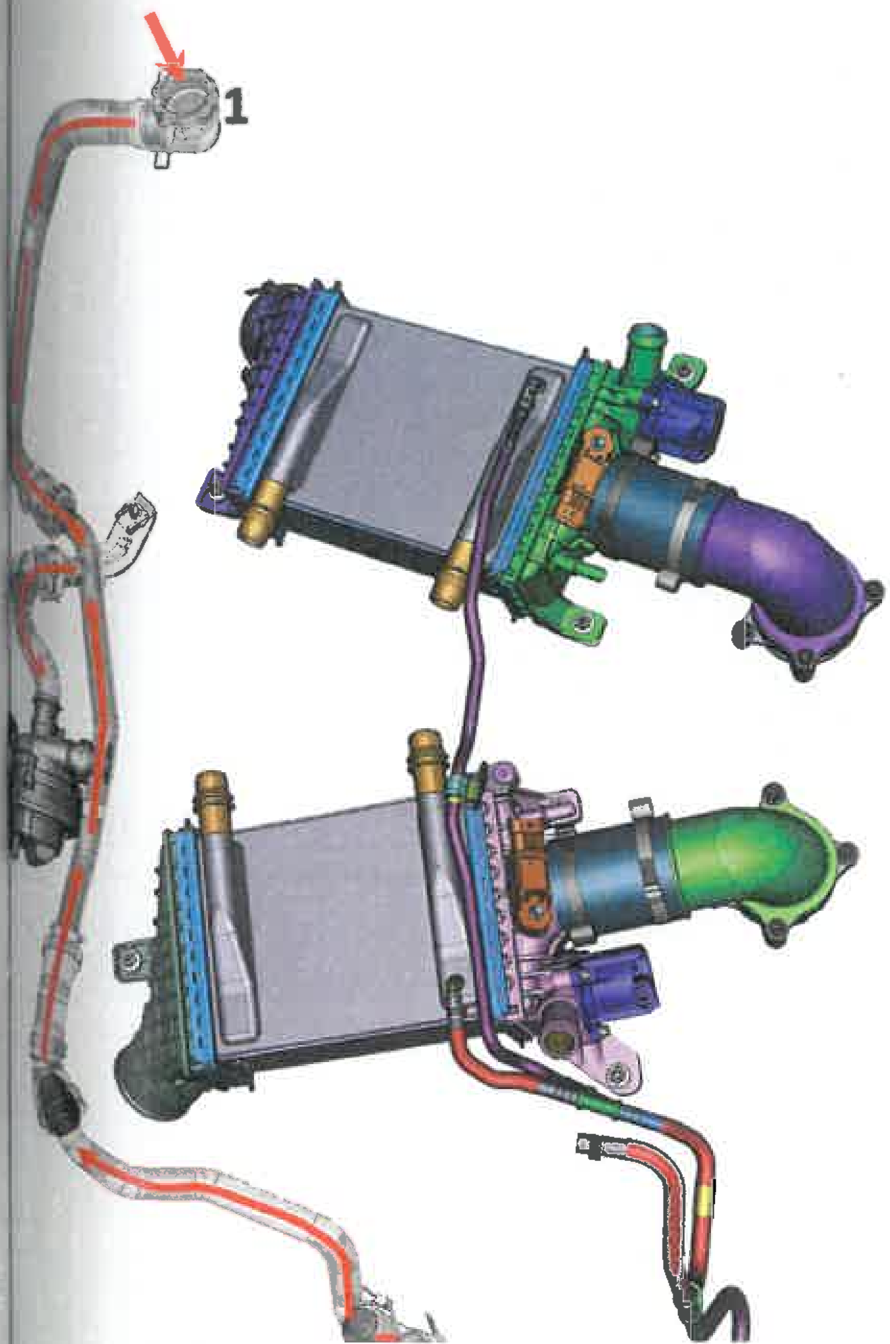



The electric pump's electric motor is the brushless tri-phase type and is controlled when the endothermic motor starts up.

The pump's rotation speed is determined by the ECM based on the intake air's temperature value.

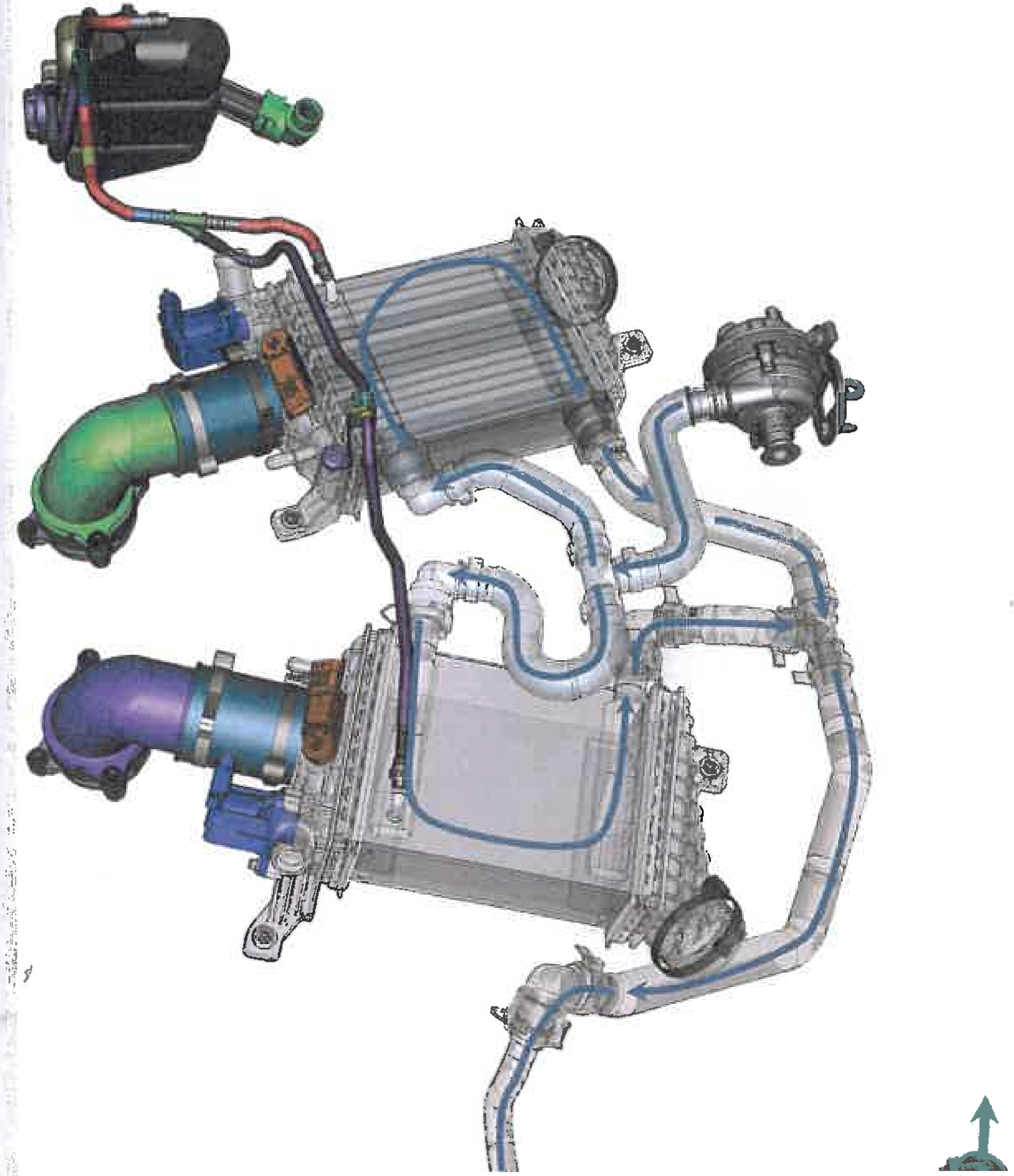
**Hydraulic circuit of the cooling liquid.**

*Electric pump intake.*



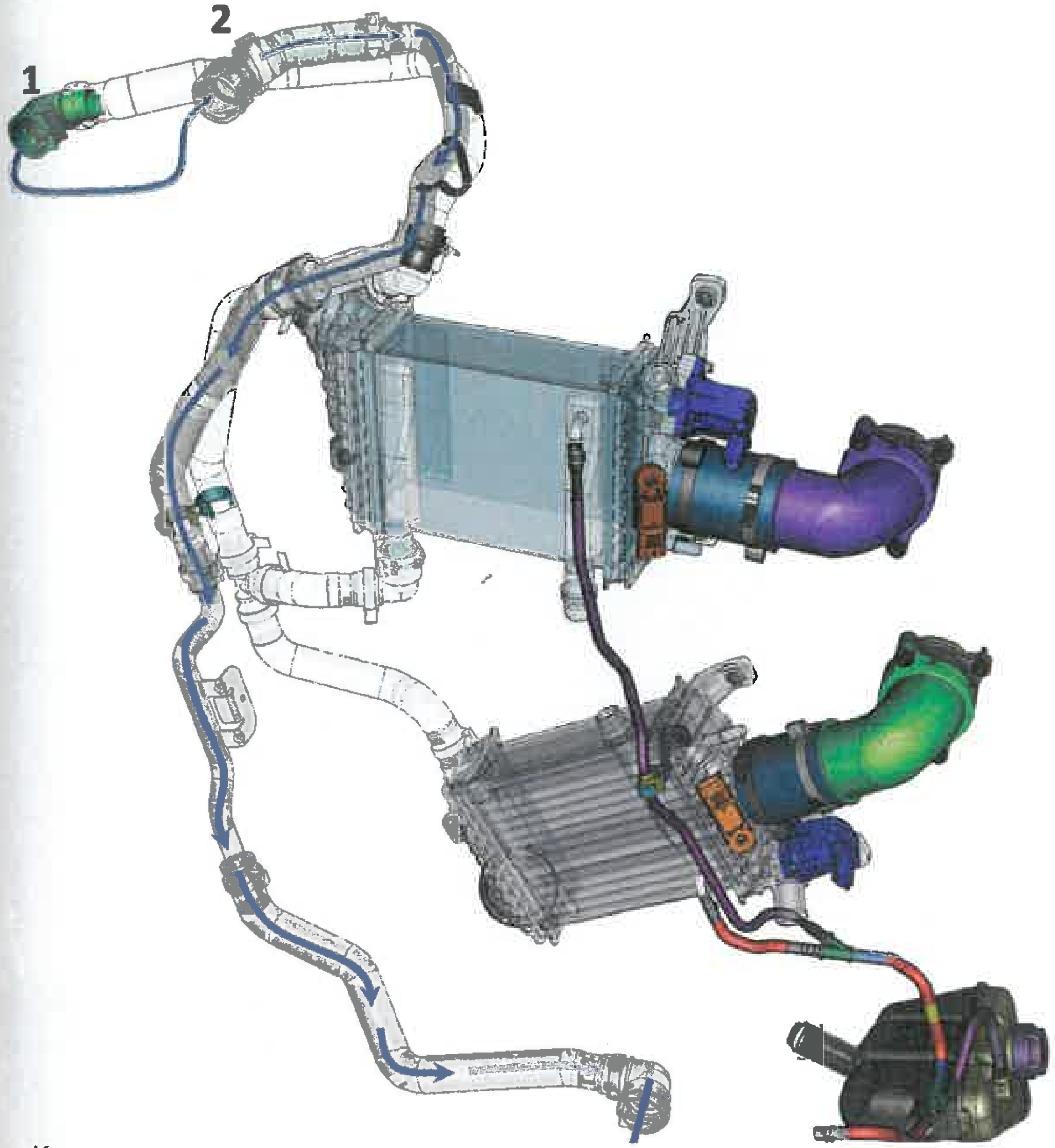

Key:
1 – Lower outlet of the central radiator.

*__Electric pump supply.__*



Key:
1 – Lower outlet of the additional radiator.

*Radiator connection.*




Key:
1 – Lower inlet of cooling liquid to the additional radiator.
2 – Upper inlet of cooling liquid to the additional radiator.
3 – Upper inlet of cooling liquid to the main radiator.

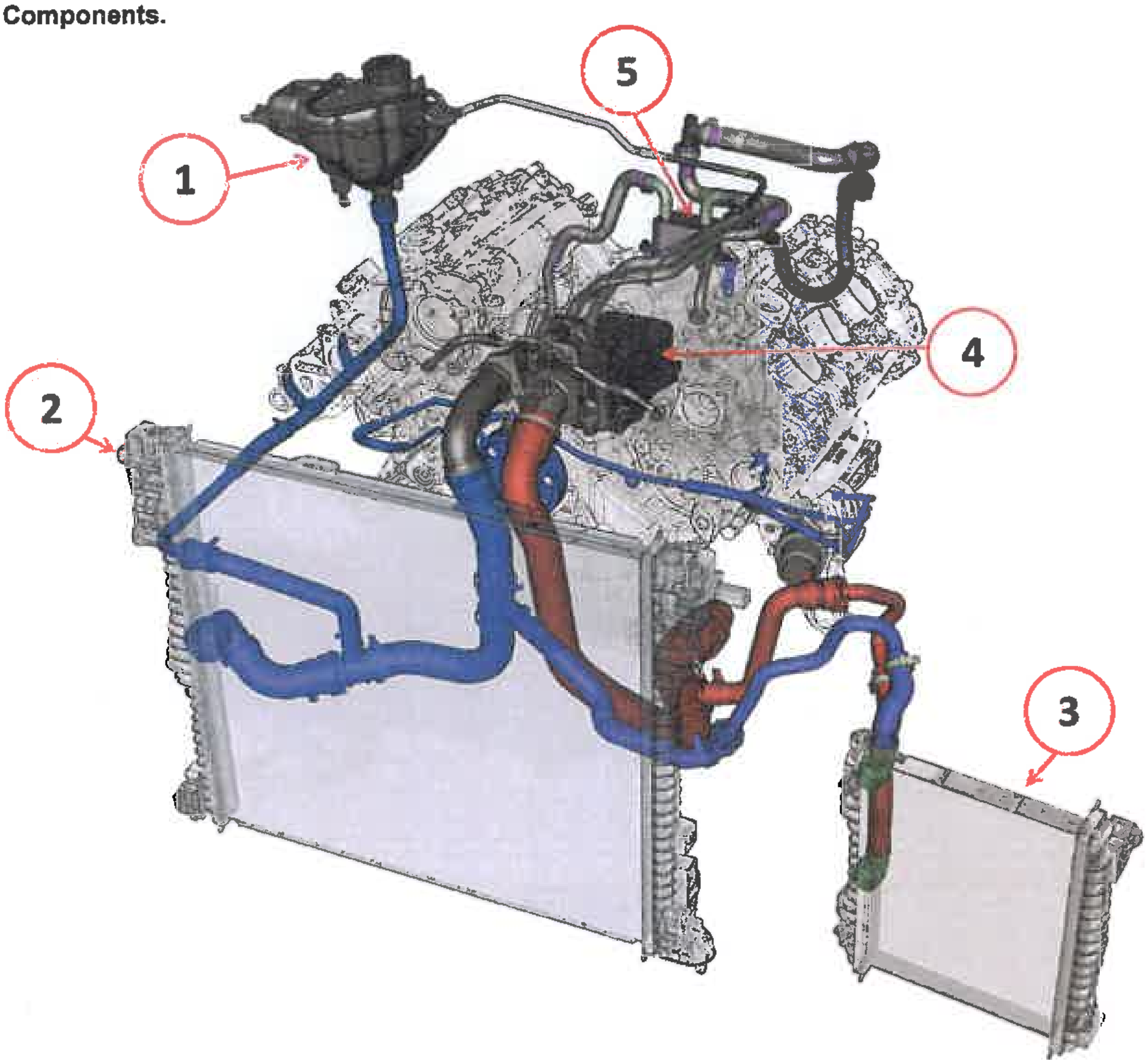
### A high temperature HT cooling system

The high temperature HT plant provides cooling for the following systems:

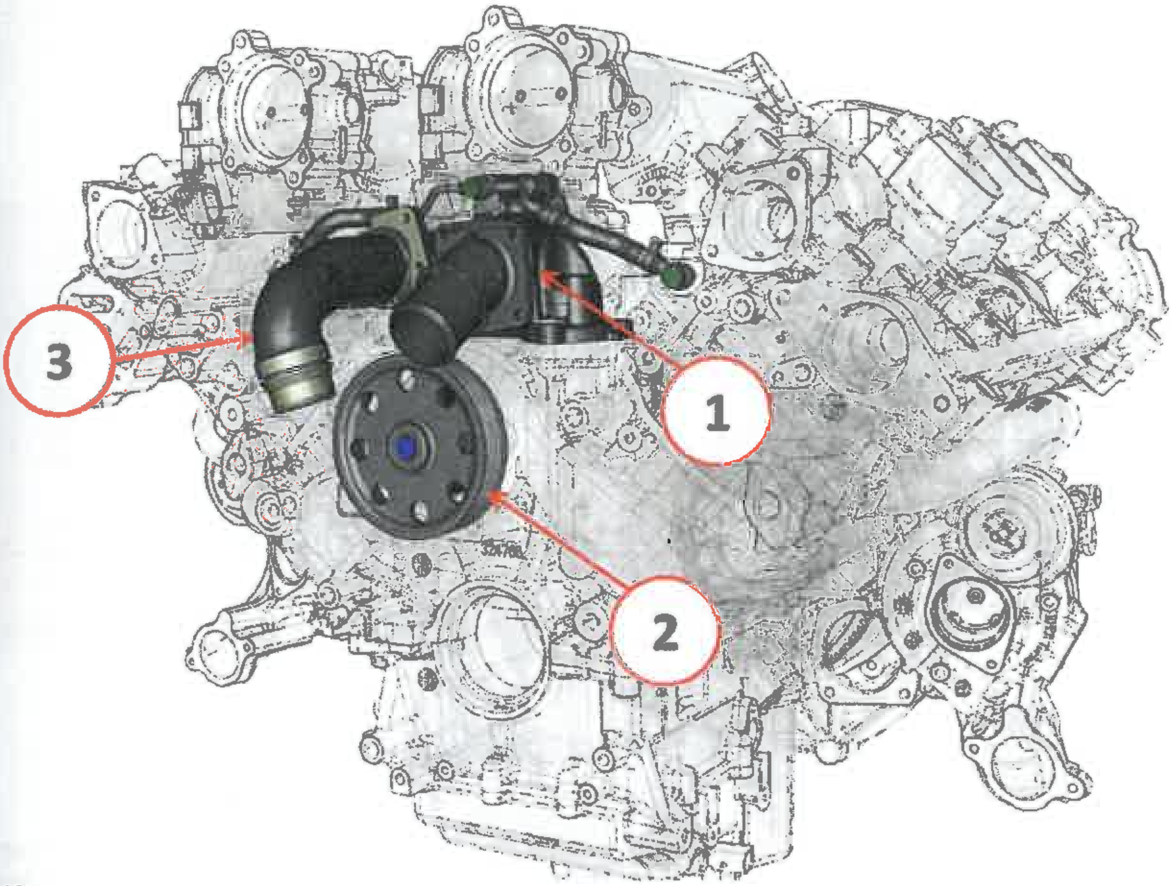
- Engine bed.
- Cylinder head.
- Turbochargers.
- Engine oil.
- Transmission oil.

The cooling liquid is cooled by a main radiator and an additional one. The main radiator uses the dynamic air flow produced by the vehicle's speed and the air flow forced by the cooling fan. The additional radiator only uses the dynamic air produced by the vehicle's speed.

**Components.**



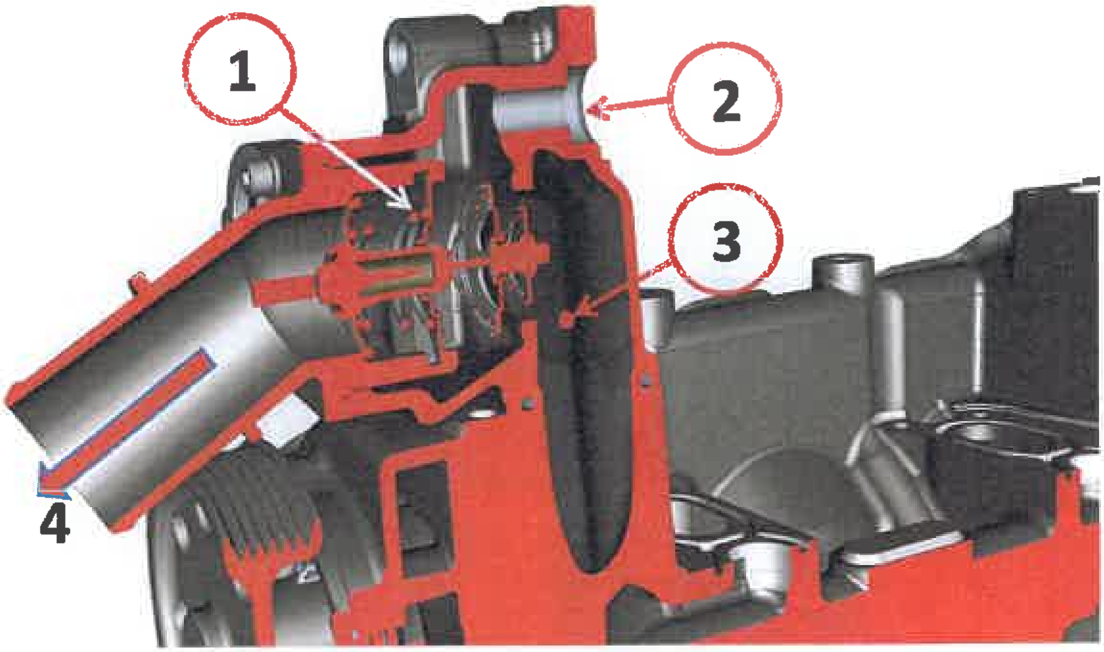

Key:
1 – Expansion tank for HT system.
2 – Main radiator.
3 – Additional radiator.
4 – Engine oil coolant heat exchanger.
5 – Transmission oil coolant heat exchanger.




Key:
1 – Thermostat.
2 – Water pump drive pulley.
3 – Water pump intake pipe.

*Thermostat.*

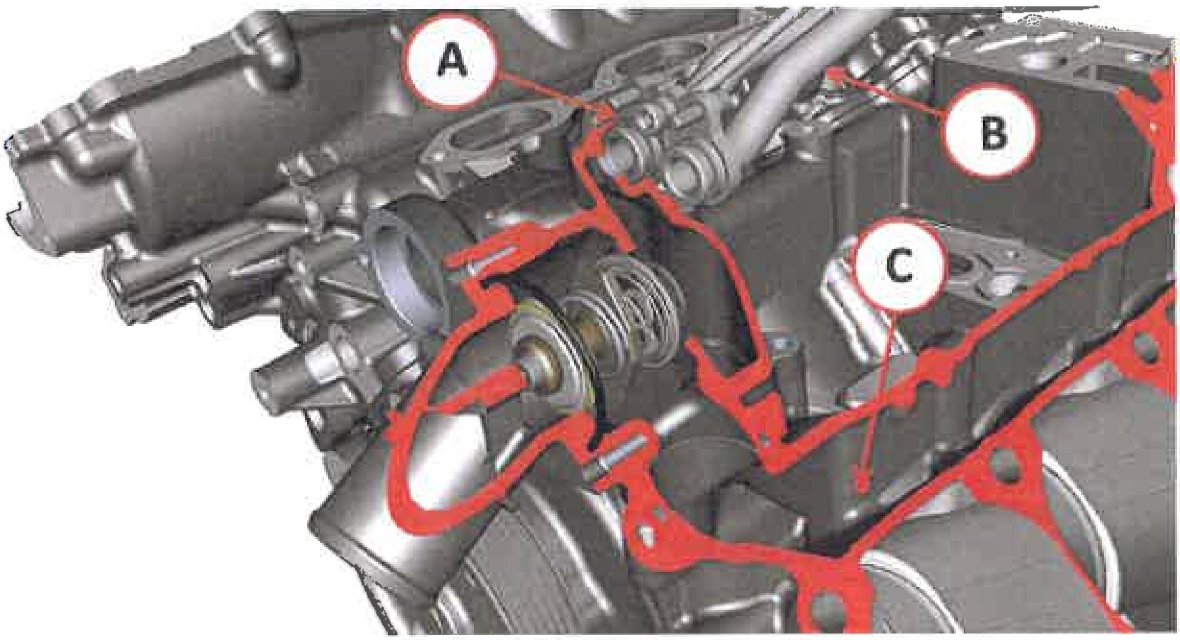
The engine thermostat is located in the central part between the two banks (services side). There is an opening when the cooling liquid temperature is 85°C±2°C.



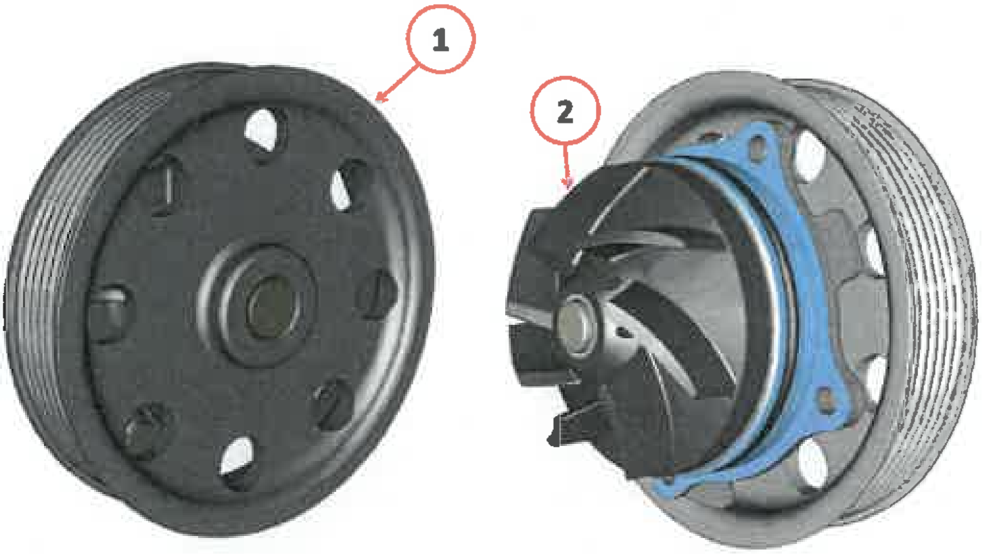

Key

1 – Thermostat.
2 – Inlet for cooling liquid by the heat exchanger to cool the transmission oil.
3 – Accumulation chamber for intake pump.
4 – Exhaust pipe towards radiator.

You can see from the image that the thermostat has a double stage. When it is closed, as often happens, the cooling liquid cannot go towards the radiator. In this case, the cooling liquid coming from the heat exchanger to cool the transmission oil (2) and the engine (bed and heads) is diverted by the first thermostat stage towards the accumulation chamber where the pump is sucking. When the thermostat reaches the opening temperature, the second stage opens up while the first one closes. In this last condition, the cooling liquid from the transmission water-oil exchanger and the engine (bed and heads) is diverted towards the radiator. In the image below, you can see the channel (C) formed in the bed conducts return engine water towards the intake pump (thermostat closed) or towards the radiator (thermostat open). The two pipes (A) and (B) are respectively the passenger compartment heater and the return of the transmission water-oil exchanger.

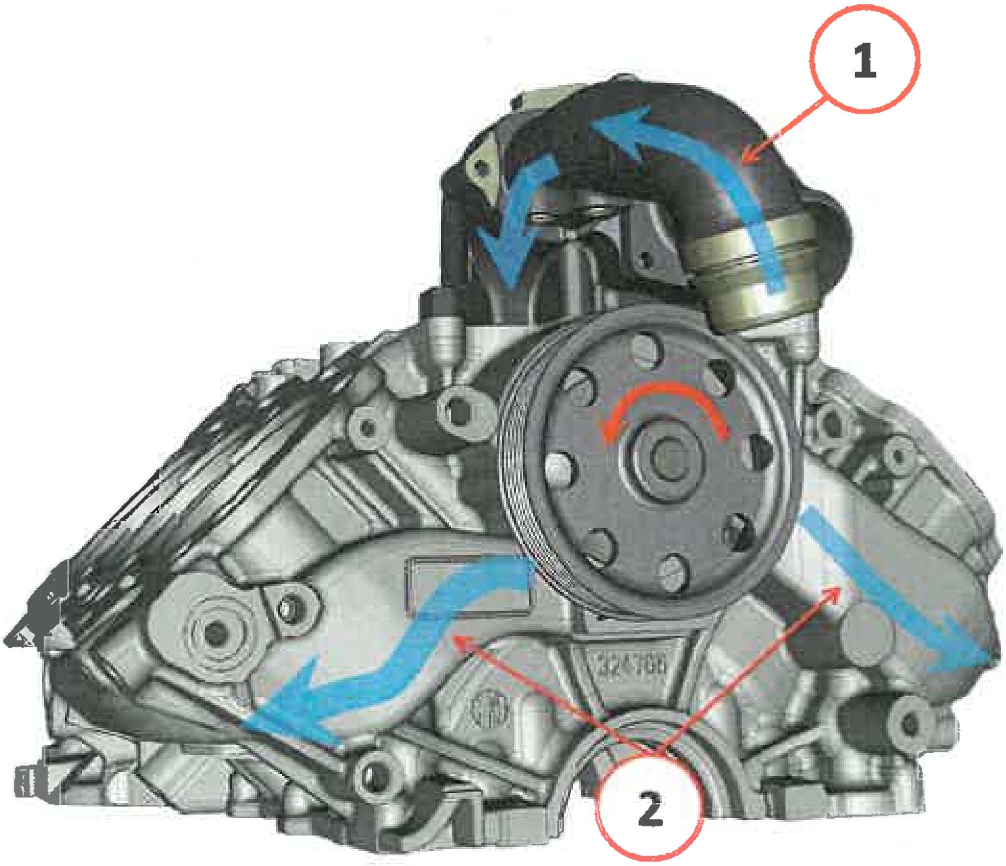


*Water pump.*

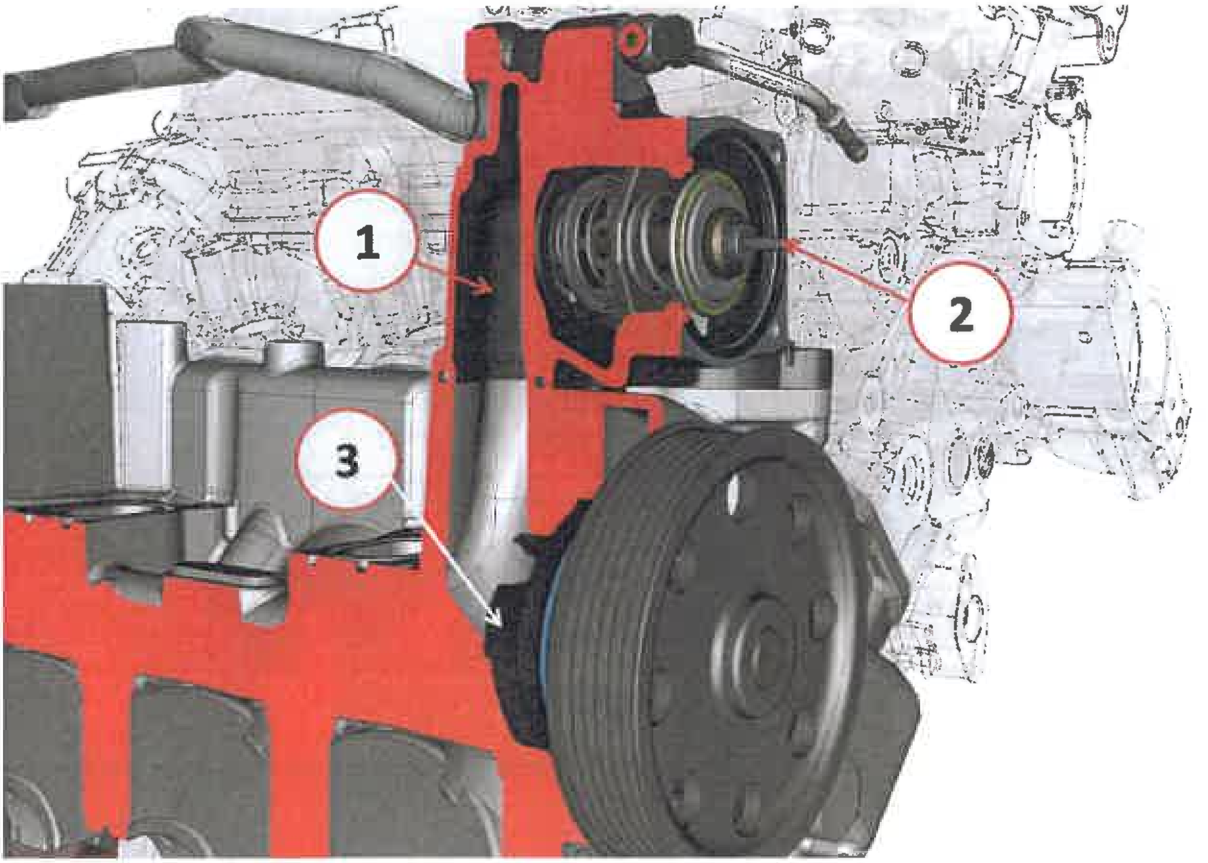



Key:
1 – pump pulley
2 – centrifuge impeller.

The water pump is centrifuge type. It is located frontally in the area below the thermostat in a housing formed inside the bed.




Key:
1 –intake pipe (made up of the pipes coming from the radiator, the expansion tank and the additional radiator).
2 – Sent from the pump in the channels formed in the bed.




Key:

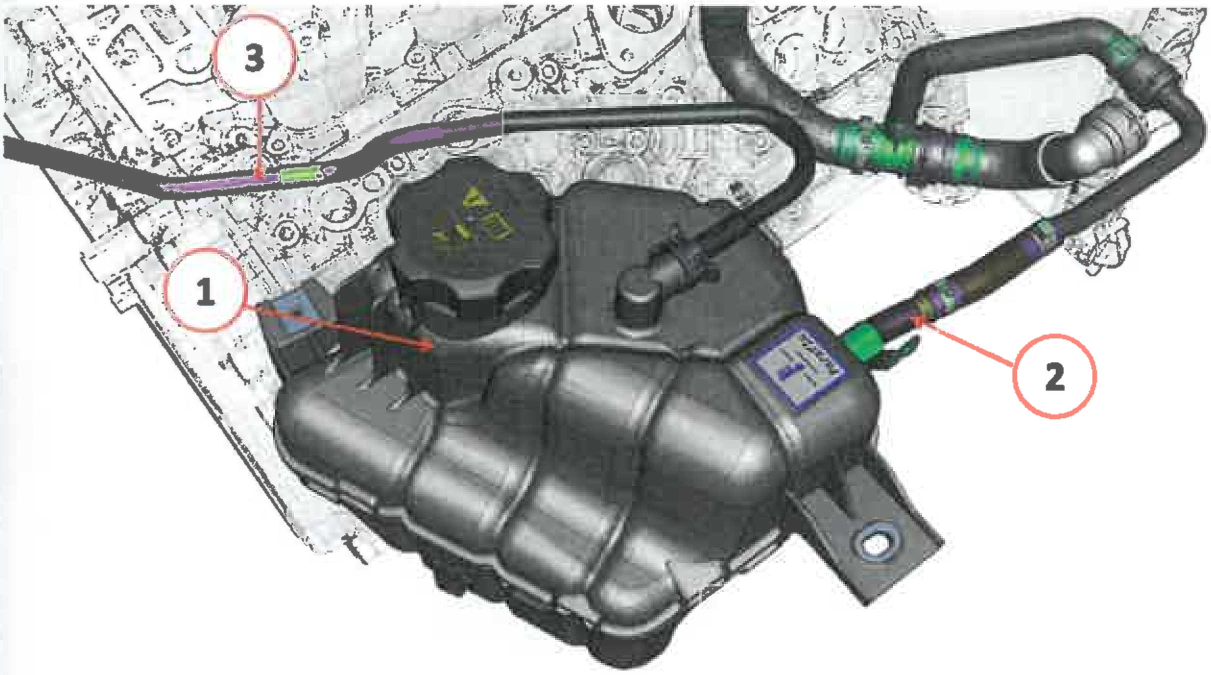
1 – Intake chamber for pump.

2 – Thermostat.

3 – Water pump impeller.

The pump that moves the cooling liquid sucks it from the same chamber facing the thermostat.

*HT system expansion tank.*

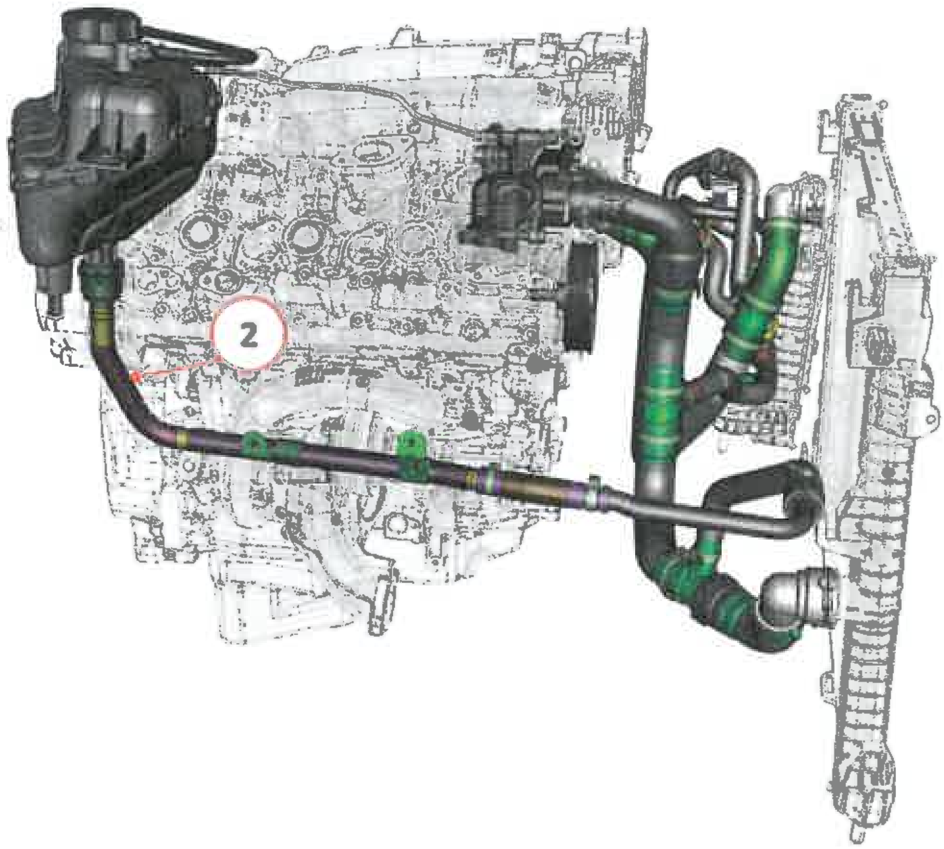



Key:

1 – Expansion tank for HT system.

2 – Intake pipe connected to the lower part of the expansion tank.

3 – Gas vent pipe coming from the thermostat.

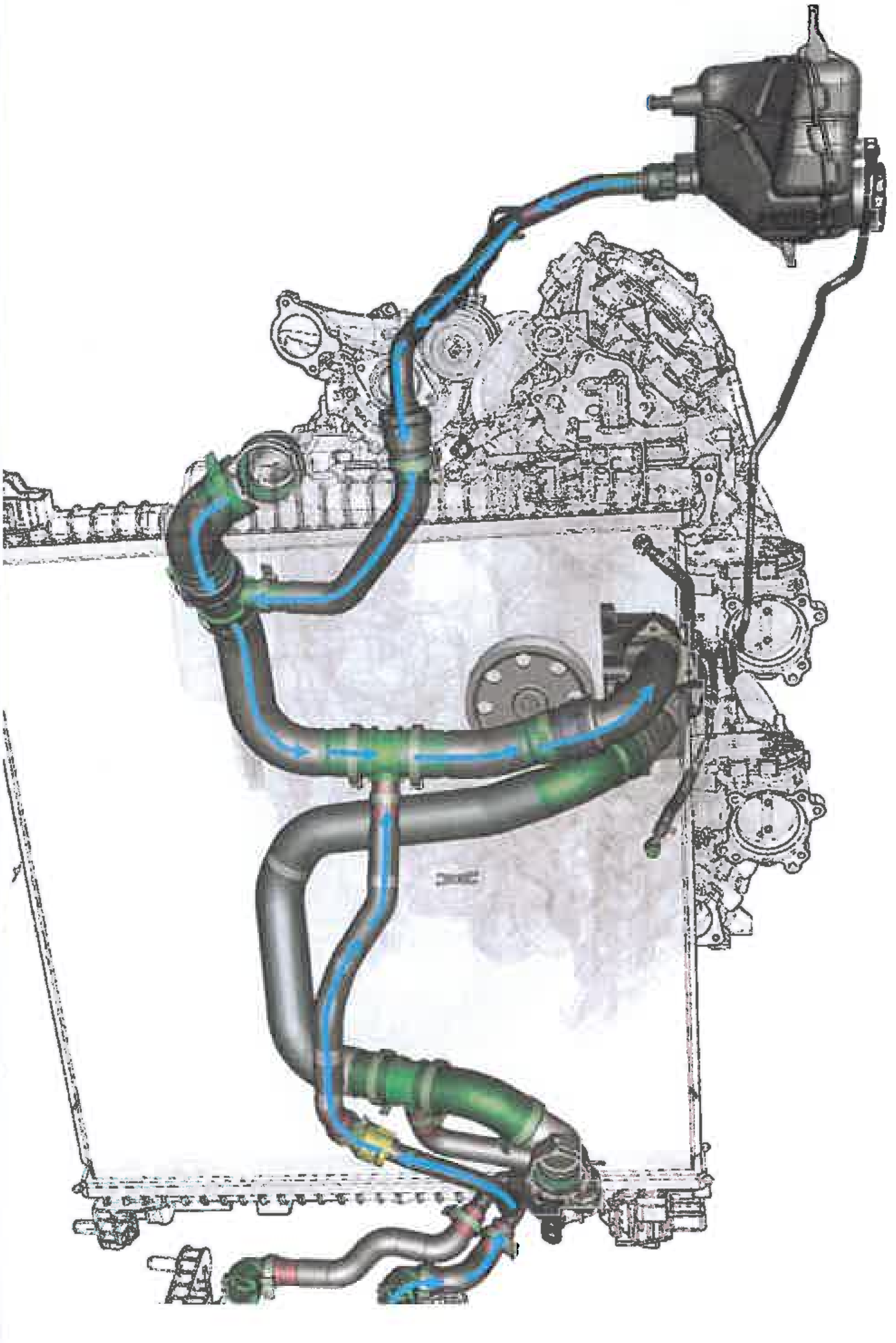



The HT cooling system is kept at a pressure of 1.4 bar.

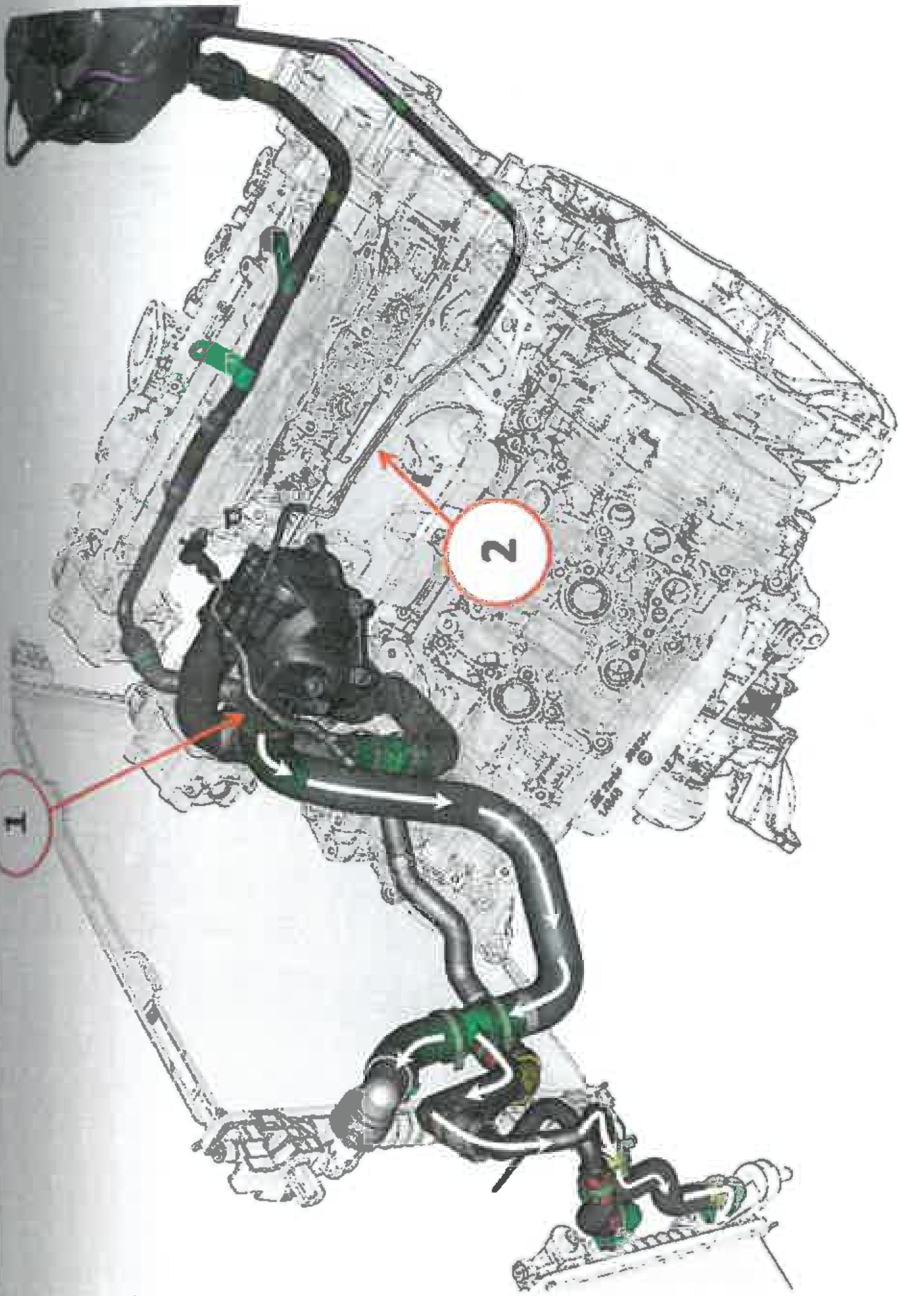
**Engine Cooling Circuit.**

Below are the images that show the cooling liquid floe between the engine and the radiators.

*Intake flow from the radiators to the pump.*



*Flow from the thermostat to the radiators.*

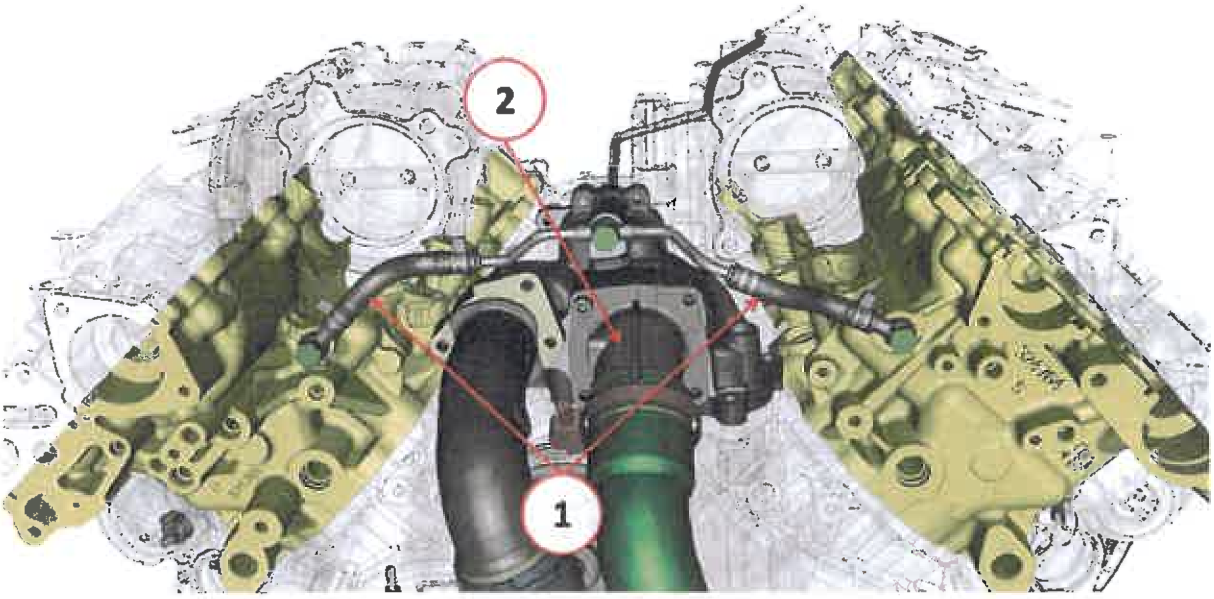



Key:

1 – Thermostat.

2 – Gas vent pipe from the thermostat.

*Cylinder head gas vent pipes*




On the front part of the cylinder heads there atre two pipes that connect these last to the upper part of the thermostat's exterior body. The two pipes the cooling liquid to "exhale" (or gas venting); the liquid is circulating around the upper part of the combustion chambers inside the cylinder heads.

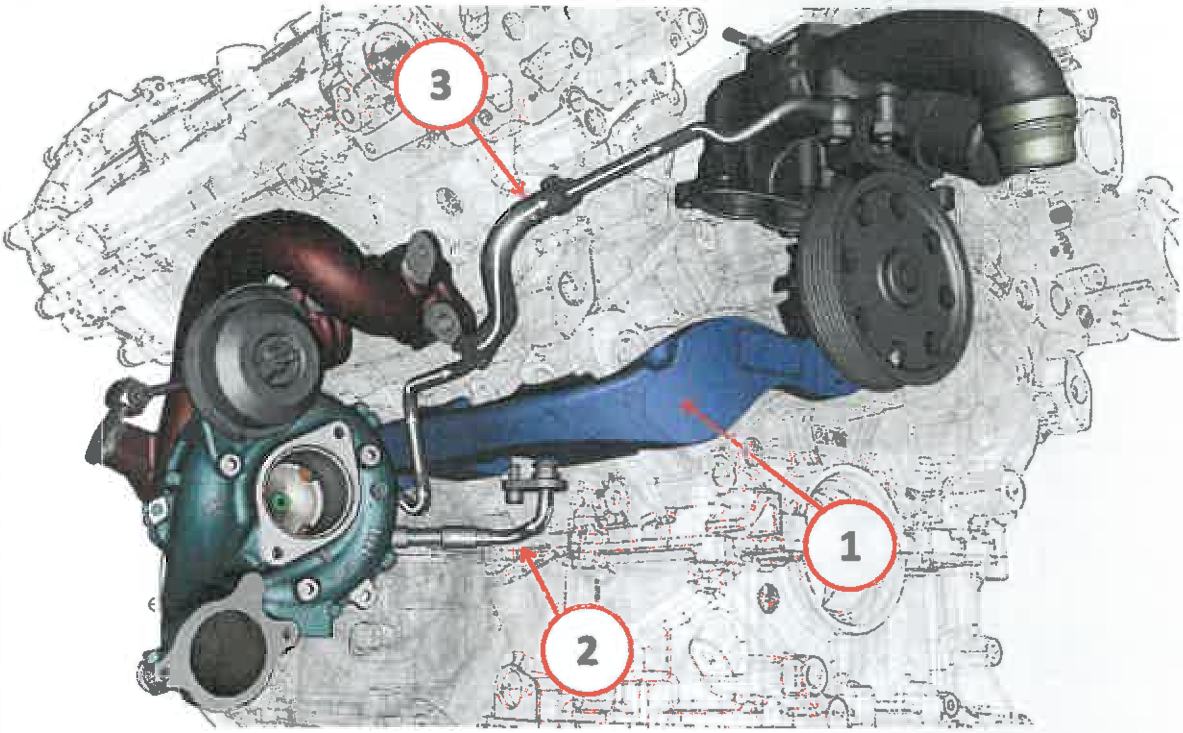

Key:

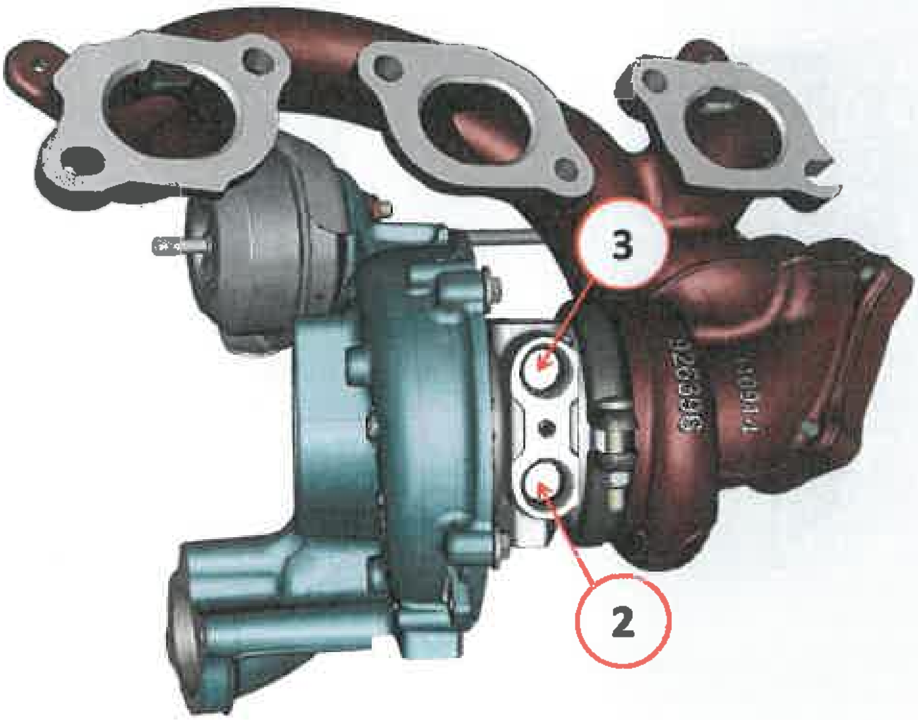
1 – Cooling liquid flow around the cylinders' combustion chambers.

2 – Gas venting at the thermostat's entry.

## Turbocharger cooling circuit.

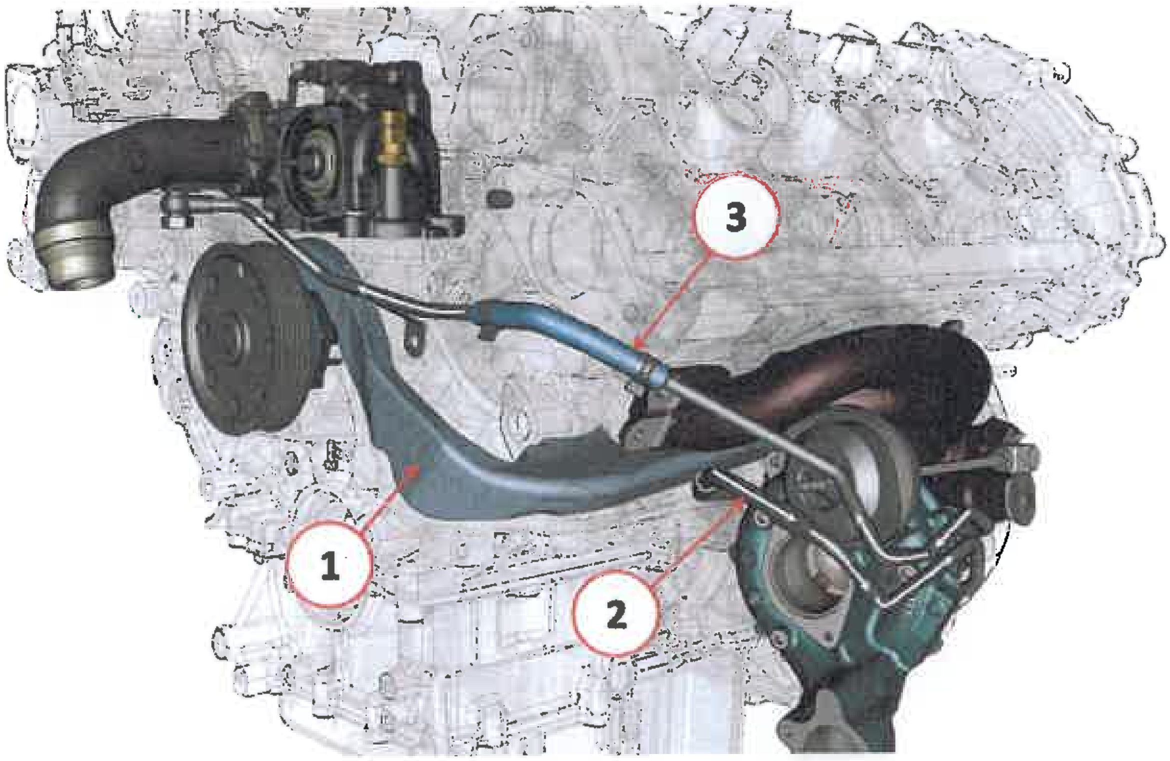
*Right bank*

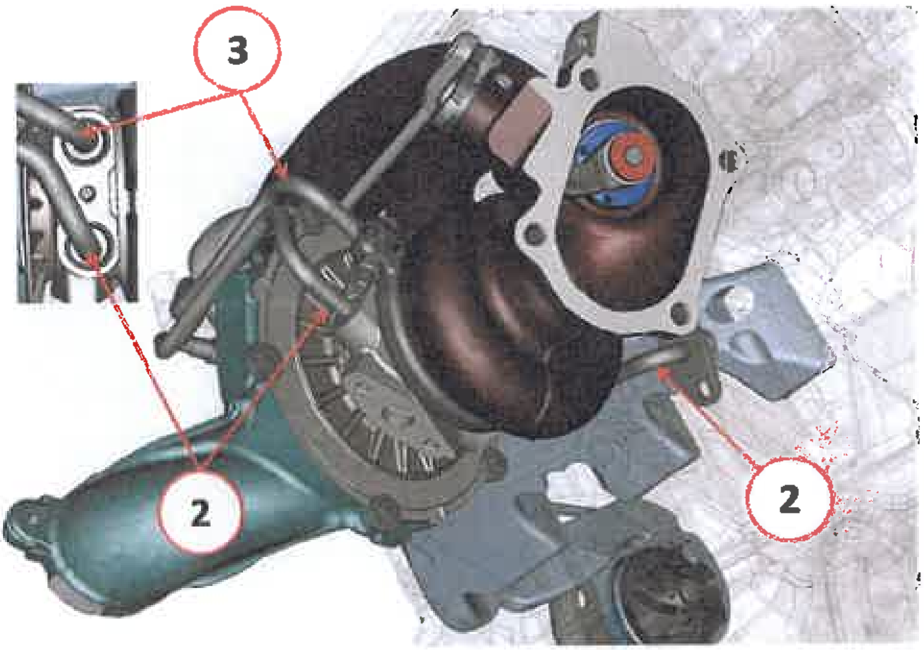



Key:
1 – Cooling liquid flow sent from the pump.
2 – Cooling liquid entry to the turbocharger.
3 – Cooling liquid exit from the turbocharger.

*Left bank.*



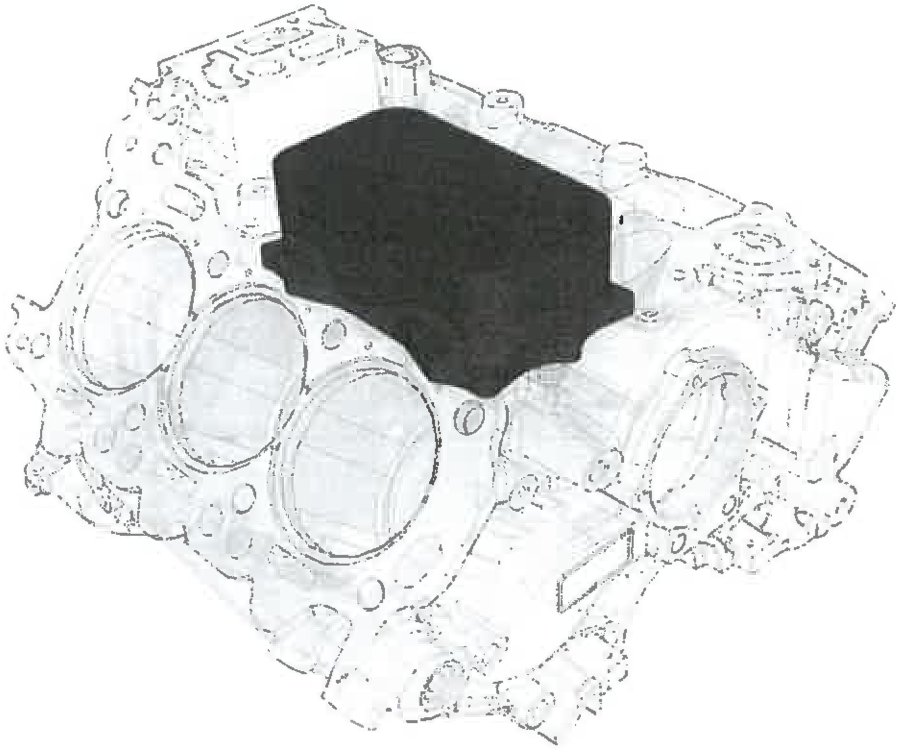




Key:
1 – Cooling liquid flow sent from the pump.
2 – Cooling liquid entry to the turbocharger.
3 – Cooling liquid exit from the turbocharger.

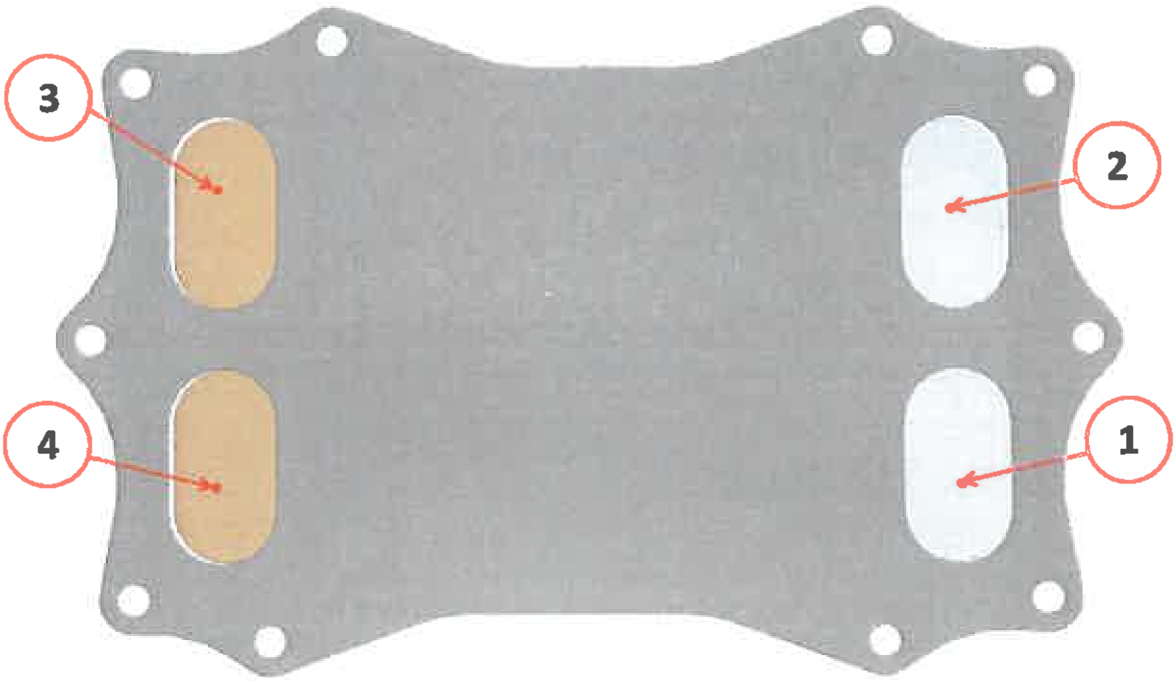
The cooling liquid flow is "tapped" by the bed and sent into the turbochargers. The liquid outflow from these last is sent to the intake pump. You can see from the images that the liquid inlet and output pipes are in the rear of the turbocharger on the right bank, but on the left bank, the pipes are connected to the front part of the turbocharger.

## *Engine oil heat exchanger.*

The heat exchanger for cooling the engine oil is located between the two engine banks.

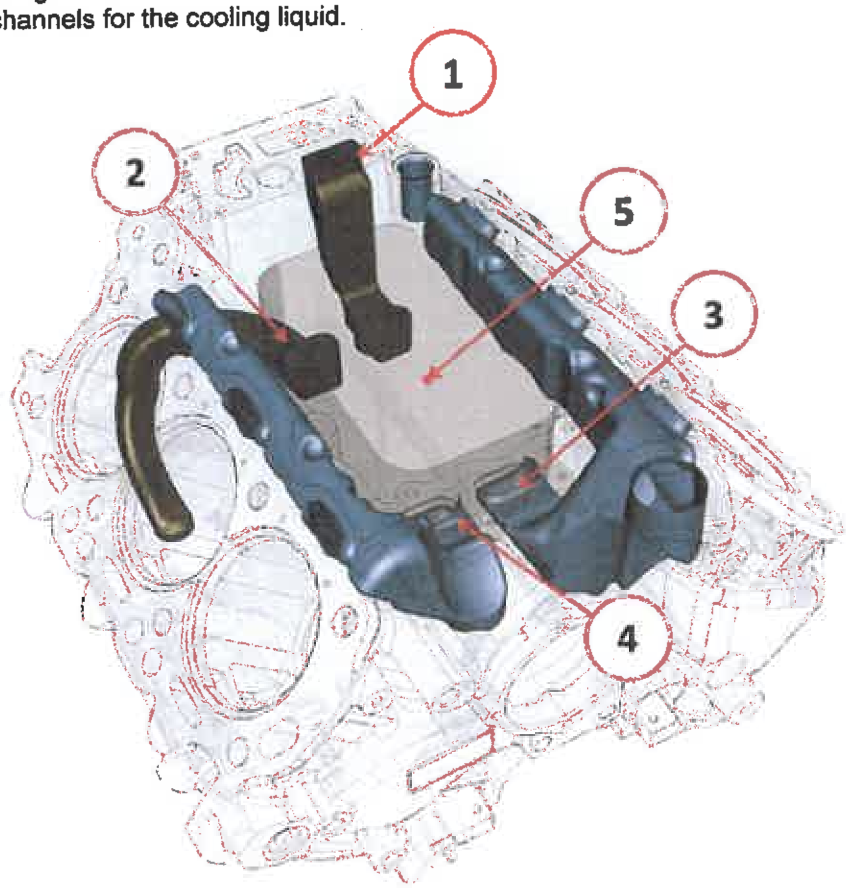


The exchanger's lower surface has 4 holes for water and oil flows.



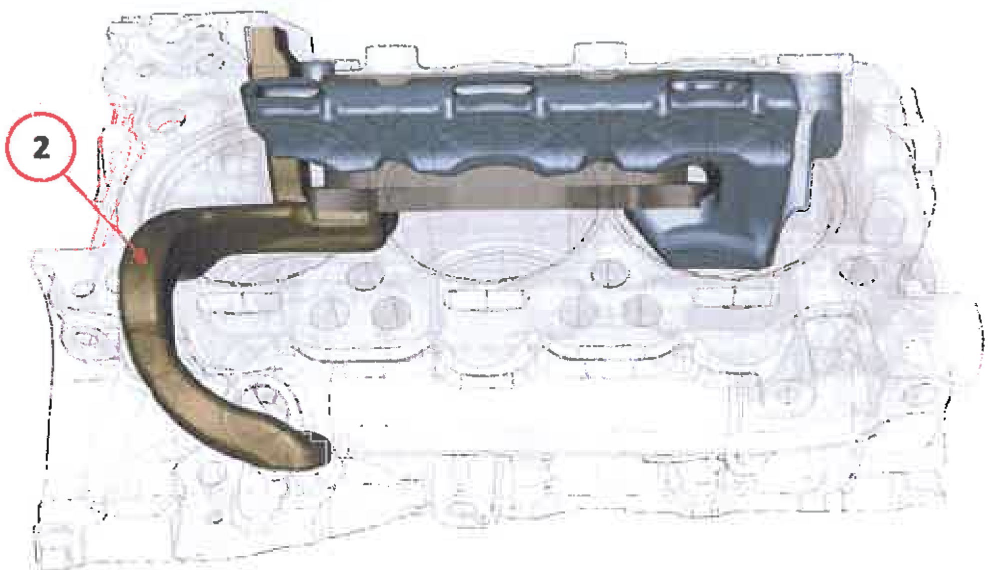

Key:
1 – Cooling liquid exit.
2 – Cooling liquid entry.
3 – Engine oil entry (from the oil filter).
4 – Engine oil exit (towards the oil sump).

The engine oil sent by the oil pump goes into the heat exchanger entry. Once cooled, the oil comes out of the exchanger and heads towards the filter. In the door opposite the exchanger there are the entry and exit channels for the cooling liquid.

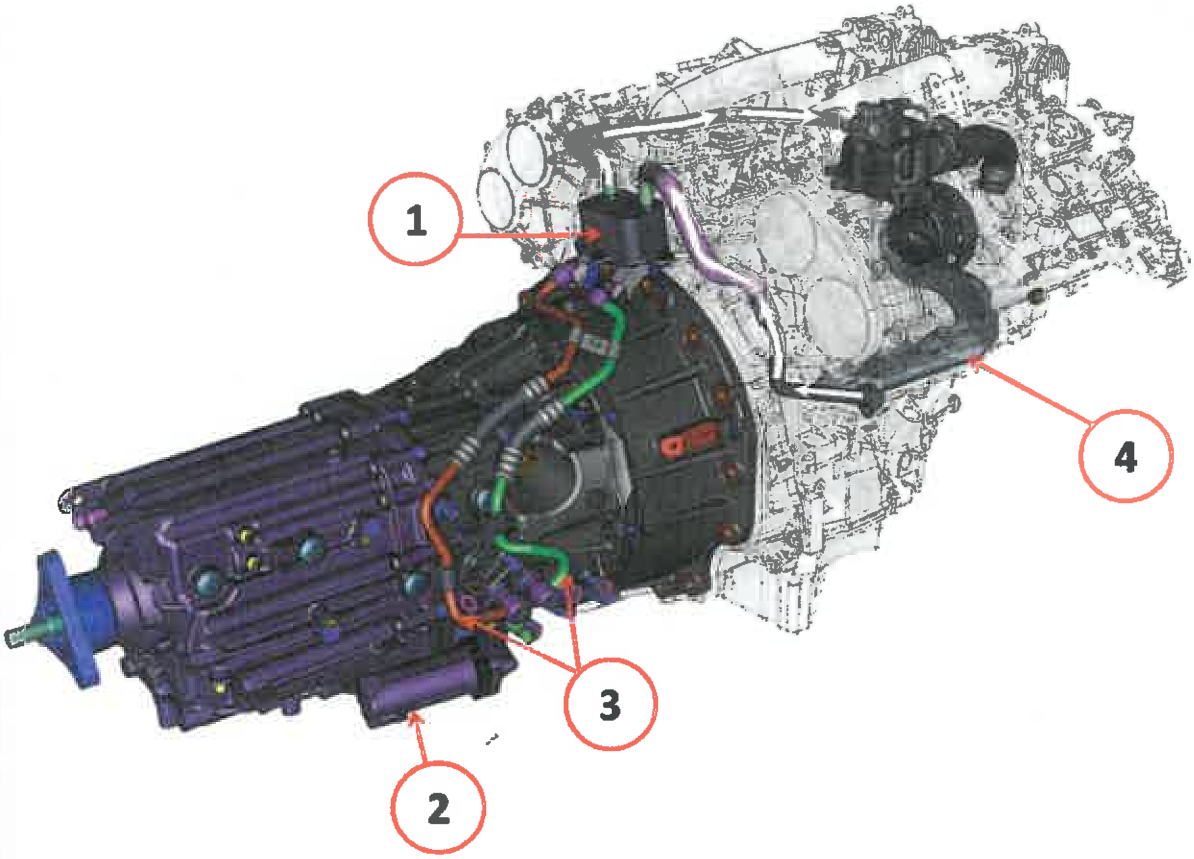



Key:
1 – Exit for oil from the exchanger for the oil filter.
2 – Engine oil entry in the oil pump exchanger.
3 – Cooling liquid exit from the heat exchanger.
4 – Cooling liquid entry from the heat exchanger.

Right bank view.



**Transmission oil cooling circuit.**




Key:
1 – Transmission oil coolant heat exchanger.
2 – Electric pump to circulate transmission oil.
3 – Sending pipes for the exchanger and oil return from the exchanger.
4 – Cooling liquid flow sent from the bed.

Because of the high amount of engine torque steam, transmission oil is subject to very high levels of shaking. Such a high level of shaking causes a constant increase in the temperature. Oil cooling is done by a heat exchanger located above the gearbox, near the engine oil filter.

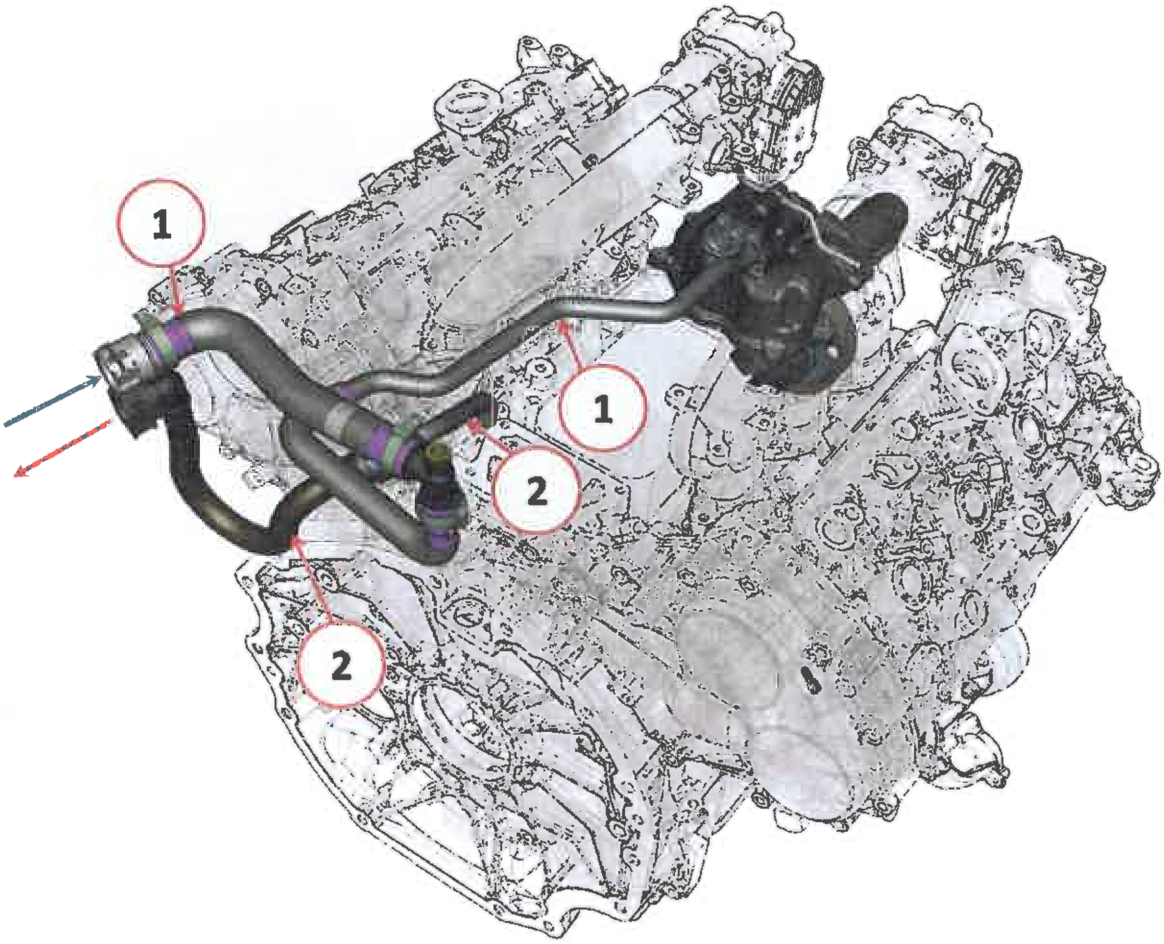
The transmission oil is sent towards the thanks to a electric pump located on the right side of the gearbox. The electric pump supplies an appropriate relay. The relay is controlled by the $ECM_1$ Master.

The refrigeration liquid needed for correct transmission oil cooling is "tapped" by the right side of the engine bed. The engine pump pushes the liquid back up towards the exchanger.

The cooling liquid exit from the exchanger is connected to a pipe that returns the liquid itself in the engine's air intake pump.

On the gearbox there is a temperature sensor whose function is to measure the gearbox oil's temperature. The $ECM_1$ module uses the sensor signal to activate the oil circulation electric pup towards the heat exchanger.

**Passenger compartment heating circulation.**




Key:
1 – The return cooling liquid pipe from the compartment heater.
2 – The sent cooling liquid pipe towards the compartment heater.

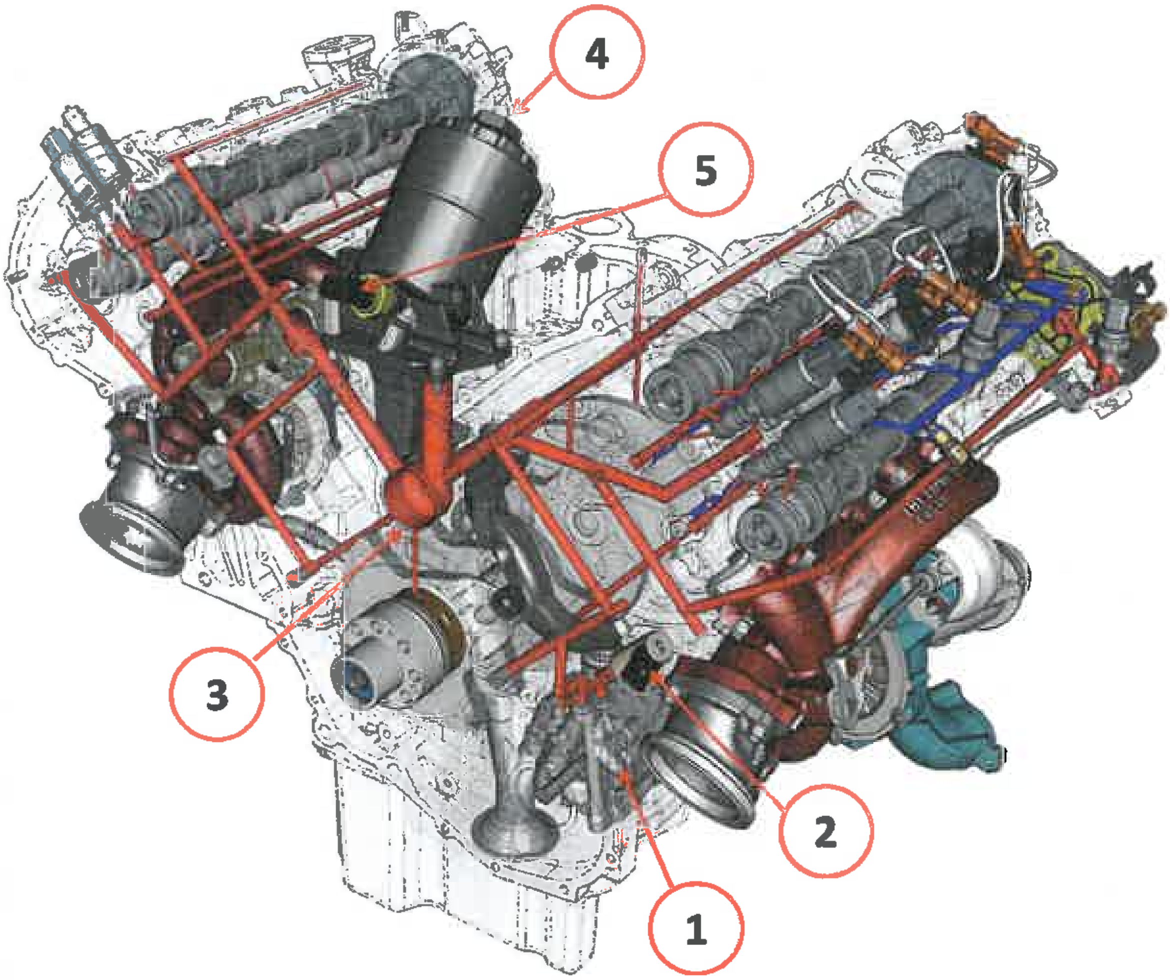
The cooling liquid entering the compartment heater comes via its piping (2) from the cylinder heads.

The cooling liquid exiting the compartment heater is conducted via its piping (1) towards the thermostat.

**Lubrication system.**

The mechanical parts of the engine are lubricated by a complex system of internal channelling to the bed, the cylinder heads and to the respective tappet covers. The lubricating system owes its complexity also to the systems whose functions are based on the oil "push" (pressure) like the phase variators and the right bank cylinders' deactivation system.

The lubrication system consists of the following components:

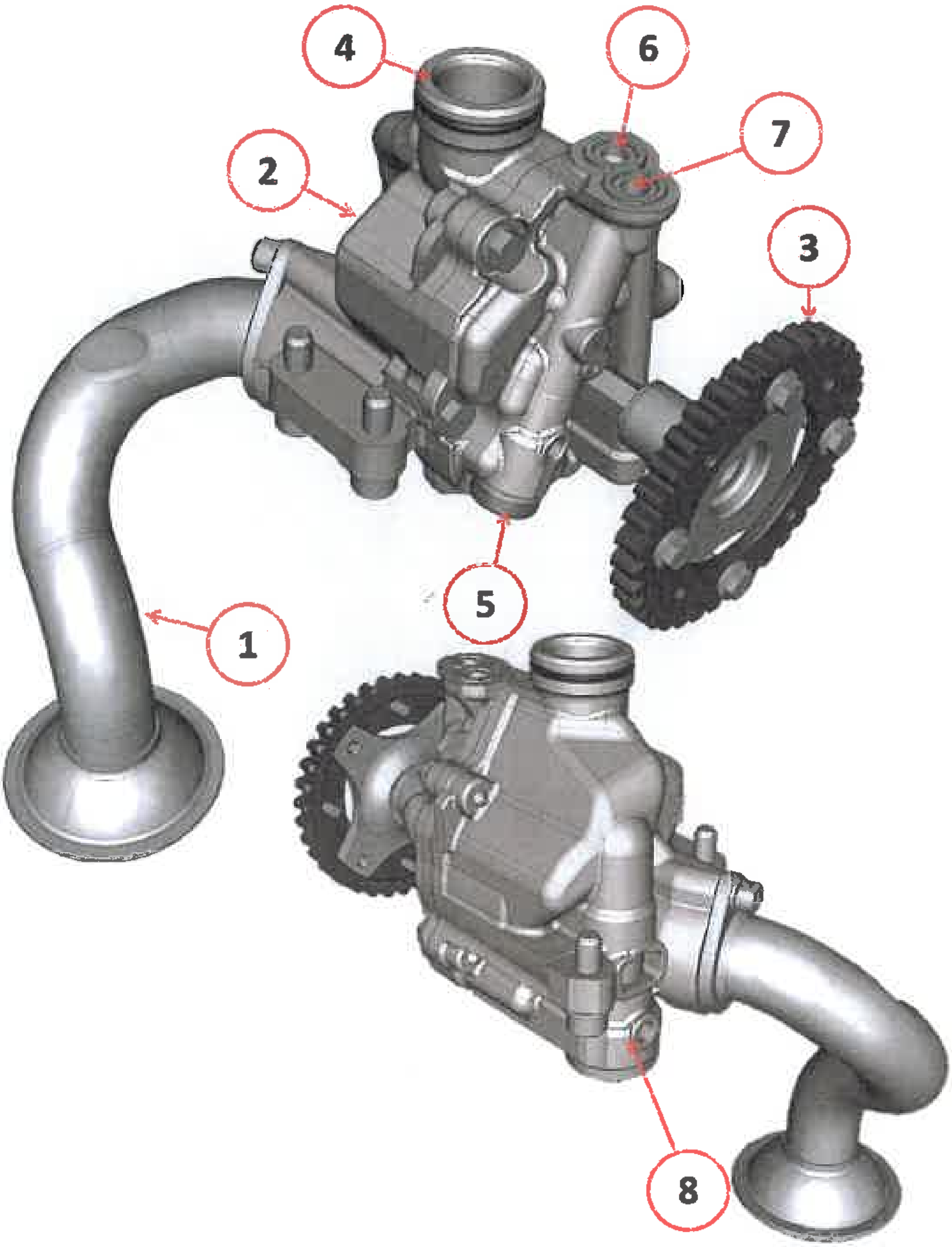



Key:

1 – Variable displacement oil pump.
2 - Oil exit regulatory solenoid valve.
3 – Oil timing chamber for cylinder heads and bed channels.
4 – Oil filter.
5 – Oil pressure sensor.

*Variable displacement oil pump.*

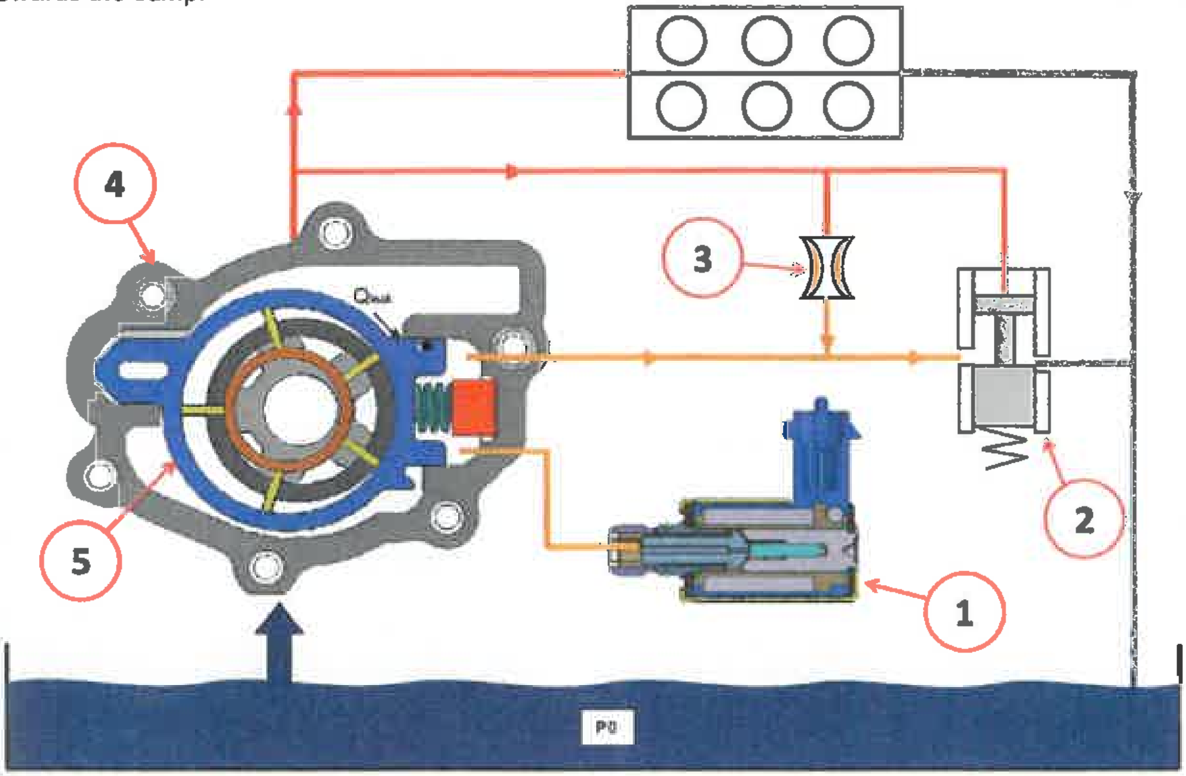
The oil pump has the characteristic of assuming a minimum or maximum displacement configuration depending on the engine charge.



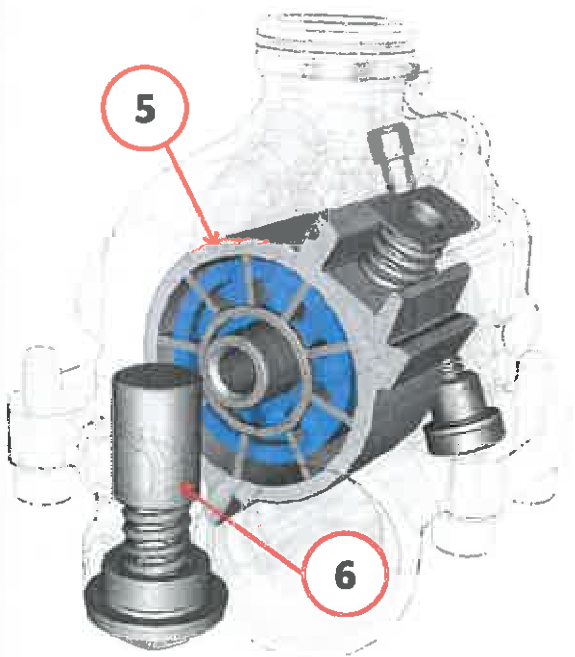

Key:
1 – Oil pump float.
2 – Pump body.
3 – Pump actioning gear.
4 – Pump supply.
5 – Mechanical regulation of the oil flow towards the sump drain.
6 – Oil drain towards the sump intercepted by the oil drain solenoid valve regulator.
7 – Oil intake (this entry's function is to allow for regulator 5 to function properly).
8 – Oil supply pressure regulation.

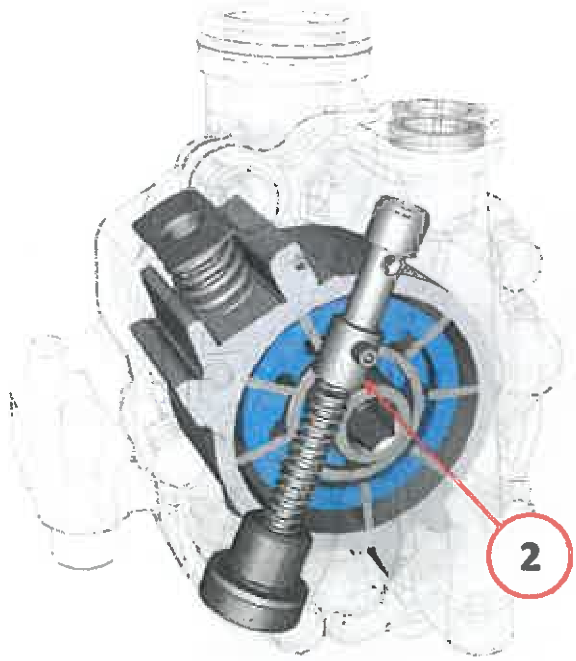
*Diagram of the variable displacement pump operation.*

To vary the oil pump displacement, the $ECM_1$ Master uses an electronic that regulates the oil drain towards the sump.

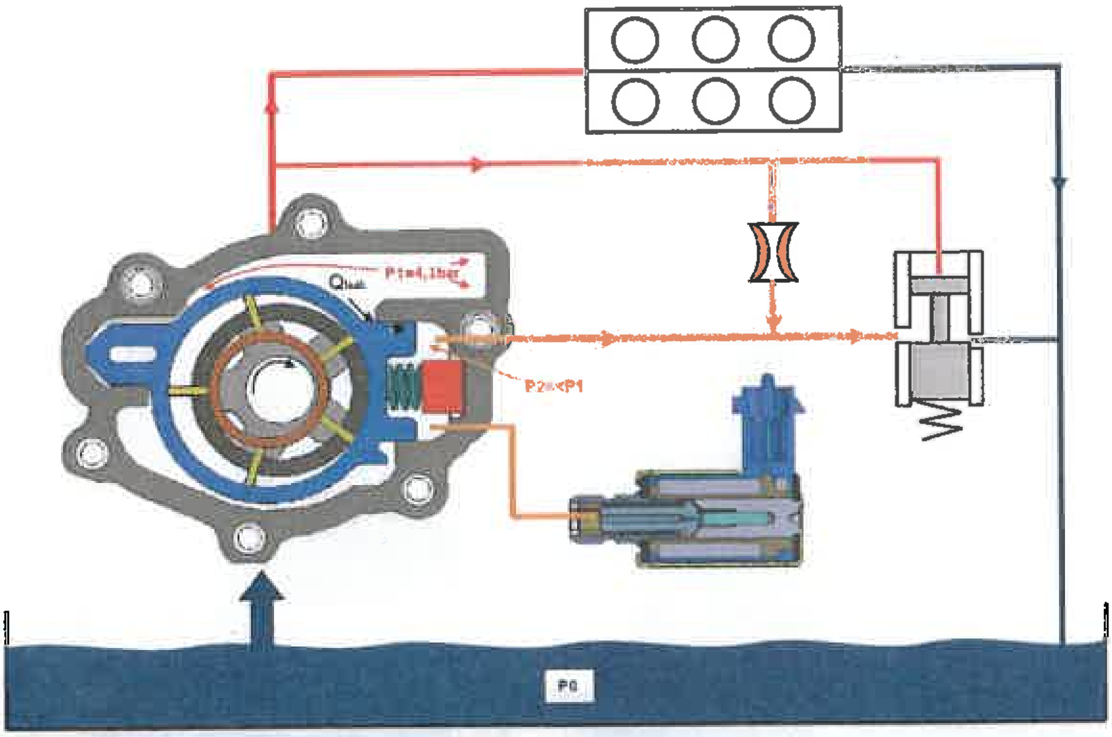



Key:
1 – Solenoid valve to regulate the oil pump drain.
2 - Mechanical valve to regulate oil drain.
3 – Restriction to reduce pressure.
4 – Pump body.
5 – Pump floating stator.
6 – Supply pressure regulator.

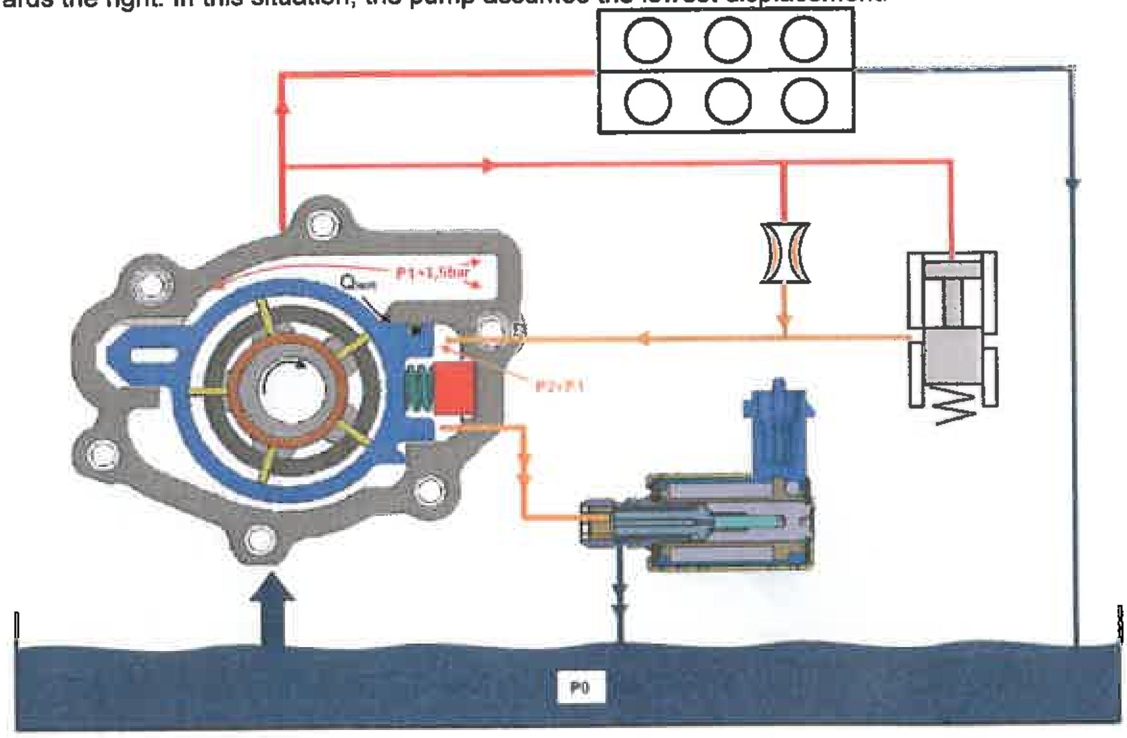


The pump changes its configuration when the $ECM_1$ Master controls (in earthing On/Off) the solenoid valve that regulates the oil drain. When this last is not controlled, the pump is in maximum displacement.




When the solenoid valve is Off, the pump's floating stator is completely moved to the left because the pressure in the oil drain chamber (to the left of the stator) is about equal to the sent oil supply.
When the solenoid valve is On, the oil in the chamber to the right of the stator goes into drain and consequently the oil pressure there decreases significantly, determining the stator's movement towards the right. In this situation, the pump assumes the lowest displacement.

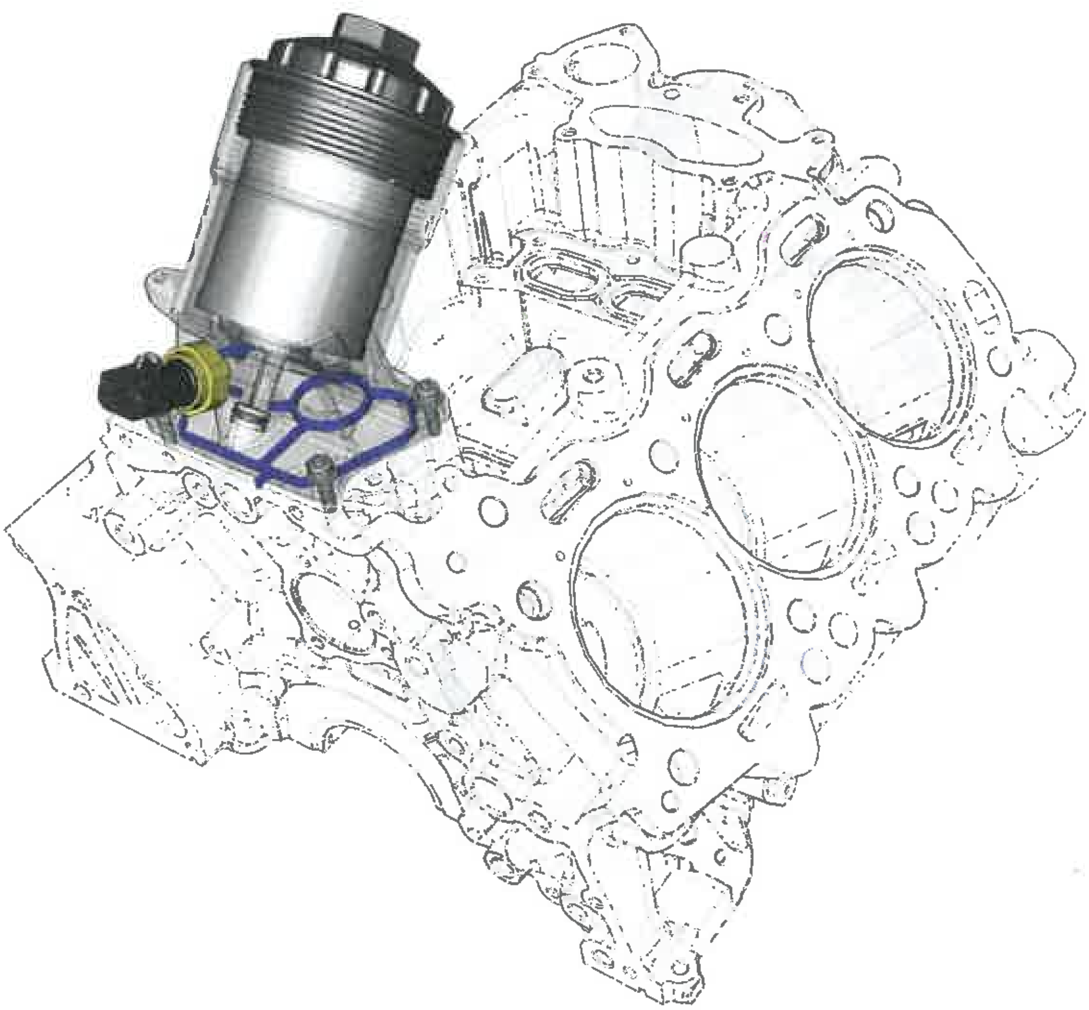


In conditions of minimum displacement, the pump transfers the oil supply enough power so it assumes a low pressure value (LP).
In conditions if maximum displacement, the pump transfers the oil supply enough power so it assumes a high pressure value (HP).

The nominal pressure values are as follows:
HP – 4,1 bar ±0,3bar a 4000 rpm ±100rpm - engine charge >50% - T oil 90°C ± 5°C.
HP – 1.5 bar ±0,3bar at 2500 rpm ±100rpm - engine charge >20% - T oil 80°C ± 5°C.

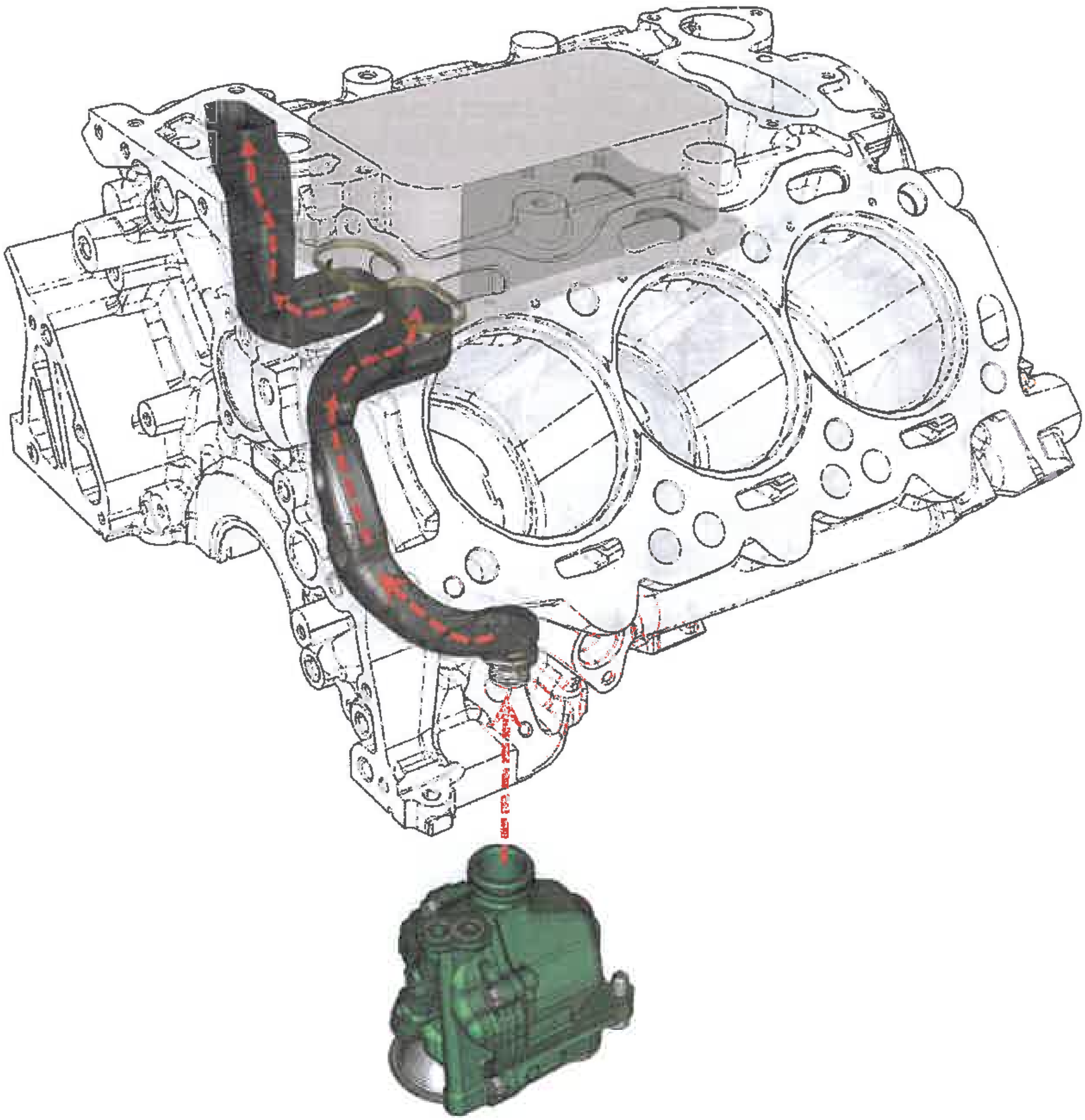
*Oil filter.*

The oil filter is the cartridge type and located on the bed between the two banks (transmission/timing side).



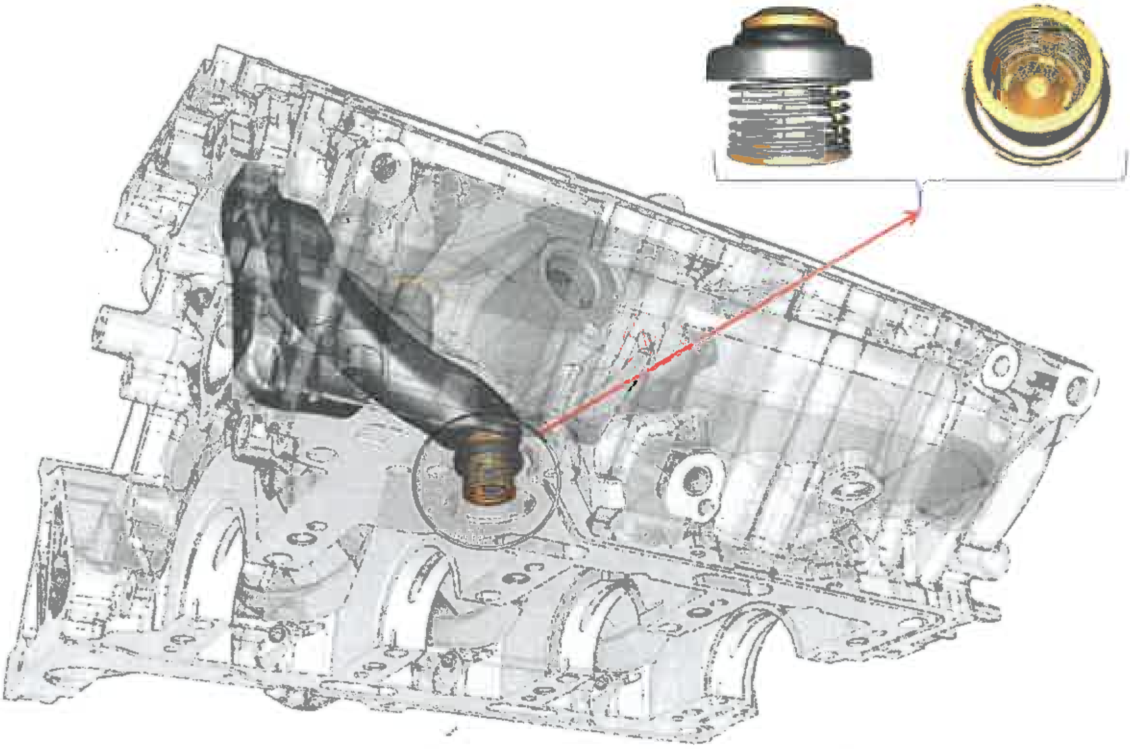
The oil pressure sensor is positioned on the filter support. There is a rubber gasket on the filter support interface and the bed.

The oil pump exit corresponding to the supply is inserted on the housing created in the engine bed.

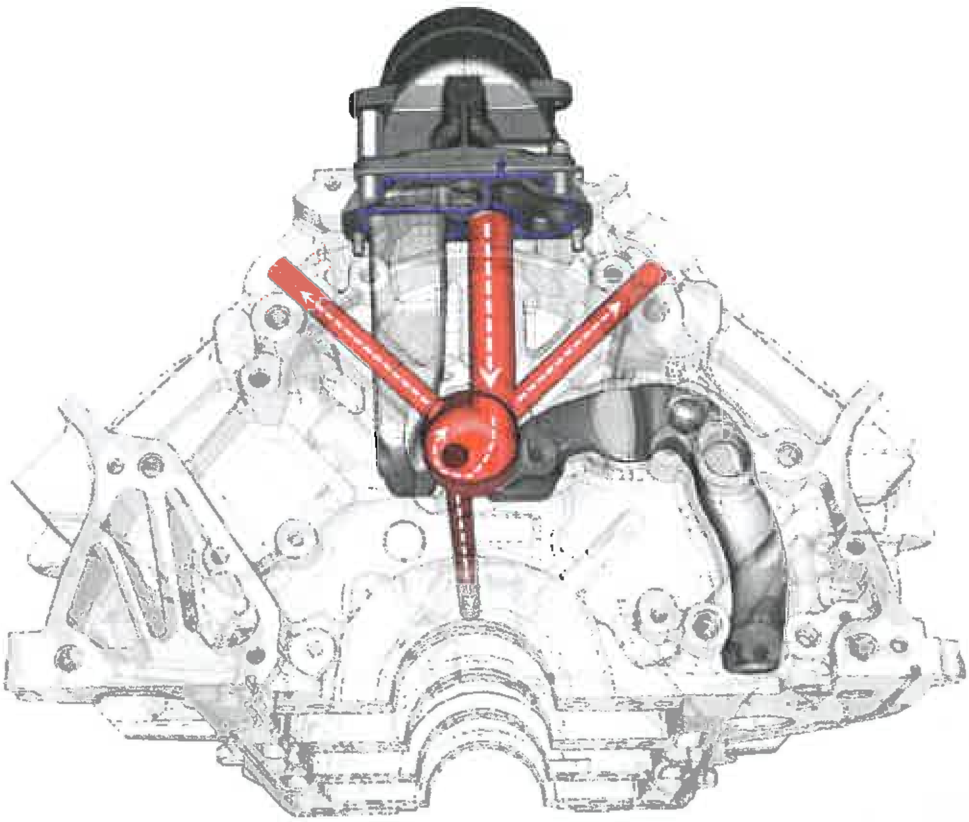


The outgoing oil from the pump raises the bed along the channel to the heat exchanger inlet placed between the two banks. Once cooled, the oil goes out of the exchanger to head towards the oil filter inlet where it will be filtered.

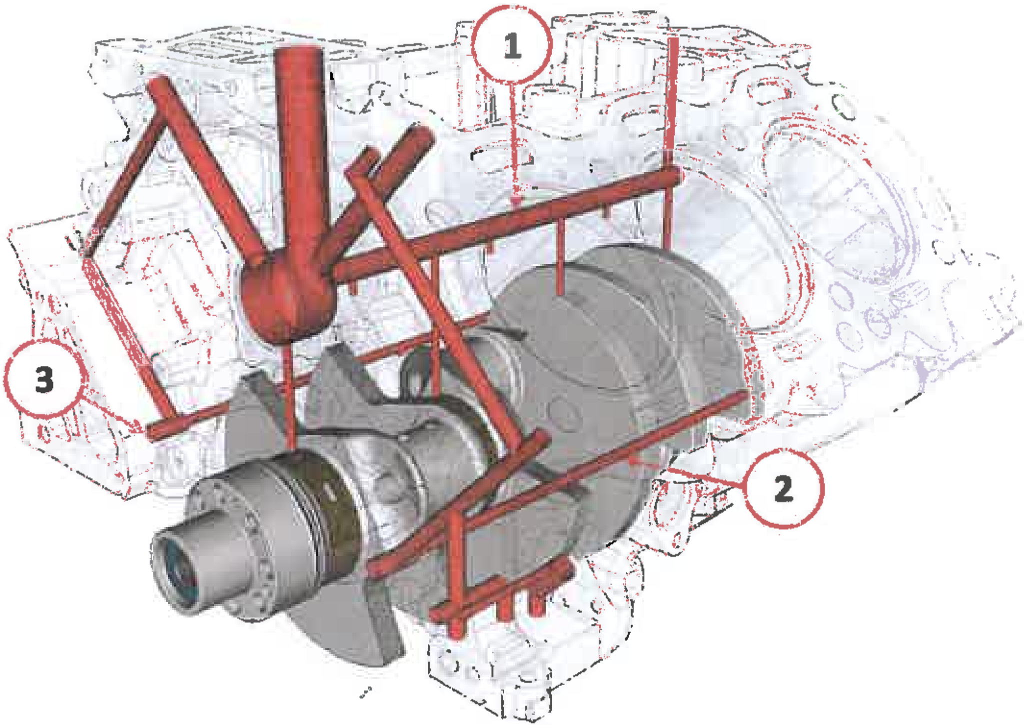
There is a single directional mechanical valve in the bed housing where the oil pump supply is inserted that allows the oil to pass only from the pump to the bed and not the other way.



Once filtered, the oil comes out of the filter and runs along the main conduit to reach a timing chamber where the oil is misted towards the cylinder heads and in the bed lubrication's main channel.



The channels carrying oil to the camshaft bank ball bearings are connected to the main bed lubrication.




Key:
1 – Main lubrication channel in the bed.
2 – Oil feed channel for the piston crown cooling nozzles (right bank).
3 – Oil feed channel for the piston crown cooling nozzles (left bank).

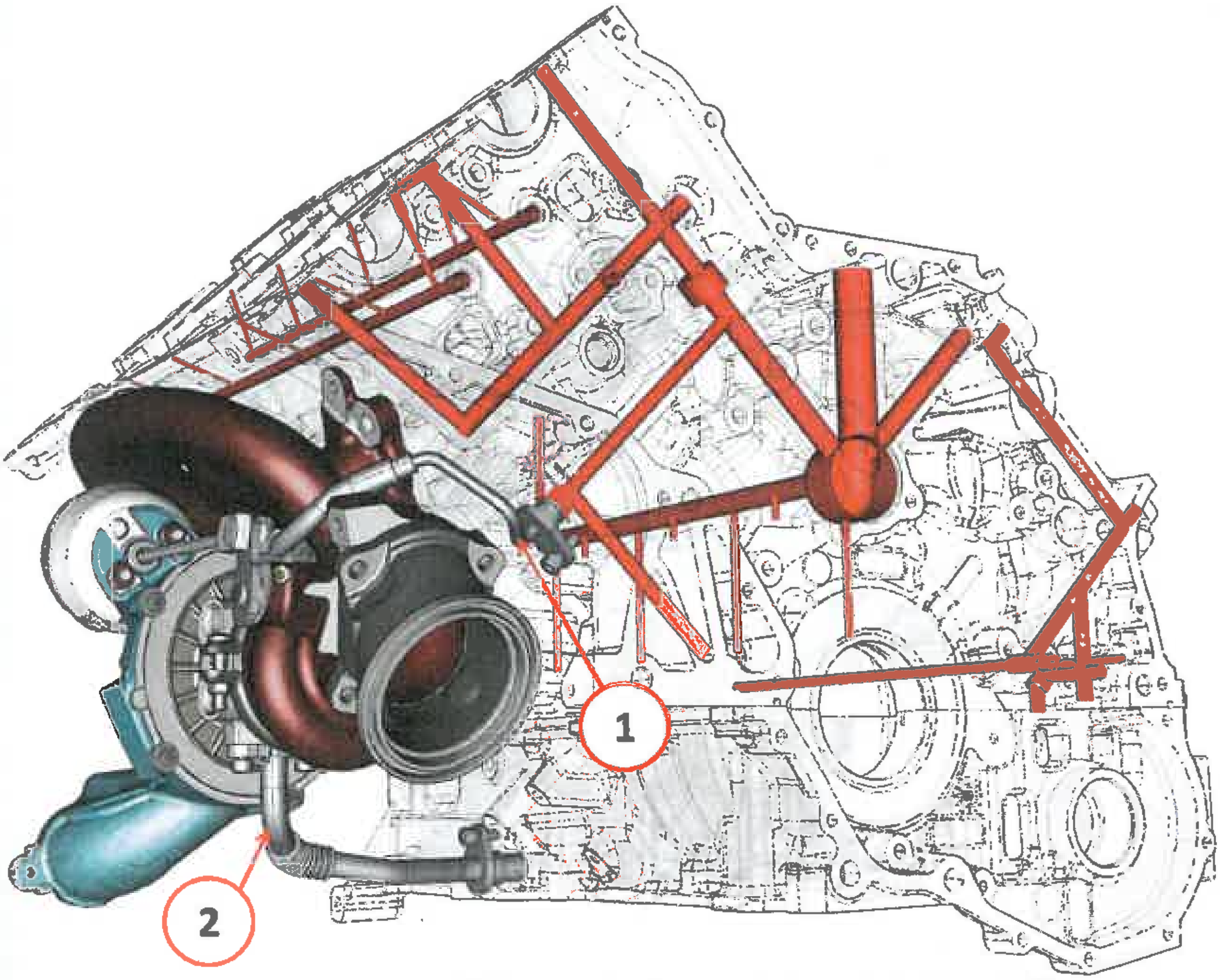
From the oil feed channels for the cylinder heads, through the right connections, the oil arrives where it can supply the conduits that take the oil to the side drain nozzles used to aim the stream under the piston crowns to ensure their cooling.

There is also another series of nozzles that cool the piston on the intake side.

*Turbocharger lubrication*

The two turbochargers get lubrication oil for the interior bushing from the pipes connected to the two bed sides.

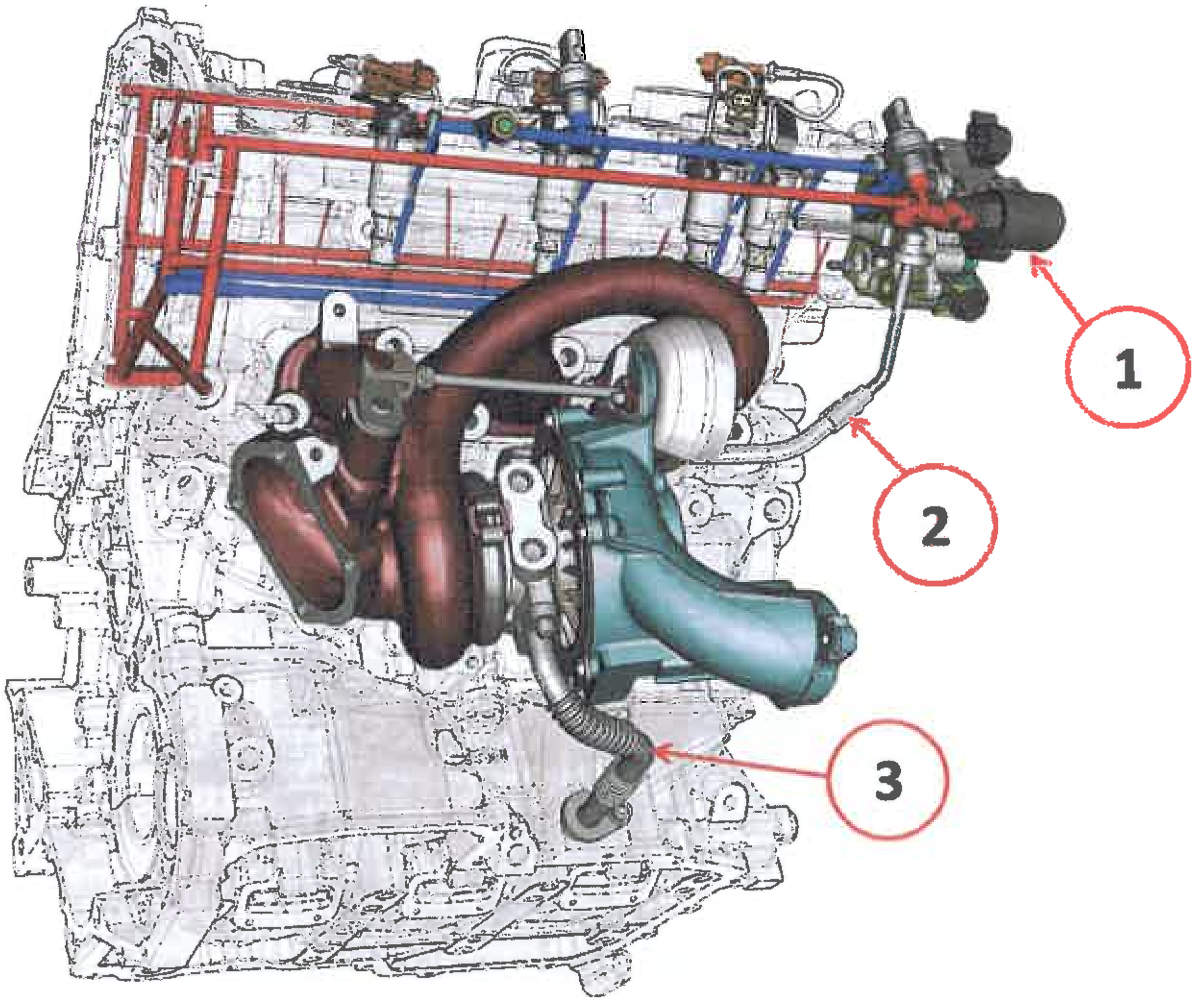
*Left bank turbocharger.*




The left bank turbocharger uses the oil flow coming from an internal bed channel. This last is connected to the channel that carries the oil towards the cylinder heads. The oil is carried to the turbocharger body inlet through the pipe (1). After lubricating the camshaft bushing impellers, the oil flows back from the turbocharger to fall back into the oil sump through the pipe (2).

*Right bank turbocharger.*

The right bank turbocharger receives the lubricating oil from the cylinder heads.




The oil in the turbocharger inlet is regulated by a solenoid valve placed on the cylinder heads. The reason there is a solenoid valve to control the oil flow is because there is a cylinder deactivation system in the right bank. Greater detail on how the system functions is shown in the specific chapter of this document.

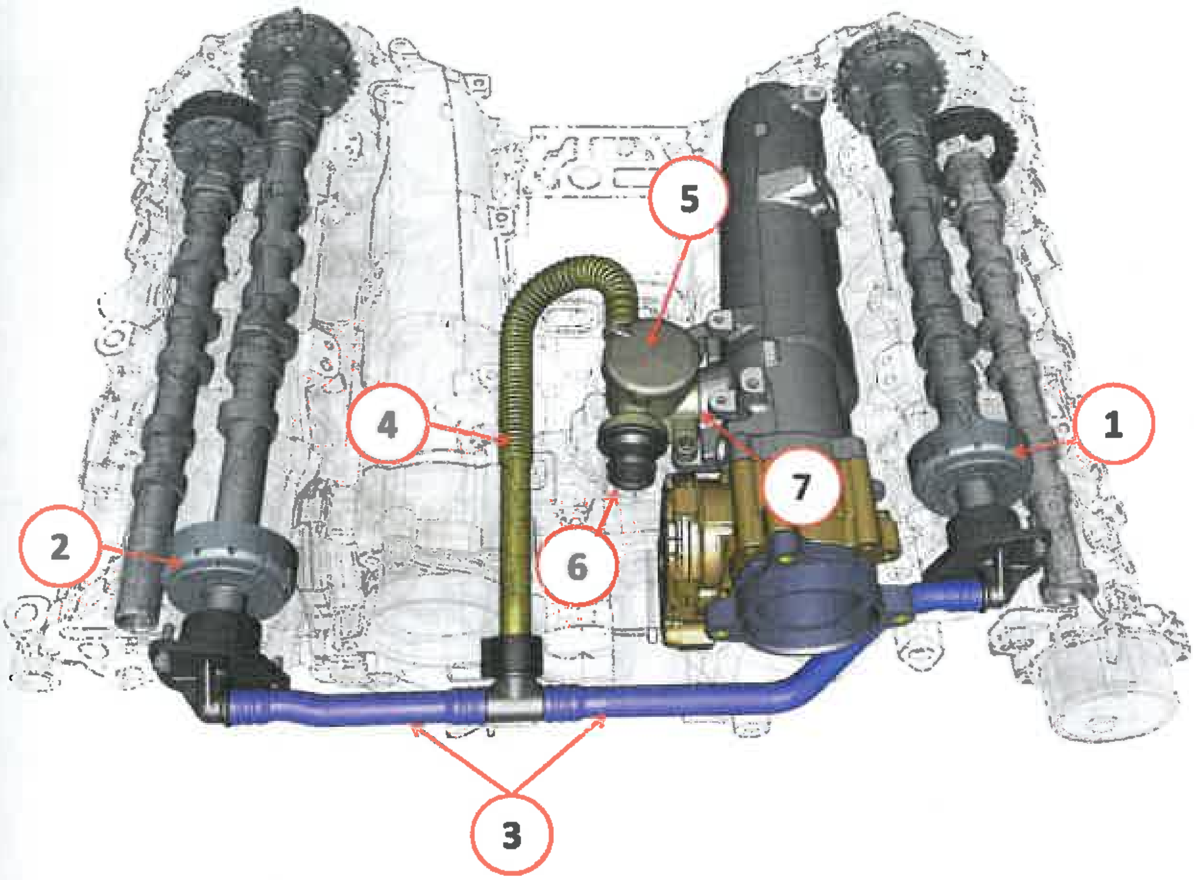
When the solenoid valve allows its passage, the oil arrives through the pipe (2) to lubricate the camshaft bushings that connect the two turbocharger impellers.

The oil leaves the turbocharger and drains off via pipe 3.

**Oil vapour recirculation system (Blow-by).**

The vapour recirculating system channels these last towards separators, whence then the vapours are sent to the engine air intake system to be burned in the combustion chamber.

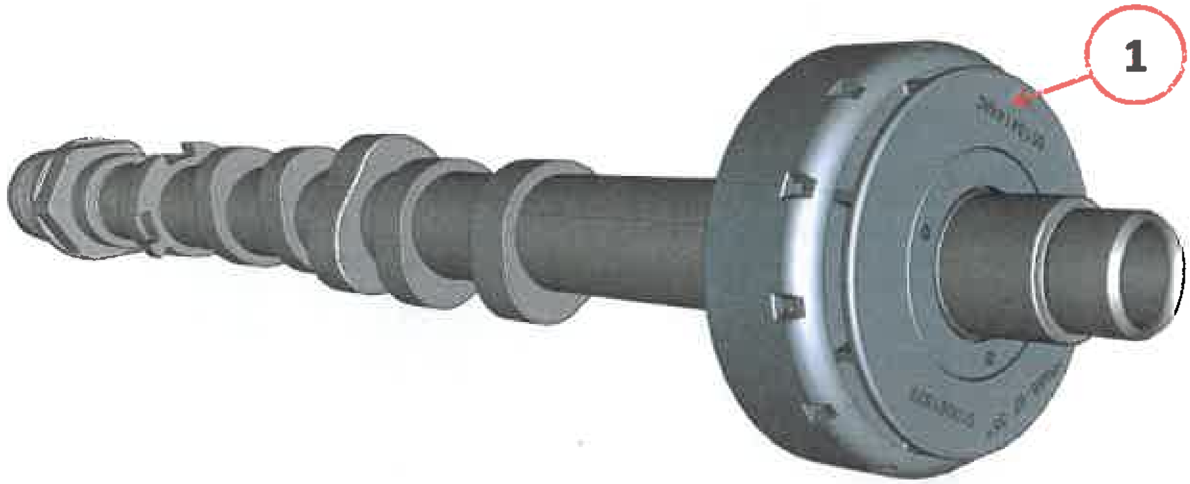
The system consists of the following components:




Key:
1 – Left bank oil vapour separator.
2 – Right bank oil vapour separator.
3 – connection pipe for the two separators.
4 – Inlet pipe for vapours to the by-pass diaphragm.
5 – Diaphragm valve for by-pass and maintaining depression in the block.
6 – Oil vapour outlet towards the left bank turbocharger air intake sleeve.
7 – Oil vapour outlet towards the left bank collector.

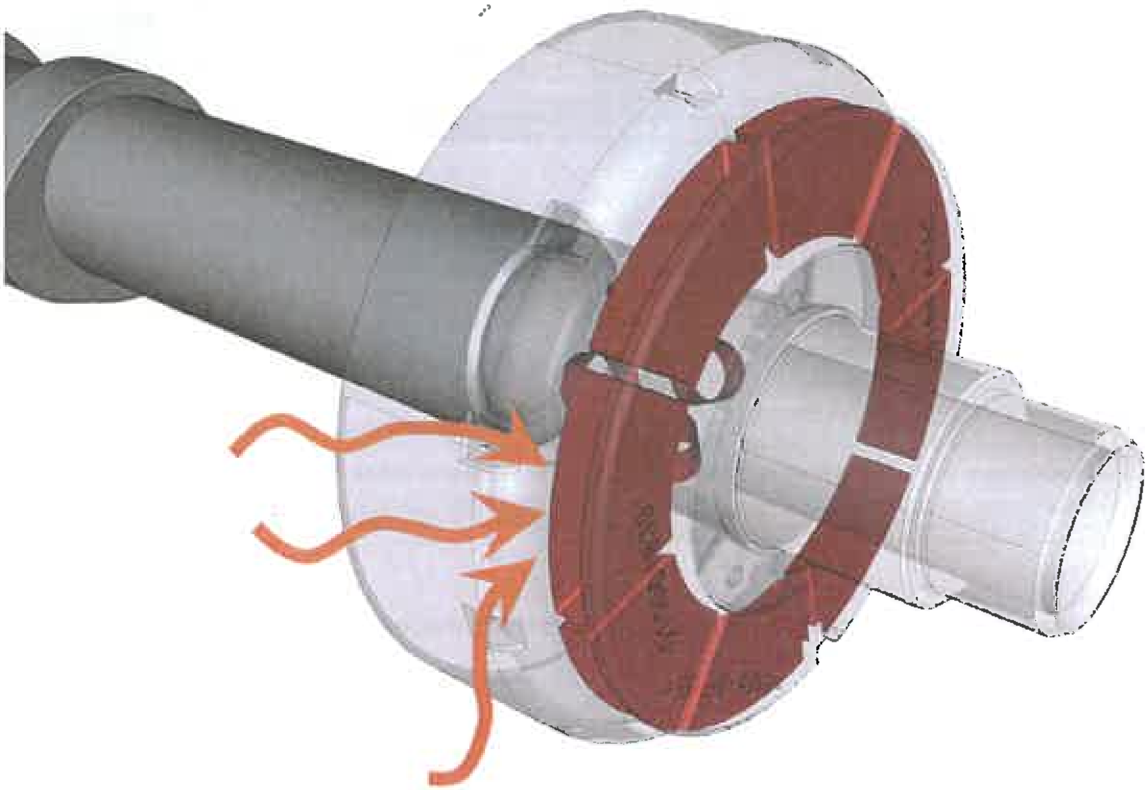
The oil vapours are recirculated and sent exclusively to the left bank air intake system. The result is that they are burned only in the same bank's cylinders.

<u>*Oil vapour separator.*</u>



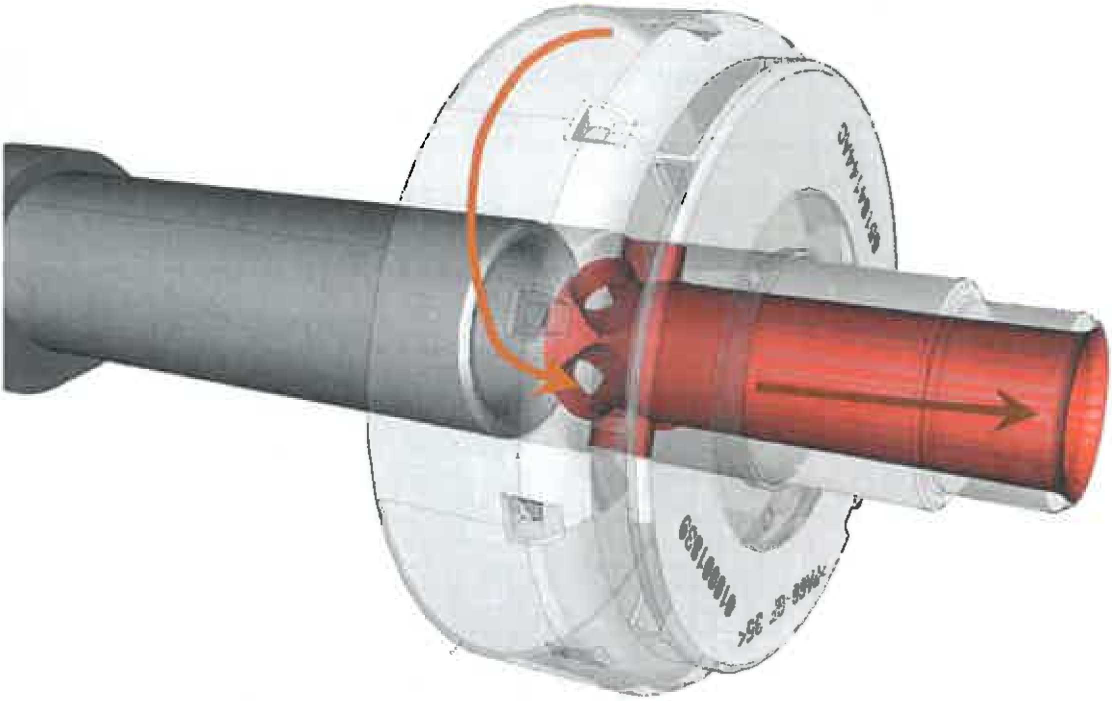

Key:
1 – Oil vapour separator.

The two engine banks have to collect the oil vapours and separate them from the oil drops in suspension.
The right and left bank oil vapour separators are moved from their respective axes to the intake cams.



The oil vapours are recalled by the separator because of the depression that this last creates following its rotation. Once in the separator, the centrifugal force pushes the droplets in suspension towards the separator walls themselves, causing the droplets to separate from the vapours.

The vapours exit through the holes in the separator's interior walls, then they are conducted along the pipe that will unite them with the vapours coming from the other bank. After which, they head towards the by-pass diaphragm valve.

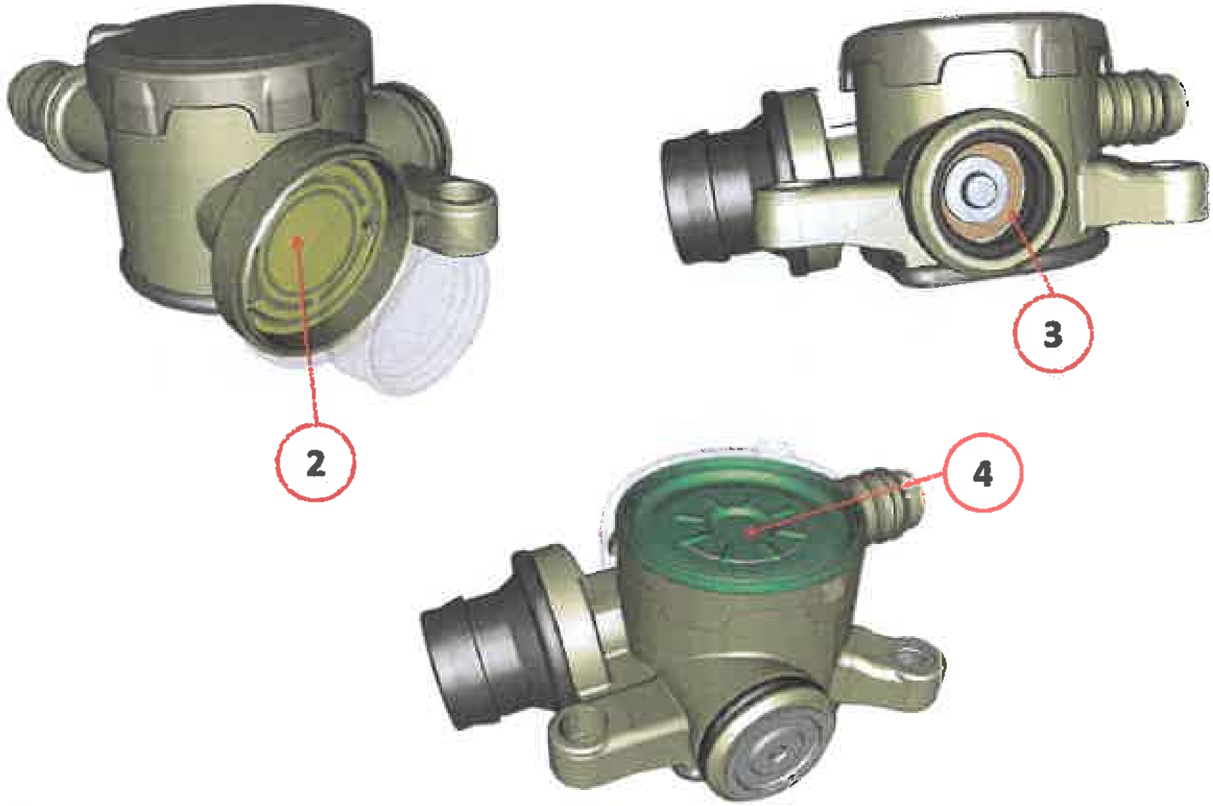


*Diaphragm valve for by-pass and regulating depression in the block.*

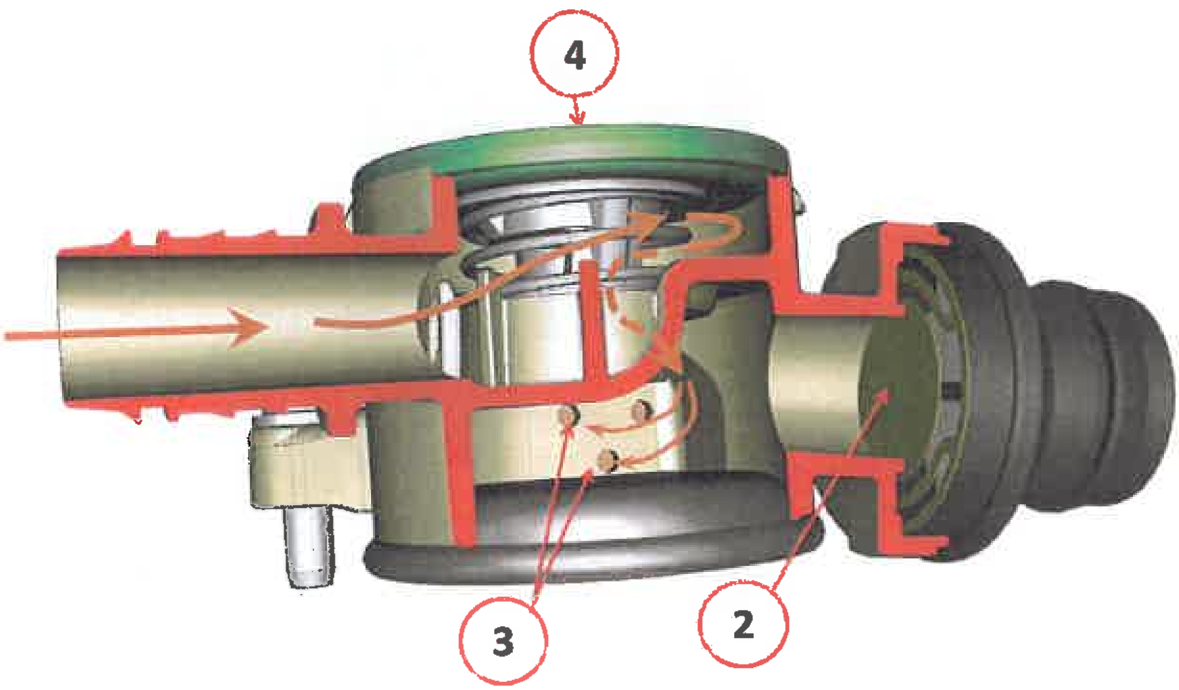
The valve diverts the vapour flow to the downstream environment, which is in depression at that time.


Key:
1 – Oil vapour inlet from the separators.
2 – Outlet of oil vapours towards the turbocharger intake.
3 – Outlet of oil vapour flows towards the intake collector (after the throttle body).

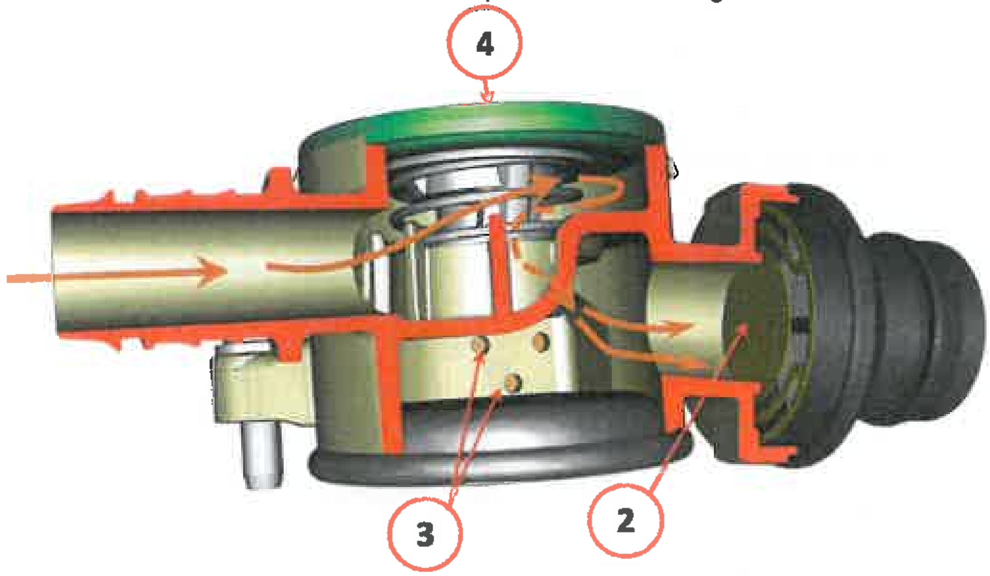
Inside the valve there are diaphragms that are affected by the depression of the environment with which the valve is in contact. The diaphragm's movement determines the oil vapour flow direction.



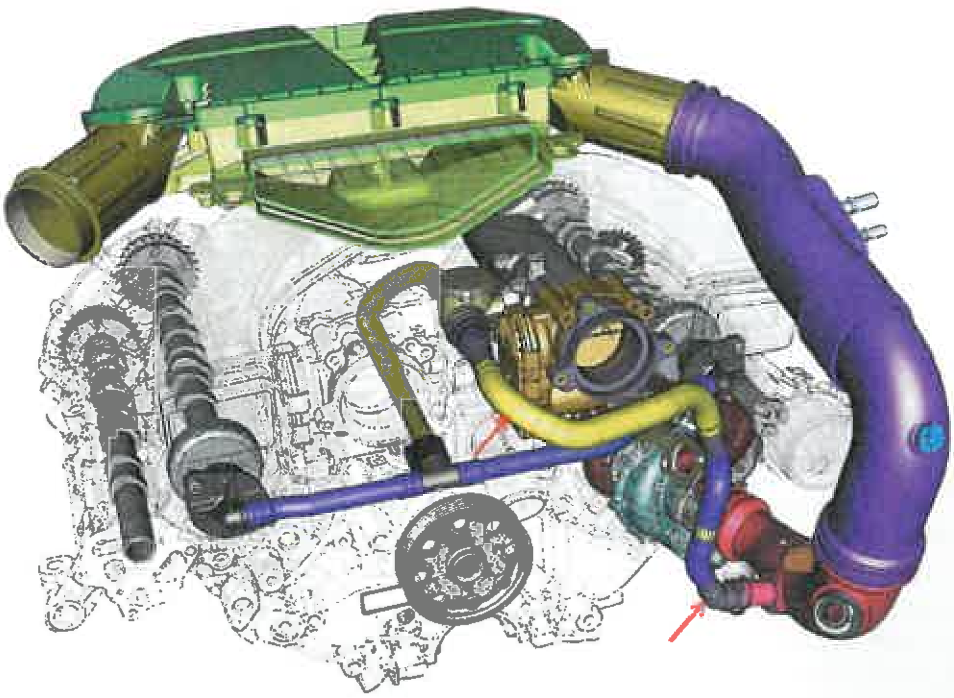

Key:
2 – Outlet hole diaphragm for oil vapours towards the turbocharger.
3 – Outlet hole diaphragm for oil vapours towards the intake collector.
4 – Diaphragm placed in the valve's upper area.



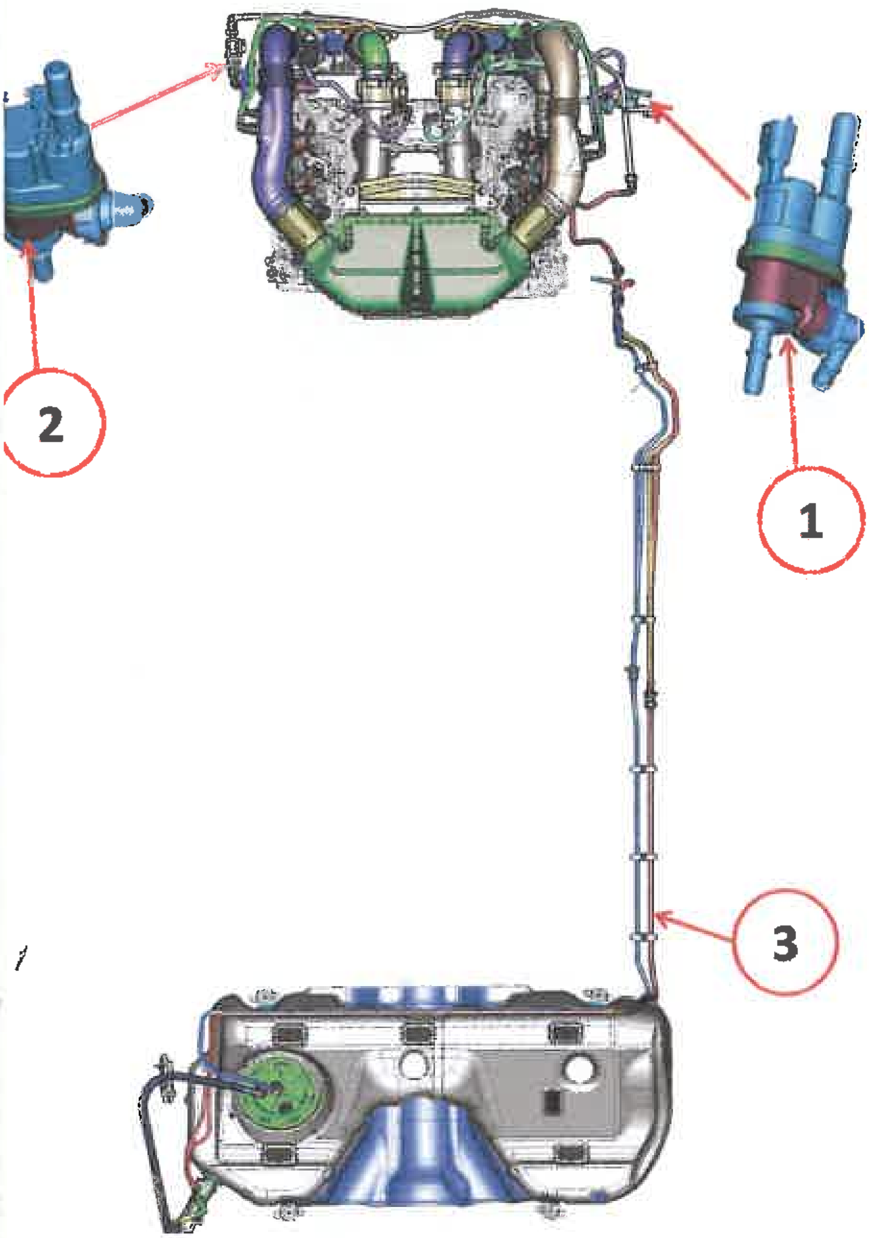
The valve has two internal chambers. The first (upper) is the one that accepts the oil vapours coming from the separators. The second (lower) is the chamber that connects the two outlets (2) and (3). The upper and lower chambers are connected. The oil flows coming into the upper chamber go towards the lower one, but the passage is regulated by the diaphragm (4).. This last is affected by the environmental depression that the two outlets are connected to (2) and (3). If for example, the engine is operating with the throttle body in a minimally closed position, the intake collector is in strong depression. It follows that diaphragm (3) opens the passage and consequently the diaphragm (2) closes. The result is that the oil vapour flows towards the intake collector.
If instead the engine is operating in full acceleration with the throttle open, the turbocharger is sucking in a lot of air, creating a vacuum in the air inlet sleeve. In these conditions, diaphragm (2) opens the passage and the diaphragm (3) closes at the same time.
Moreover, diaphragm 4 effectively regulates the depression at which the block must be. The block depression must not exceed certain thresholds to prevent the oil being sucked in.




In the picture you can see the pipe connecting the valve to the intake sleeve that connects the turbocharger to the air filter box.



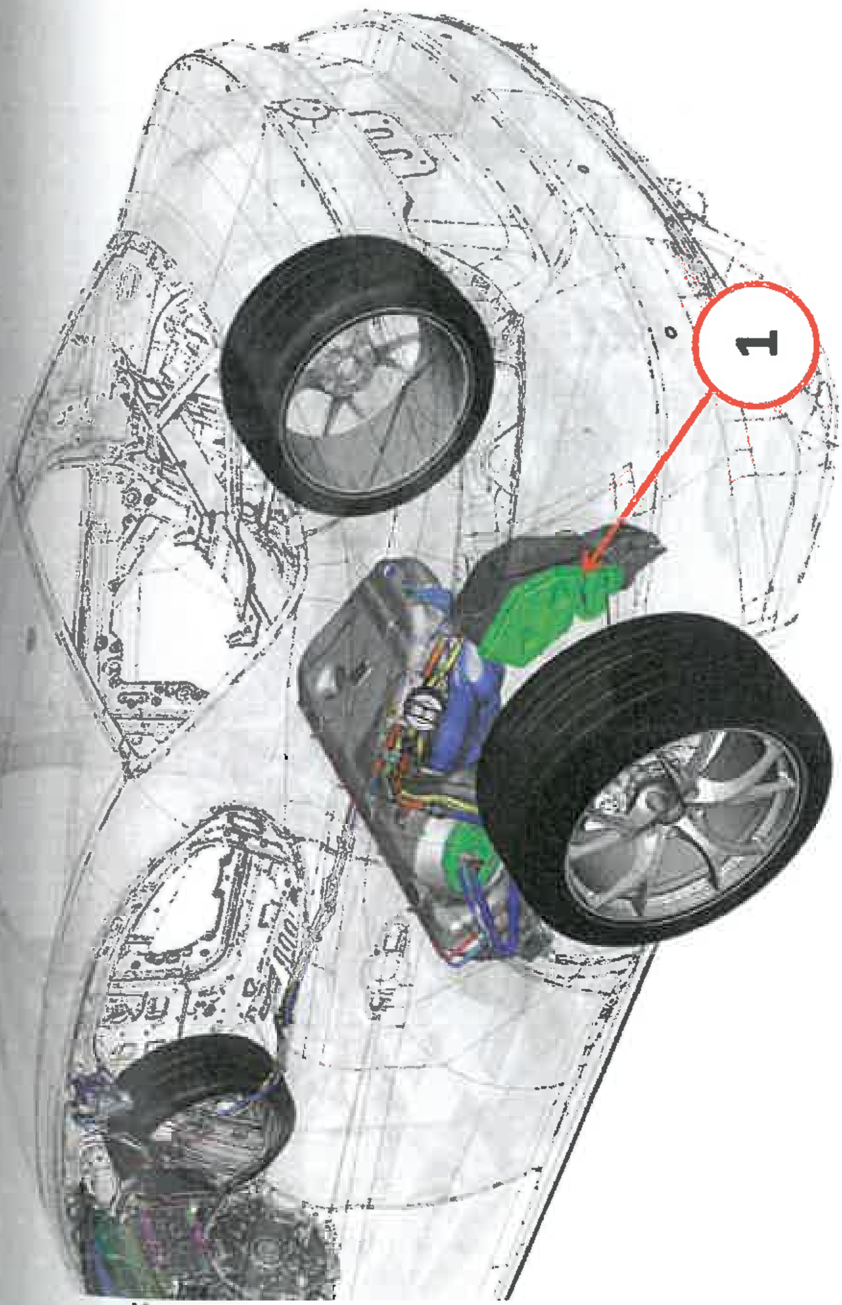
**Petrol vapour recirculation system.**
The vapour recirculation system consists of the following components:



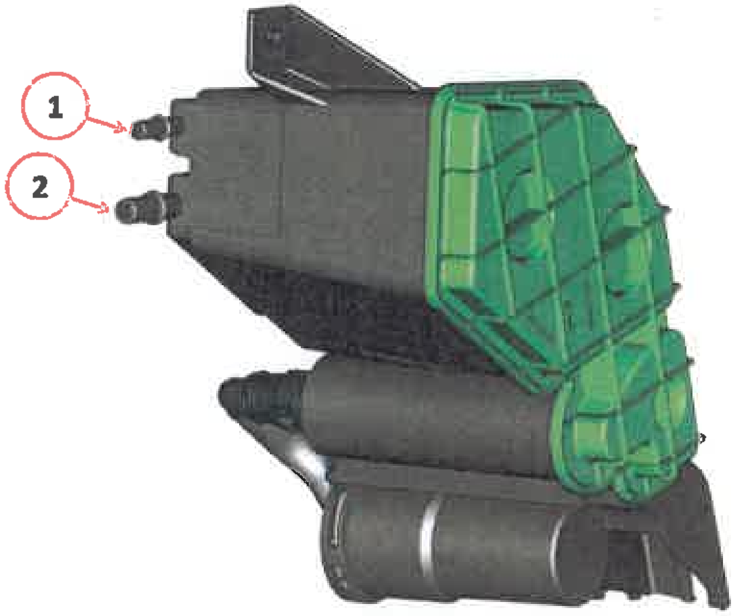

Key:
1 – Right bank solenoid valve canister.
2 – Left bank solenoid valve canister.
3 – Petrol vapour supply pipe from the charcoal filter to the solenoid valve canister.
4 - Active charcoal filter.

## *Active charcoal filter*

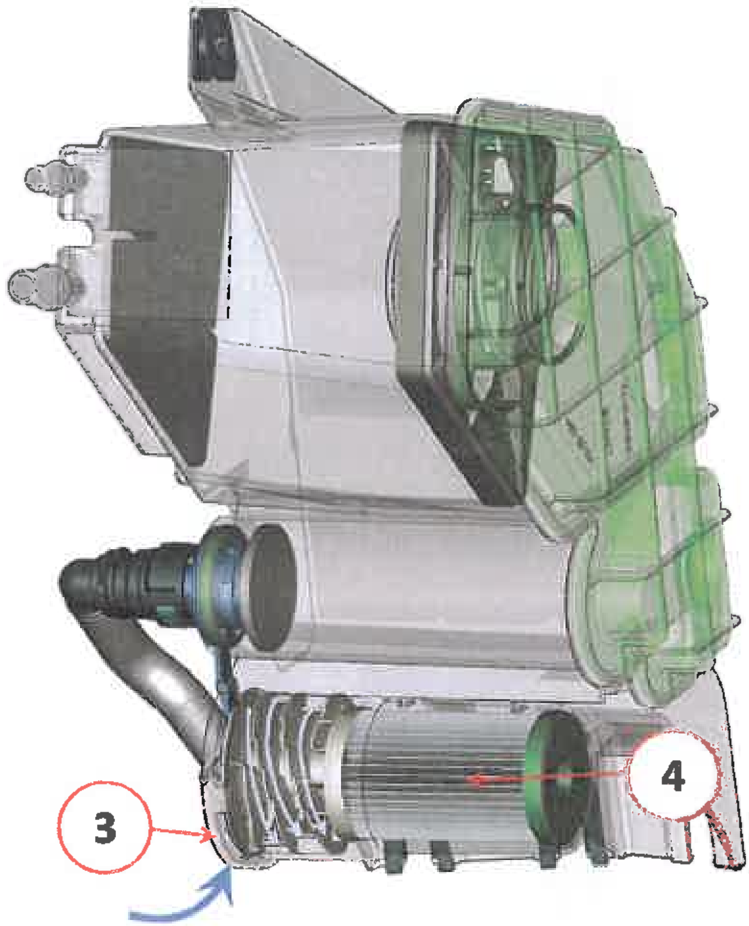
The active charcoal filter is located behind the rear left wheel arches.



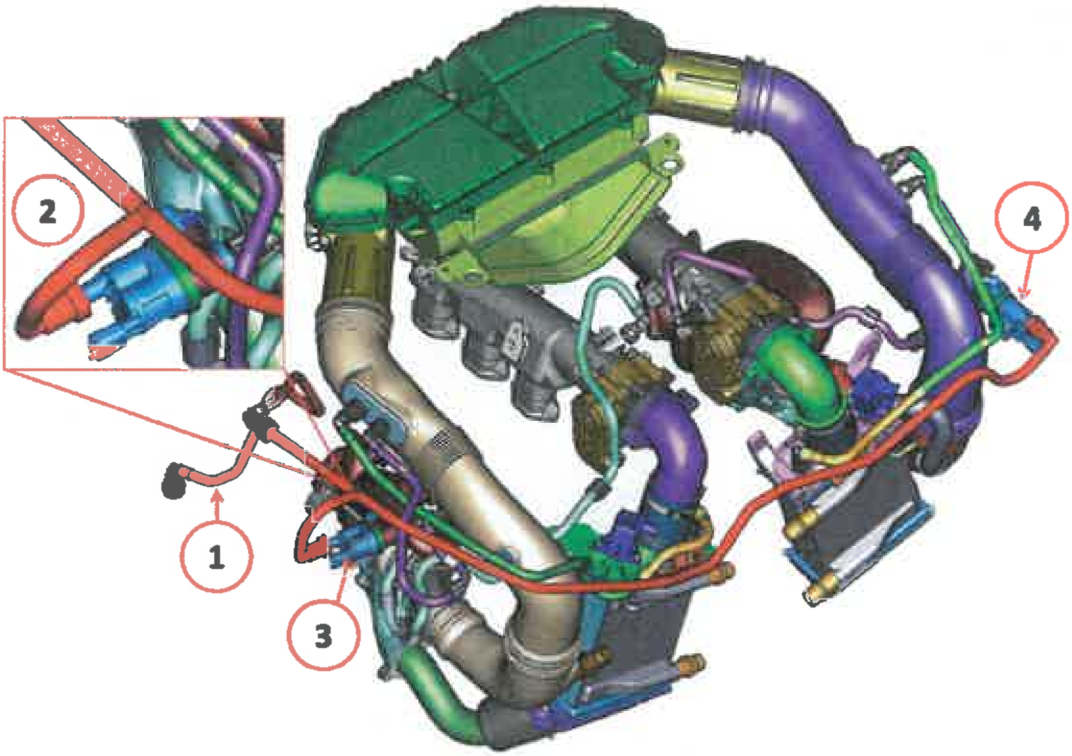

Key:
1 - Activated charcoal filter.




Key:
1 – Petrol vapour intake coming from the combustible tank.
2 – Outlet for petrol vapours from the filter box behind the solenoid valve canister.

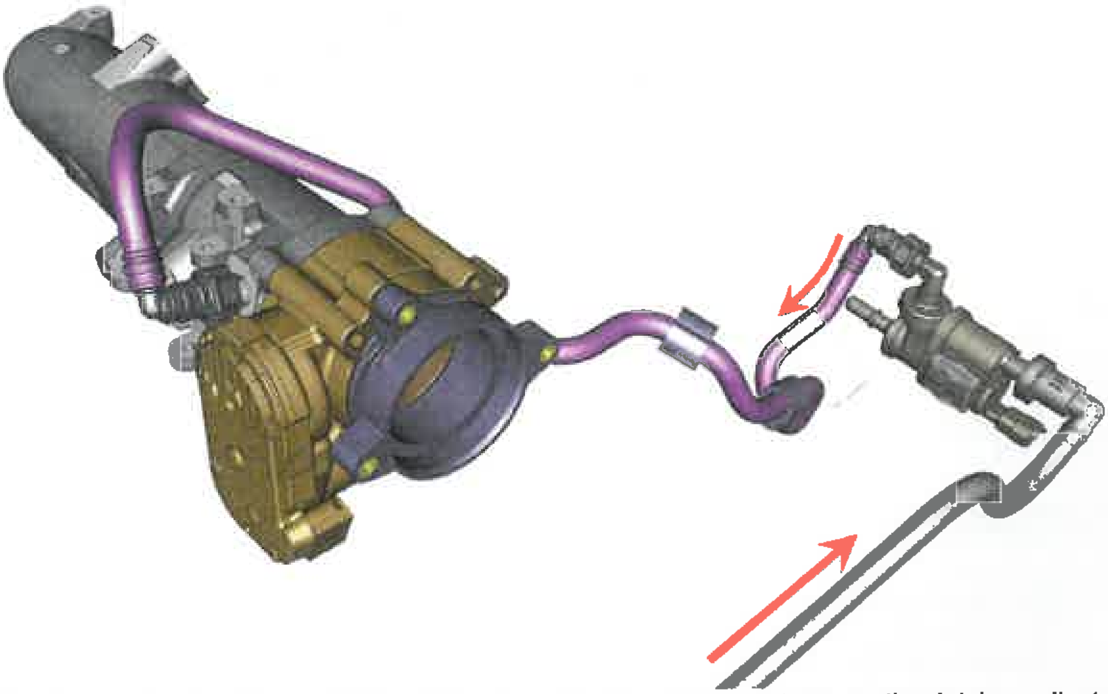



When the solenoid valve canisters are closed, the petrol vapours enter the filter box inlet (1) and move downwards towards the entire box until they reach the active charcoal filter (4) where they are deposited. When the canisters open (controlled by the ECM), the outside air enters the filter through the side slits (3). Under the effect of engine intake, the air constricts the vapours to rise up in the opposite direction to the filter box until they exit via the outlet (2) and are recirculated in the engine intake.



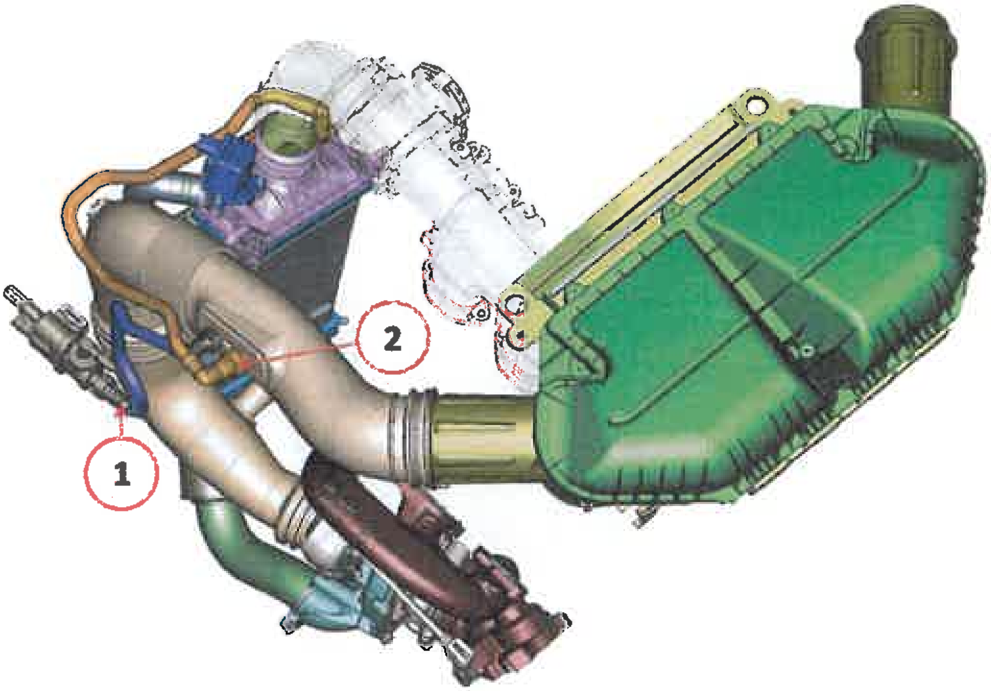

Key:
1 – Petrol vapour piping coming from the active charcoal filter.
2 – T joint.
3 – Right bank solenoid valve canister.
4 – Left bank solenoid valve canister.

The pipe coming from the active charcoal filter is divided into two branches by a T joint. The two branches allow the vapours to be sent to the entry to the two solenoid valve canisters (left and right banks).

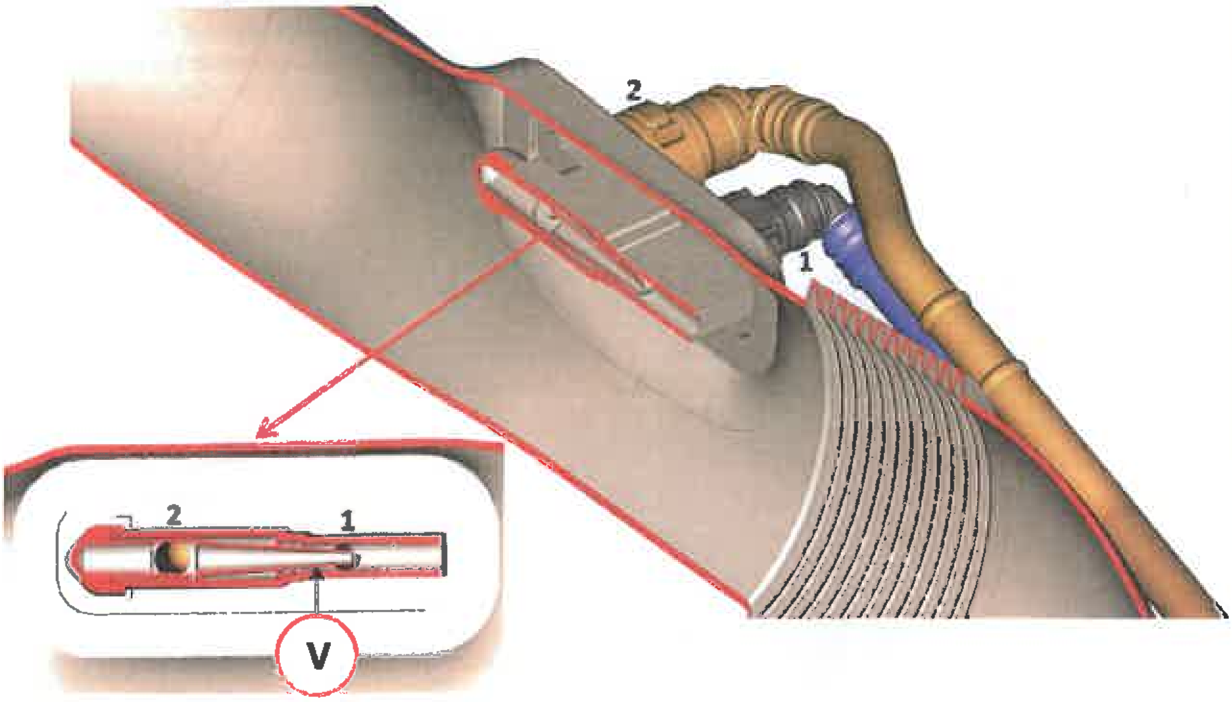


In the image above, the connection from the solenoid valve canister to the intake collector is highlighted.

The vapour recirculation towards the intake sleeve entrance is possible because of a venturi created where the vapour pipe is connected to the sleeve itself.

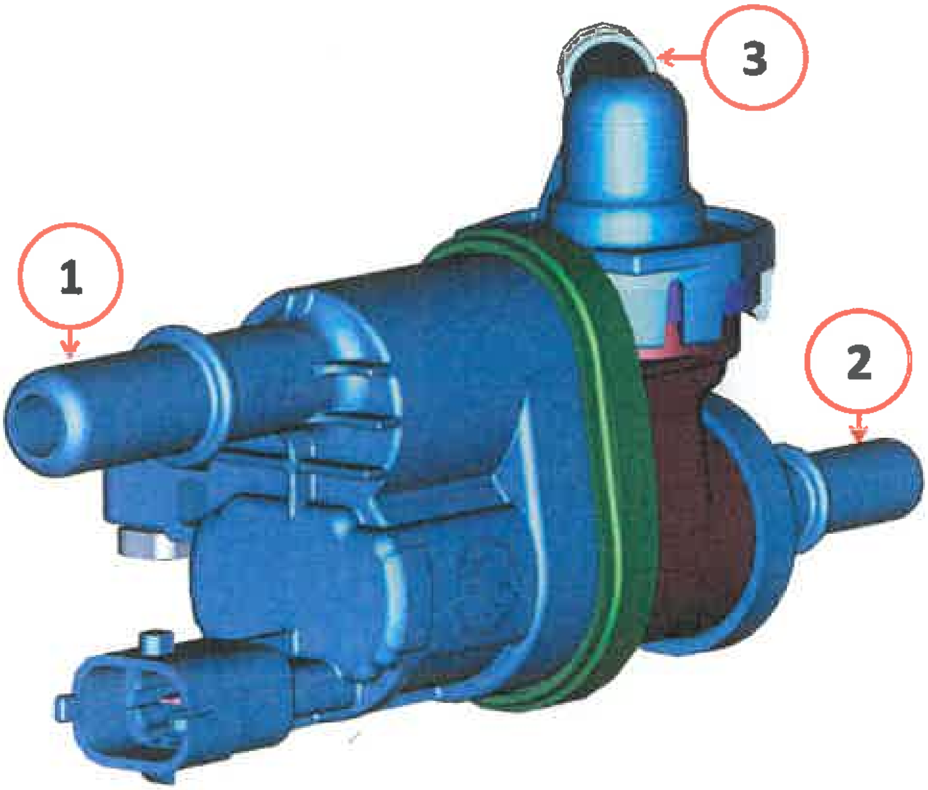



Key:
1 – Solenoid valve canister connection pipe - intake sleeve at the entrance to the turbocharger.
2 – Intercooler air outlet connection pipe - intake sleeve at the entrance to the turbocharger.

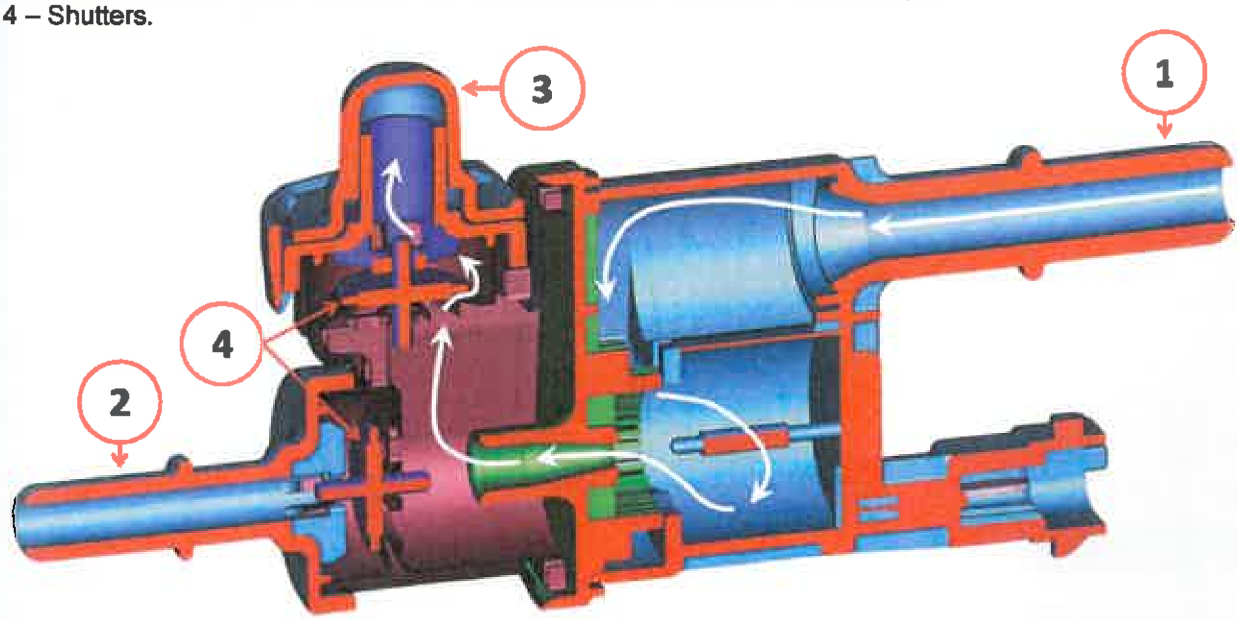



The image shows it all. In point (2), the air under pressure enters from the intercooler. It runs along the "V" channel, creating a venturi effect in correspondence to point (1) where the petrol vapours enter. The venturi effect facilitates the entry of the vapours themselves.

*Solenoid valve canister*



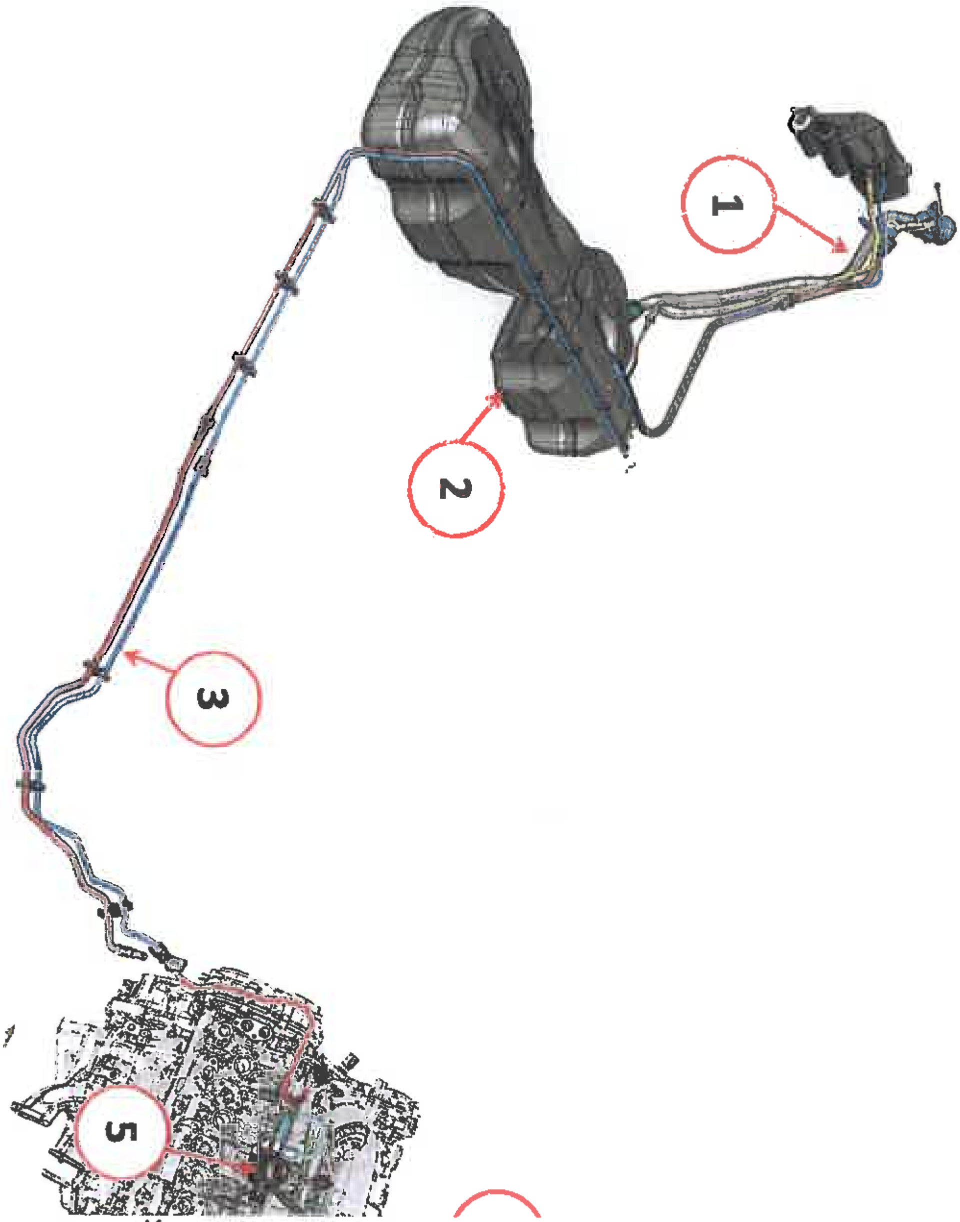

Key:
1 – Petrol vapour entry coming from the active charcoal filter.
2 – Outlet of petrol vapour towards the intake collector (after the throttle body).
3 – Outlet of petrol vapour towards the intake sleeve (air entry into turbocharger).
4 – Shutters.




When the ECM orders the solenoid valve, communication opens up between the petrol vapour entry and exit. If at that time the greatest vacuum ambient is the intake sleeve at the inlet to the turbocharger, the exit shutter (3) opens while the exit one closes (2).

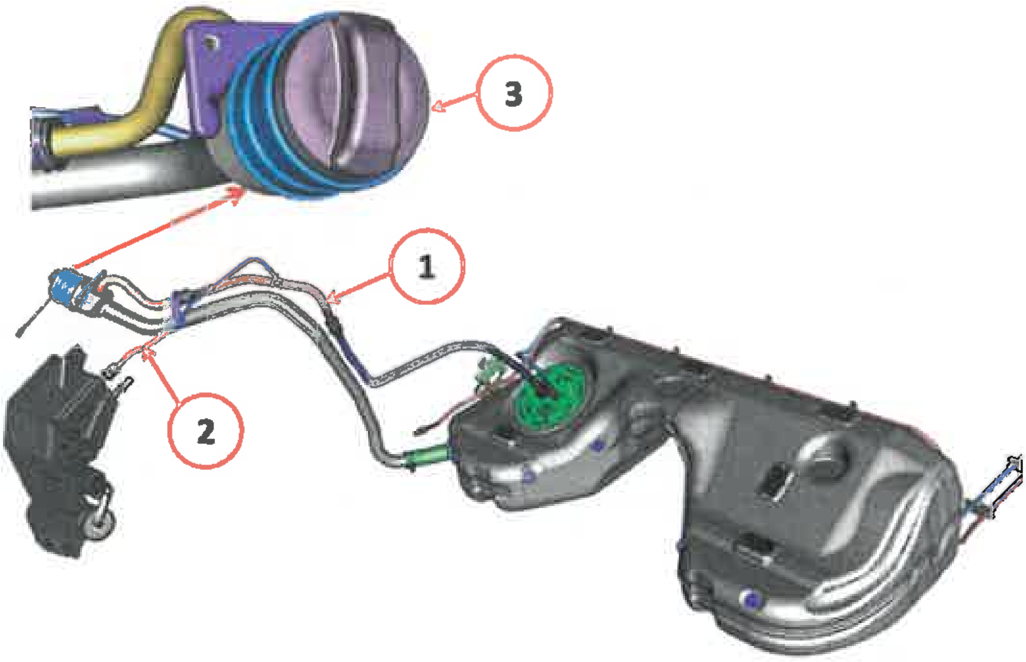
On the contrary, if the greatest vacuum ambient is the intake collector, the exit shutter (2) opens while the exit one closes (3).

**Fuel supply system.**
The system that satisfies the 2.9 V6 petrol engine consists of the following main components:



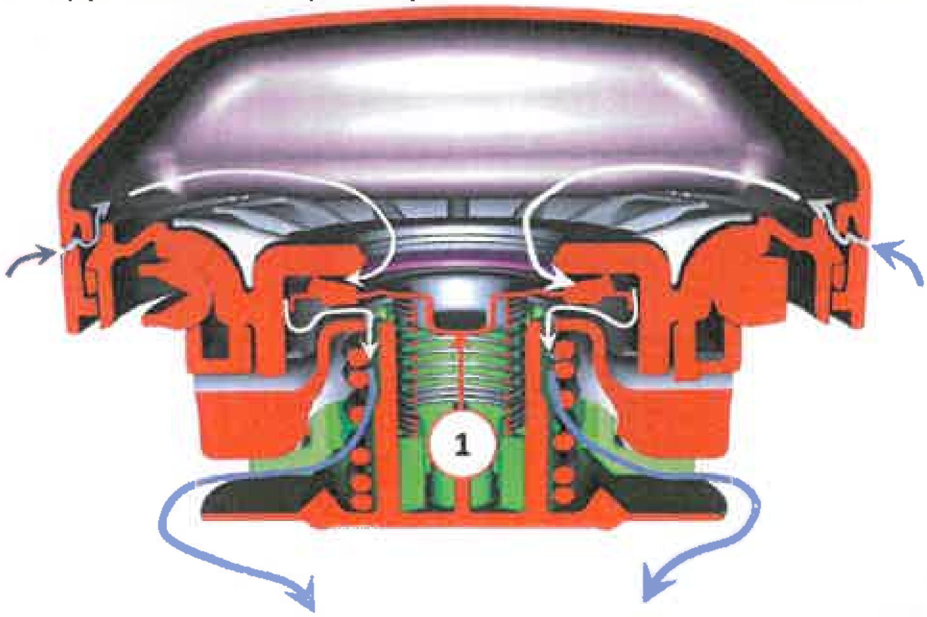

Key:
1 – Refuel tank pipe.
2 – Tank complete with submerged electric pump and level sensors.
3 – Petrol supply pipe from the electric pump to the high pressure system.
4 – High pressure pump (left bank)
5 – High pressure pump (right bank)
6 – High pressure petrol accumulation collector (Rail - left bank)
7 – High pressure petrol accumulation collector (Rail - right bank)

## *Refuelling tank pipe.*

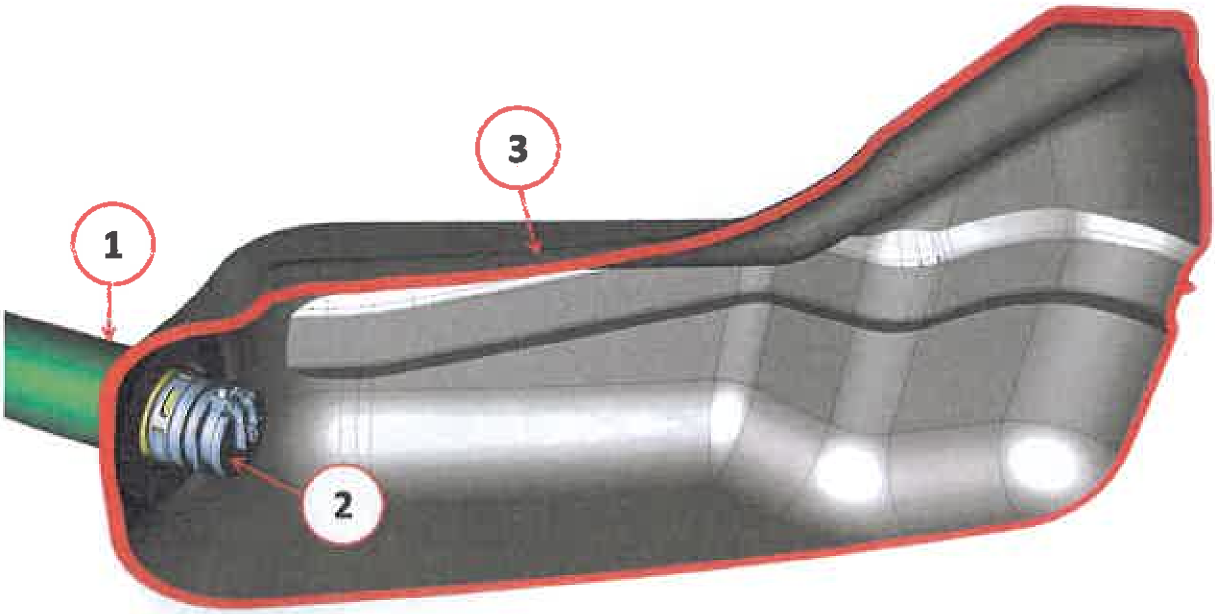



Key:
1 – Overflow pipe.
2 – Petrol vapour inlet to the active charcoal filter box.
3 – Refuelling cap.

The refuelling tank pipe is closed at the end with a cap that has no key-closure device.
The "overflow" pipe is positioned a few centimetres lower from where petrol is introduced. This last is connected with a pipe that carries the petrol vapours to the inlet to the active charcoal filter box.




The petrol introduction pipe's closure cap has a device inside it that allows air to enter the tank but at the same time prevents the petrol vapours from exiting. When the petrol level in the tank goes down, the air ventilation needed to empty it comes in because valve 1 overtakes the spring load (thanks to the depression created in the pipe following emptying) and the air comes in via small slits in the cap's sides.



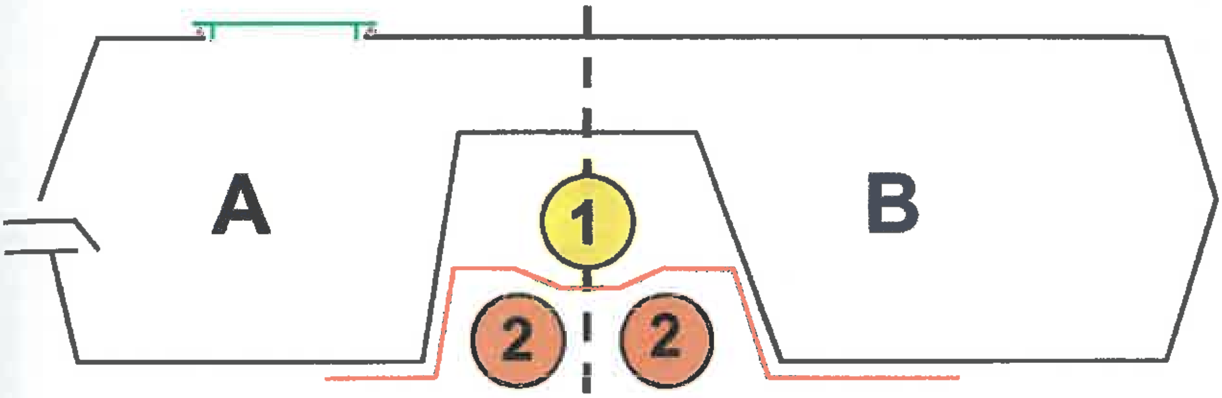

Key:
1 – Refuel tank pipe.
2 – Petrol entry door.
3 – Tank.

There is a small door in the joint in the refuel tank pipe that allows the petrol inside the tank but prevents it (including the vapours) in the tank from going back up the refuelling pipe.

*Tank.*

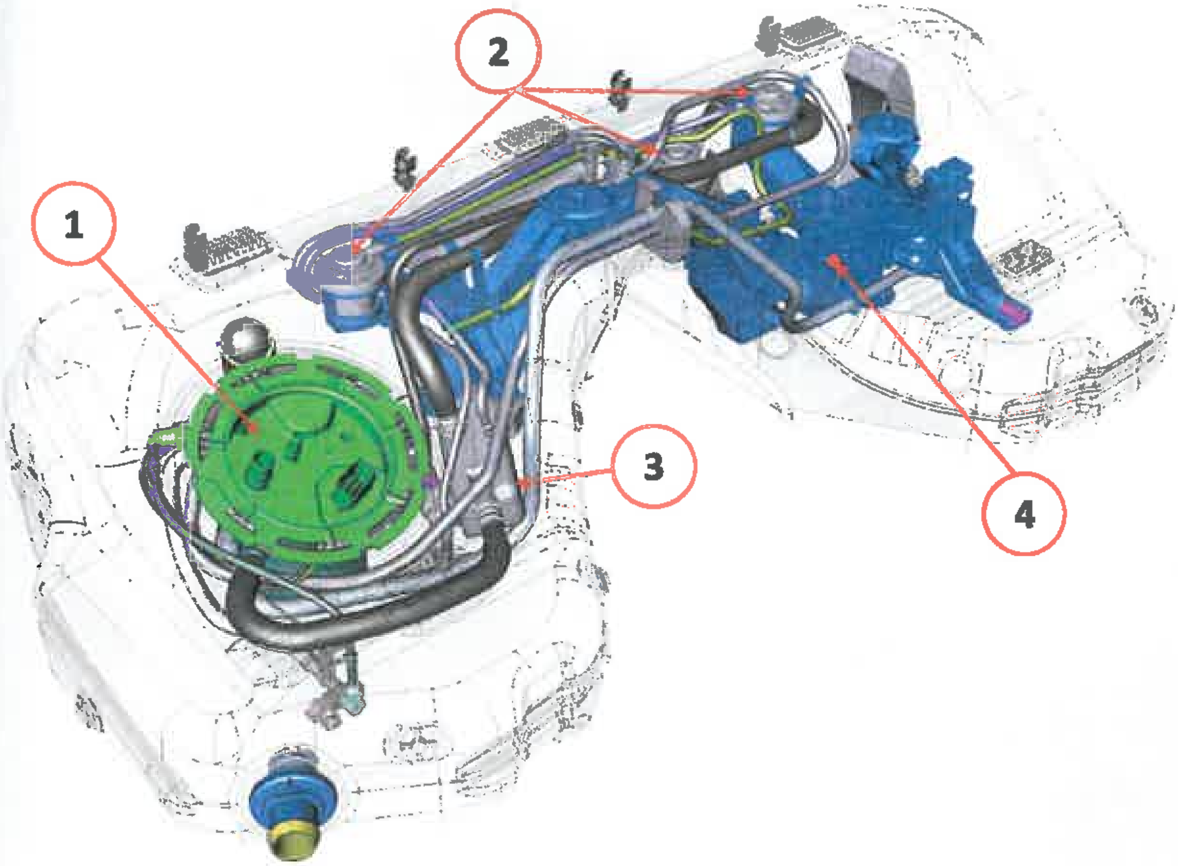
The tank has the classic "saddle" shape in order to create the space needed for the transmission shaft and the exhaust pipes.

It is divided into two communicating chambers: the main chamber A and the transformation chamber B. The second tank is the larger.




Key:
1 – Transmission shaft.
2 – Exhaust pipes.

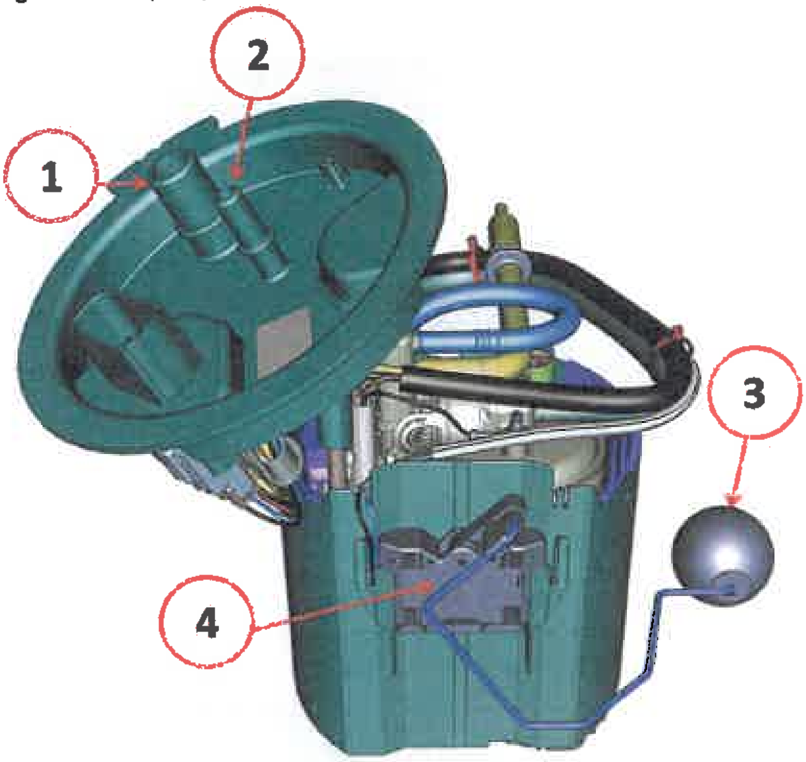
There are devices inside to suction the petrol and send it to the high pressure petrol supply system. There are also devices needed to channel and "vent" the petrol vapours towards the active charcoal filter.



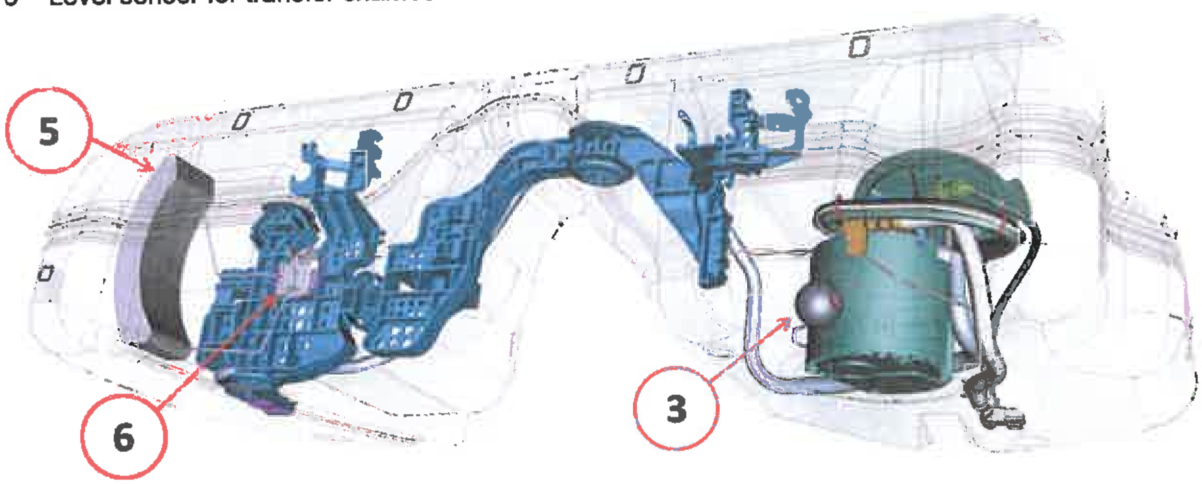

Key:
1 – Submerged combustible electric pump.
2 – Petrol vapour vent valve.
3 – Petrol vapour accumulator.
4 – Anti-shock support.

The combustible electric pump is placed in the main chamber A and is controlled by a special module called a PEM (outside the tank) which supplies electrical power in order to make the pump turn at varying speeds (for greater detail, see the specific paragraph in the Engine Management chapter).

The tank has a single electric pump.

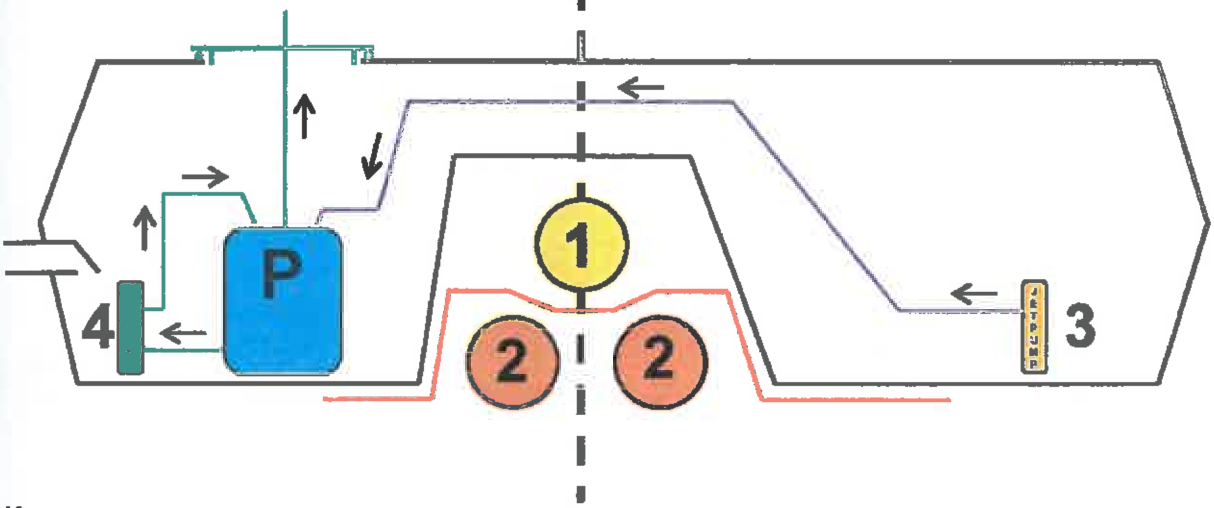



Key:
1 – Pipe connection to send petrol vapours to the active charcoal filter.
2 - Pipe connection to send petrol vapours to the high pressure system.
3 – Main chamber A float.
4 – Main chamber A level level sensor.
5 – Transfer chamber B float.
6 – Level sensor for transfer chamber B.

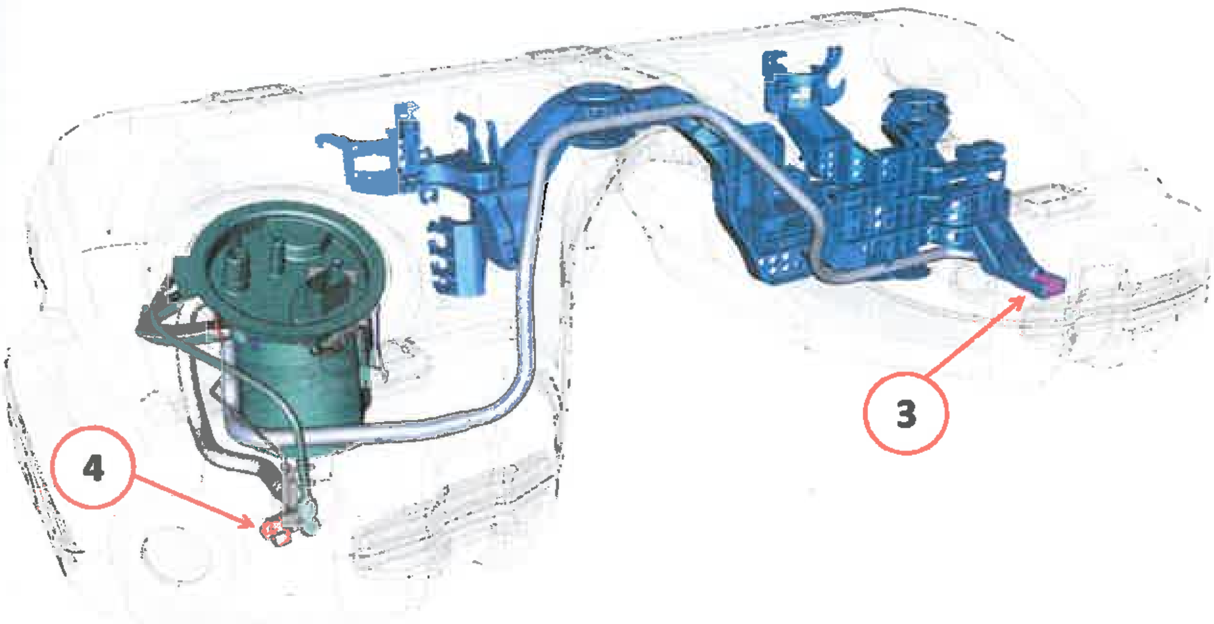



There are two level sensors inside the tank. The sensor that measures the main chamber level and one that measures the level in the transfer chamber.

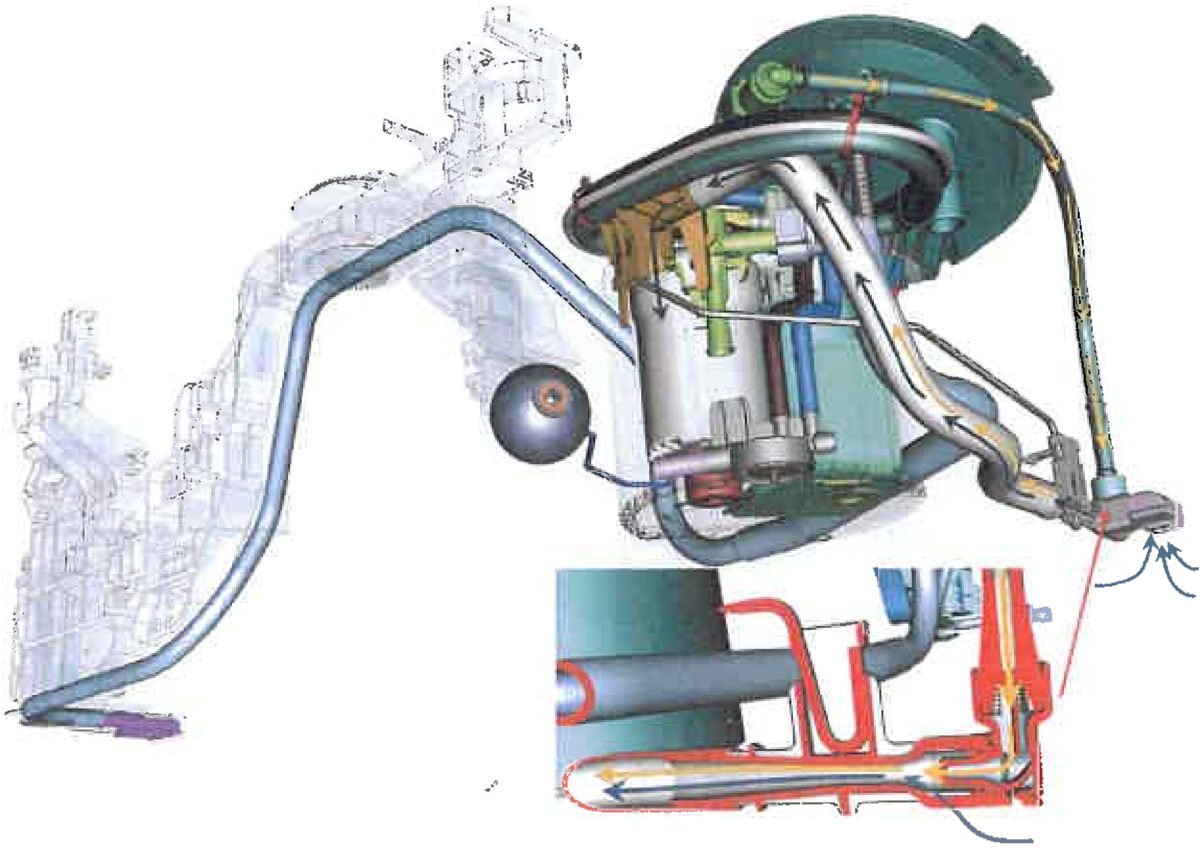
As well as the double level sensor, the electric pump has three petrol floats. The need for three floats is due to the tank shape. In the main chamber A, the pump suctions the petrol from the float in the lower part of the basket and from a side float 4: In race car cases with strong side accelerations, if the petrol level is low, moving it towards the tank's outside wall could suction air from the electric pump. Float 4, in the side area of the main chamber prevents this type of drawback.




Key:
1 – Transmission shaft.
2 – Exhaust pipes.
3 – Transfer chamber float.
4 – Main chamber float.
P – Combustible electric pump.

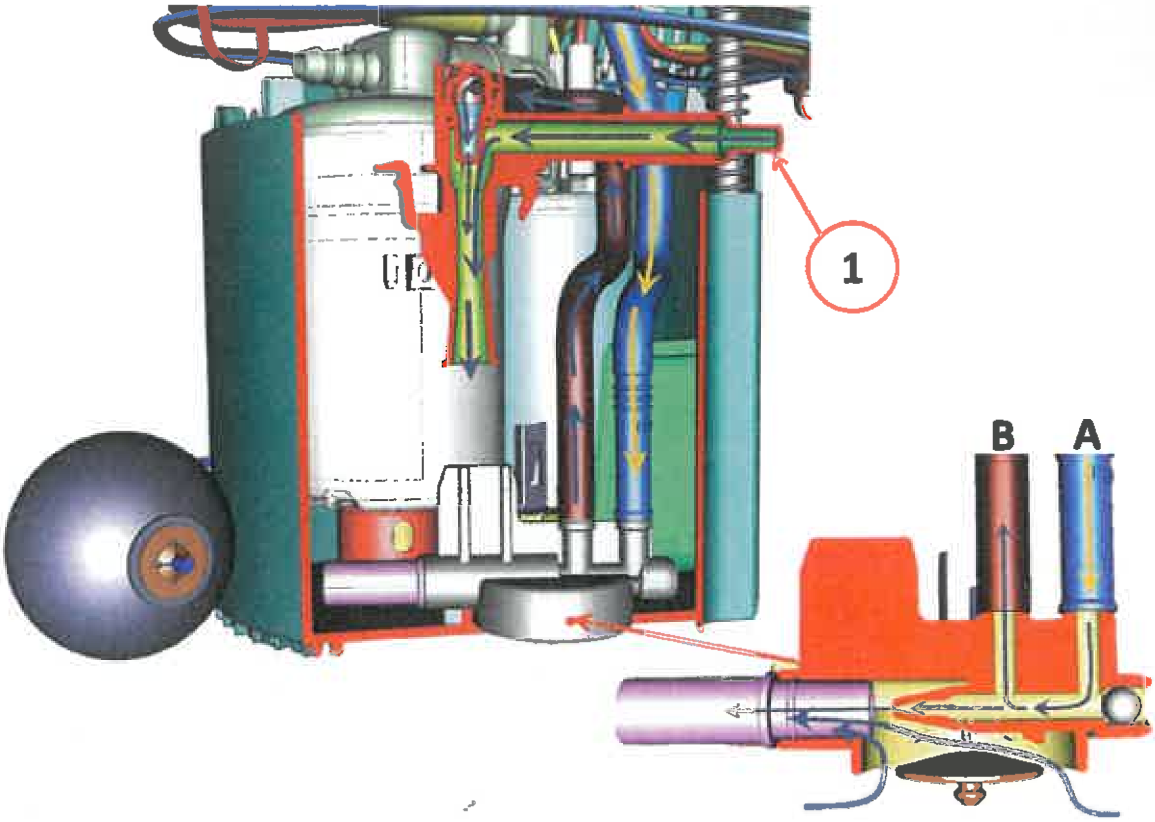



The purpose of the three floats is to make the pump basket (where the pump suctions) is always full of petrol. The three floats use the venturi effect principle to make petrol go into the basket.



The side float in the main chamber is connected to a venturi which receives a constant flow of petrol (1) from one of the electric pump's supplies. The petrol flow sent from the electric pump, passing through the venturi converging/diverging channel, creates a certain vacuum corresponding to the lowest section of the venturi itself. This area communicates with the float. It follows that the vacuum "recalls" tank petrol to the inside of the venturi itself. Petrol coming from the electric pump supply mixes with that suctioned and the subsequent flow goes back up to the upper part to fill the basket.

The operating principle that allows the pump to suction from the float in the basket is the same one as the transfer chamber float.

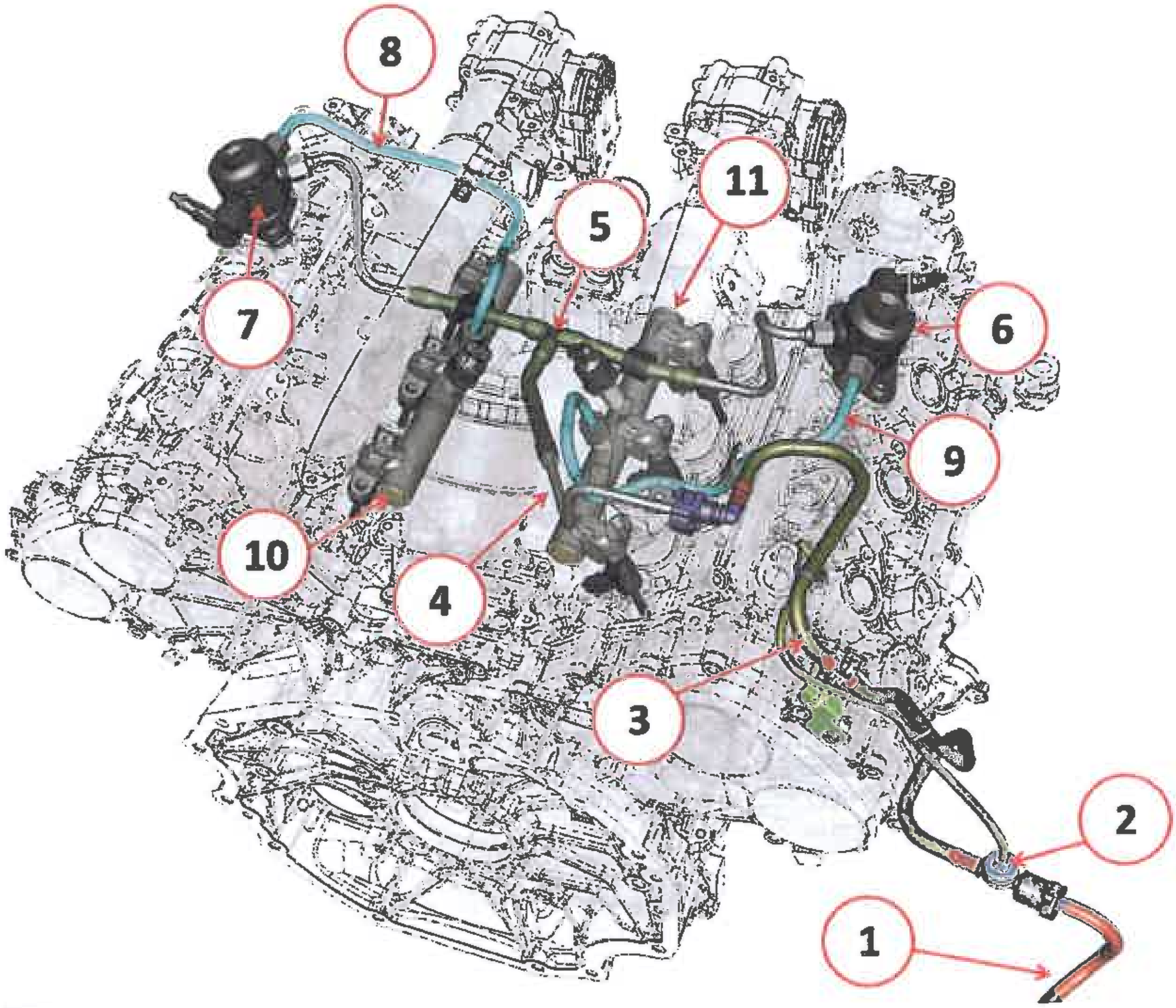



To suction combustible through the basket float, a flow of petrol A from one the electric pump sends to a venturi placed in communication with the float itself. The petrol flow passing through the venturi creates the necessary vacuum to suction the petrol from the tank. The suctioned petrol contributes to maintaining the petrol level in the basket.

The petrol flow sent from the pump to the venturi, in part flows back upwards through pipe B. This last flow goes in turn to supply the venturi that allows suction from the transfer chamber float.

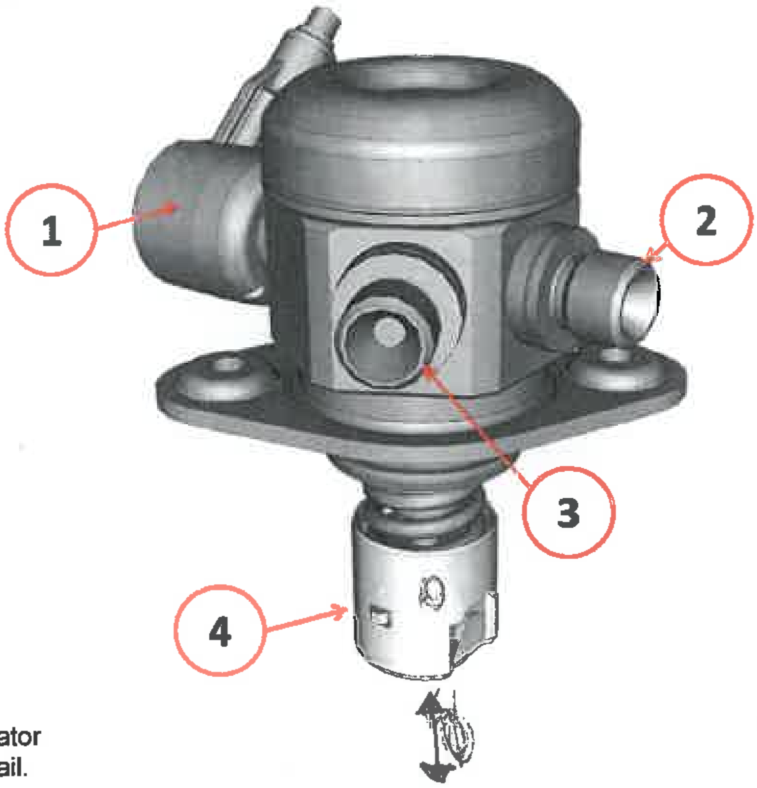
The connection shown in image no.1 receives the petrol flow from the transfer chamber's float. The connection is linked to a venturi which is powered by the petrol flow B. This allows the transfer chamber to suction petrol via the float there.

From the electric pump submerged in the tank, the petrol is sent to the high pressure pump's intake from the two banks via piping along which there are pressure and temperature sensors.
The high pressure system consists of the components shown in figures (starting with number 6)



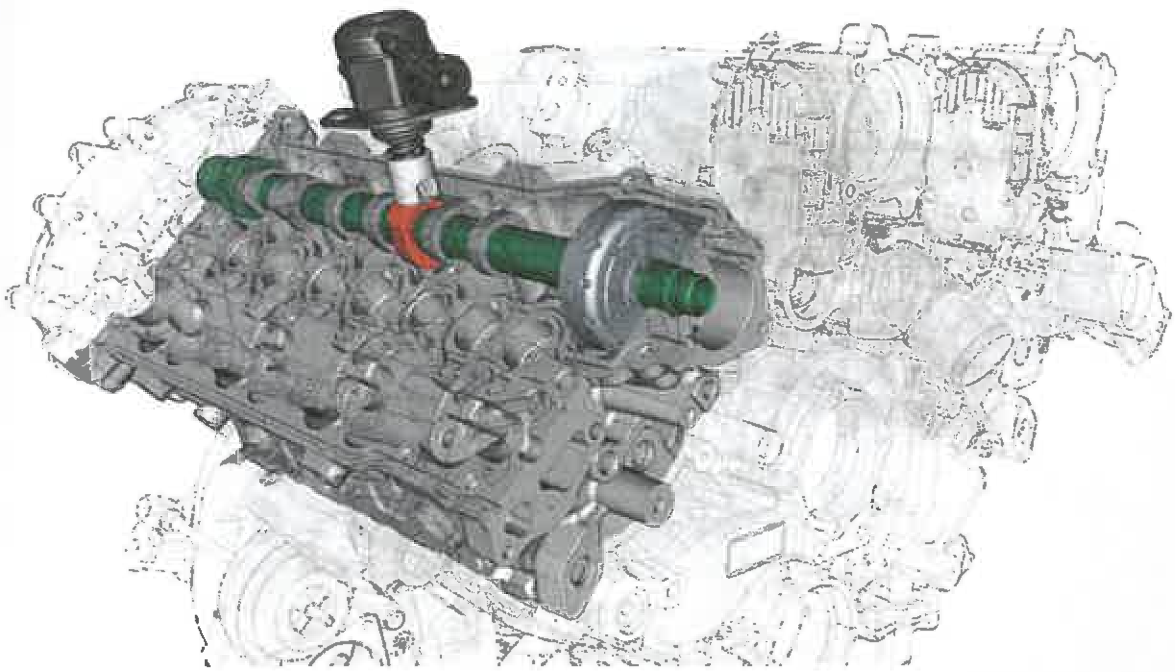

Key:
1 – Submerged electric pump piping.
2 – Pressure and temperature sensor
3 – Connection pipe
4 – Metal connection pipe
5 – T joint.
6 – Right bank high pressure pump.
7 – Left bank high pressure pump.
8 – Supply pipe from the left high pressure pump to the left rail.
9 – Supply pipe from the right high pressure pump to the right rail.
10 – Left bank petrol accumulation rail.
11 – Right bank petrol accumulation rail.

*High pressure pump.*

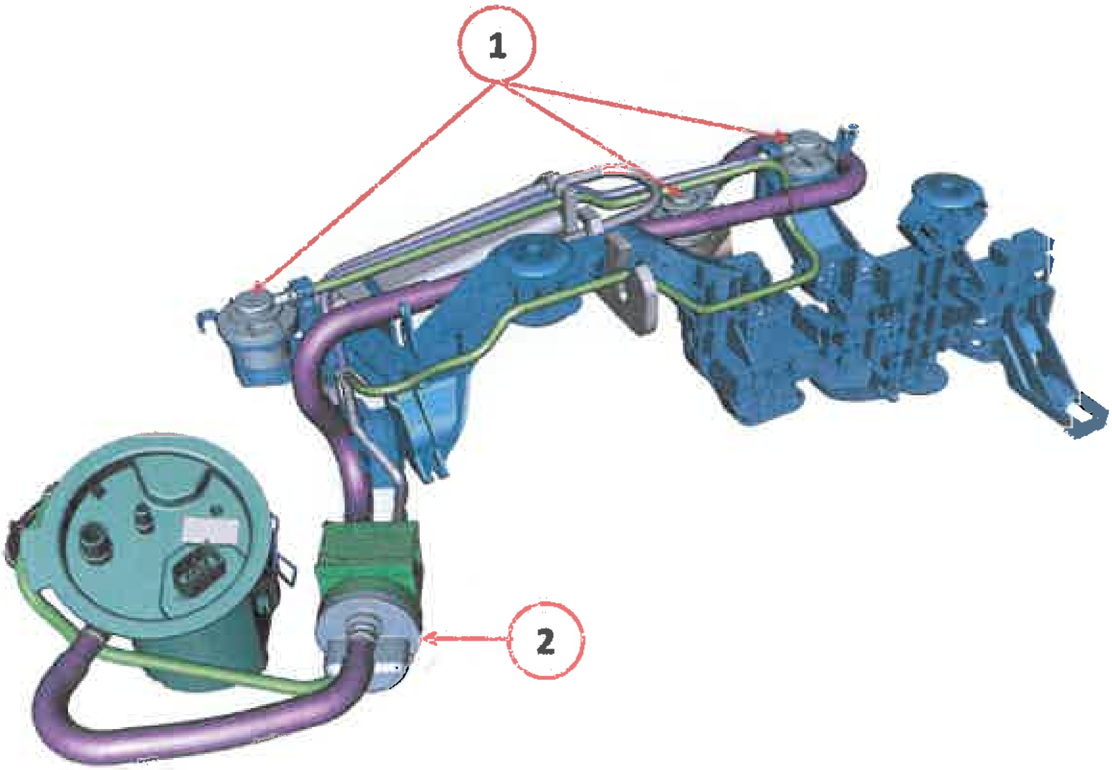



Key:
1 – Flow rate regulator
2 – Supply line to rail.
3 – Intake pipe.
4 – Roller cup.

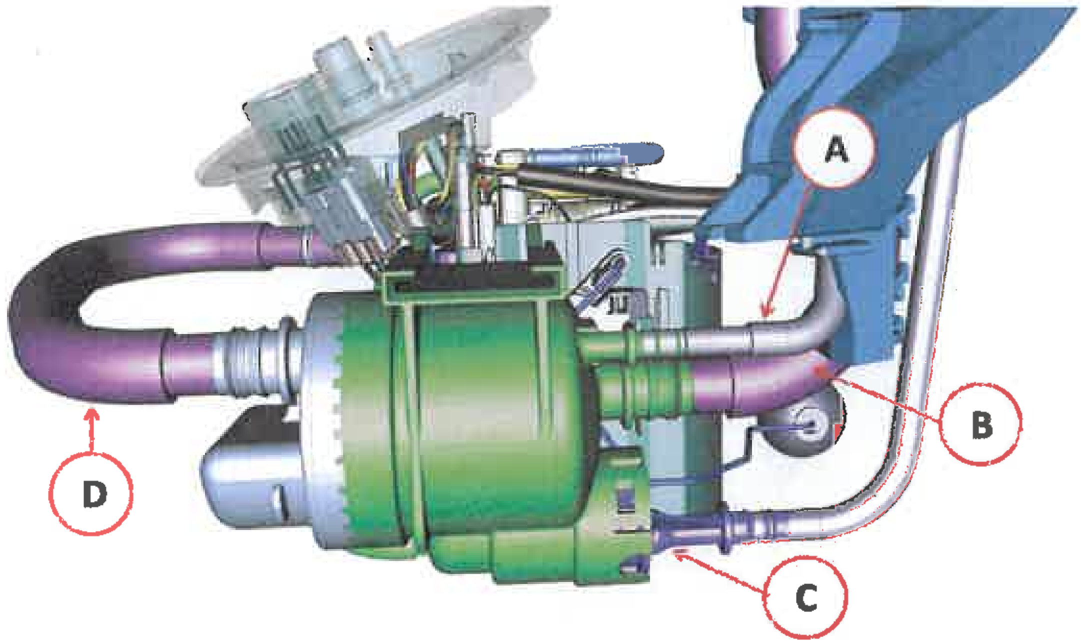
The high pressure pump is directly controlled through a specific intake timing axle cam. There is a roller cup between the cam and the pump plunger stem, which reduces the frictions that occur after sliding.



There is also a petrol vapour separation system (2) inside the tank that uses the vent valves (1). These last help prevent the petrol flow to go towards the vapour channels but allow the vapours to pass.

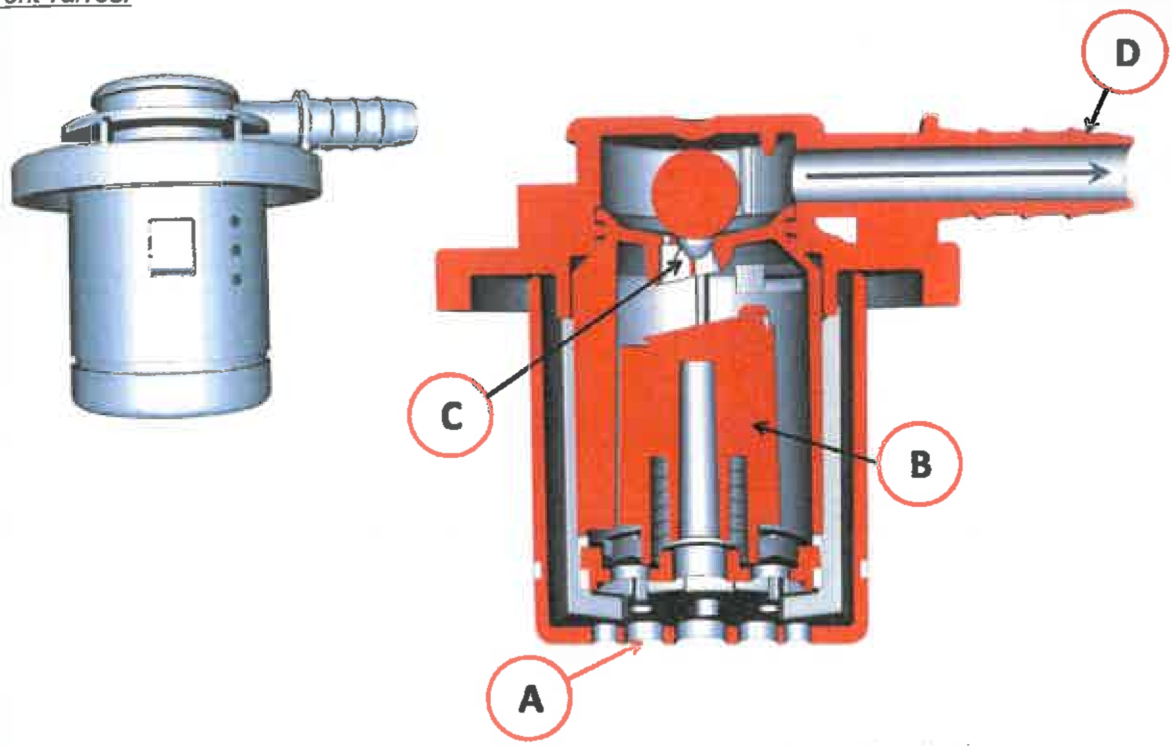



Via the vent valves and connection pipes, the petrol vapours converge inside the separator (2). The vapours are sent from the separator towards the active charcoal filter.




Key:
A – Petrol vapour intake pipe from the side vent valves.
B – Petrol vapour intake pipe from the central vent valve.
C – Venturi pipe to suction petrol from the separator.
D – Petrol vapour supply pipe.

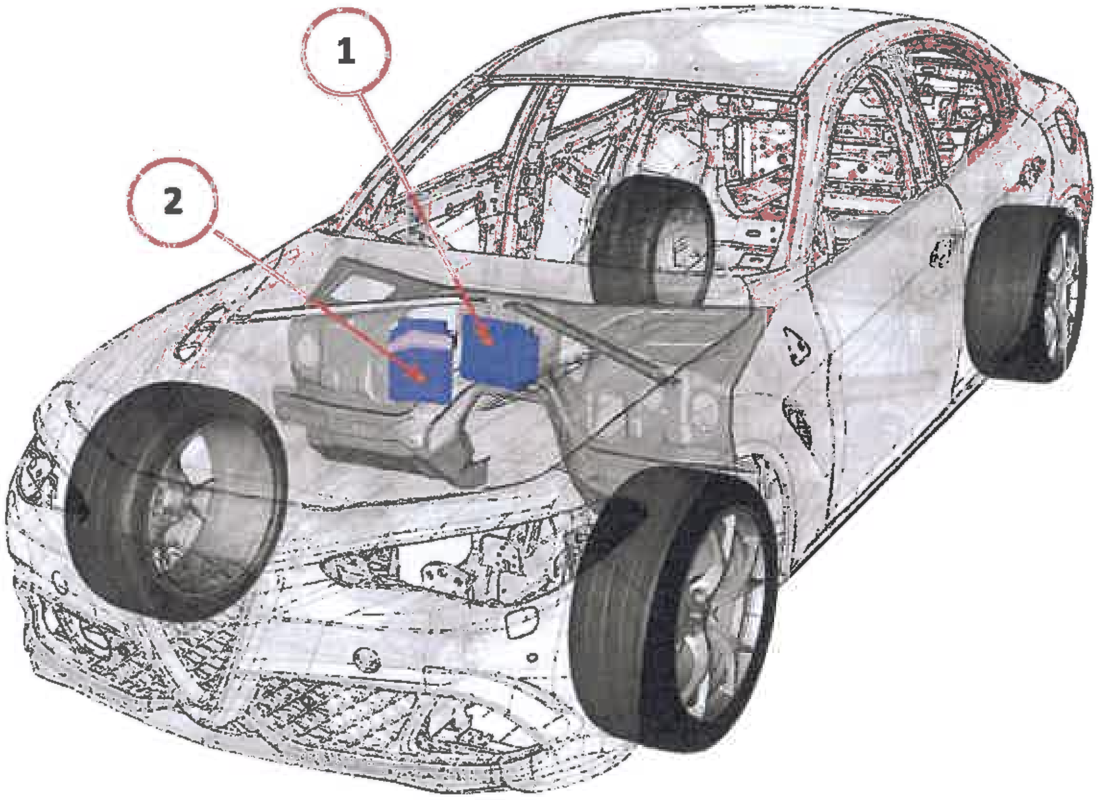
## *Vent valves.*




Inside the vent valves there is a mechanism that prevents petrol to reach exit D through the lower intake holes A. The vent valves are placed in the upper part of the tank. When refuelling, the petrol level rises until it enters into the hole valve A. The B float goes up at the same time as the petrol level until it gets to the closure of the passage hole C. This way, petrol is prevented from going back into the vapour channels. When the petrol level is below the vent valve, float B opens up passage C. When the vapour pressure rises inside the tank, the ball in passage C's upper part lifts up, allowing the vapours going towards the separator to pass.

## ENGINE MANAGEMENT.

Engine management is provided by two control units (modules): $ECM_1$ Master and $ECM_2$ Slave.




Key:

1 – $ECM_2$ Slave module

2 – $ECM_1$ Master module

Managing the 2.9 V6 engine has a level of complexity that requires control by two ECMs. From the viewpoint of electronic management, it is a though we were faced with two engines that shared a single drive shaft and that work in symbiosis. One of the main reasons that prompted the adoption of dual control, is doubtless the presence of two discrete air supply systems, which in some conditions work differently (deactivation of bank cylinders). Such a complex system from a management viewpoint can only be controlled with two ECMs. In particular, $ECM_1$ Master manages the right bank, while $ECM_2$ Slave manages the left bank.

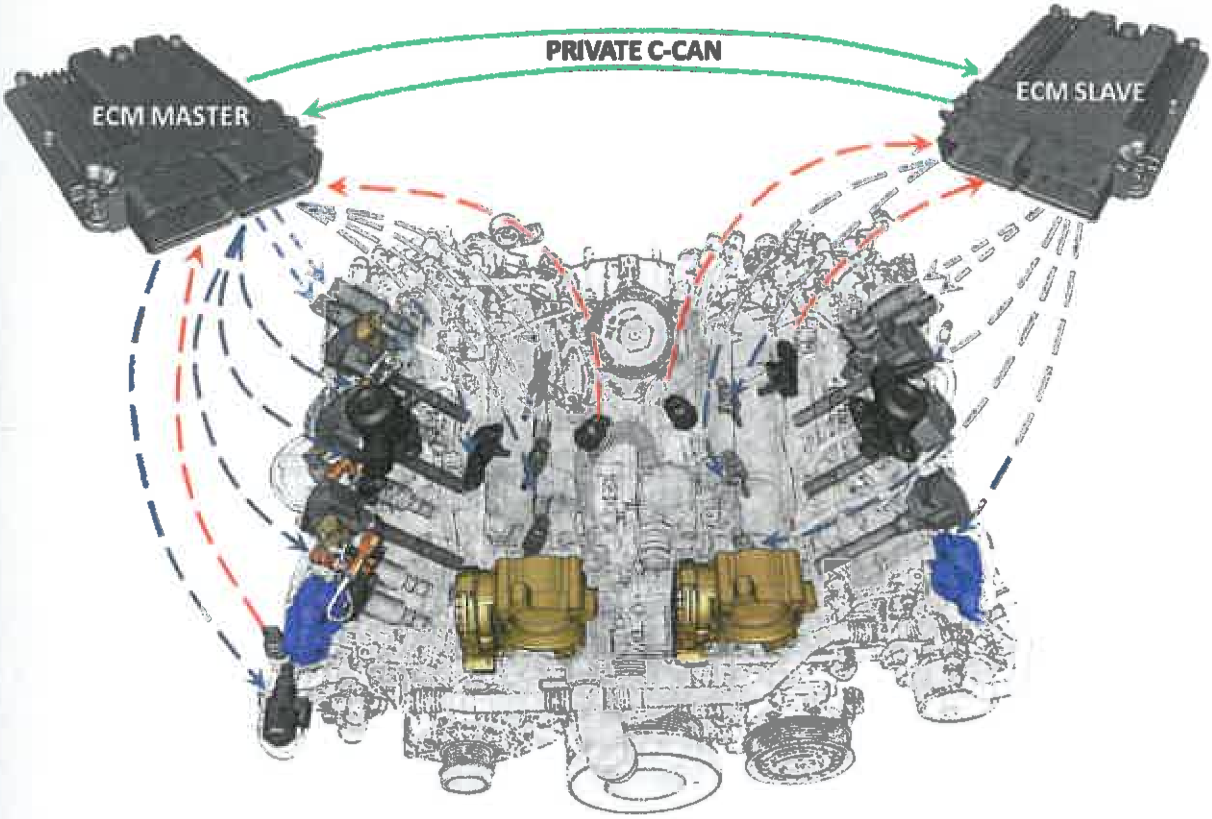
The engine management system is designed with the following goals:

- Achieve the performance goal in terms of Power, Torque profile and fuel consumption.
- Comply with the emission limits expected in each market.

Below, is a list of the main requirements for electronic engine management:

- Direct petrol injection with fuel demand control via high-pressure pump solenoid valve and high-pressure injection into the combustion chamber.
- Multi-injection capacity (up to 2 injections per cycle)
- Right bank cylinder deactivation system (Fuel Saver Mode)
- Oxygen level check at exhaust via 1 broadband lambda sensor upstream of each catalytic converter and 1 On/Off lambda sensor downstream of each catalytic converter.
- Turbocharger with supercharge pressure control via Wastegate valve with pneumatic actuator.
- ECM control modules installed in the engine bay of the vehicle
- ECM control modules that interface on Next-Gen vehicle architecture.

The two ECMs (Master and Slave) manage the various engine systems through specific sensors and actuators. The $ECM_1$ Master manages operation of the right bank, while the $ECM_2$ Slave manages operation of the left bank. It follows that all sensors and actuators of the right bank respond to $ECM_1$ Master, and the sensors and actuators of the left bank respond to $ECM_2$ Slave.




The engine has mechanical components that must be installed or managed by the ECMs. Some of these components are present in both the right and the left bank (e.g.: camshafts, spark plugs, phase transformers, etc.). It follows that the same type of sensors the ECM uses to control or manage them are on both banks (e.g.: timing sensors; coils; phase transformer control solenoid valves, etc.). Some mechanical components are unique to the engine (e.g. the crankshaft, the flywheel, the thermostat, etc.), some systems are also unique (e.g.: the lubrication system; cooling system). Among the sensors and actuators that control these latter components or systems, there are some that only respond to $ECM_1$ Master, and others that respond only to $ECM_2$ Slave.

The two ECMs communicate with one another exchanging data via a private CAN-C network.

Below is a list of sensors and actuators that only respond to $ECM_1$ Master and $ECM_2$ Slave:

**$ECM_1$ Master:**

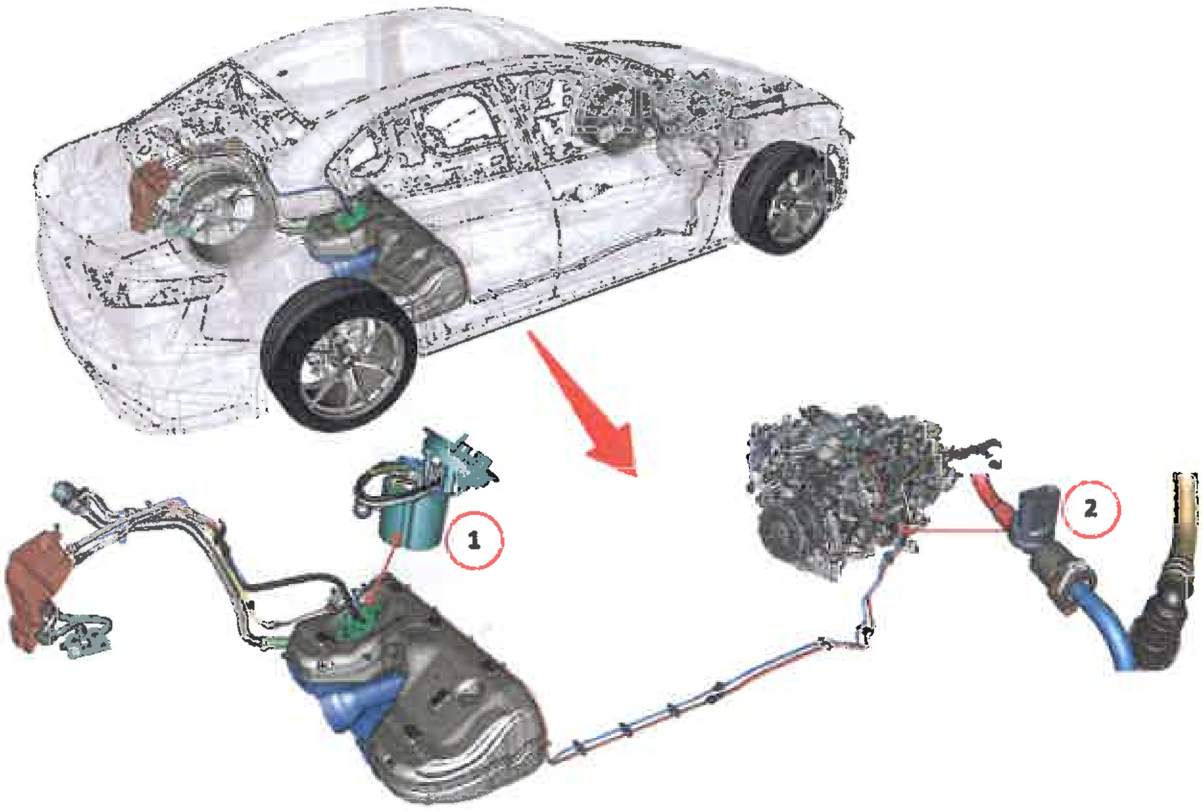
- Rpm sensor
- Engine oil temperature sensor
- Gearbox input shaft revolution sensor
- Supercharger pressure sensor (right bank)
- Clutch pedal position sensor
- Reversing switch
- Hood switch (where provided)
- HT cooling temperature sensor (where provided)
- Transmission oil temperature sensor
- Gearbox neutral position sensor
- HT cooling system expansion tank level switch
- Accelerator pedal position sensor
- On/Off lambda sensor downstream of catalytic converter (right bank)
- Broadband planar lambda sensor upstream of catalytic converter (right bank)
- Canister solenoid valve (right bank)
- Dump solenoid valve (right bank)
- LT cooling circuit electric pump
- PEM module
- Electric fan activation module
- Fuel supply system high-pressure pump flow regulator (right bank)
- Variable displacement oil pump solenoid valve
- Wastegate solenoid valve (right bank)
- Cylinder deactivation solenoid valve (right bank)
- Turbocharger lubrication deactivation solenoid valve (right bank)
- Intake side phase transformer solenoid valve (right bank)
- Exhaust side phase transformer solenoid valve (right bank)
- Injectors (right bank)
- Filter input oil pressure sensor
- Oil pressure sensor of cylinder deactivation circuit (right bank)
- Oil pressure sensor of turbocharger lubrication circuit (right bank)
- Rail fuel high-pressure sensor (right bank)
- Intake air pressure and temperature sensor (right bank)
- Low-pressure system fuel pressure and temperature sensor
- Inlet side timing sensor (right bank)
- Exhaust side timing sensor (right bank)
- Motorised throttle body (right bank)
- Knock sensor (right bank)
- Right bank coils (via ELDOR module)
- Coolant temperature sensor.

**ECM$_2$ Slave:**

- Canister diagnostics air pump (where provided)
- Supercharger pressure sensor (left bank)
- Climate control system linear pressure sensor
- Lambda sensor downstream of catalytic converter (left bank)
- Lambda sensor upstream of catalytic converter (left bank)
- Blow-by system diagnostics (where provided)
- Engine oil level and temperature sensor
- Rail fuel high-pressure sensor (left bank)
- Intake air pressure and temperature sensor (left bank)
- Inlet side timing sensor (left bank)
- Exhaust side timing sensor (left bank)
- Motorised throttle body (left bank)
- Knock sensor (left bank)
- Climate control system compressor relay
- Fuel high-pressure pump flow regulator (left bank)
- Wastegate solenoid valve (left bank)
- Intake side phase transformer solenoid valve (left bank)
- Exhaust side phase transformer solenoid valve (left bank)
- Injectors (left bank)
- Left bank coils (via ELDOR)

**Low-pressure fuel supply system management components.**

The low-pressure fuel supply system continuously supplies the high-pressure pumps enslaved to the two engine banks. In order for the high-pressure pumps to continuously receive fuel, the $ECM_1$ Master module manages the following components:

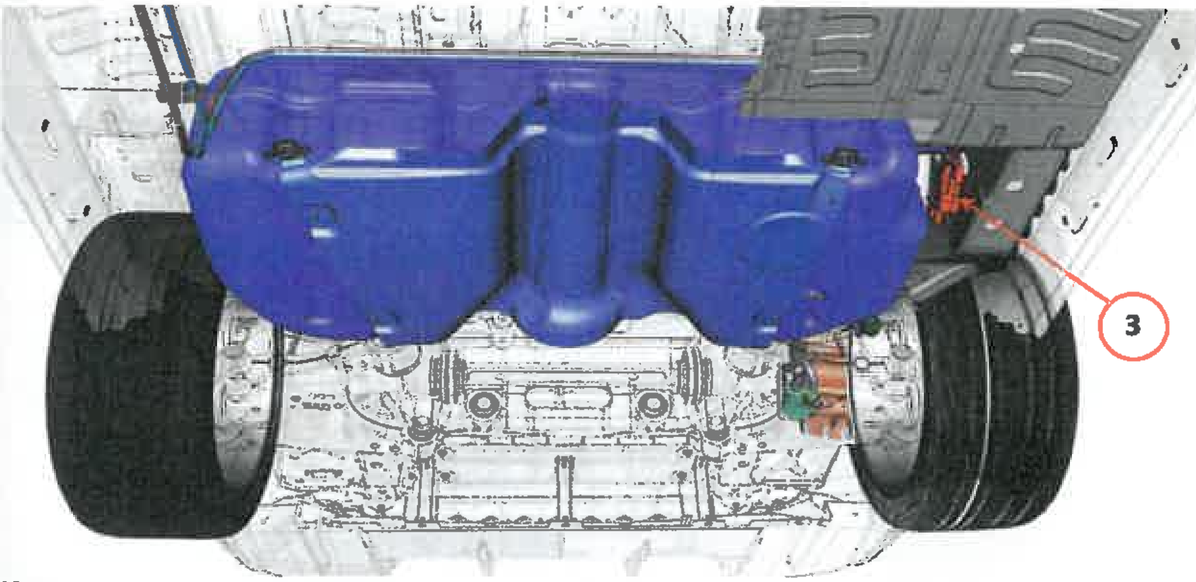



Key:

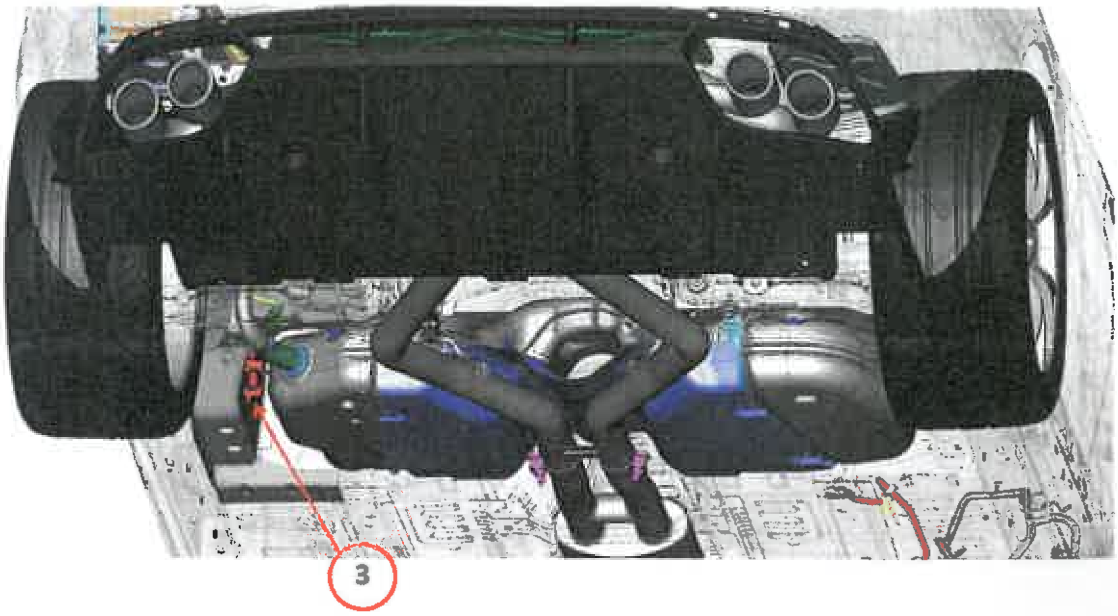
1 – Low-pressure electric pump submerged in the tank.

2 – Low-pressure fuel pressure sensor.

FRONT




Key
3 – Control module of fuel electric pump submerged in the tank.

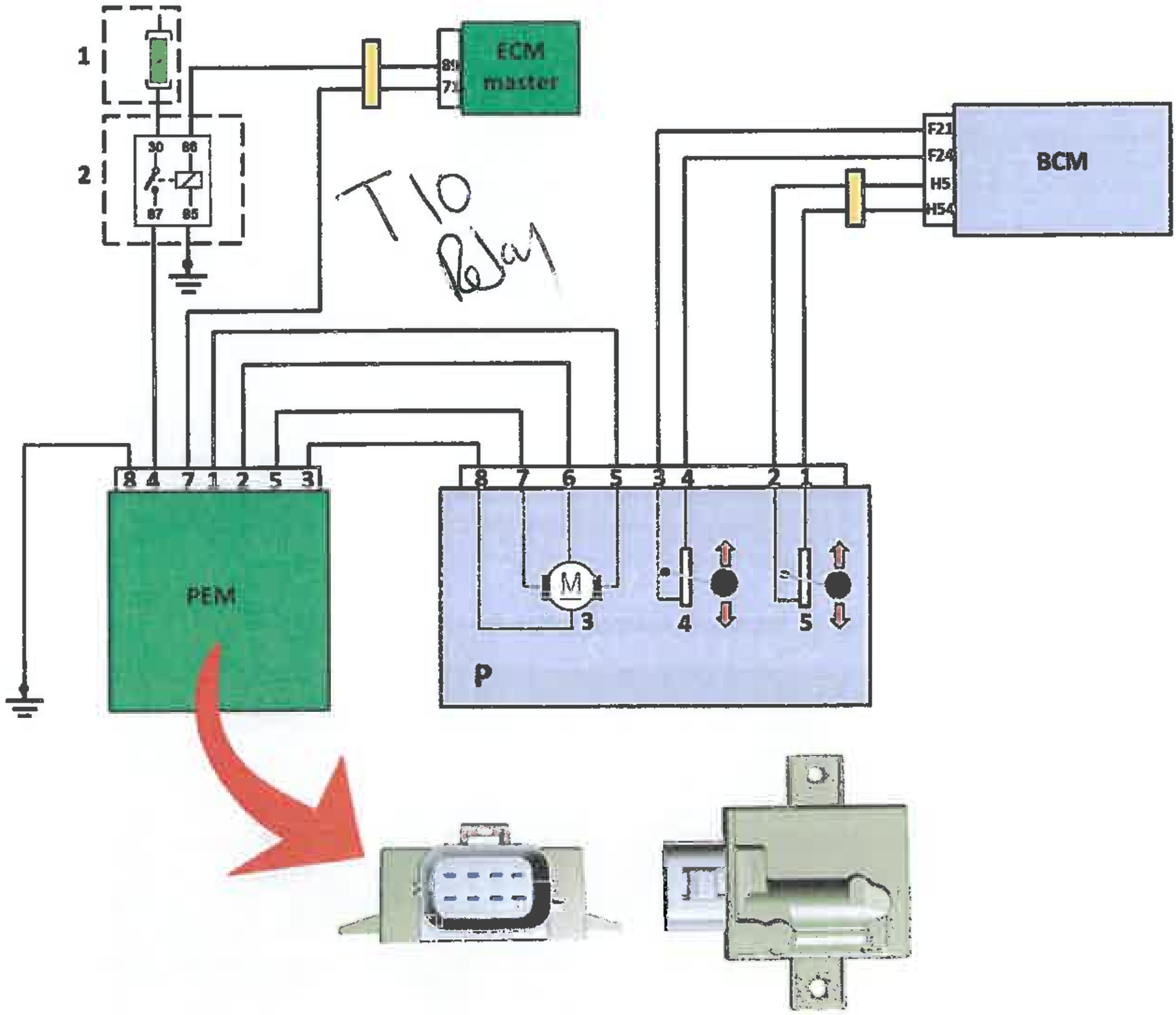



fuel pump controller -
control pump pressure

(Rem)

**Low-pressure electric pump control module.**

The electric pump submerged in the tank is managed by a special module located on the body of the car (left side of tank as shown in the figure in the previous page).

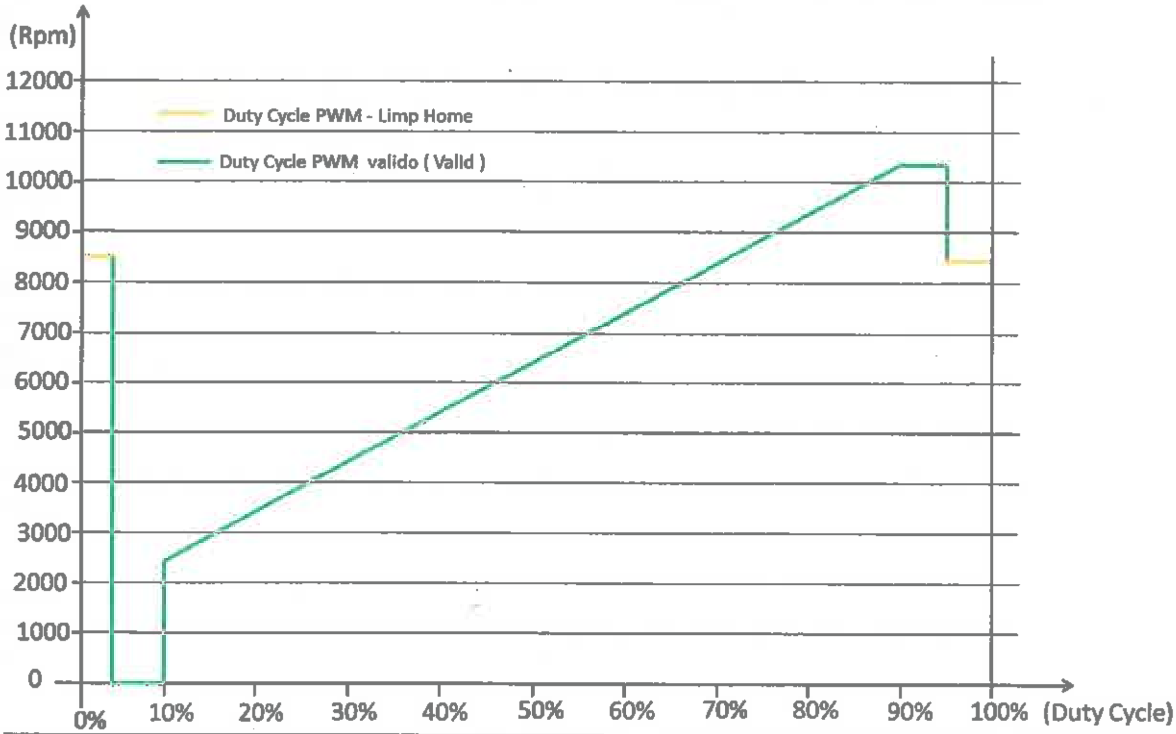



Key:
1 – Fuse rear base
2 – Relay rear base where relay T10 is located
3 – Fuel electric pump electric motor
4 – Float 1 with level meter 1
5 – Float 2 with level meter 2
P – Fuel electric pump unit submerged in the tank.
PEM – Electric pump electronic control module

The electrical diagram shows that the brushless (3-phase) small electric motor of the electric pump submerged in the tank receives three power supplies (u, v, w) and earth directly from the PEM control module (respectively: pins 1, 2, 5 and 3). Via the cable exiting pin 71, the $ECM_1$ Master engine control sends commands to the PEM module. The command that the PEM receives is type PWM. Depending on the duty cycle, $ECM_1$ Master communicates to the PEM the way in which it should drive the electric pump small motor. The outcome is a low-pressure fuel electric pump that rotates at a number of revolutions (rpm) that varies in function of the PWM signal that $ECM_1$ Master sends the PEM.
The goal is to allow the LP low-pressure pump to send the HP high-pressure pump the fuel flow strictly necessary to meet the engine's demand for fuel.

In this way, the fuel quantity that the low-pressure pump must push is lowered, with a consequent reduction in the absorbed current. The lower current absorption by the LP low-pressure pump results in a lower load on the alternator (lower engine fuel consumption).

The table below shows the rotation speed of the electric pump submerged in the tank as a function of the duty cycle characteristic of the PWM signal that $ECM_1$ Master sends the PEM module.




| PWM Duty Cycle | Rpm |
|---|---|
| 0% | 8500 |
| < 3% | 8500 |
| ≥ 3% | 0 |
| < 10% | 0 |
| ≥ 10% | 2500 |
| 90% | 10350 |
| < 95% | 10350 |
| ≥ 95% | 8500 |
| 100% | 8500 |

The table shows that there can be two intervals where the PWM signal is not valid: for duty cycle values between 0%-3% (e.g.: short to ground) and for values between 95%-100% (e.g.: short to positive).

The moment the PWM signal (from $ECM_1$ Master) takes on values between the invalid ranges, the electric pump will be driven by the PEM module in Limp Home mode (8500 rpm rotation speed).

Operating logic.

Each Duty Cycle value corresponds to a determined rotation speed value of the pump, which in turn corresponds to a determined value of the fuel flow. As the fuel flow changes, the pressure stays at nearly constant values at each operating point of the engine (≈6 bar)
The value of the PM signal duty cycle is processed by the $ECM_1$ Master depending on the needs of the engine fuel at each of its operating points, the temperature of the engine coolant, and the pressure and temperature of the fuel in the low-pressure system.

At each "ON Key", the following actions take place:

- $ECM_1$ Master activates the T10 relay;
- $ECM_1$ Master processes the PWM signal in function of the engine coolant temperature and sends it to the PEM module.
- The FCPM module supplies the electric pump's small electric motor submerged into the tank for a calibrated period of time (≈3s).
- If the engine doesn't start, the $ECM_1$ Master sets the fuel request to zero and deactivates relay T10.

During the starting phase (cranking – starter motor dragging) the following actions take place:

- $ECM_1$ Master activates the T10 relay;
- $ECM_1$ Master processes the PWM signal and sends to the PEM module.
- The PEM module sends fuel supply to the electric pump small electric motor until the calibrated time elapses (≈10s) and fuel pressure reaches the minimum value to start the engine (≈4bar)*.

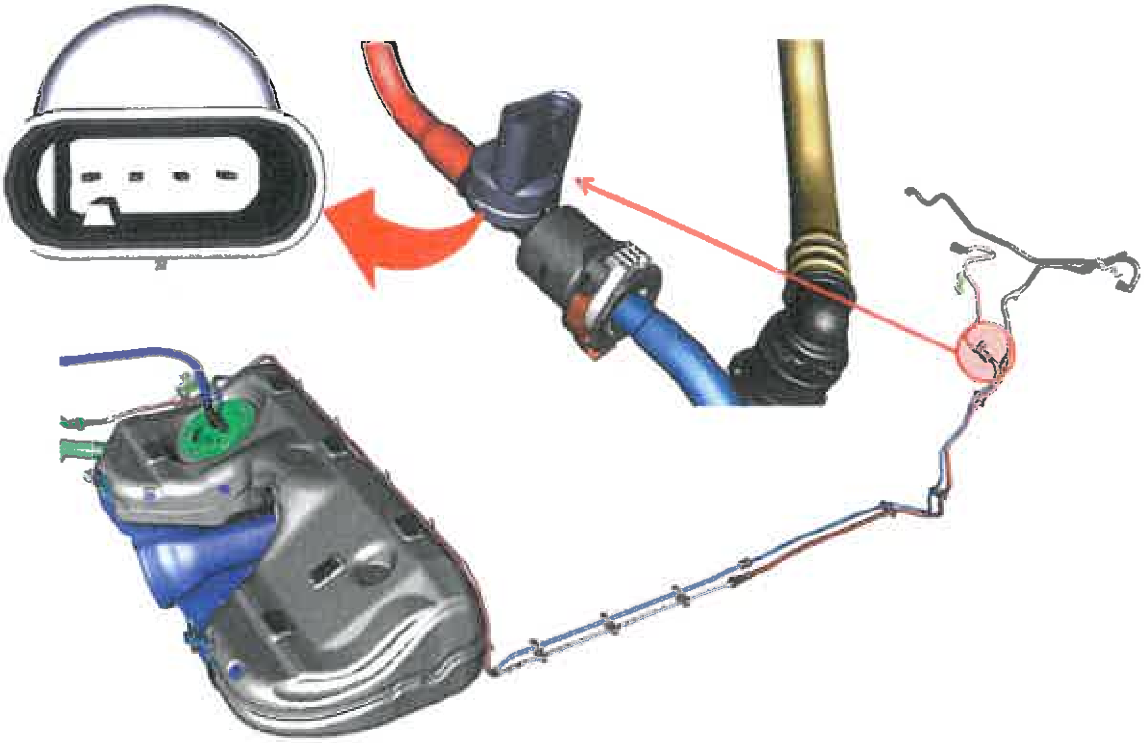
*If the minimum pressure value for starting is reached no later than the time calibrated in the $ECM_1$ Master memory and the engine starts regularly, the relay T10 status will continue to stay active. Otherwise, if the calibrated time expires before reaching the minimum pressure value deemed sufficient to start the engine, $ECM_1$ Master will set the fuel request to zero and will deactivate relay T10.

Under condition "Key On" and "Engine started", the PEM module supplies the electric pump small electric motor to create the fuel flow and pressure conditions required by the engine under "minimum" conditions and for other operating points of the engine.

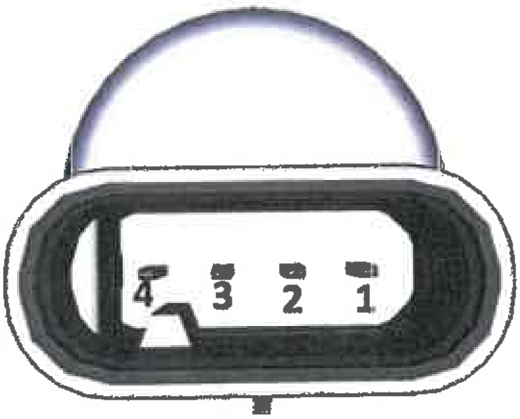
When the "Key ON with engine started" condition switches to "Key Off", the PEM module will continue to supply the fuel electric pump to keep the low-pressure line slightly under pressure in order to avoid vapour lock phenomena (vapour bubbles). After this brief stage keeping pressure after "Key Off", the $ECM_1$ Master will deactivate the T10 relay.

**Pressure and temperature sensor (low-pressure circuit).**

The fuel pressure and temperature sensor located on the fuel electric pump supply pipe, allows the $ECM_1$ Master module to have direct feedback on the real pressure value of the fuel throughout the low-pressure line. In function of the direct pressure measurement, the $ECM_1$ Master can control and adjust the low-pressure value according to a closed loop cycle:

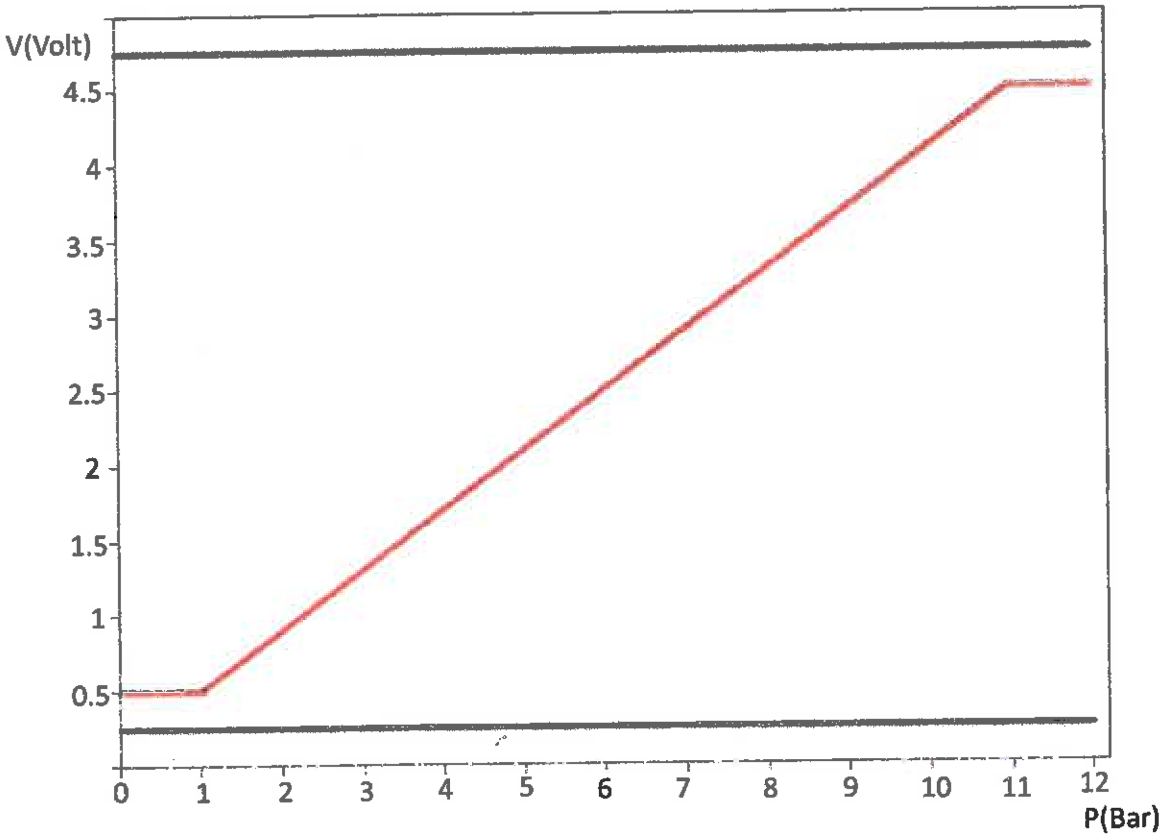


**Pinout**




Key:
1 – 5V power supply
2 – Pressure signal
3 – Earth
4 – Temperature signal.

**Sensor signal as function of pressure.**

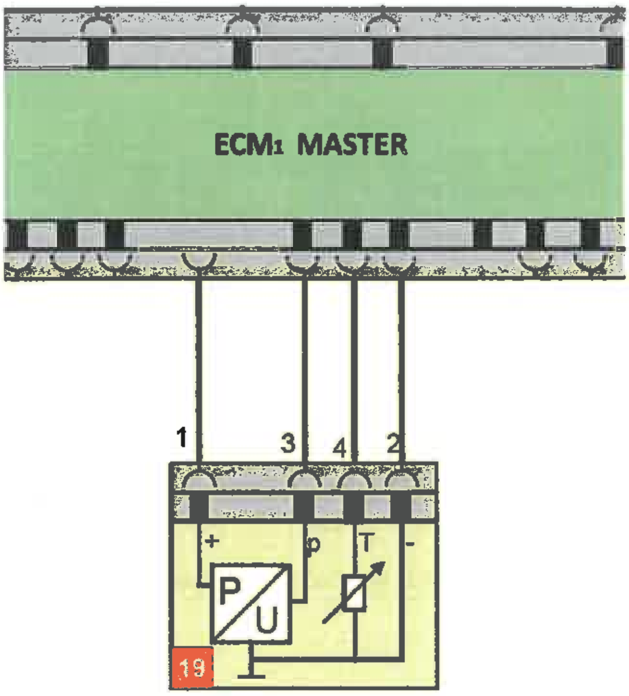



**NOTE:** The values on the x-axis of the graph show the absolute pressure values. The sensor is calibrated to read pressure values up to 11-12 bar. Obviously, this does not mean that the fuel supply system low-pressure system can reach these values.

The sensor's sensitive probe to detect fuel temperature is type NTC. The table below shows the correlation between temperature and resistance in the NTC probe.

| T (°C) | R(Ω) | T (°C) | R(Ω) | T (°C) | R(Ω) |
|---|---|---|---|---|---|
| -55 | 44.605 | 15 | 1.4703 | 85 | 0.1451 |
| -50 | 33.281 | 20 | 1.2093 | 90 | 0.12663 |
| -45 | 25.044 | 25 | 1 | 95 | 0.11088 |
| -40 | 19.033 | 30 | 0.83113 | 100 | 0.097381 |
| -35 | 14.536 | 35 | 0.69418 | 105 | 0.085788 |
| -30 | 11.206 | 40 | 0.58255 | 110 | 0.07595 |
| -25 | 8.7041 | 45 | 0.49112 | 115 | 0.067155 |
| -20 | 6.8104 | 50 | 0.41587 | 120 | 0.059663 |
| -15 | 5.3665 | 55 | 0.35365 | 125 | 0.053146 |
| -10 | 4.2576 | 60 | 0.30197 | 130 | 0.047463 |
| -5 | 3.4001 | 65 | 0.25888 | 135 | 0.042493 |
| 0 | 2.7326 | 70 | 0.22278 | 140 | 0.38134 |
| 5 | 2.2096 | 75 | 0.19243 | 145 | 0.034302 |
| 10 | 1.7973 | 80 | 0.16681 | 150 | 0.030925 |

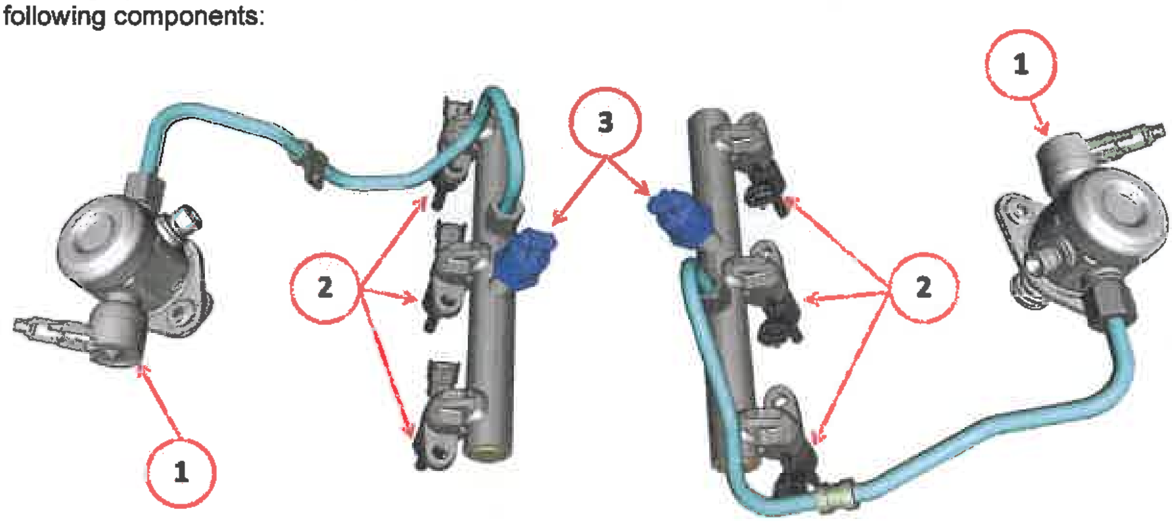
*Fuel low-pressure and temperature sensor wiring diagram*




Depending on the engine's operating point, both ECMs process the engine's fuel requirement; they refine it in function of the coolant's temperature and $ECM_1$ Master sends a signal (PWM) to the submerged PEM electric pump control module. The latter, in function of the PWM signal received, commands the electric pump to ensure the required fuel quantity in terms of flow and pressure. At this point, the $ECM_1$ Master, via the temperature and pressure sensor, checks whether the target pressure values requested are being reached along the low-pressure line. If it finds a deviation between "target" and "required", it will regulate it by "adjusting" the PWM signal previously sent to the PEM module. The temperature control allows the $ECM_1$ Master to avoid cavitation phenomena at the high-pressure pump inlet.

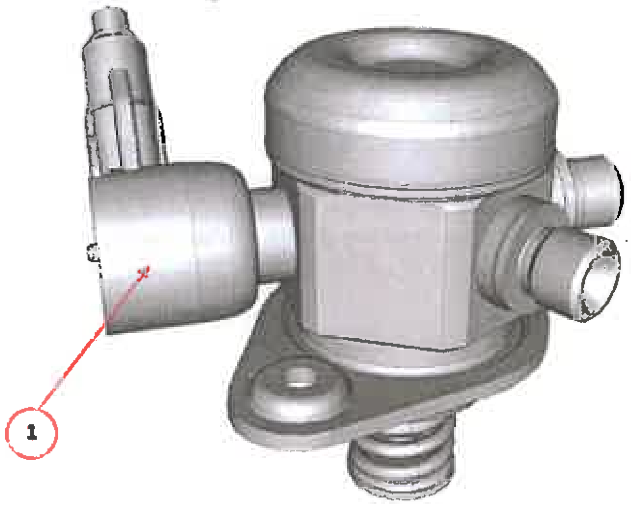
**High-pressure fuel system management components.**

The high-pressure fuel supply system is managed by the $ECM_1$ Master and the $ECM_2$ Slave via the following components:



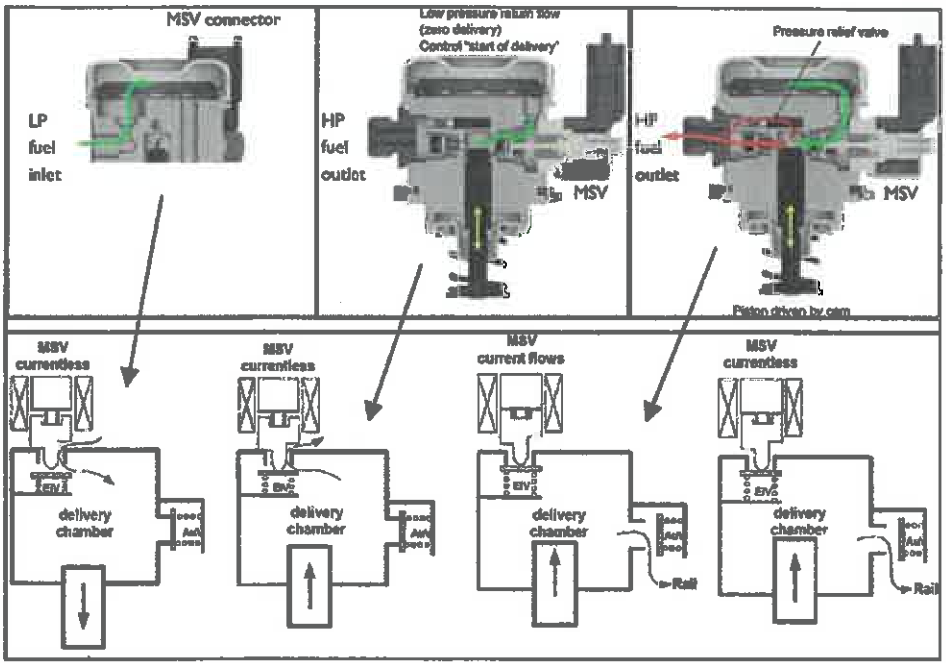

Key:
1 – Solenoid valve to adjust flow integrated into the high-pressure pump
2 – Injectors
3 – Rail high-pressure sensor.

**1 – Solenoid valve to adjust flow integrated into the high-pressure pump (1 per bank).**




Key:
1 – Flow adjustment solenoid valve.

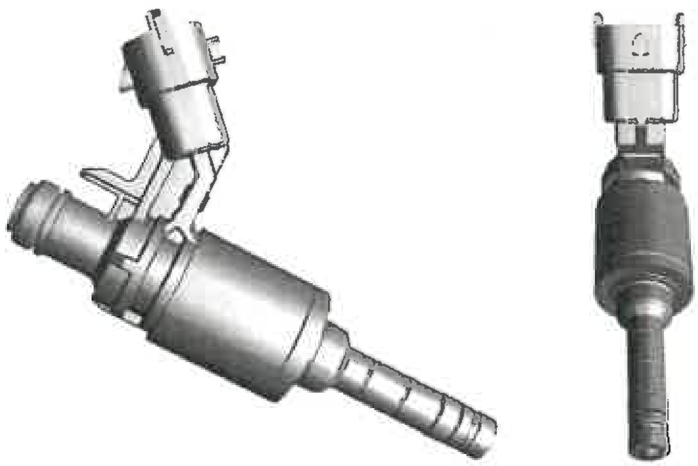
The high pressure fuel pump is used to increase the input fuel pressure (approx. 6 bar) to the max. value of 200 bar (pressure detected within the rail). Pressure control is achieved through a regulation valve, directly installed on the pump and managed by the engine control module. By regulating the fuel flow at the pump exit (towards the rail), the rail pressure varies in proportion to the flow itself.



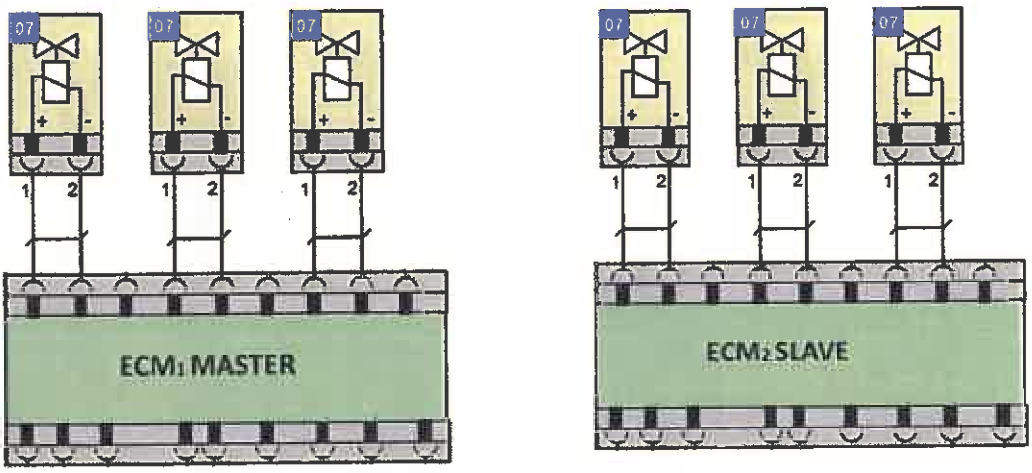

Adjusting the flow takes place by closing the pump's internal recirculation during the piston push stage at the command of the engine control module: thus, only the quantity strictly necessary to maintain the desired pressure of fuel flow to the rail is achieved, while the rest returns to the low-pressure circuit.

The fuel operating pressure in the high pressure system must range between 20 bar and 200 bar.

**2 - Injectors.**



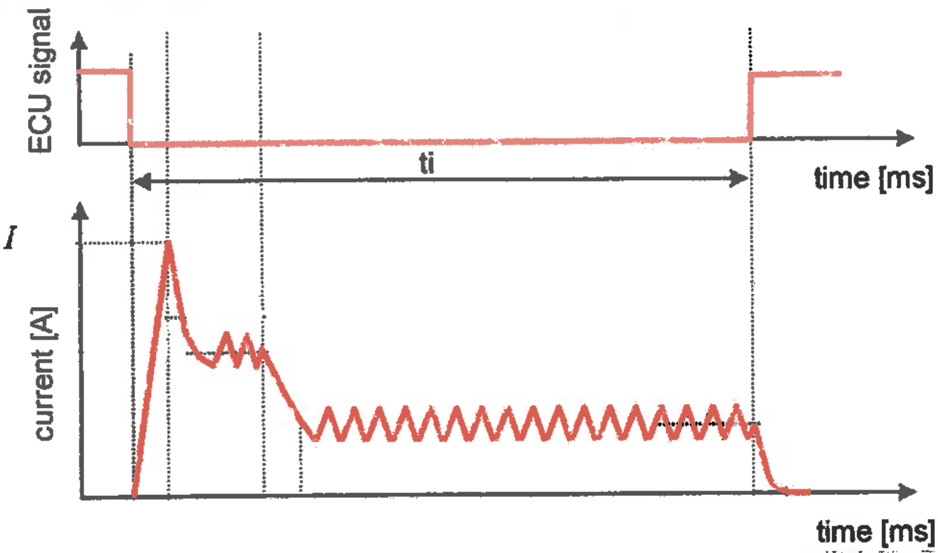
Installed directly onto the cylinder heads, they spray fuel directly into the combustion chamber. They are electrically connected to the ECMs that manage their respective banks. The injector opening time and the quantity of fuel injected depend on the characteristics of the electronic command the relevant ECM sends to the injector.




The injector opening time and the quantity of fuel injected are managed by the electric signal that the control module sends to the injectors themselves.
The engine control module calculates the injection times and the injection start time as a function of the following parameters:

- Intake air pressure and temperature
- Accelerator pedal position
- Fuel pressure in the rail
- Engine rpm
- Engine coolant temperature
- Quantity of fuel vapour introduced in the engine intake circuit.
- Oxygen quantity present in exhaust gas.

The command by the engine control module has the following features:

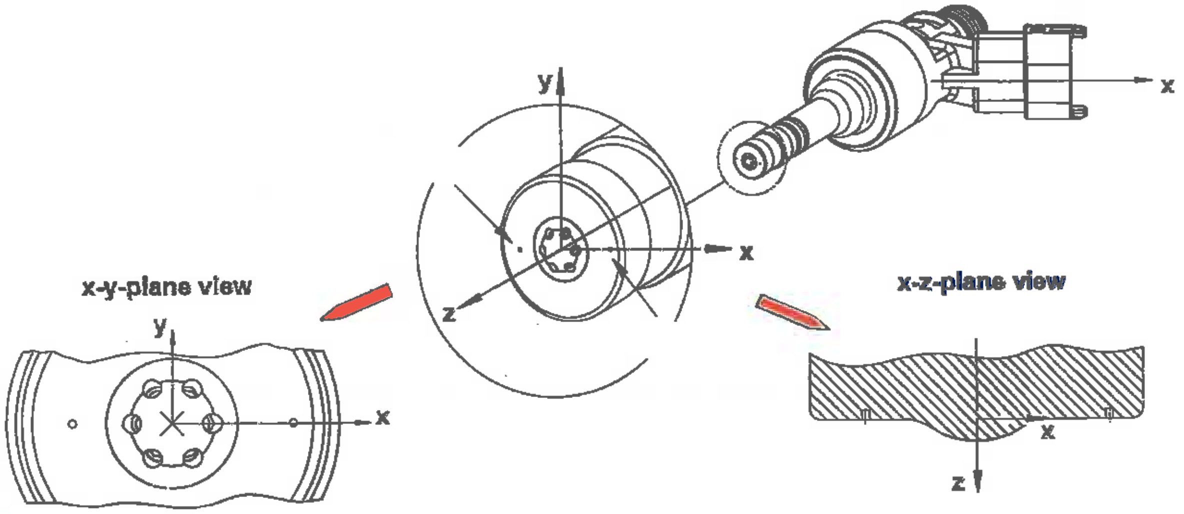


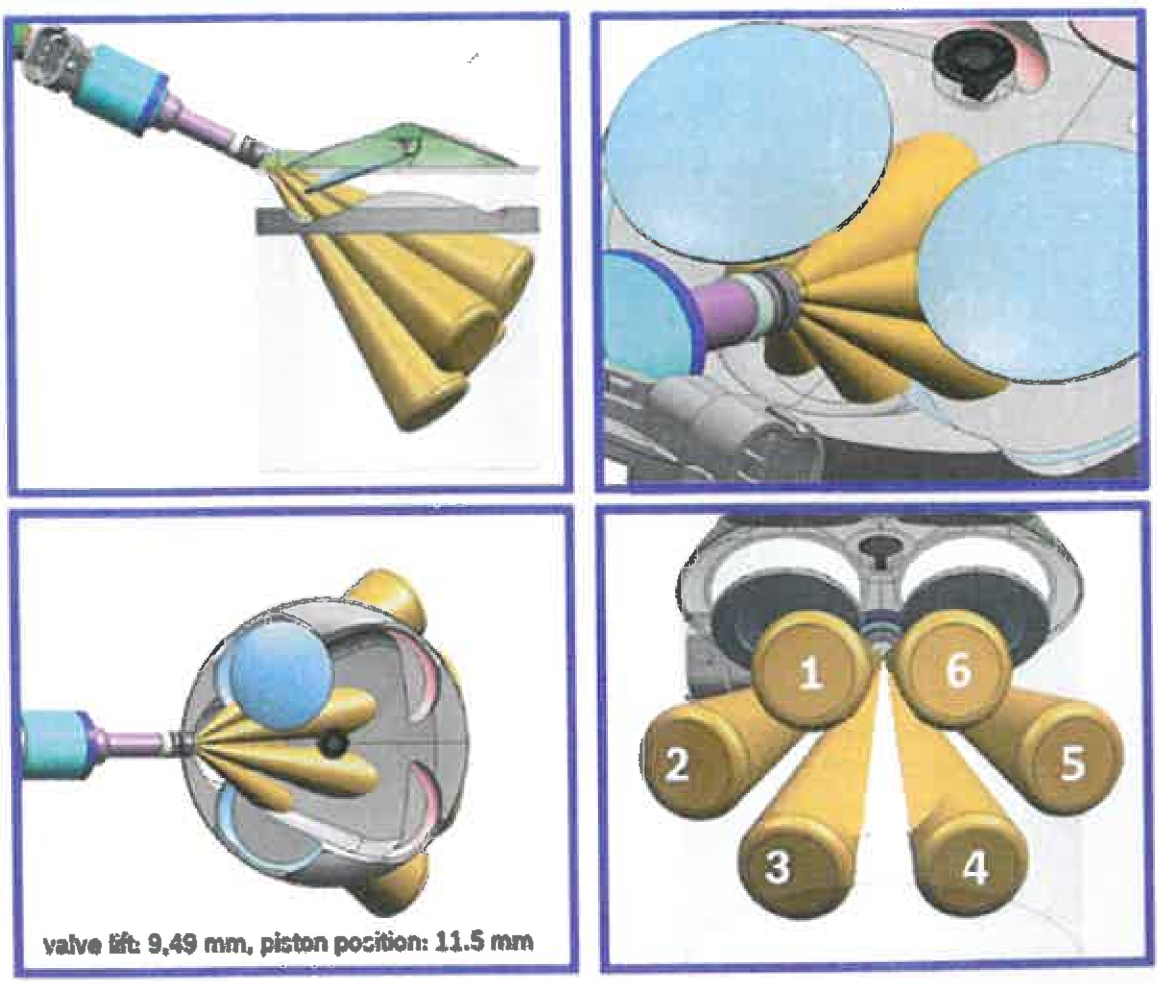

The graph shows that the current sent by the engine control module to the injector has a Peak-type pace and maintenance. During the first stage, the current takes on an Ip peak value to allow the injector to open completely. Then the injector absorbs a lower Im maintenance current. The lower Im current value helps keep the injector open and at the same time ensures shorter closure times for the latter.

The injector is designed to operate with the following fuel pressure operating values:

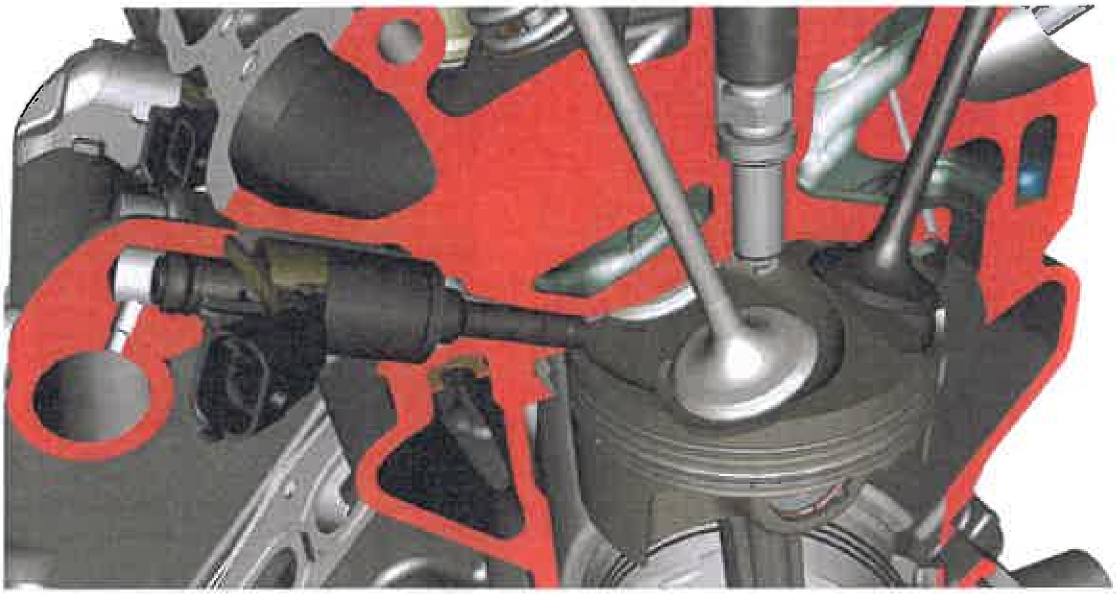
- Begin start: 4 bar (this datum is to be understood as the minimum pressure value the moment starting begins)
- Rated pressure interval: 50 bar – 200 bar
- Maximum pressure peak it can reach: 265 bar

Injectors are type high-pressure, electromagnetic, and 6-hole. The petrol spray consists of 6 small sprays that allow a greater breakup of petrol droplets with a subsequent increase in vaporisation speed.

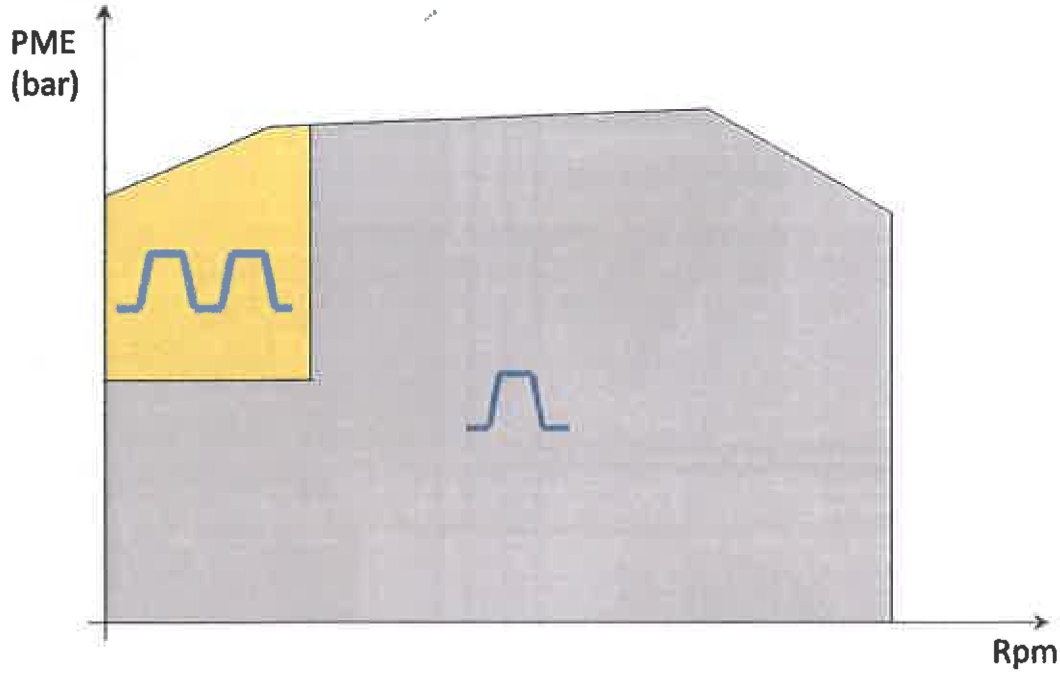


the air-fuel mixture that forms after petrol injection will always be homogeneous and not stratified.

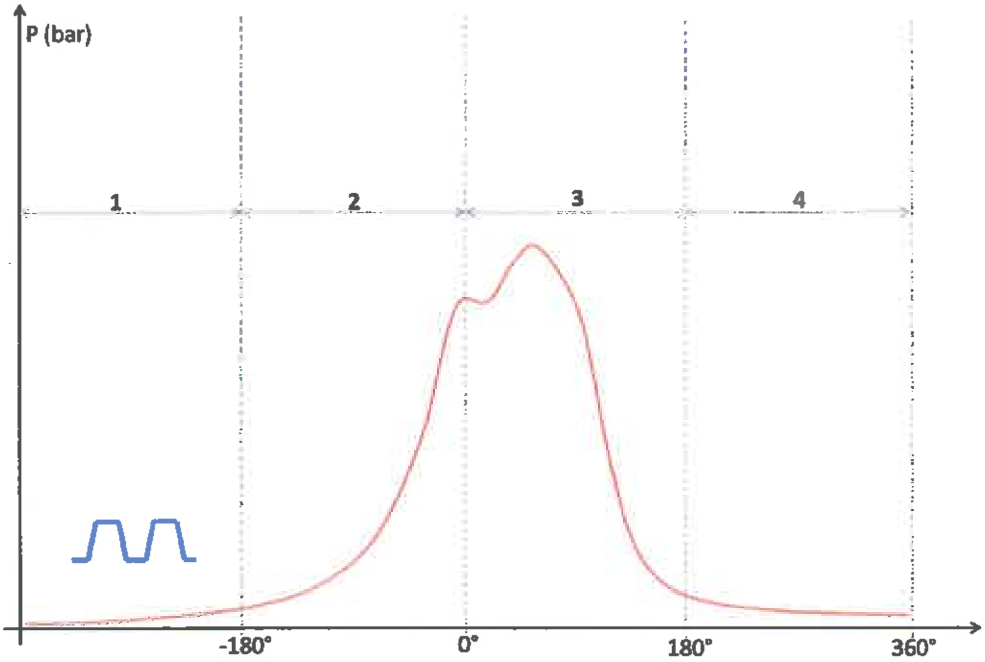


In some engine operation conditions, the ECM modules can manage up to two injections per cycle. It should be pointed out the ECM software can manage up to three injections per cycle, but in the context of managing the 2.9 V6 engine only two can be achieved.

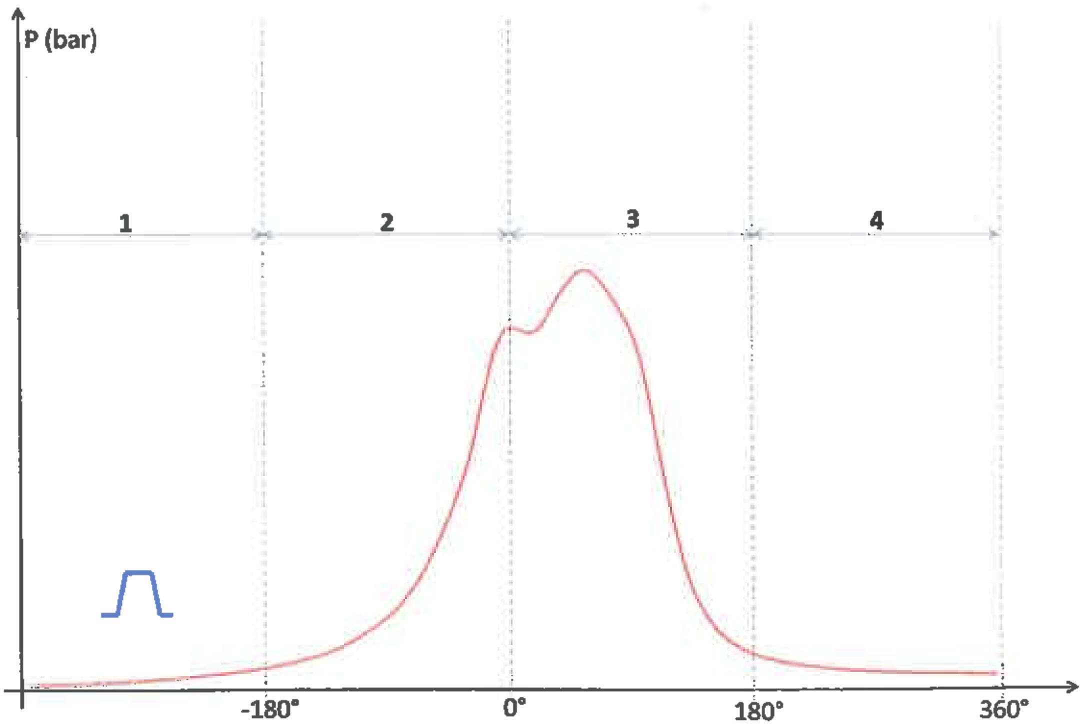



In low rev and high engine load conditions, the ECMs command two injections per cycle while in the remaining area of the engine's field of operation, only one injection per cycle is commanded.

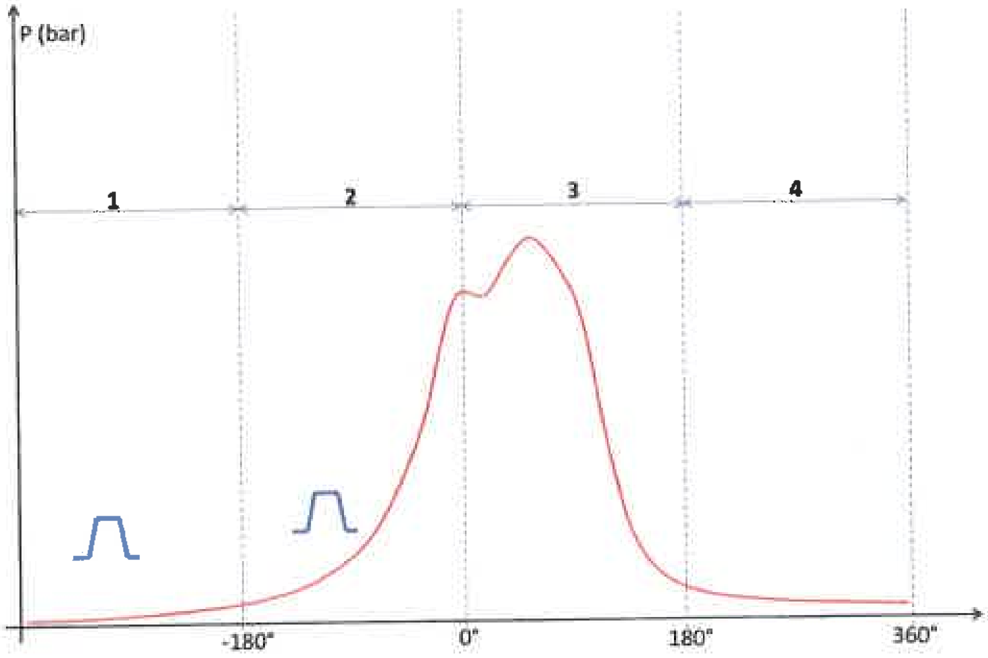
In both conditions (two injections per cycle: yellow area; one injection per cycle: grey area), the injection phase is always done during the intake stroke.




Key:
1 – Intake stroke.
2 – Compression stroke.
3 – Combustion/expansion stroke
4 – Exhaust stroke.

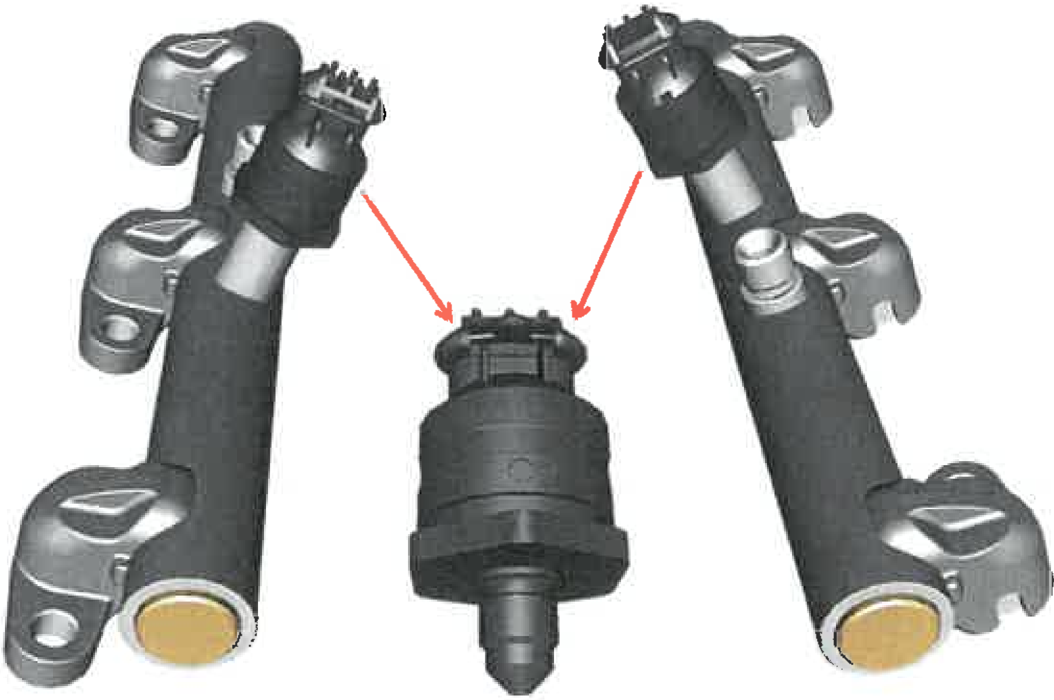


The double injection is also managed during the first 30 seconds from a cold start in order to speed up the heating of the catalytic converters.



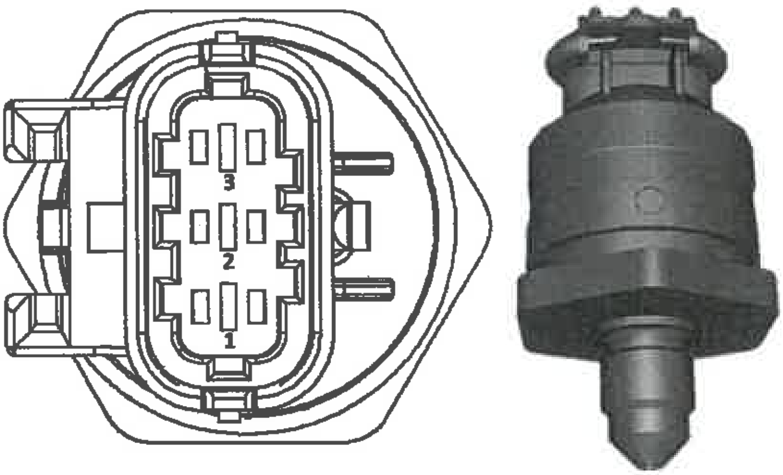

Only in this specific condition is the first injection done during intake, while the second takes place during compression. The latter injection lets the heat release shift towards the exhaust more.

## High-pressure sensor (1 per bank).



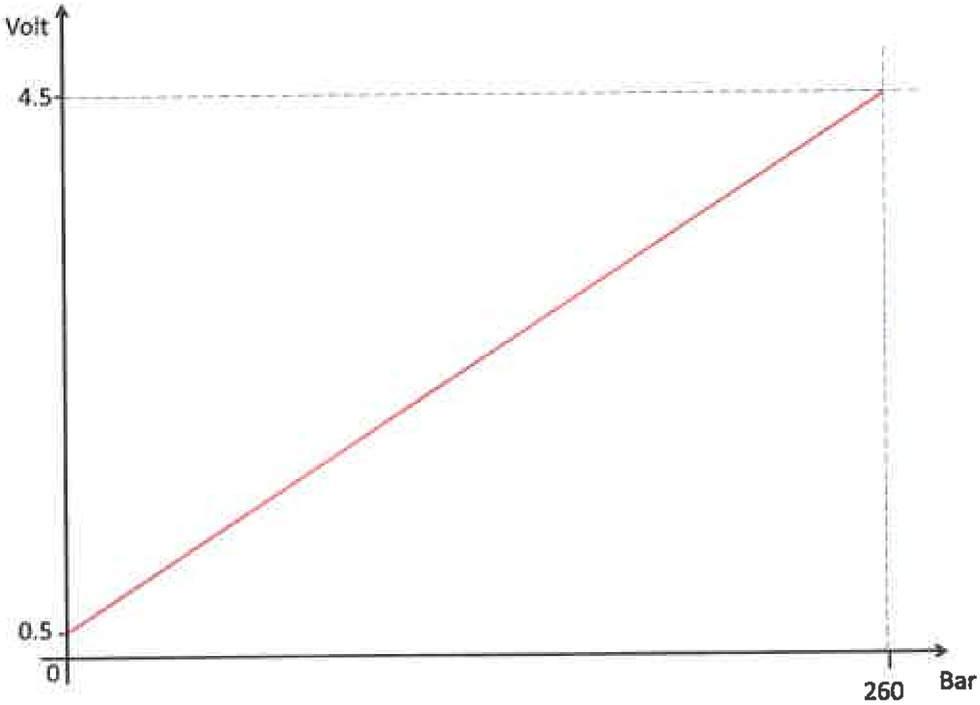
The fuel high pressure sensor measures the fuel pressure in the rail on which it is installed, supplying the injection control unit with a feedback signal for regulating the pressure and the duration of the injection.
The metal part includes a diaphragm pressure meter; the plastic part contains a 3-pin connector (one for power supply, one to send the signal to the control unit and one for the earth).

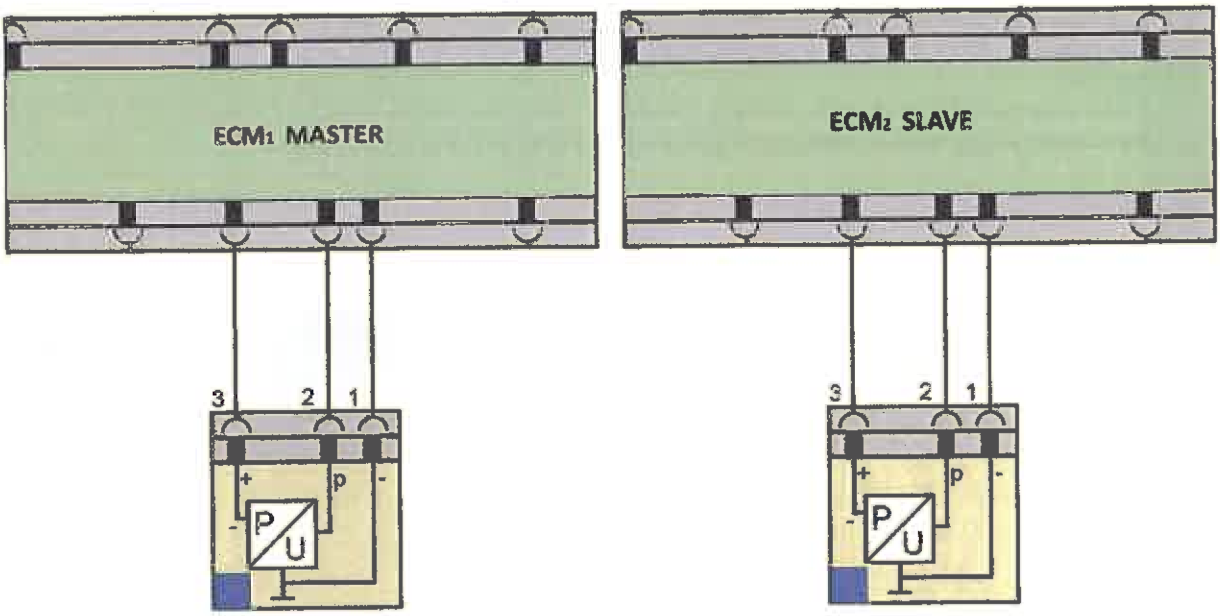
Pinout




Key.
1 – Earth
2 – Signal
3 – 5V power supply

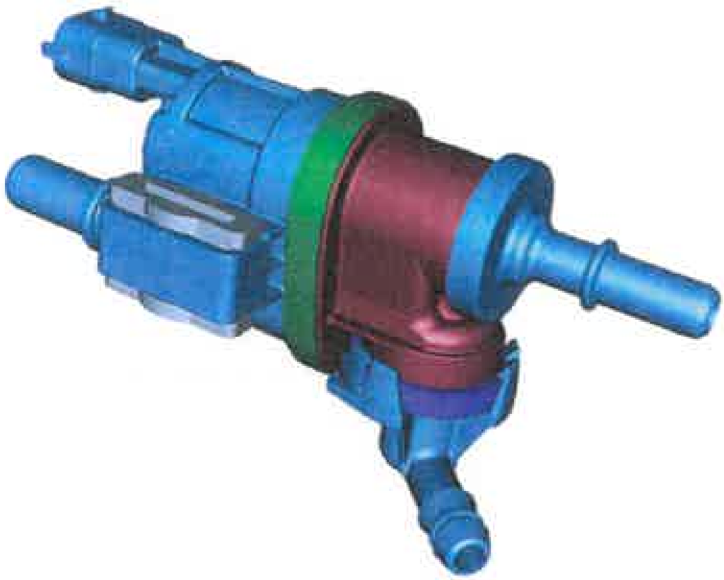
Pressure sensor signal.

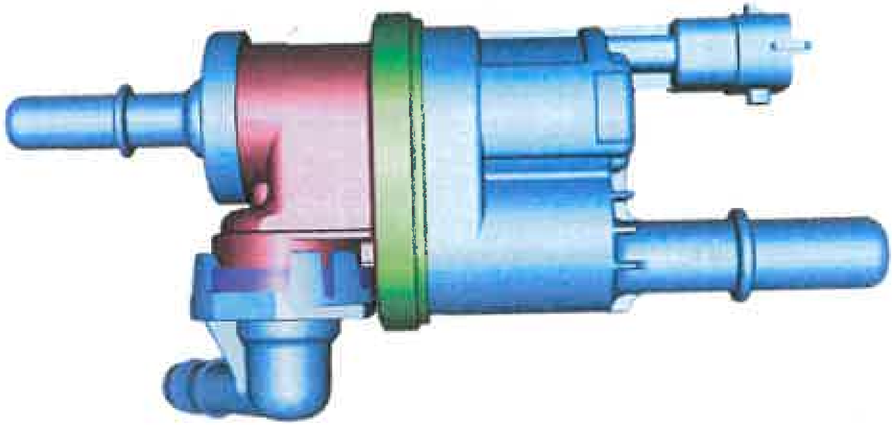


**Petrol vapour recirculation system management components.**

The petrol vapour recirculation system is managed by the $ECM_1$ Master and the $ECM_2$ Slave via Canister solenoid valves (one per bank: one commanded by the $ECM_1$ Master and the other commanded by the $ECM_2$ Slave).





It is the component that allows the engine control modules to empty the active charcoal filter of the anti-evaporation system.

The solenoid is normally closed: With no electric power, the solenoid valve prevents the petrol vapour recirculation, thus avoiding excessively enriching the air-petrol mixture.

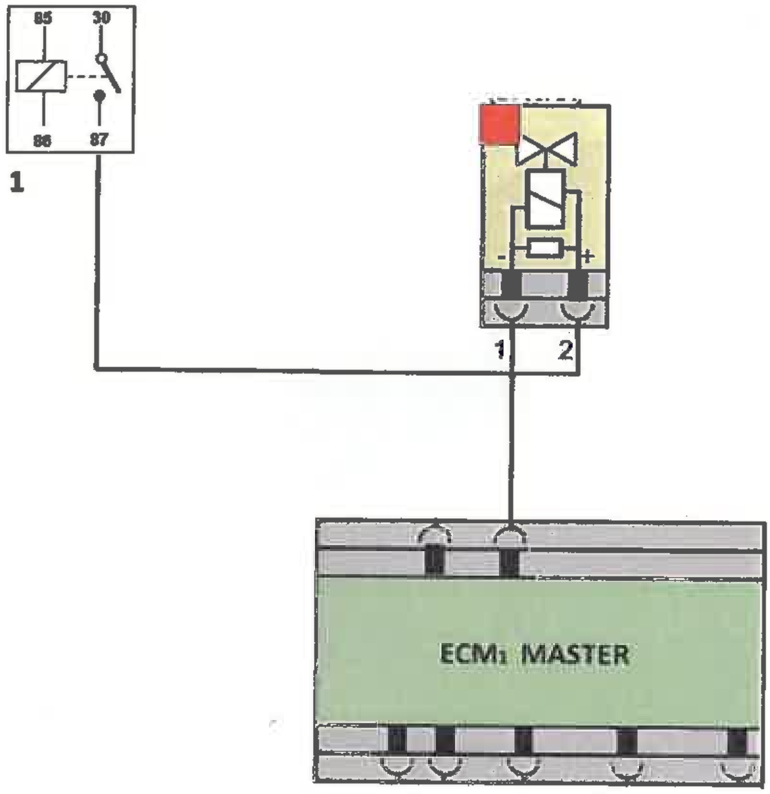
It is PWM powered and in function of the duty cycle, it varies the fuel vapour flow delivered by the solenoid valve.

The solenoid valve has one inlet and two outlets. The two outlets are connected to their respective vapour recirculation pipes upstream of the turbocharger and downstream of the throttle body.

*Electrical specifications:*

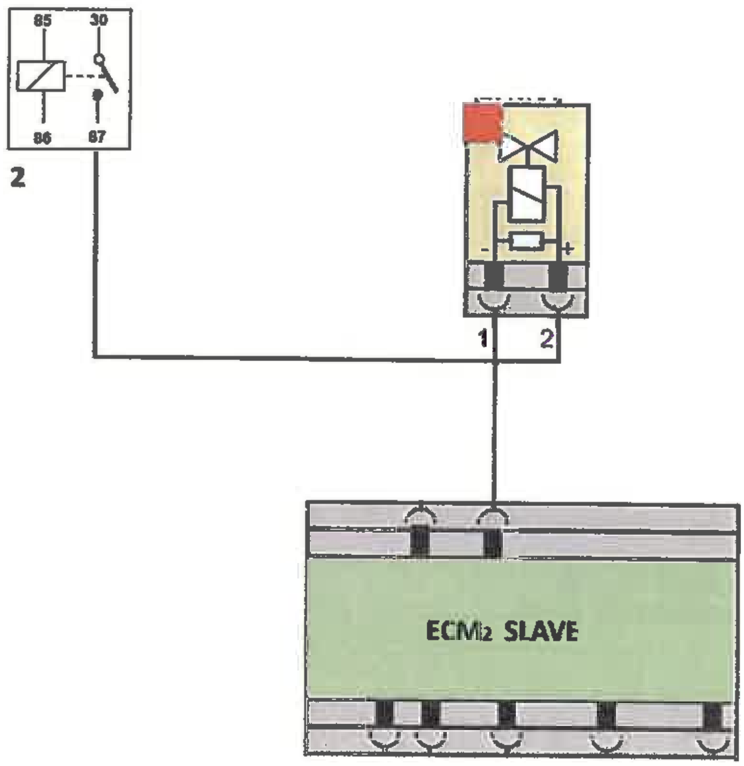
Electrical resistance: 21±3Ω

*Wiring diagram of the canister solenoid valves.*




Key

1 – Main relay, right bank.

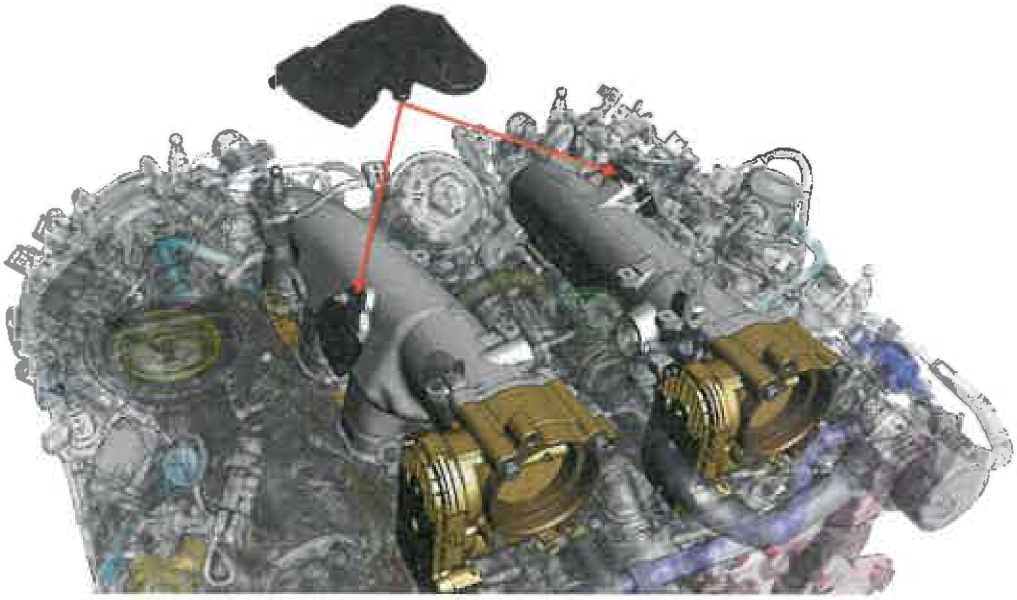



Key

2 – Main relay, left bank.

**Air intake system management components.**

**Pressure and temperature sensor (1 per bank).**

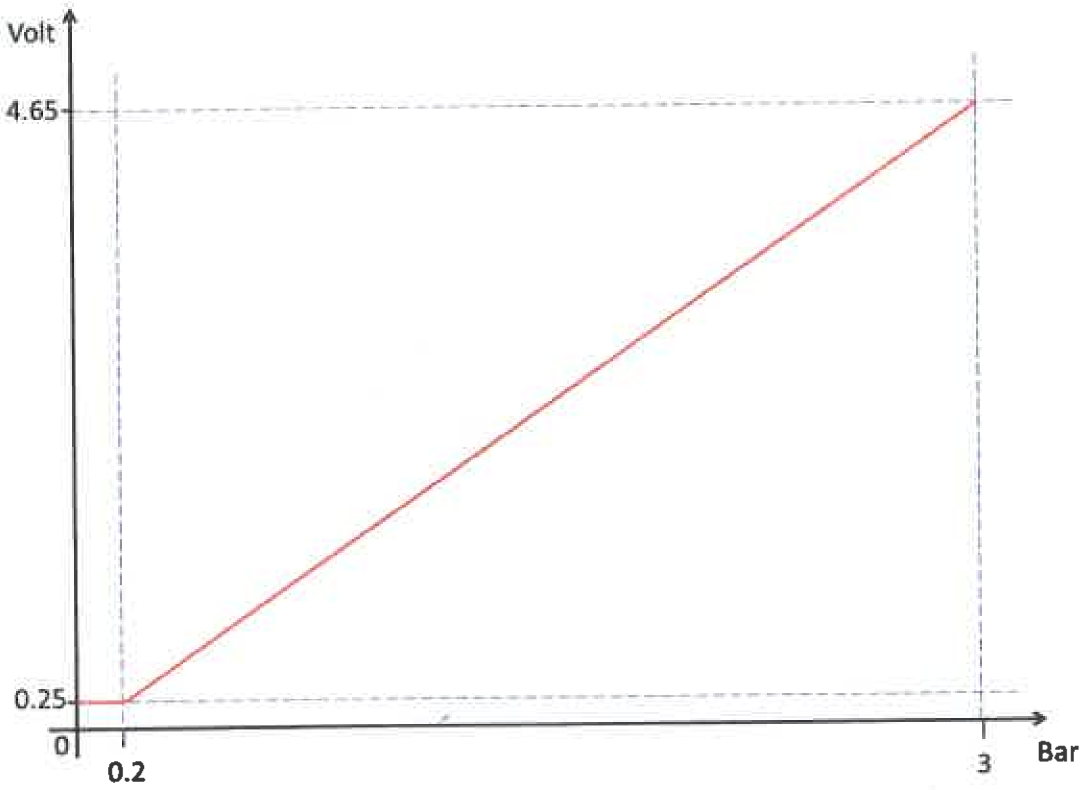


The pressure and temperature sensor allows the engine control modules to calculate the air mass entering the engine cyclically. The calculation model in the $ECM_1$ Master and $ECM_2$ Slave memory uses air pressure and temperature values to calculate its density, and the engine revolutions to calculate the air mass that develops in the engine from cycle to cycle. The latter parameter is fundamental to correctly calculate injection times.

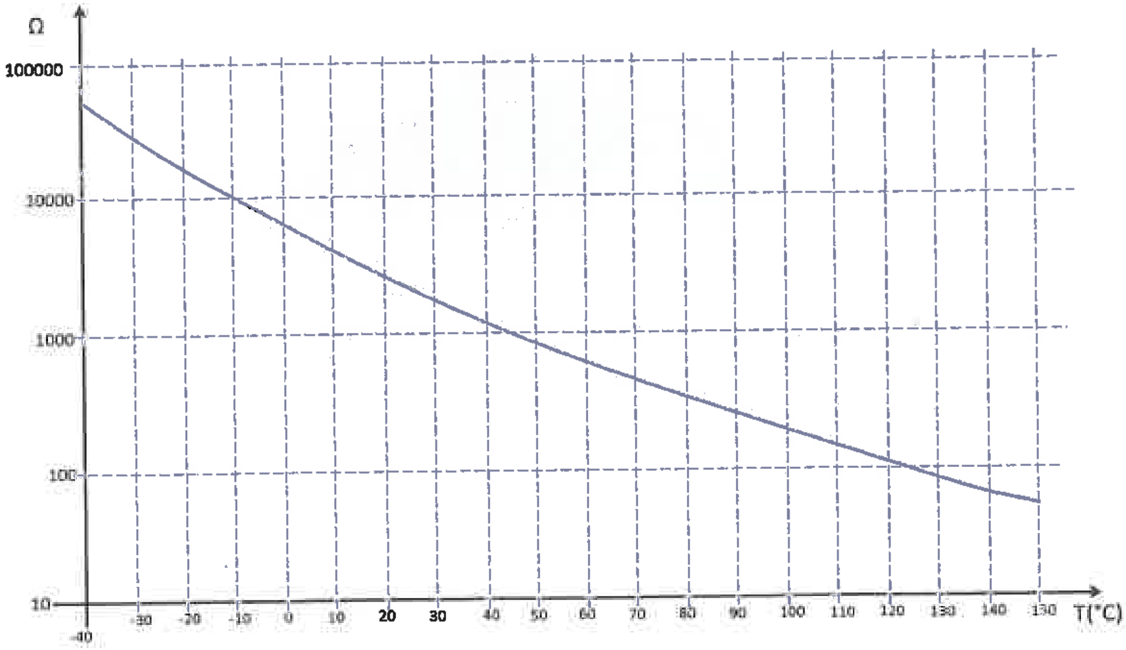
Pinout

Key:
1 – Earth.
2 – Air temperature signal in intake manifold.
3 – 5V power supply
4 – Air pressure signal in intake manifold.

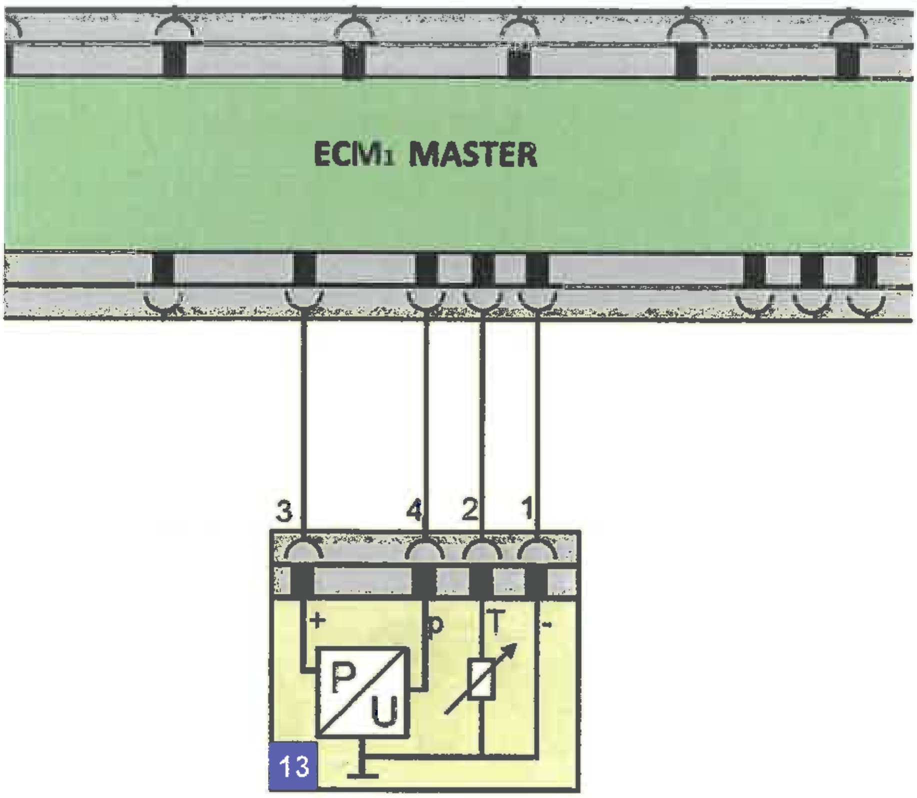
Air pressure signal in the intake manifold

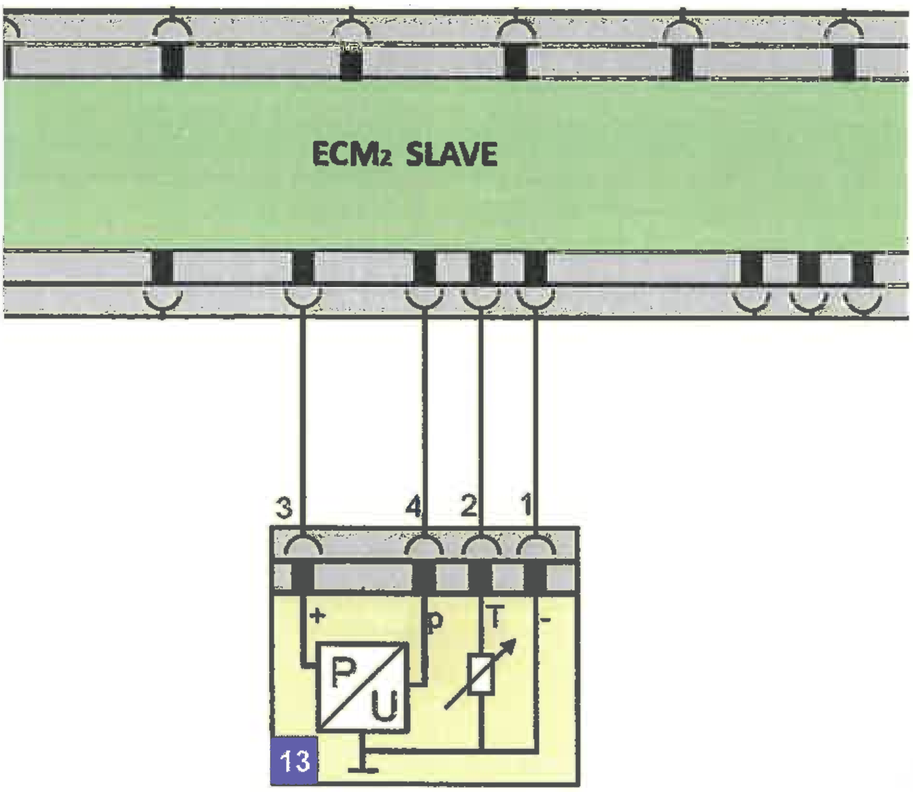



Electrical Resistance-Temperature correlation of the Sensor.

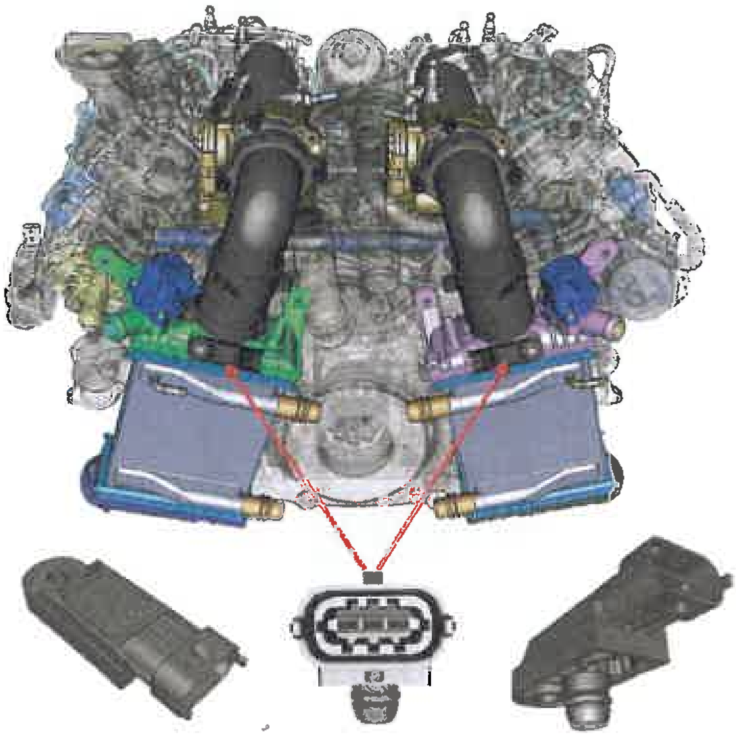


**Intake air pressure temperature sensor wiring diagram.**



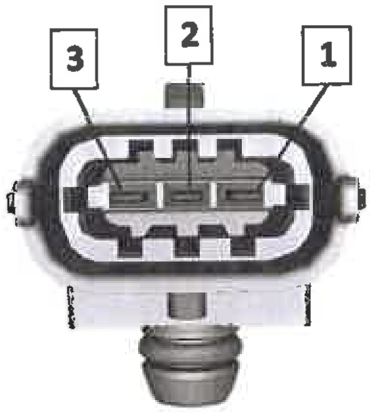



## Supercharger pressure sensor (1 per bank).



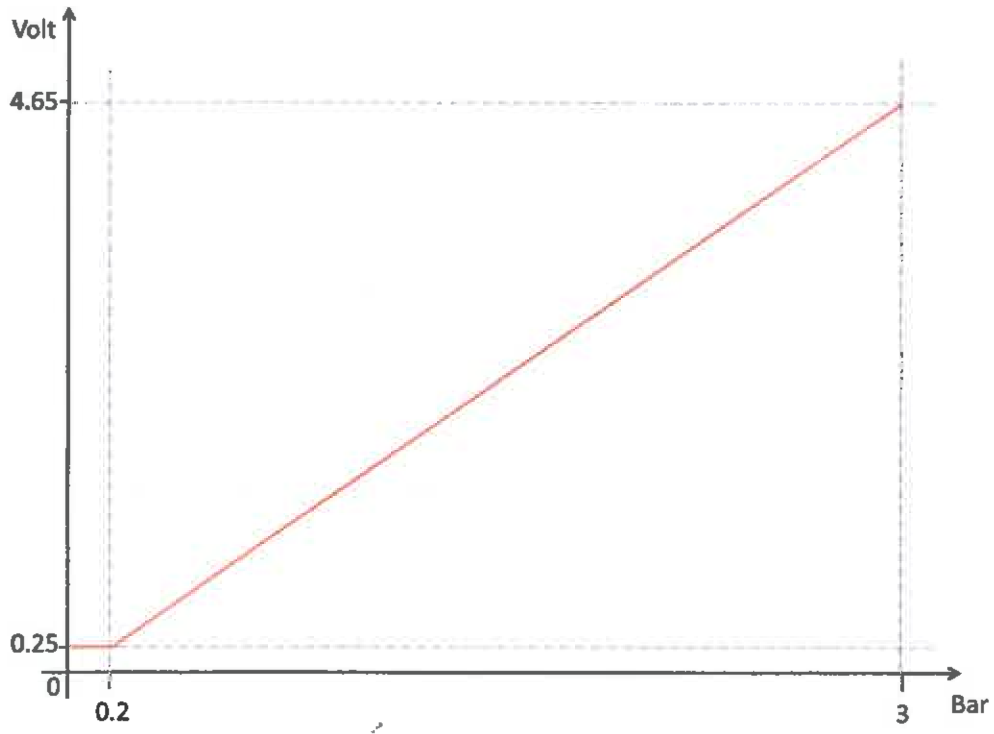
The supercharger pressure sensors are located on the upper part of the intercoolers and exactly against the air sleeve attachment connecting the intercoolers to the throttle bodies.
By virtue of the signal generated by the sensor, the ECM engine control modules can manage the supercharger pressure value by properly commanding the Wastegate actuators of the two turbochargers. The sensors allow the ECM modules to control supercharging pressure in a closed loop: depending on the engine operating point, the ECMs extract from the calculation models the supercharger pressure target value and operate on the Wastegate actuators to reach it. Via the sensors, the ECMs measure the effective supercharger pressure and as a function of this latter datum, they correct the command on the wastegate to maintain the target.

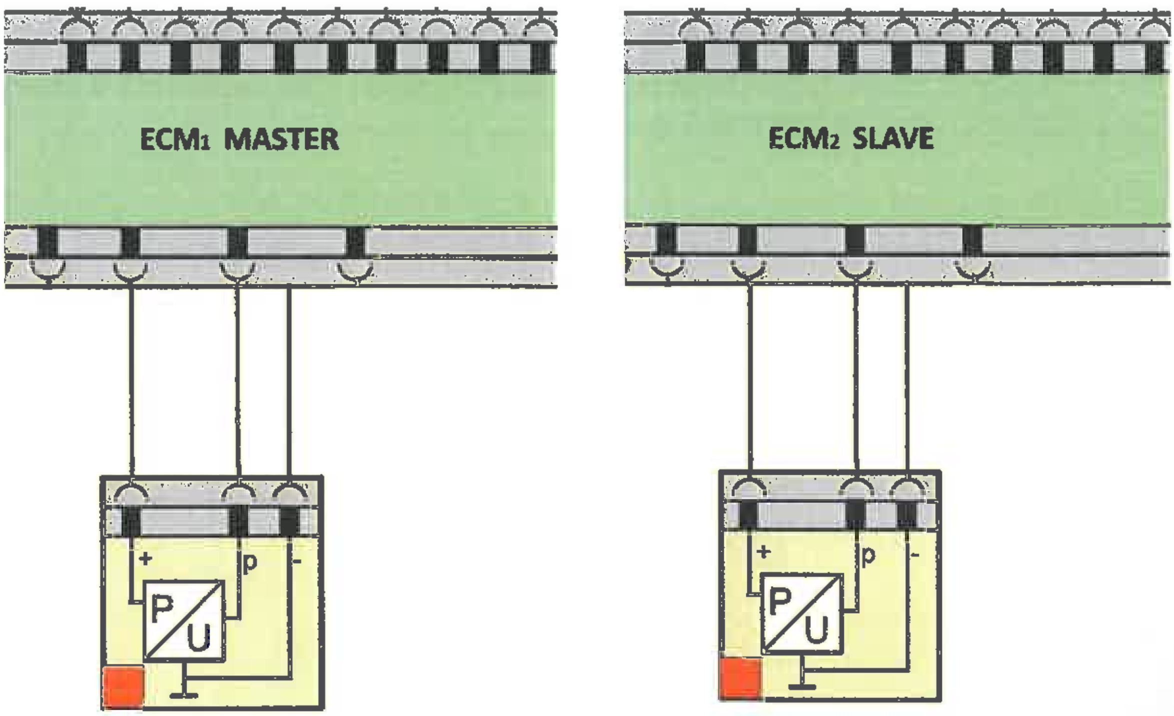
Pinout



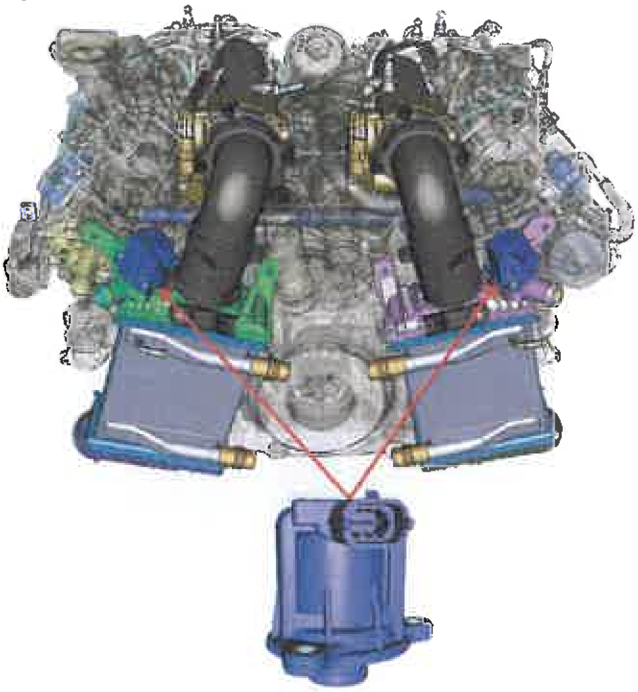

Key:
1 – 5V power supply
2 – Earth
3 – Signal.

Supercharger pressure sensor signal.



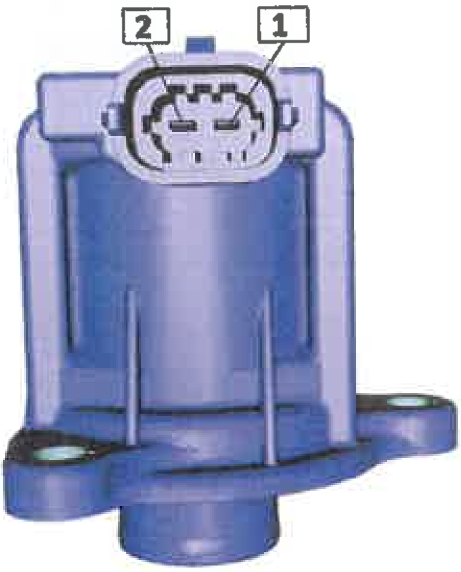



## Dump solenoid valve (1 per bank).



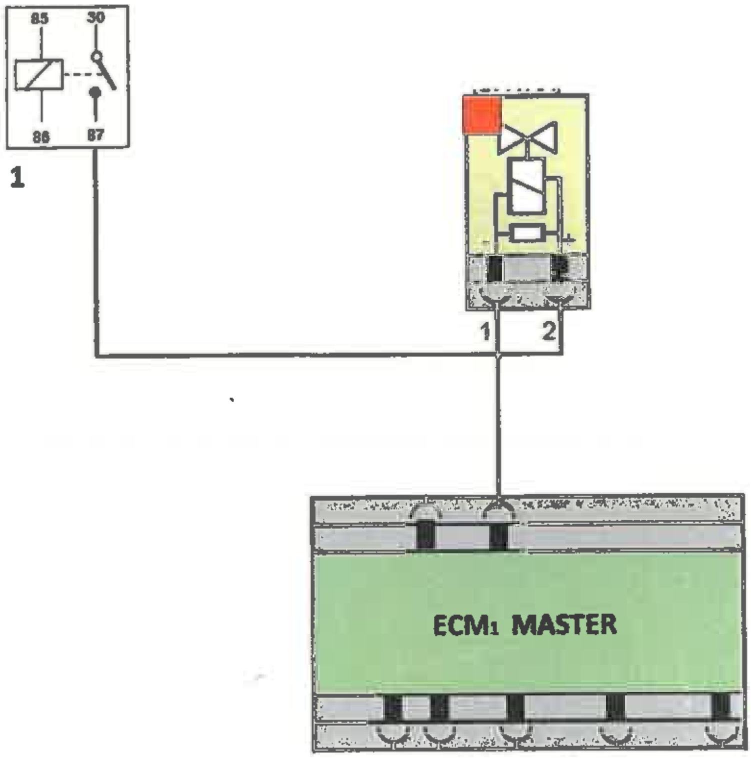
The Dump solenoid valve is the actuator that limits the air pressure inside the sleeve connecting the intercooler with the throttle body.
Limiting the pressure peak is especially necessary in cut-off conditions where the throttle body closes and the sleeve pressure tends to increase due to the inertia of the turbo, which continues to "push" for a few moments after cut-off. To limit pressure peak, the ECM engine control module commands the Dump solenoid valve to "dump" excess air.

*Pin out*

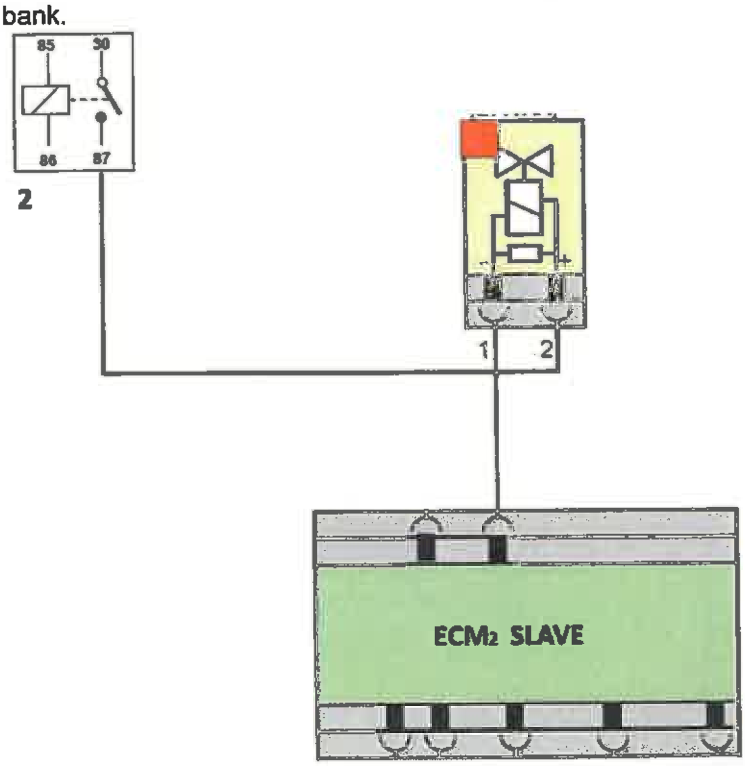



Key:
1 – Earth command by ECM
2 – Power supply from main relay.

The Dump solenoid valves receive power supply from the battery via the main relays (right bank and left bank) at pin 2 (power supply shared with canister solenoid valve). They receive the earth command from the ECM modules (right bank and left bank) respectively.



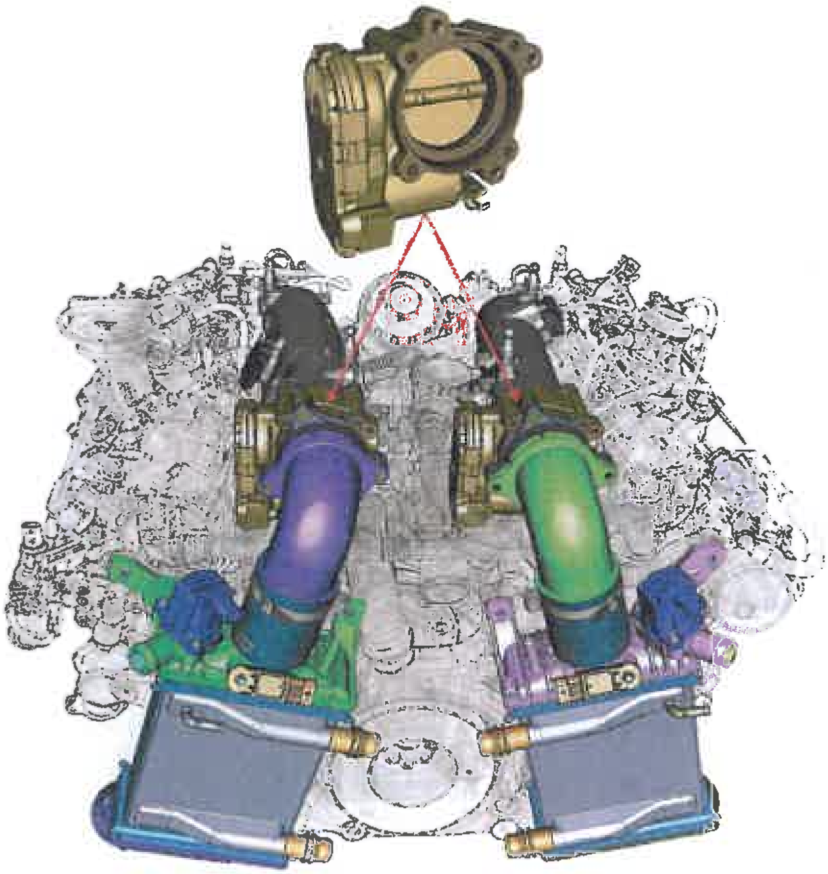

Key
1 – Main relay, right bank.



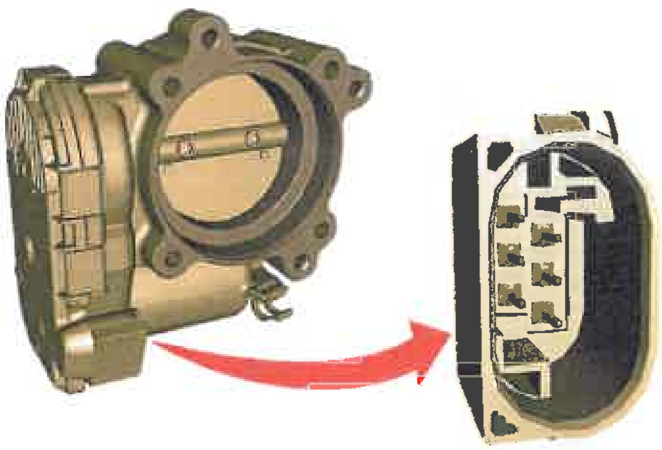

Key
2 – Main relay, left bank.

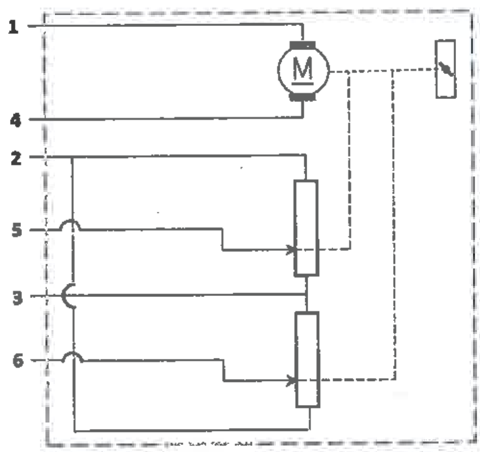
**NOTE:** for more details on the engine intake system features, please see the "Engine Systems" chapter.

**Electronic throttle body (1 per bank).**



The electronic throttle body consists of a small electric motor and two position control potentiometers.



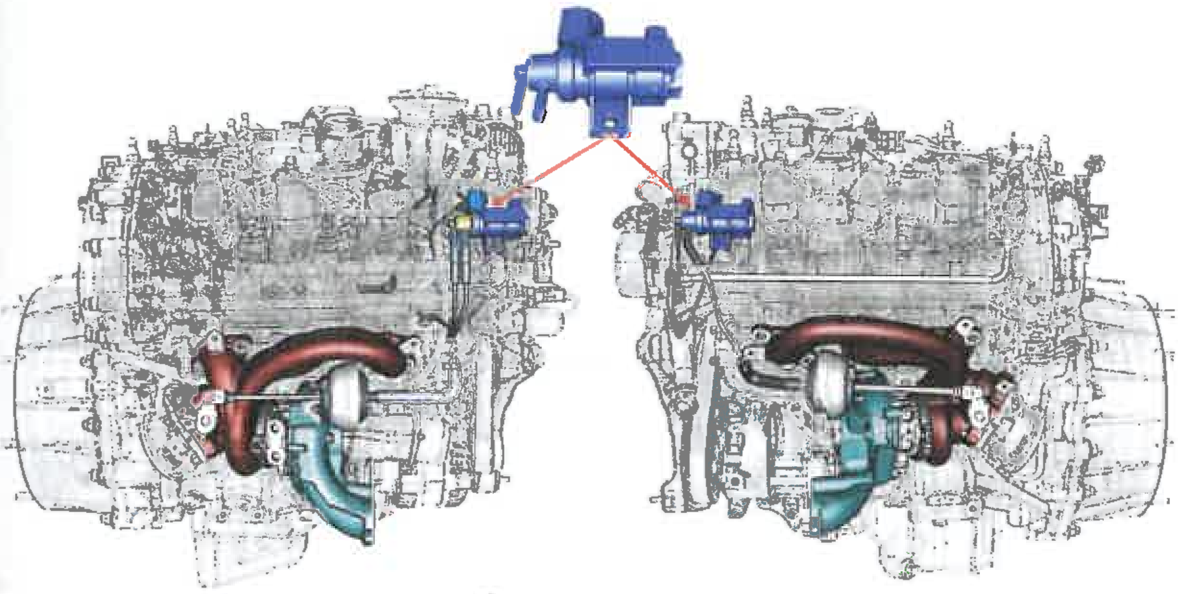



Pinout:

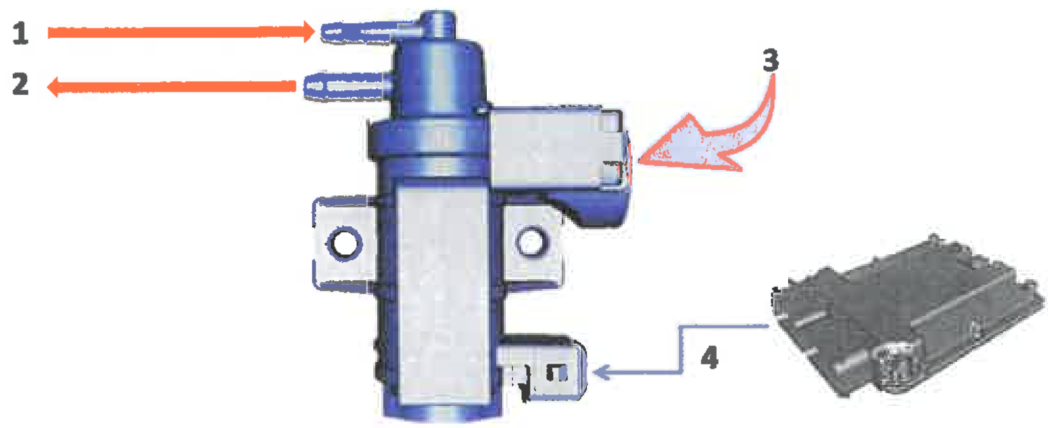
1 – Small electric motor power supply (-)
2 – Earth for potentiometers
3 – Power supply for potentiometers (+)
4 – Small electric motor power supply (+)
5 – Potentiometer 2 signal
6 – Potentiometer 1 signal

The ECM engine control modules manage their respective throttle body motor via a PWM command, and receive from them direct feedback of the position taken by the throttle from the signals coming from the two position potentiometers.

**Wastegate actuator control solenoid valve. (1 per bank).**



The ECM engine control modules manage the supercharger pressure generated by the two turbochargers, via the wastegate solenoid valves.



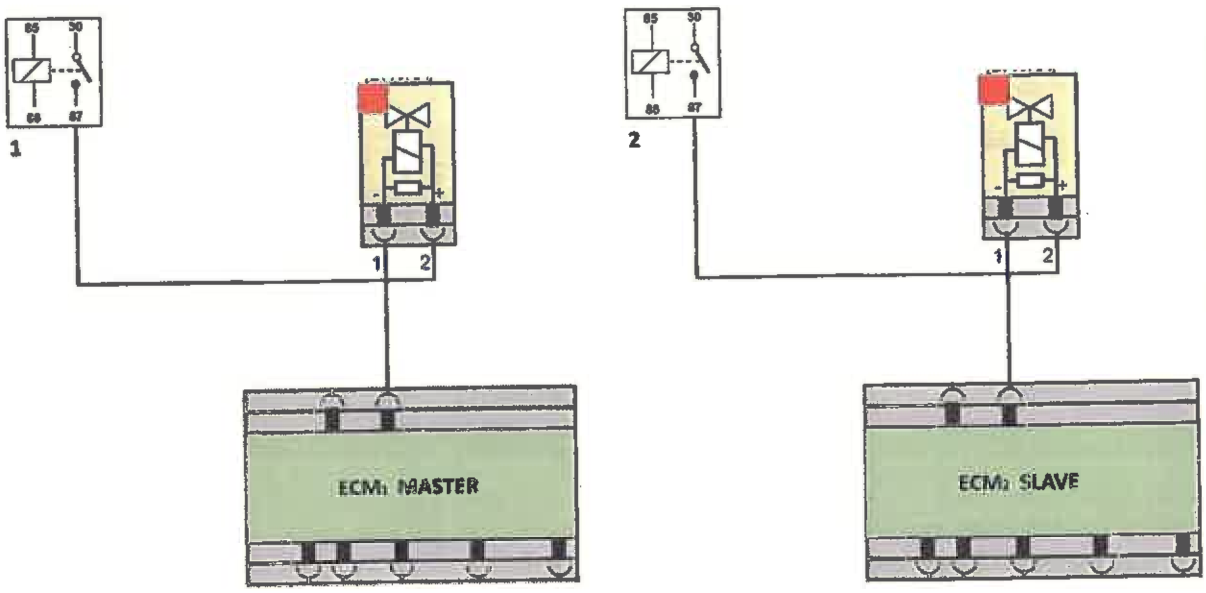

Key:
1 – Connection to the vacuum line.
2 – Connection to Wastegate actuator.
3 – Connection to outside environment (atmospheric pressure).
4 – Electrical connection to ECM Engine control module.

The solenoid valve has two inlets/outlets that allow it to place the Wastegate actuator in communication with the vacuum line (the Wastegate is normally open). The connection to the outside environment (atmospheric pressure) serves to recover pressure within the Wastegate actuator. Pressure recovery takes place in all those conditions when the solenoid valve is driven (by the ECM) to limit supercharger pressure. When the pressure inside the Wastegate actuator approaches the atmospheric pressure value, the exhaust gases entering the turbine are bypassed since the wastegate opens. Opening the Wastegate allows a portion of the exhaust gas to not come into contact with the impeller. All this translates to a lower "push" of the turbocharger.

*Solenoid valve pinout.*


1 – ECM engine control central unit command
2 – Power supply from main relay.

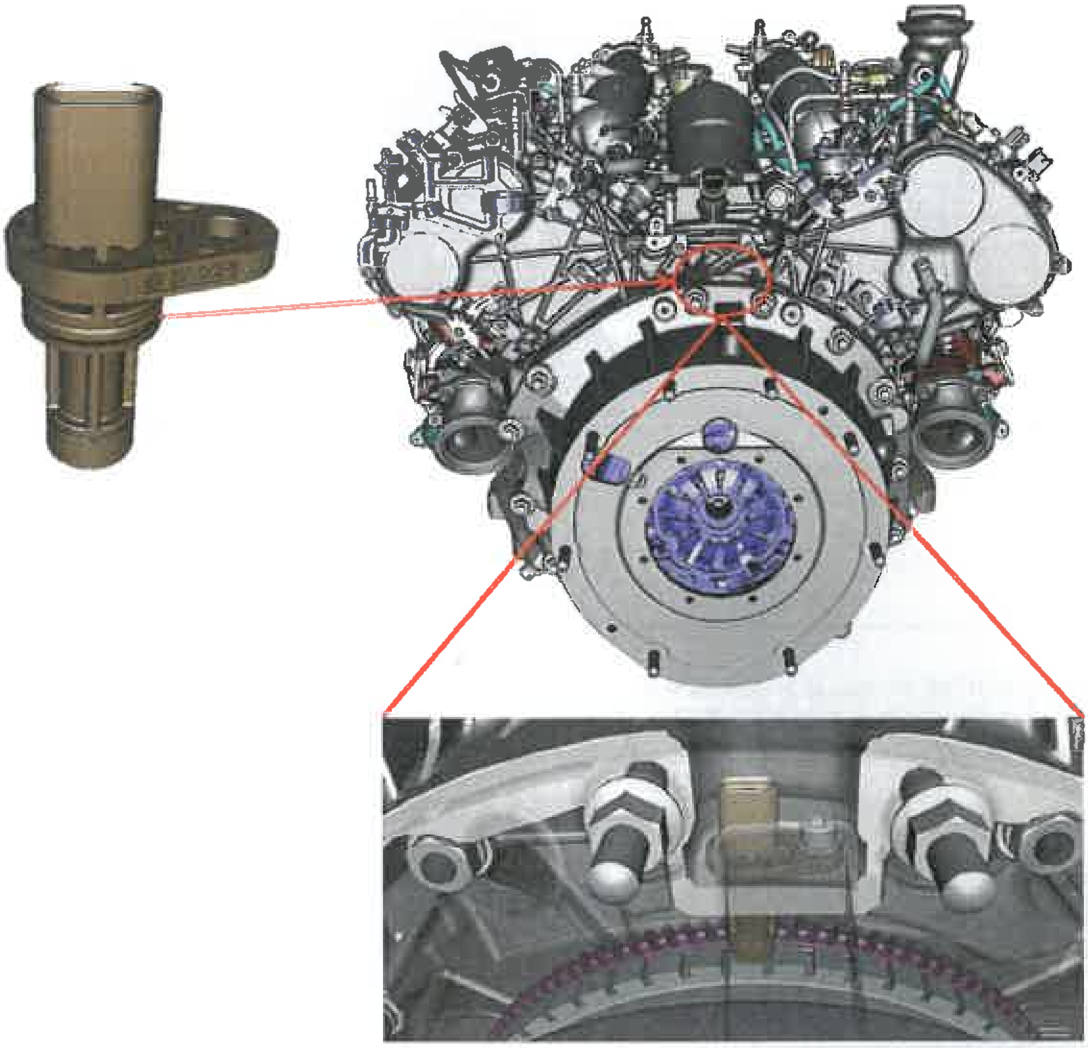
The engine control module manages the solenoid valve with a PWM command. The reason behind using a command of this type is due to the need to be able to modulate the wastegate opening.




Key
1 – Main relay, right bank
2 – Main relay, left bank.

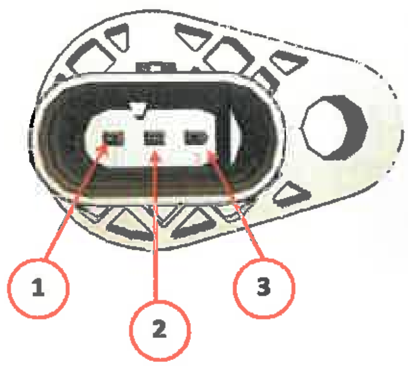
## Rpm sensor.

The rpm sensor detects the passage of each flywheel tooth and its direction of rotation. It follows that the signal the rpm sensor sends the ECM engine control module represents the speed and direction of rotation of the crankshaft.

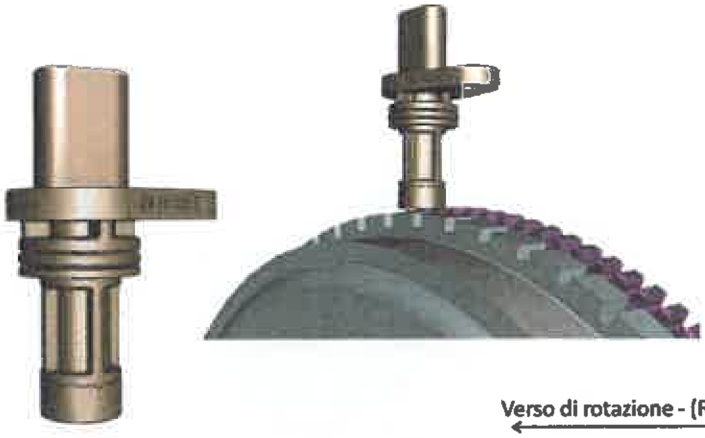


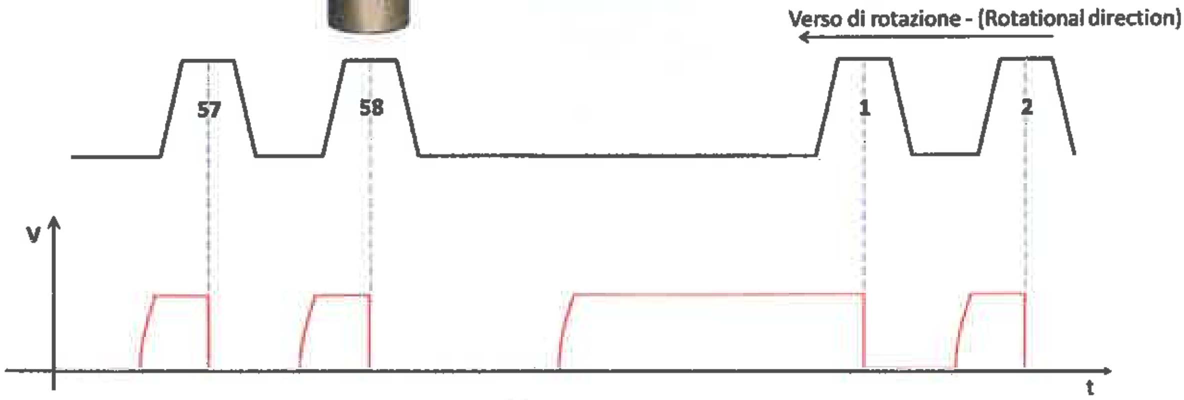
The rpm sensor exploits the Hall effect physics principle.

Pinout.

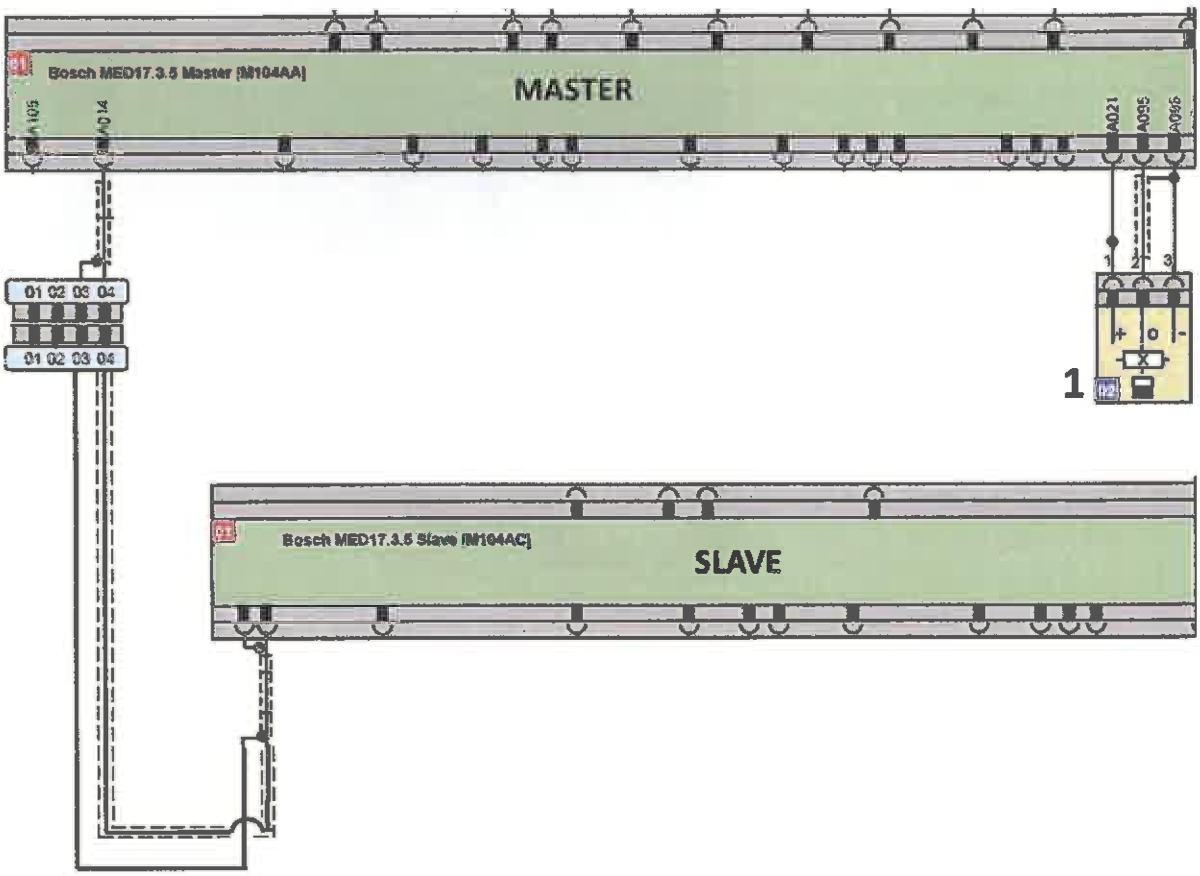



Key:
1 – 5V power supply
2 – Signal
3 – Earth.

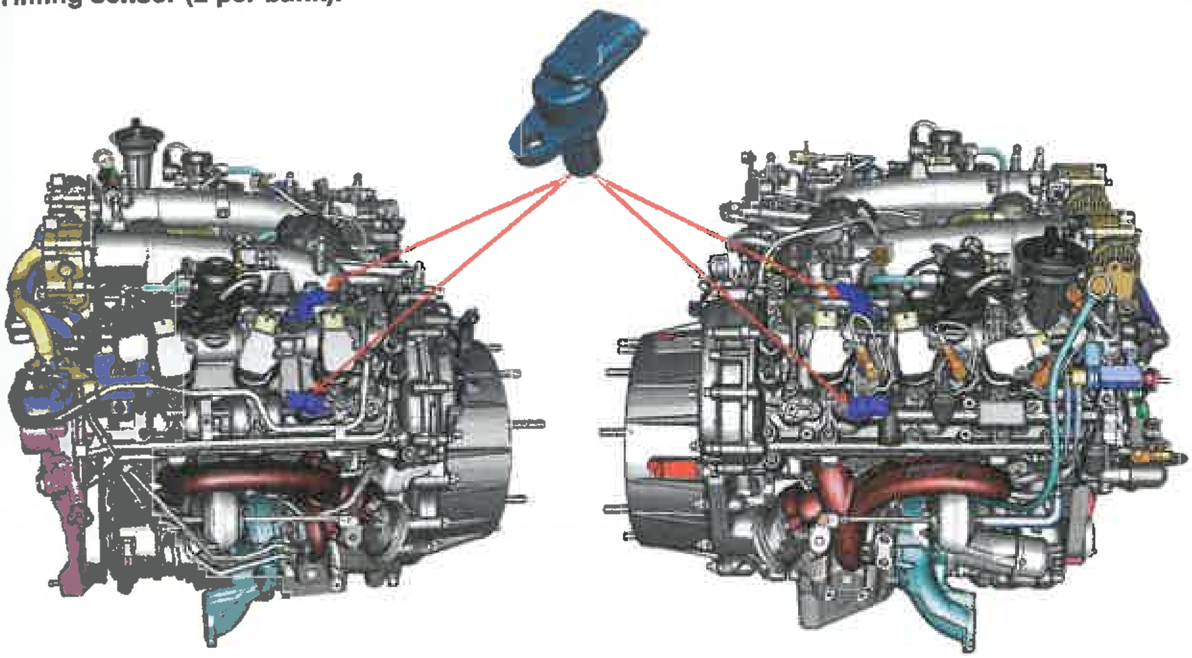




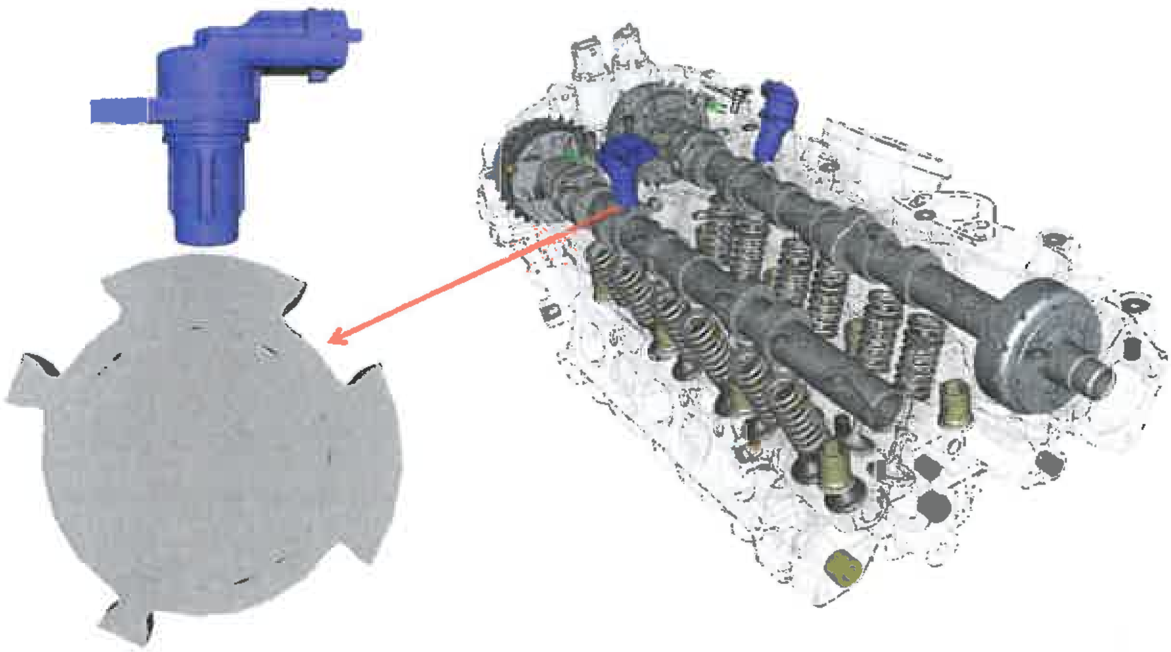

**NOTE:** The RPM sensor receives power and earth directly from the $ECM_1$ Master. The signal the sensor returns is received by both ECMs (Master and Slave): the signal is input to the $ECM_1$ Master and the latter "reflects" it to the $ECM_2$ Slave.



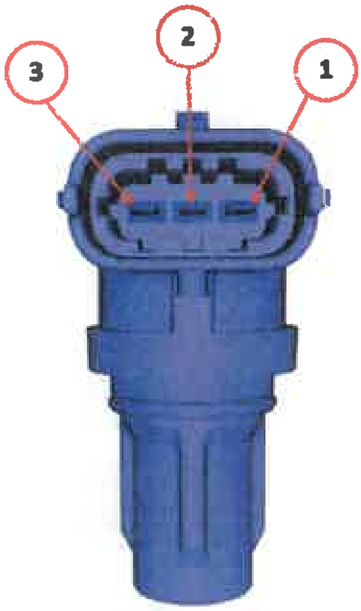
**Timing sensor (2 per bank).**



The timing sensors of both banks overlook specific phonic wheels on the camshafts.

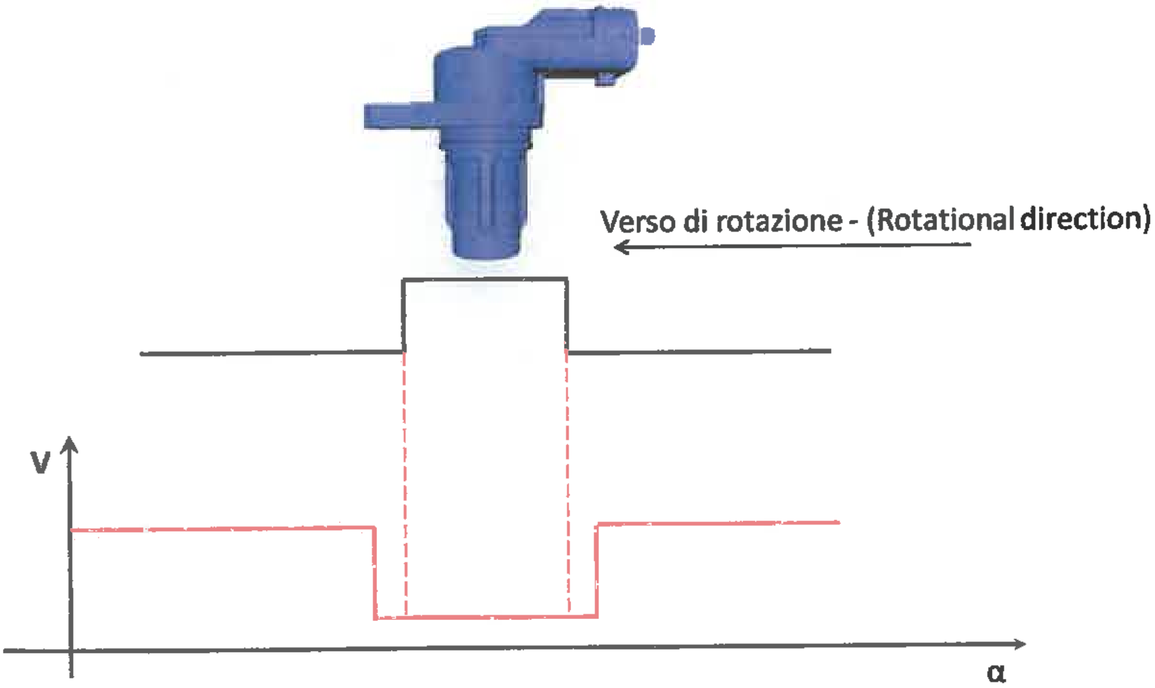


Sensor pinout



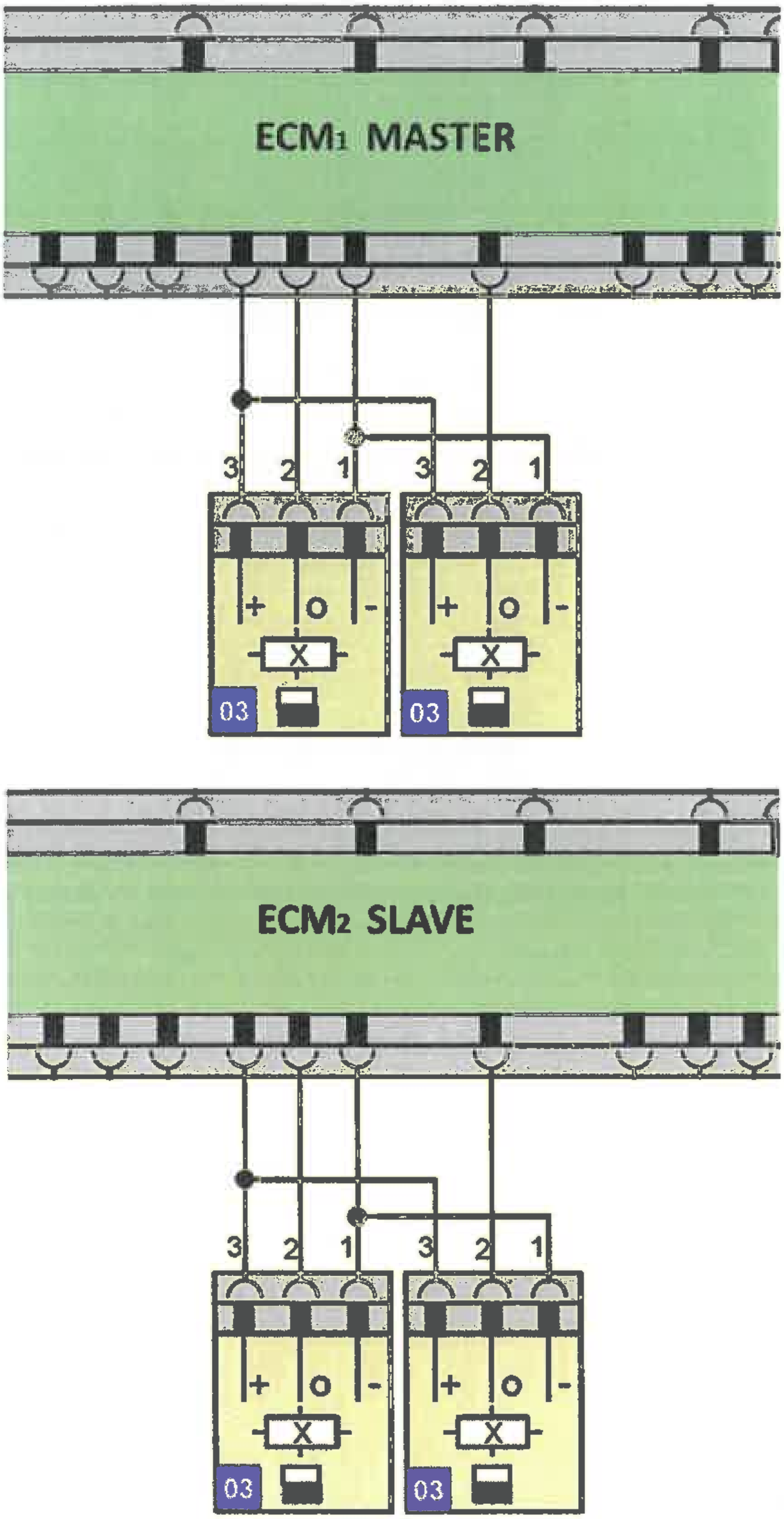

Key:
1 – Earth
2 – Signal
3 – 5V power supply

Timing sensor signal.

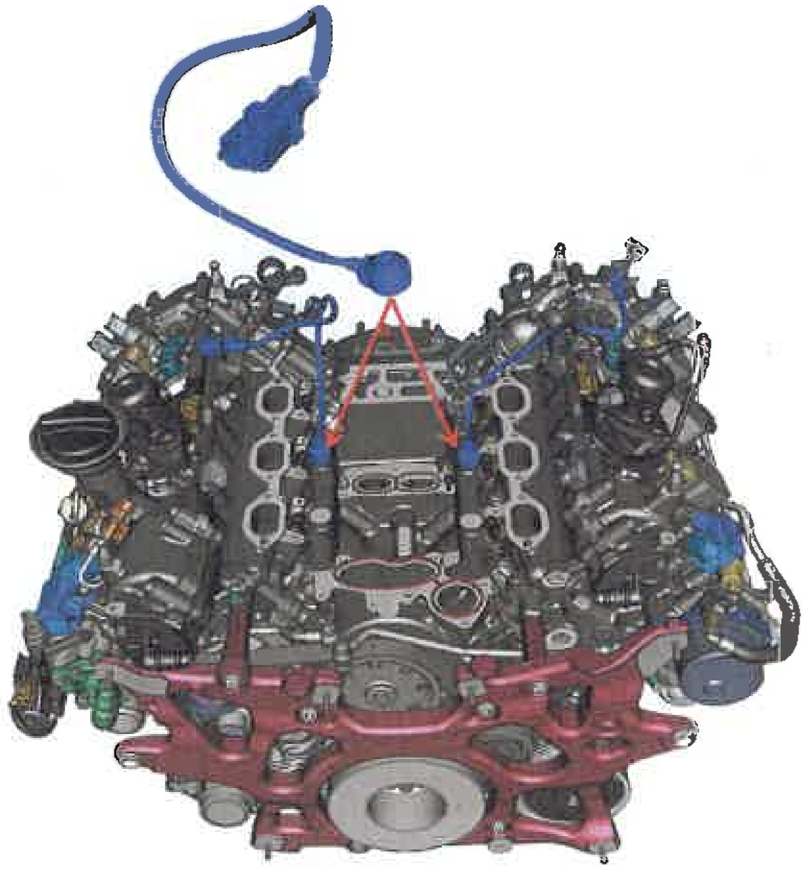



**NOTE:** The diagram shows the sensor signal as a function of rotation angle α. With this reference system, the square wave will always have the same width, independently of the rotation speed. With the measuring equipment of technical assistance, the sensor signal is detected based on time. In this case, the wave width varies as the rotation speed varies (the faster the rotation speed, the smaller the square wave width).

*Timing sensor wiring diagram.*

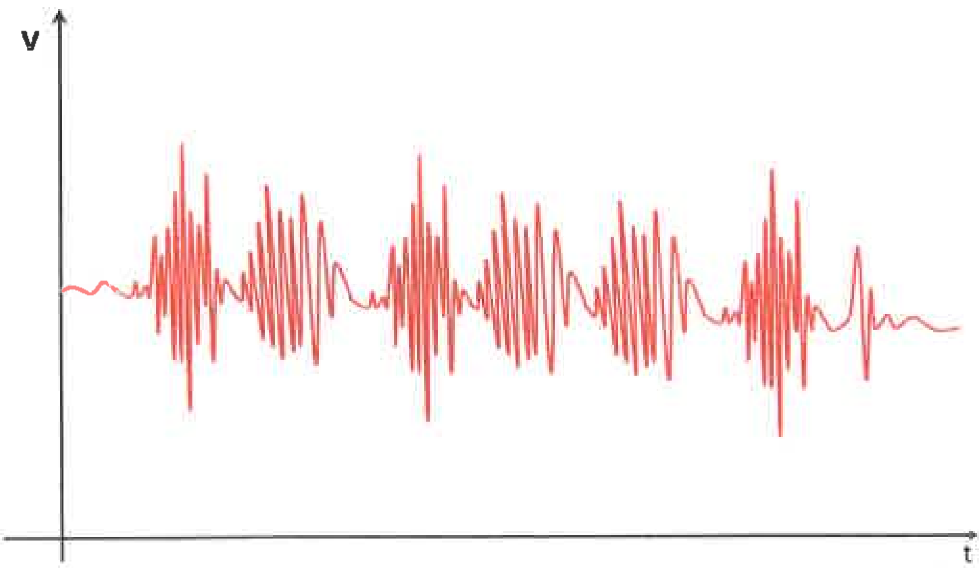


### Knock sensor (2 per bank).

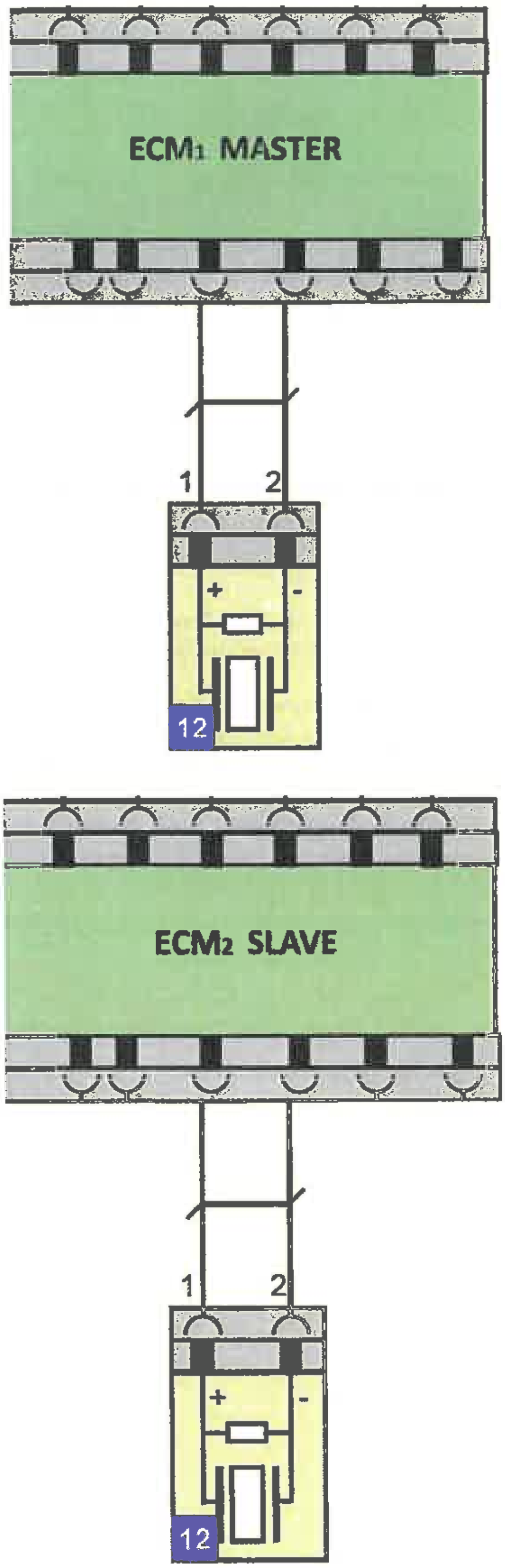


The knock sensor consists of piezoelectric material. Depending on the vibration frequency of the cylinder walls caused by ignition, the sensor generates voltage proportional to it. The ECM detects the voltage value generated by the sensor its rate of change, and as a function of the latter, it can understand whether there is knocking in the cylinder. To reduce the "pinging" phenomenon caused by knocking, the ECM starts reducing the ignition advance in order to limit the maximum pressure that can be reached in the combustion chamber (the higher the pressure, the greater the risk of knocking).

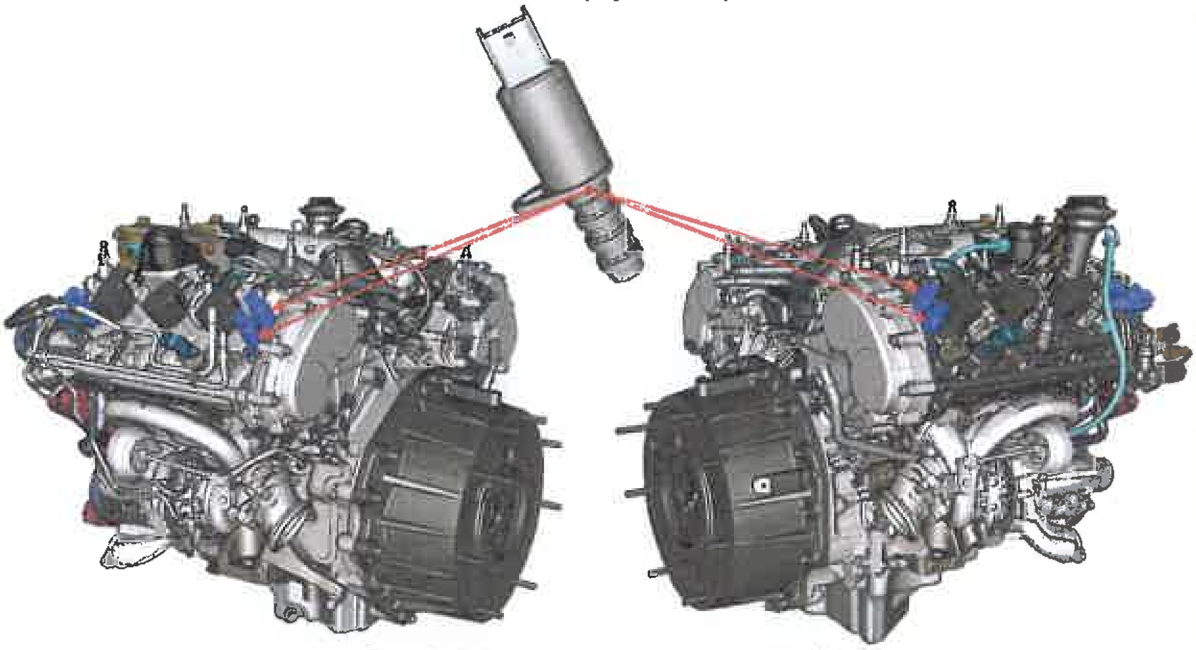
*Sensor signal*



*Knock sensor wiring diagram*



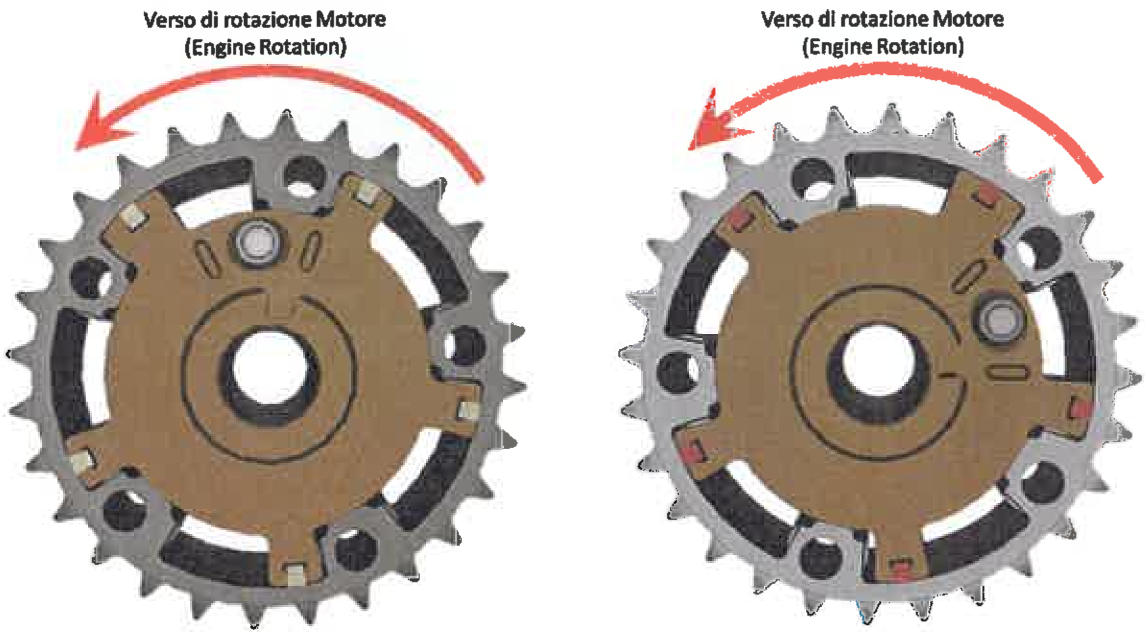
**Phase transformer command solenoid valves (2 per bank).**



The phase transformers of the right bank are managed by the $ECM_1$ Master engine control module via two OCV (Oil Control Valve) solenoid valves that regulate the flow of oil conveyed within the chambers of the phase transformers.
Similarly to the right bank, the phase transformers of the left bank are managed by the $ECM_2$ Slave engine control module via two other OCV (Oil Control Valve) solenoid valves that regulate the flow of oil conveyed within the chambers of the phase transformers themselves.

In conditions of key OFF, the phase transformers are in their resting position:

- Intake camshaft phase transformers: maximum delay position.
- Exhaust camshaft phase transformers: maximum advance position.



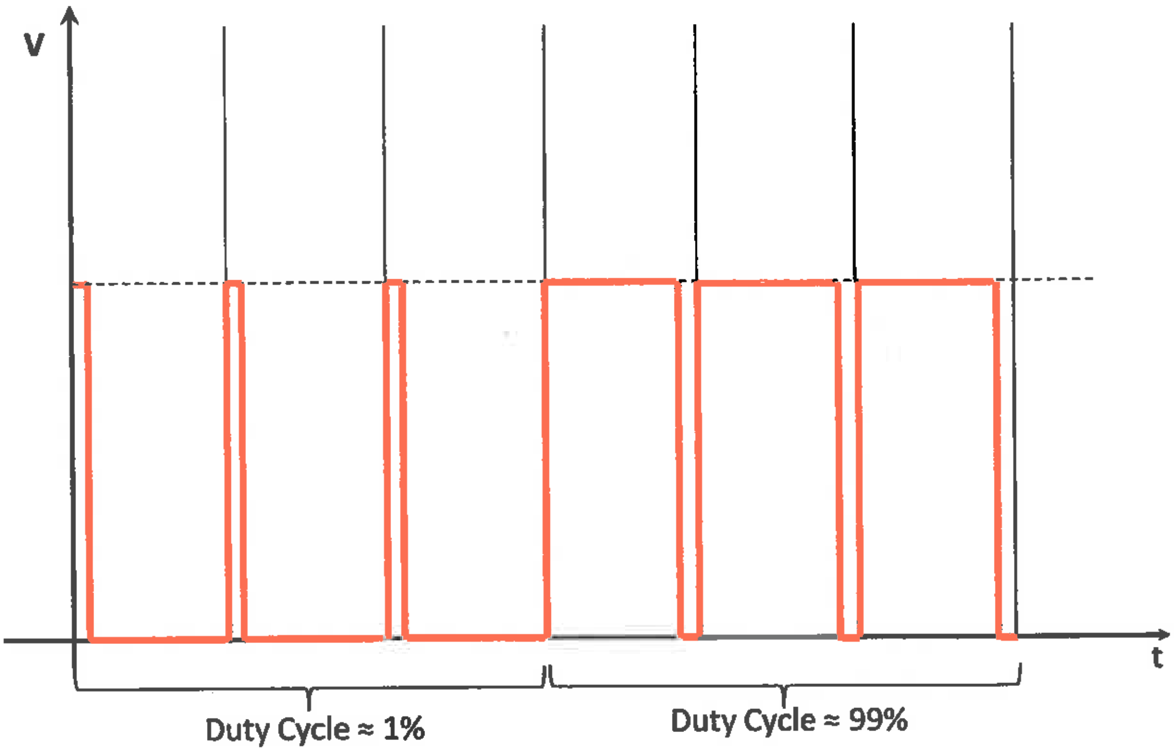

When the phase transformers are in their respective resting position or nearly, the valves do not cross.

The moment the engine is started, the oil pressure rises until it reaches operating values, and subsequently the lock pins of the phase transformers are deactivated allowing the latter to move to their resting position.

The movement of the phase transformers is allowed by the engine oil going under pressure in the chambers bound by the rotor walls and the outer body of the transformers themselves.

The engine control module activates both transformers in each bank using a specific mapping based on revolutions and engine load. Using the phase sensors of the camshafts, the engine control module can control the variable valve timing in a closed loop.

The OCV solenoid valves distribute the oil in function of the PWM command they receive from the engine control module.



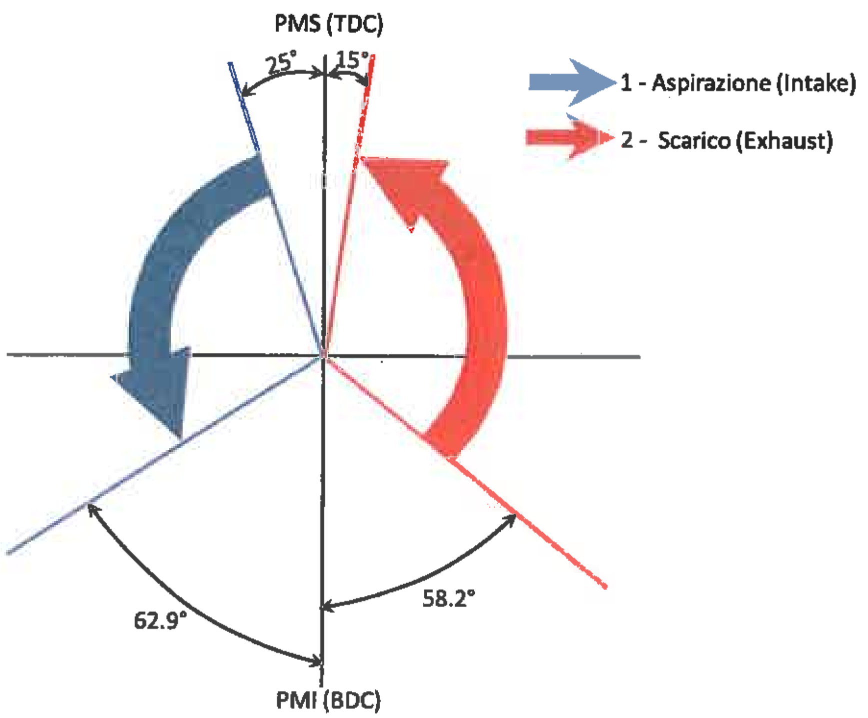

When the PWM command is characterised by a duty cycle of approximately 1%, the following conditions take place:

- The exhaust camshaft phase transformers are brought to the maximum advance position.
- The intake camshaft phase transformers are brought to the maximum delay position.

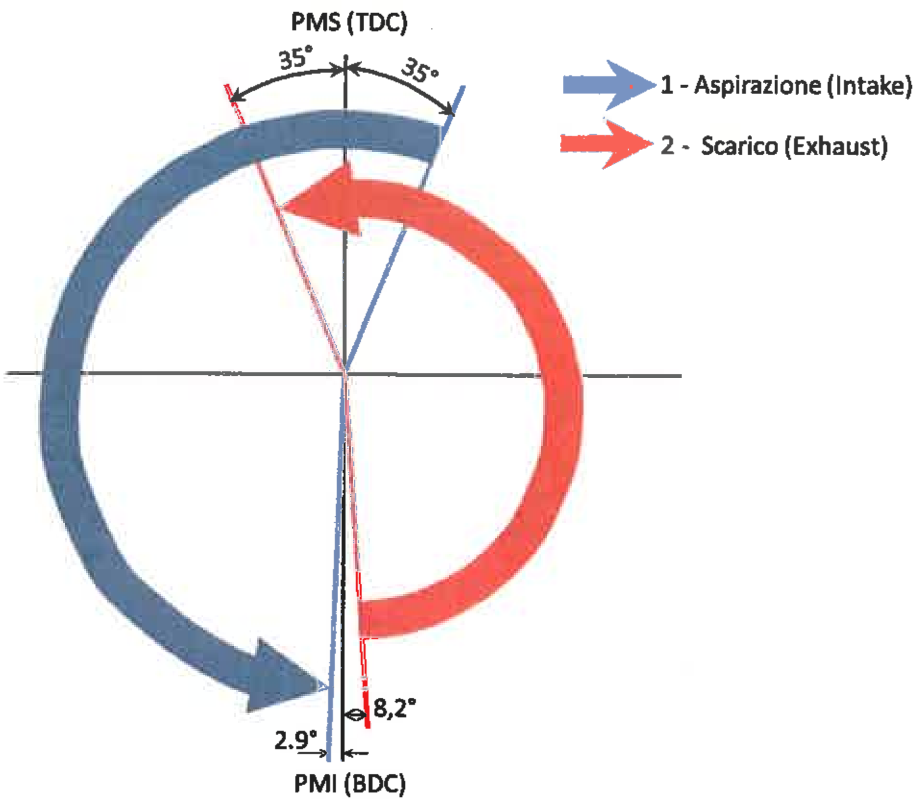
When the PWM command is characterised by a duty cycle of approximately 99%, the following conditions take place:

- The exhaust camshaft phase transformers are brought to the maximum delay position.
- The intake camshaft phase transformers are brought to the maximum advance position.

Variable valve timing diagram with phase transformers in resting phase.



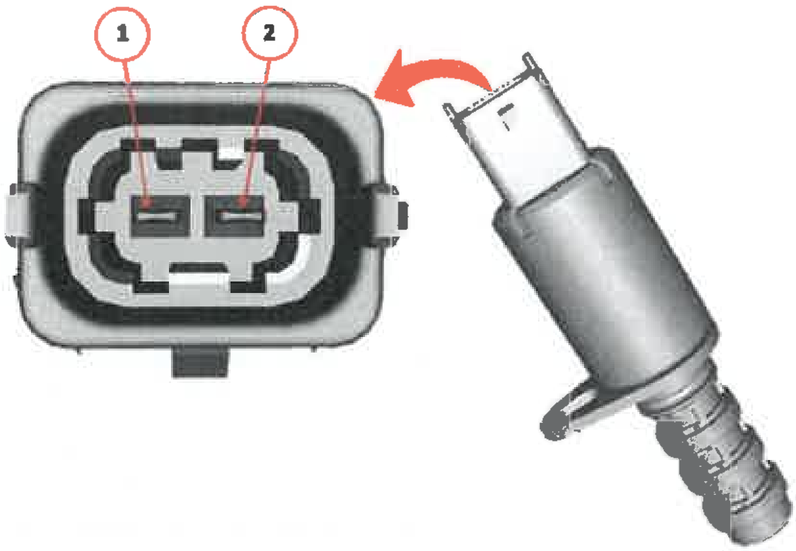

Variable valve timing diagram with phase transformers with maximum excursion.



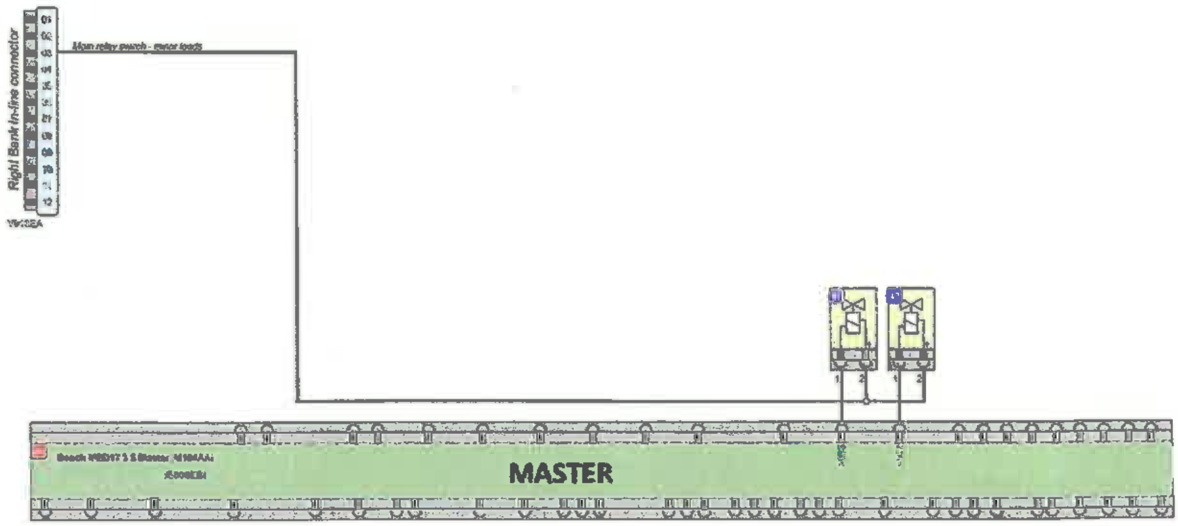

Key

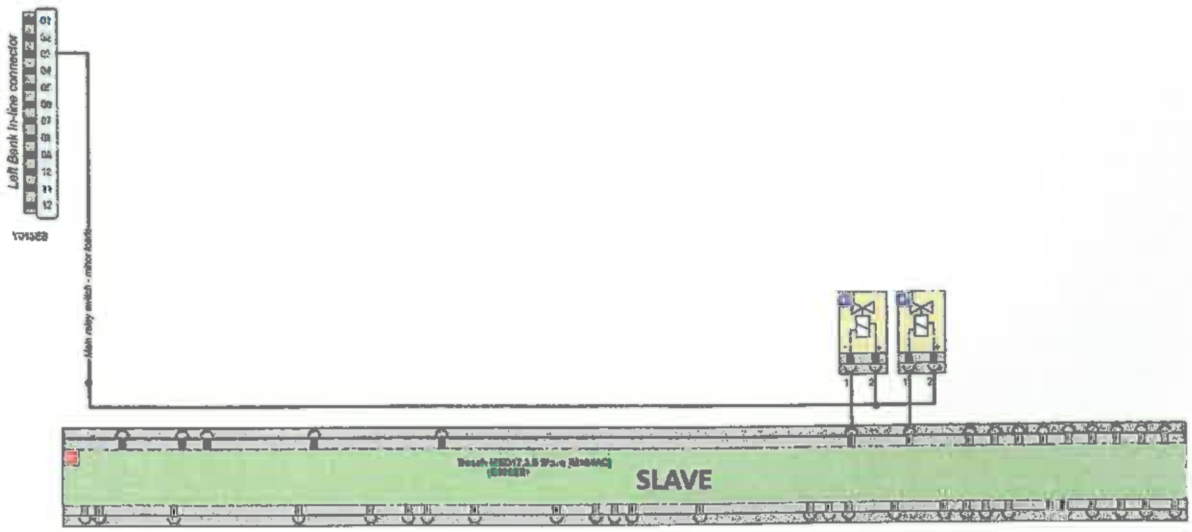
1 – Intake stroke.

2 – Exhaust stroke.

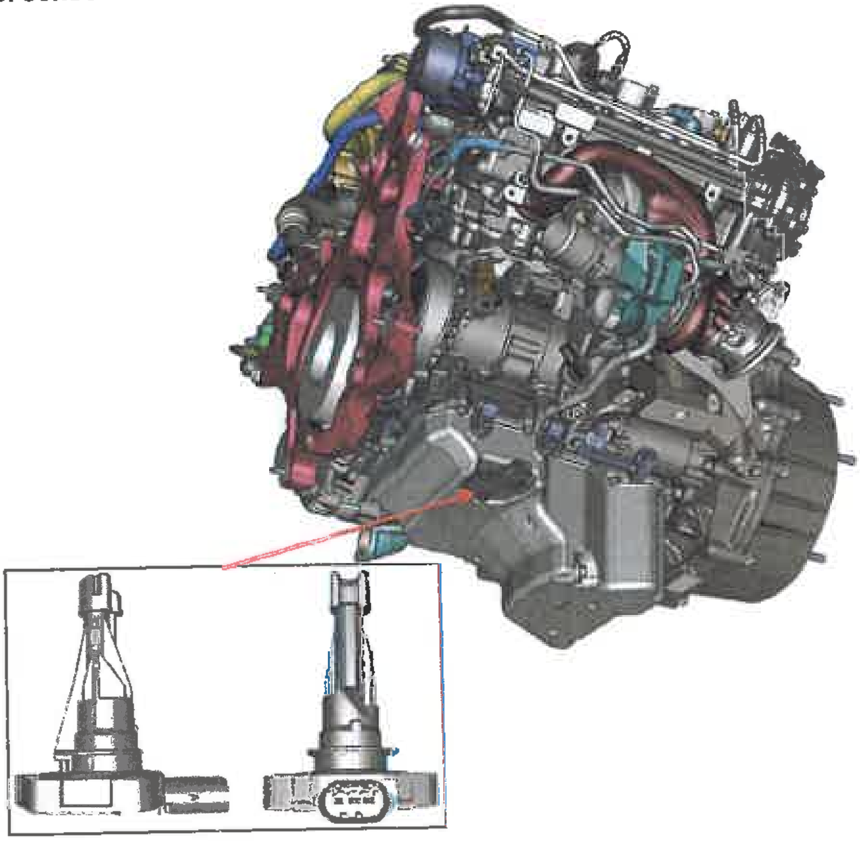



OCV solenoid valve pinout:
1 – Command by ECM
2 – 12V power supply from main relay.

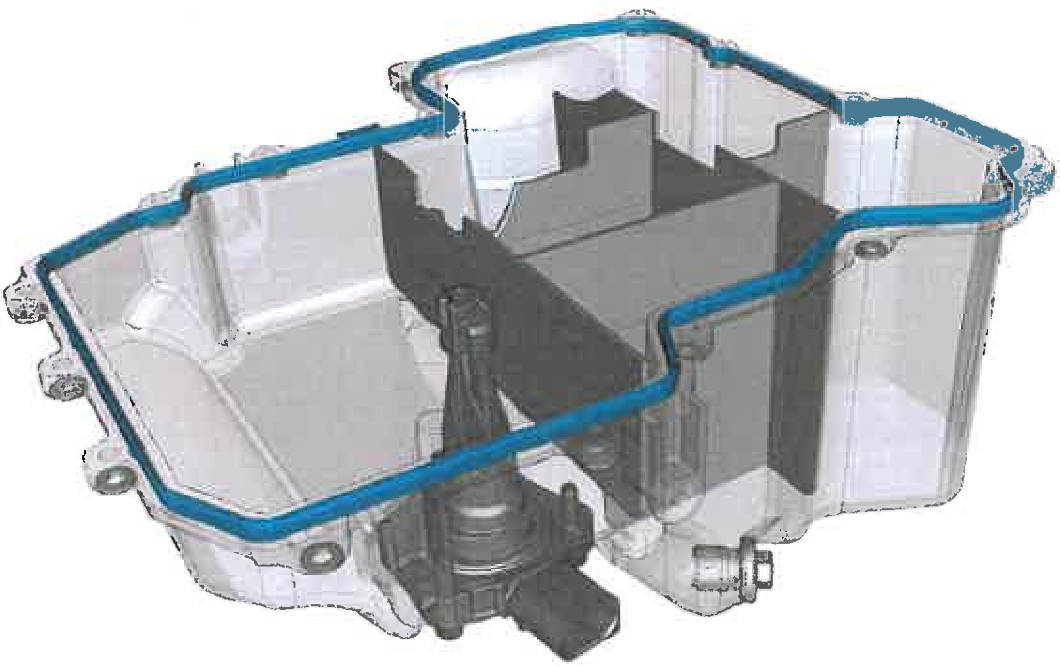


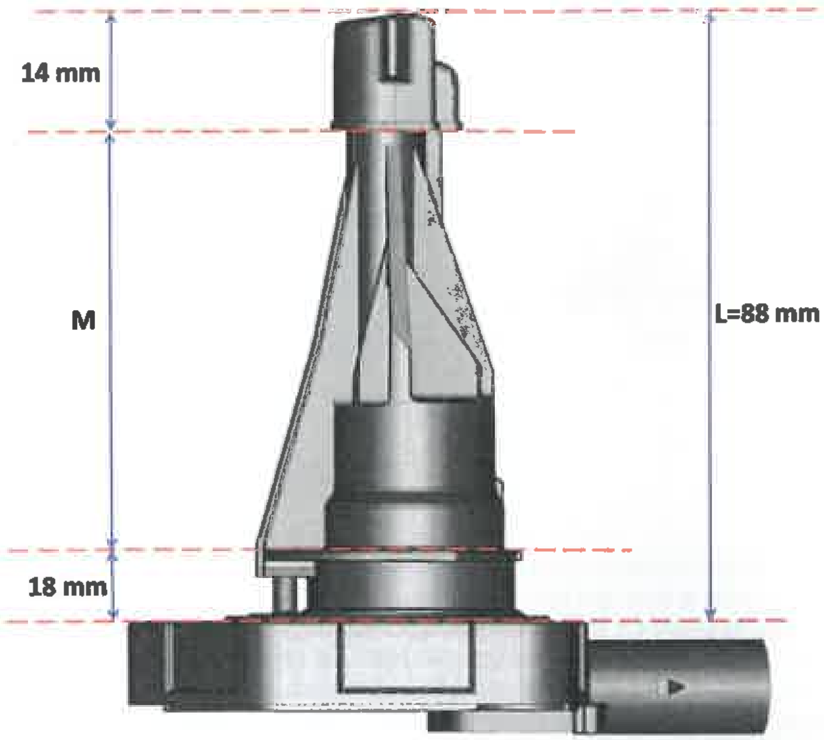



**Engine oil level sensor.**

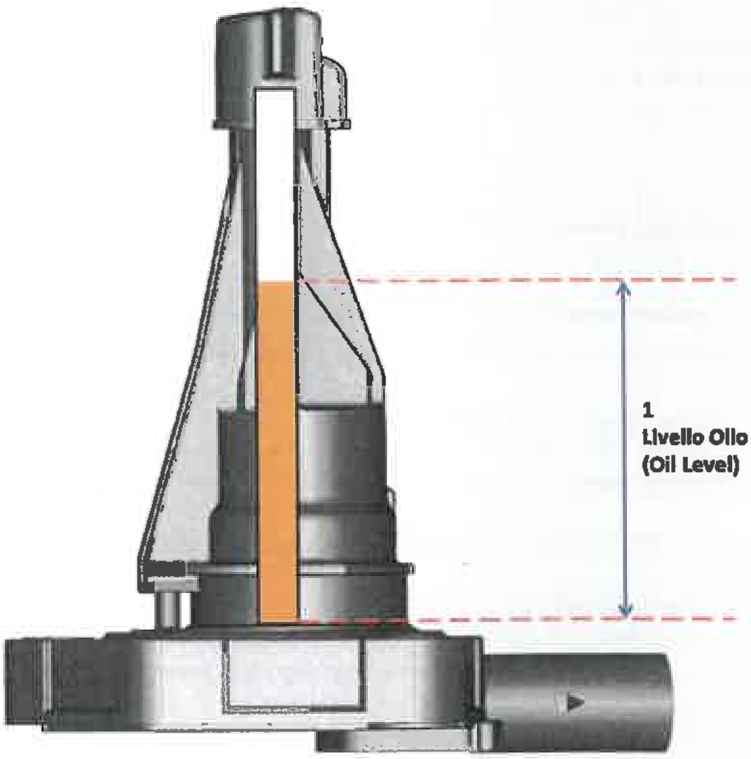


The oil level sensor is located in the engine oil sump. The sensor uses ultrasound technology to measure the oil level deposited in the sump.

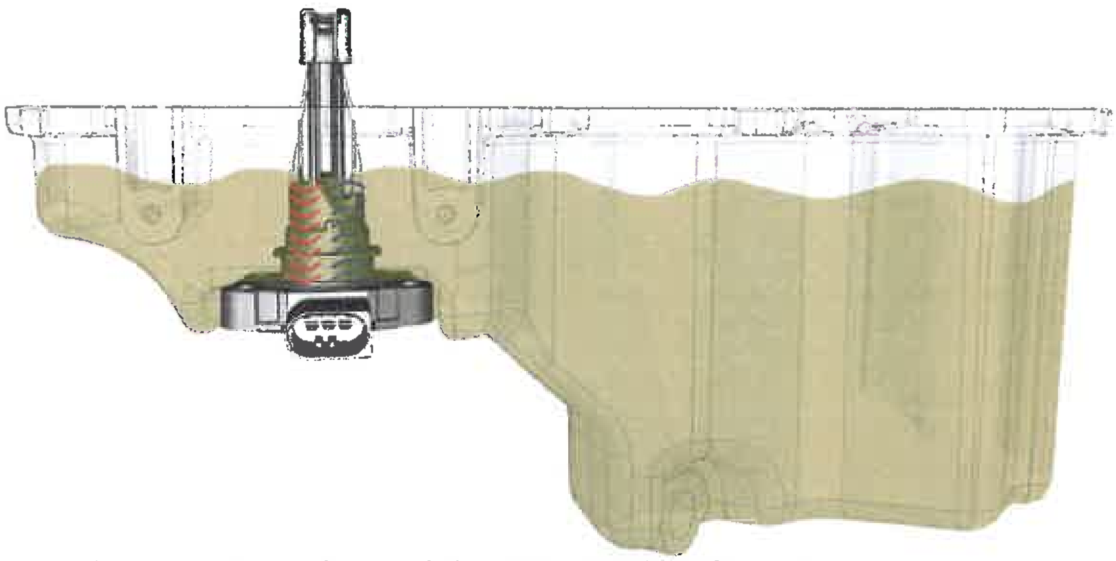





The level sensor enters the oil sump by about 88 mm. The sensor's electronics can measure the level only within measurement range M.

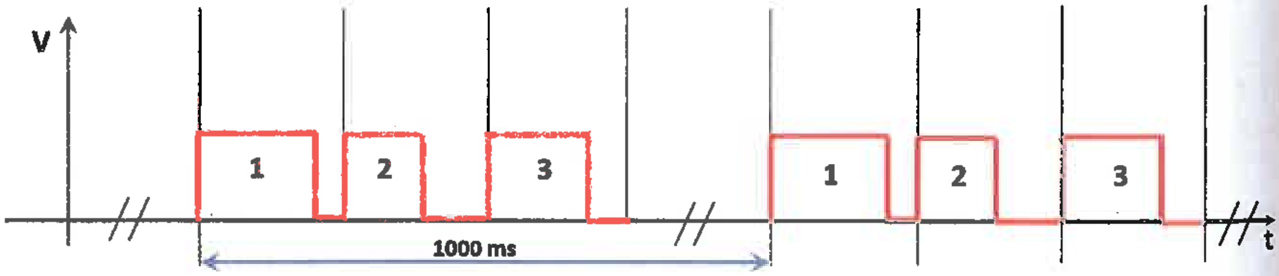



Inside the sensor there is a channel where the oil present in the sump goes into. Inside this channel, the oil reaches the same level as in the sump. The channel represents the measurement environment of the sensor. The sensor's electronics measure the level present in the measurement channel.



The oil level sensor emits an ultrasound signal. The signal is reflected the moment it meets a surface delimiting a change in matter phase (oil/air). Depending on the time the waves take to reach the free surface of the oil, reflect and return to the sensor's probe, the sensor's microchip prepares a PWM signal to send to the $ECM_2$ Slave engine control module. Depending on the duty cycle of the PWM signal, the $ECM_2$ Slave module calculates the level of oil present.
The sensor's electronics also process the oil temperature signal. The reading operating range of the sensor is: -40°C - 160°C.
Every 1000 ms, the sensor sends the $ECM_2$ Slave three PWM signals concerning the following three variables:

- Oil level
- Oil temperature
- Self-diagnostics data




Key:
1 – PWM on engine Oil Temperature variable.
2 – PWM on engine Oil Level variable.
3 – PWM on self-diagnostics data.

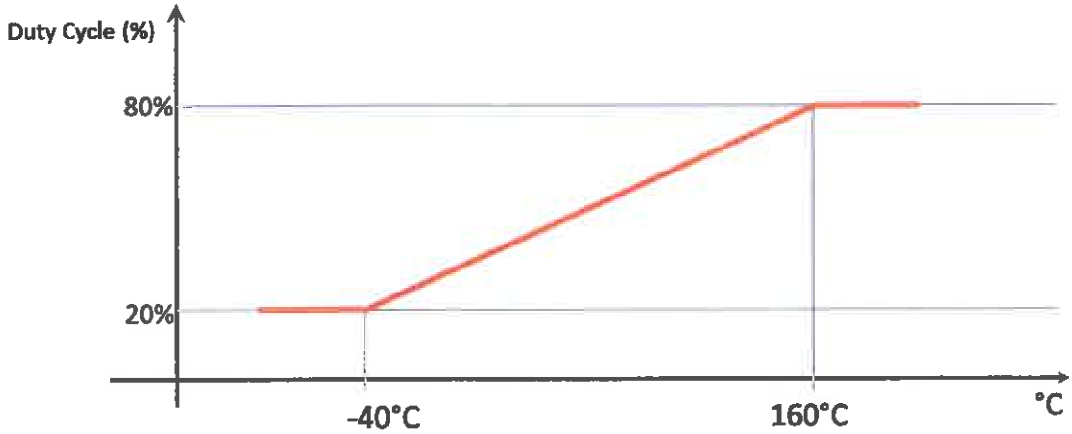
The $ECM_2$ Slave control module calculates the oil level and temperature if and only if the following conditions have occurred:

- Engine off and "Key" at ON
- Engine oil temperature when the engine is switched off in the range 80°C-90°C.
- Engine running in the previous cycle for no less than 5 minutes*
- Time for which the engine remained off not less than 3 minutes*
- Current temperature (meaning the oil temperature at the KEY ON time. The useable range is very wide.)
- Longitudinal and lateral accelerations below certain thresholds (any slopes on which the car is parked are interpreted by the control unit as lateral or longitudinal accelerations)

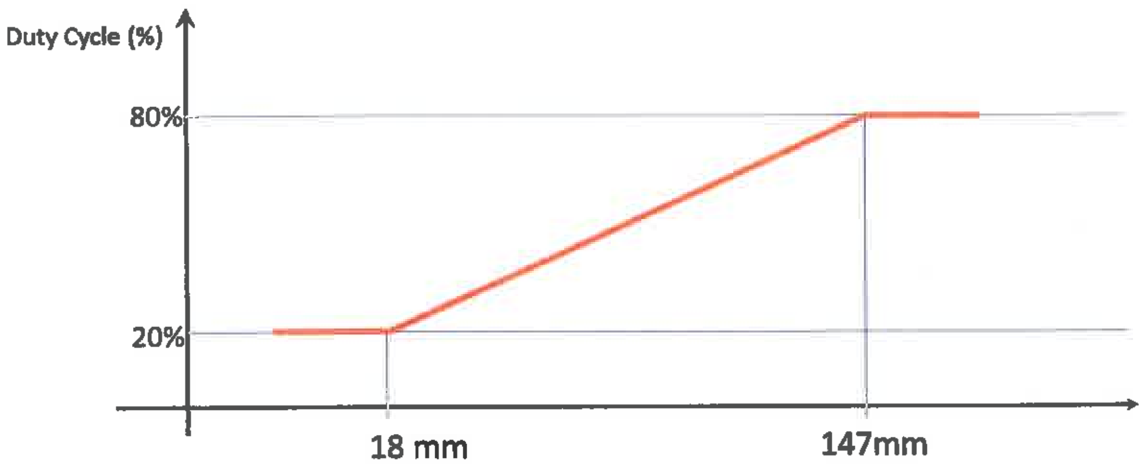
**The indicated values can be calibrated, therefore could be subject to change. At the time of writing this document, the sensor measurement strategy had already been developed but the threshold values were still subject to possible changes.*

The sensor sends a packet every 1000 ms. For every 5 packets received, the $ECM_2$ Slave module takes the average of the data (oil level and temperature) and provides on CAN the updated datum (data average value).
If the conditions necessary to take an average and update the data on CAN have not been fulfilled, the calculation will not be made.

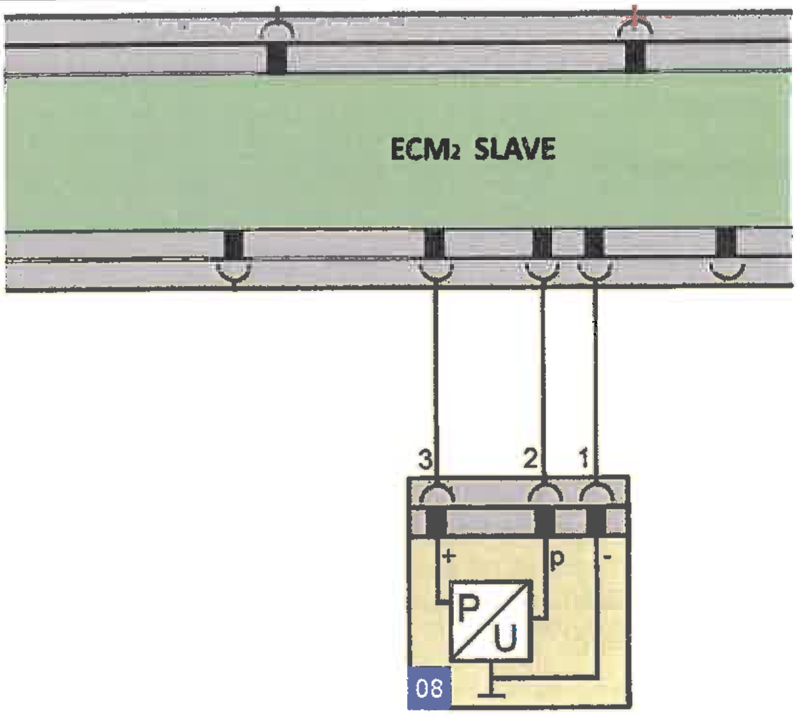
PWM on Temperature variable.

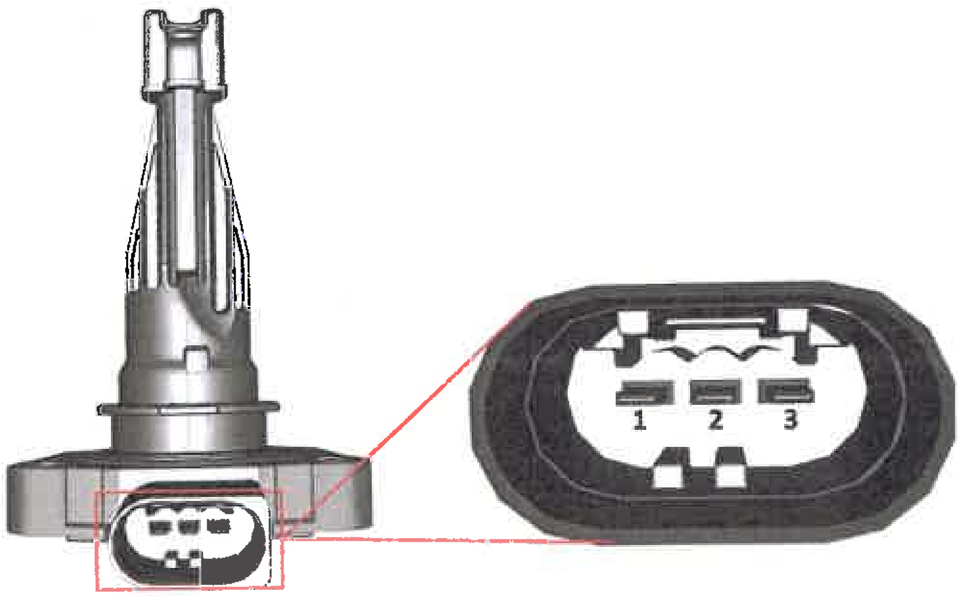



PWM on engine oil Level variable.



*Oil level and temperature sensor wiring diagram.*



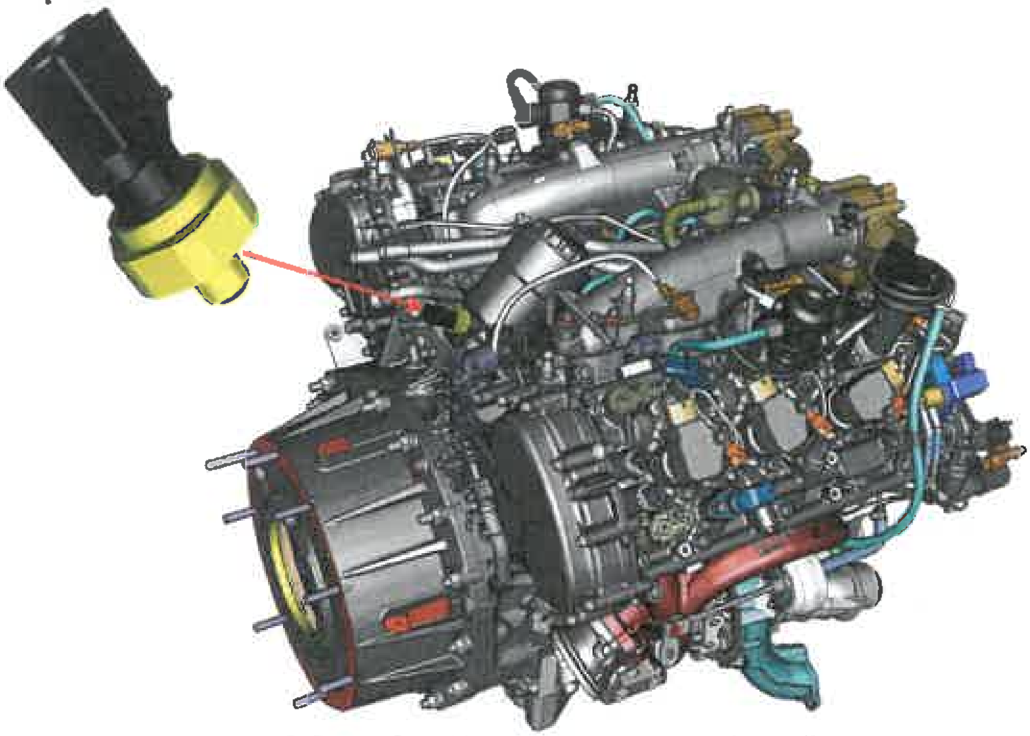

Pinout

1 – 12V Vbatt power supply

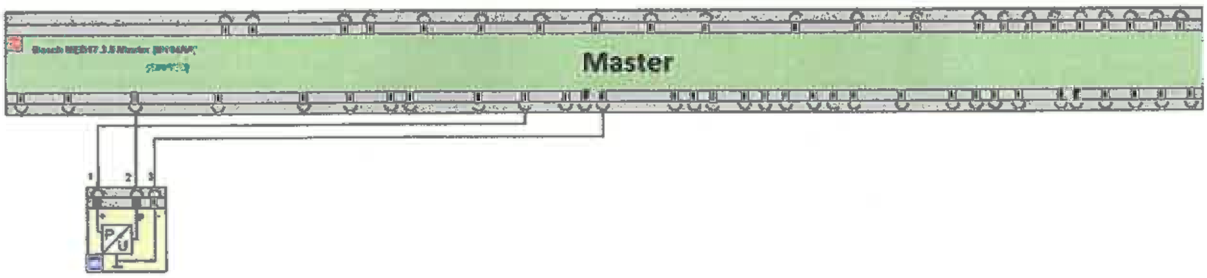
2 – Earth

3 - PWM signal

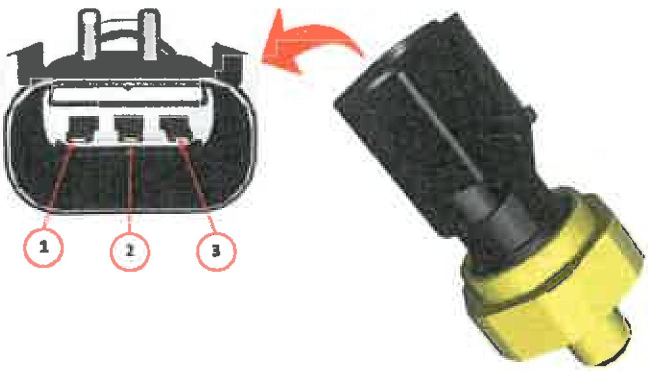
## Engine oil pressure sensor.



The engine oil pressure sensor is located on the oil filter support. The latter is located between the two banks on the distribution side. It is electrically connected to the $ECM_1$ Master engine control module.

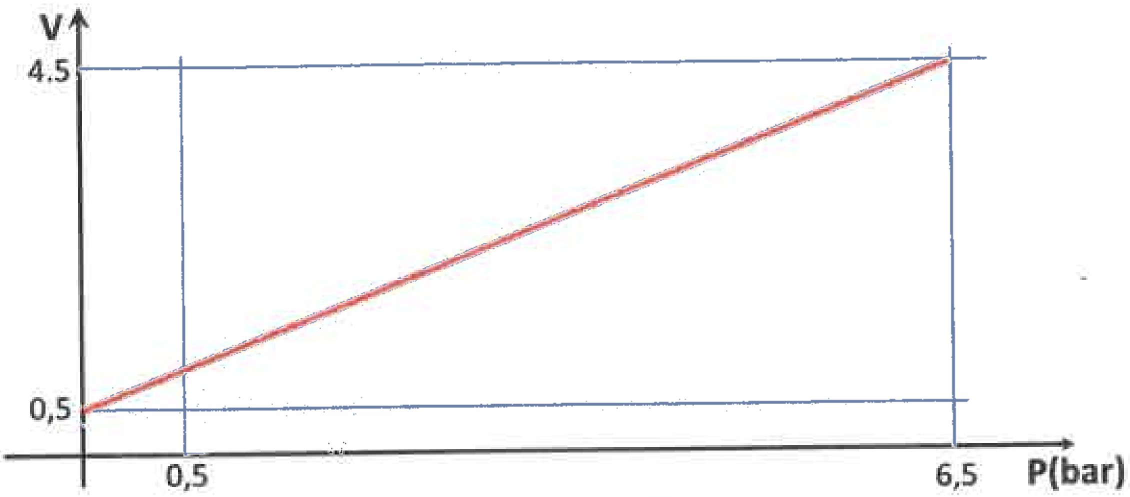



*Sensor pinout*



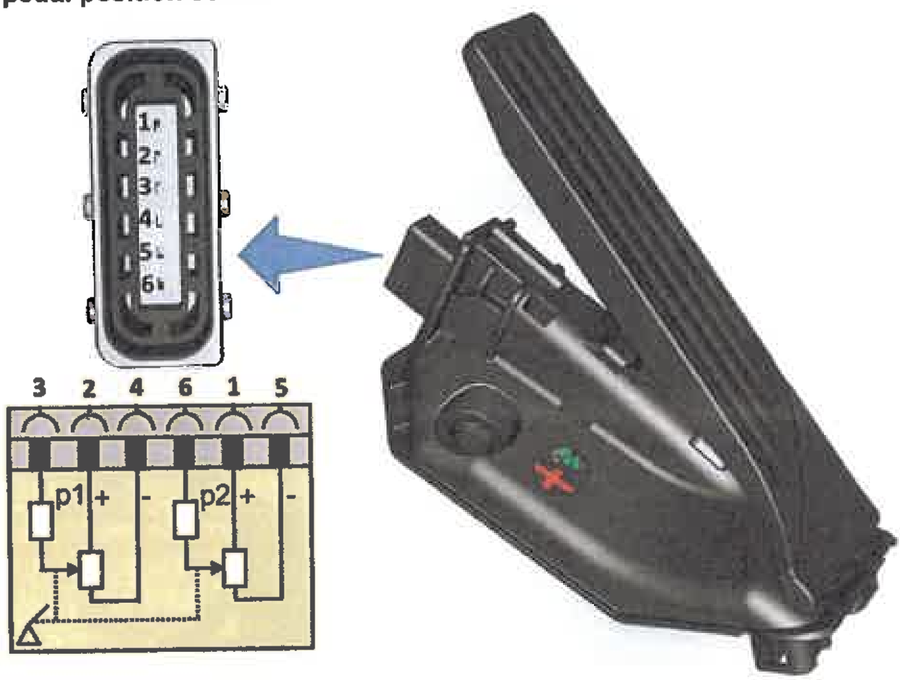

Key:
1 – 5V supply.
2 – Pressure signal.
3 – Earth.

Signal pressure-voltage correlation.

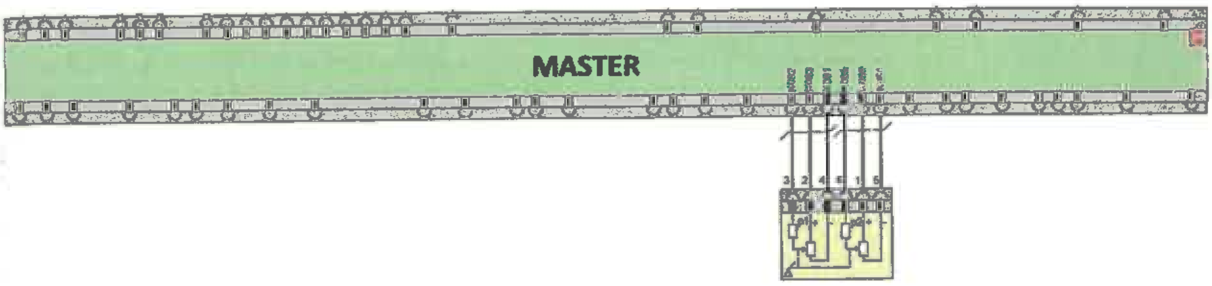



NOTE: The sensor can detect a maximum pressure of 6.5 bar, but the oil pump can produce a maximum pressure of ≈4.2bar.

**Accelerator pedal position sensor.**



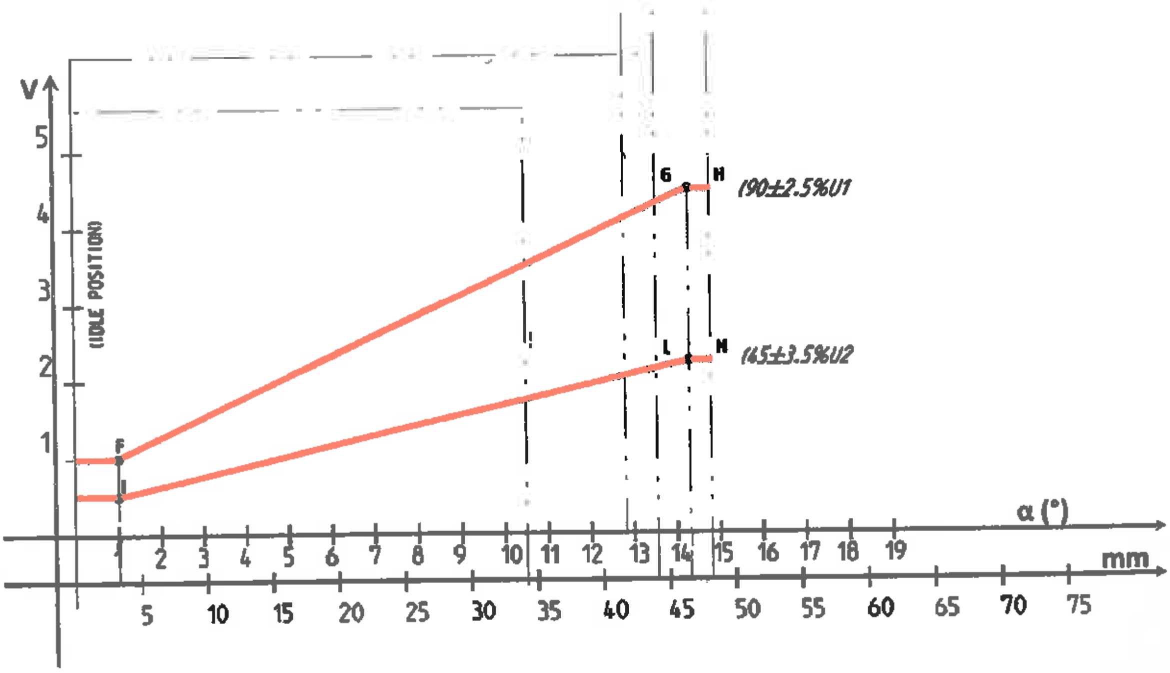

The accelerator pedal position is detected by a sensor integrated into the pedal itself. The sensor has no sliding contacts and uses a sensitive magnetoresistive probe. A flow of current goes through the sensitive probe, which at the same time is hit by an orthogonal magnetic field produced by a permanent magnet. The magnetic field alters the resistivity of the sensitive probe. The magnet is built into the pedal. Depending on the position of the pedal, the magnet's position with respect to the sensitive probe varies as well, and consequently the resistivity of the sensitive probe. The sensor transmits two signals on the position of the accelerator pedal to the $ECM_1$ Master engine control module.



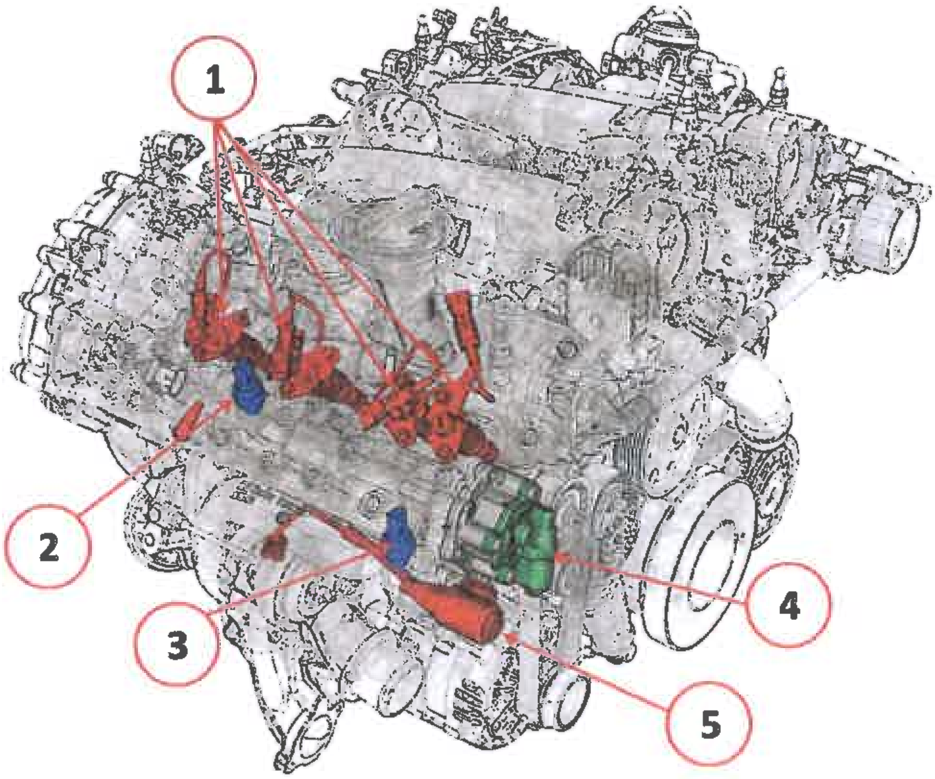

The two sensors receive a 5V power supply and earth from the $ECM_1$ Master.
The two signals to pin 2 and pin 1 respectively have the following values:

Signal 1
- Pedal released: 20%±2%
- Pedal pressed (Full): 90%±2%

Signal 2:
- Pedal released: 10%±3%
- Pedal pressed (Full): 45%±3%



**Cylinder deactivation system management components.**
The $ECM_1$ Master module to manage the cylinder deactivation system uses the following components:

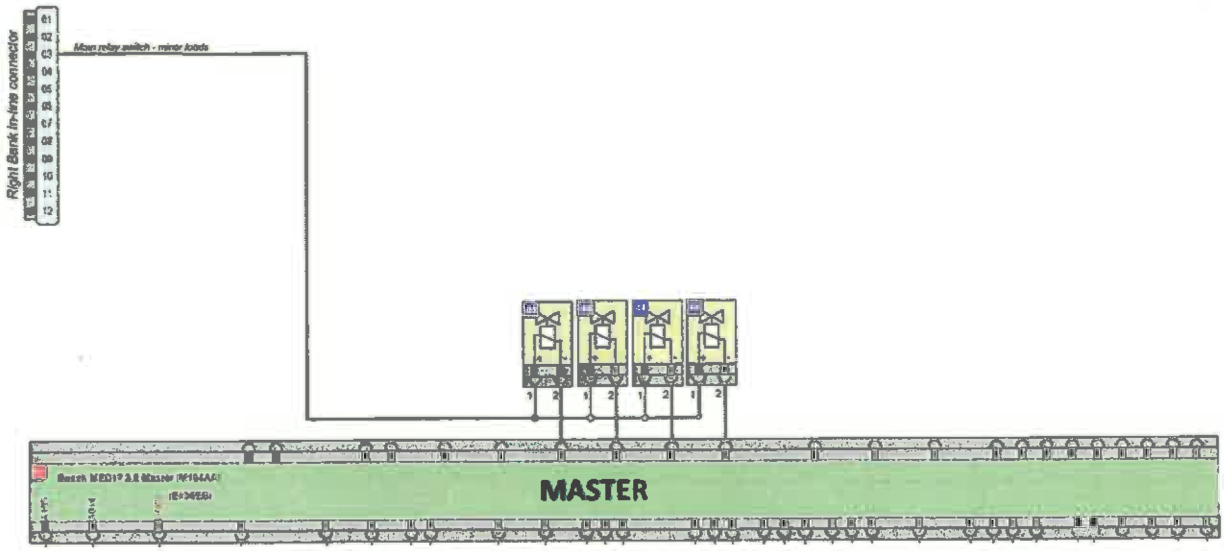



Key:
1 – Tappet deactivation OCV solenoid valves
2 – Deactivation circuit oil pressure sensor.
3 – Turbine lubrication circuit oil pressure sensor.
4 – Mechanical boost oil pump
5 – Turbine lubrication cut-off solenoid valve.

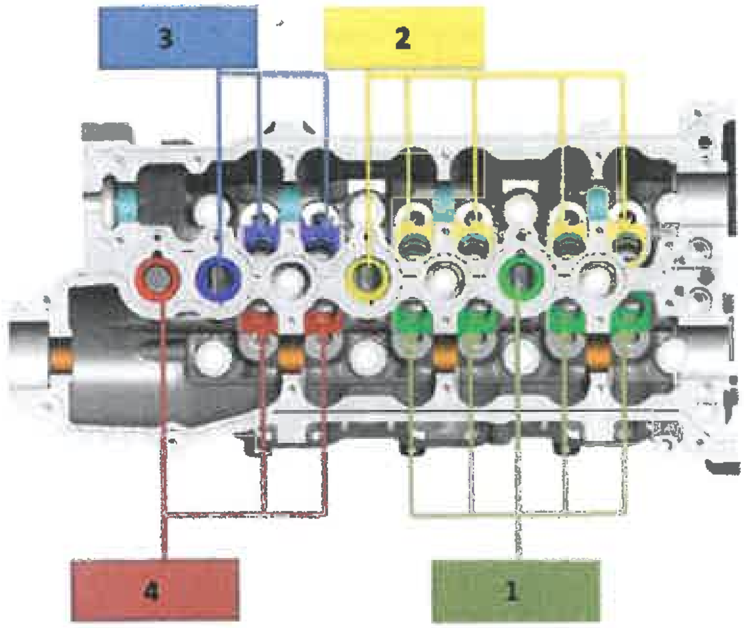
**Tappet deactivation OCV solenoid valves.**

The OCV solenoid valves are driven by the $ECM_1$ Master module in On/Off mode.

They receive a 12V power supply from the main relay and (earth) command from the ECM.




The 4 OCV solenoid valves are for deactivating the cylinders on the right bank according to the following diagram:




Key:
1 – OCV 1 solenoid valve to deactivate cylinders 2 and 3 (intake side)
2 – OCV 2 solenoid valve to deactivate cylinders 2 and 3 (exhaust side)
3 – OCV 3 solenoid valve to deactivate cylinder 1 (exhaust side)
4 – OCV solenoid valve to deactivate cylinder 1 (intake side)

**Turbine lubrication cut-off solenoid valve.**

The solenoid valve is type On/Off. It allows the oil flow to reach the turbocharger via a specific pipe. It receive at pin 1 the earth command from $ECM_1$ Master, and at pin 2 the power supply from the main relay.

If not commanded, the solenoid valve allows the oil flow to reach the turbocharger for lubrication. The moment the $ECM_1$ Master sends the earth command to pin 1, the solenoid valve closes the oil passage to the turbine so that the latter no longer receives oil for lubrication. The lubrication "cut-off" to the right turbocharger is triggered a few sêconds after deactivation of the cylinders. The turbocharger impellers will continue to rotate due to inertia for a certain time. Lubrication is necessary only for part of this residual rotation due to inertia. As they spontaneously slow down, the impellers will reach a rotation speed below which they can no longer be lubricated (danger of leakage). The $ECM_1$ Master, using a specific map, calculates the turbocharger slowdown and depending on this, it deduces the activation delay of the "cut-off" solenoid valve with respect to cylinder deactivation.

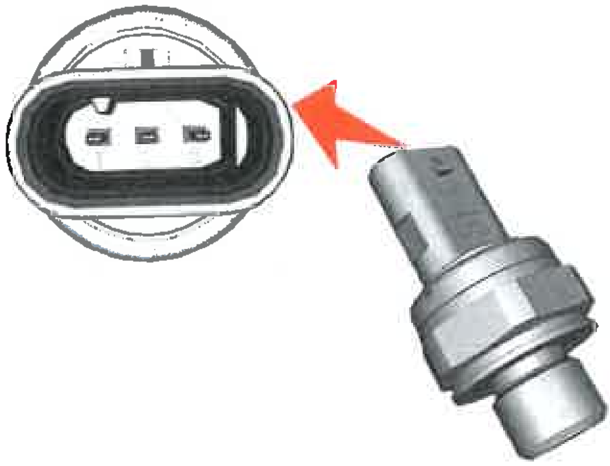
**Oil pressure sensors of deactivation circuit and turbocharger lubrication circuit.**

The pressure sensor that intercepts the oil channels of the deactivation system of the 3 cylinders, is designed to allow the $ECM_1$ Master to monitor the oil pressure in the system in order to fulfil the following goals:

- Understand whether there are optimal pressure values to implement cylinder deactivation.
- Perform diagnostics on the components of the deactivation system (OCV solenoid valves; turbine lubrication cut-off solenoid valve): if one of the components stays mechanically locked, the system pressure is affected altering its own value.

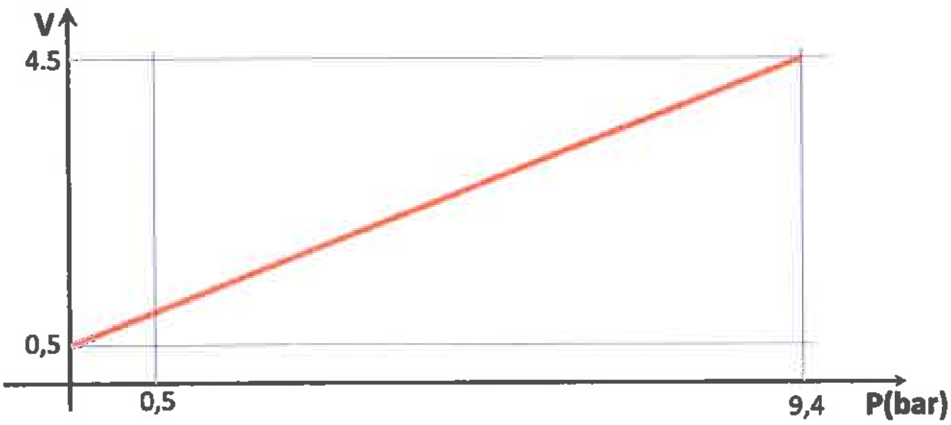
The right turbocharger lubrication circuit pressure sensor is designed to allow the $ECM_1$ Master module to perform diagnostics on the cut-off solenoid valve. If the cut-off valve should remain mechanically locked and prevent the oil from lubricating the turbocharger, the $ECM_1$ Master module will not "see" pressure in the circuit and will not reactivate the cylinders on the right bank. Consequently, the engine continues to function, for recovery, with the left bank alone.

*Pinout*

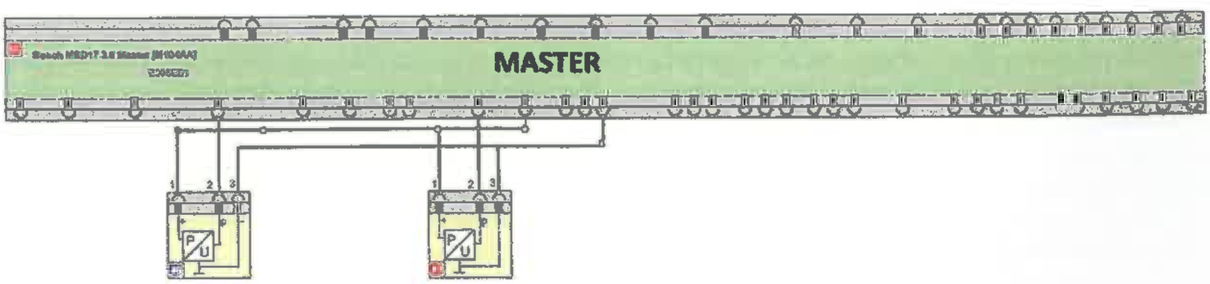


1 – 5V power supply
2 – Voltage signal
3 – Earth.

Sensor signal.




**NOTE**: The pressure sensors can read up to absolute pressure values of ≈10bar. In the cylinder deactivation system channels, normally pressure varies in the range of 2.5 bar - 5.5 bar.



In order for the $ECM_1$ Master to activate the right bank cylinder deactivation function, it is necessary for the following vehicle operation conditions to be met simultaneously:

- Coolant temperature: 50°C - 110°C.
- Gear engaged: Third - Sixth.
- Max. number of revs: 3500 rpm
- Vehicle speed: 25 km/h - 125 km/h
- MIL Check engine light: OFF
- Engine torque:

Once the above conditions are met, la $ECM_1$ Master starts the cylinder deactivation strategy only if at the same time it receives a request from the CDCM chassis dynamics control module.

The CDCM module contains in its memory an algorithm to continuously estimate the fuel consumption the engine would have if the deactivation strategy were active at that moment, and compares this data with the engine's real fuel consumption. If the comparison shows that it would be convenient to deactivate 3 cylinders, the CDCM module sends the $ECM_1$ Master module the request to deactivate the right bank. The request for deactivation by the CDCM must however be matched by the vehicle's operating conditions.

The $ECM_1$ Master module starts the cylinder deactivation strategy only if the vehicle's operating conditions have been fulfilled and if at the same time there is a request for deactivation by the CDCM module.

Once activated, the cylinder deactivation function stays active for a maximum time of ≈100s. Once this time expires, the $ECM_1$ Master module deactivates the function and the engine operates again at 6 cylinders. After deactivating the function, the $ECM_1$ Master verifies whether the conditions listed above are still occurring, and if yes, it will command again the activation of the cylinder deactivation function.

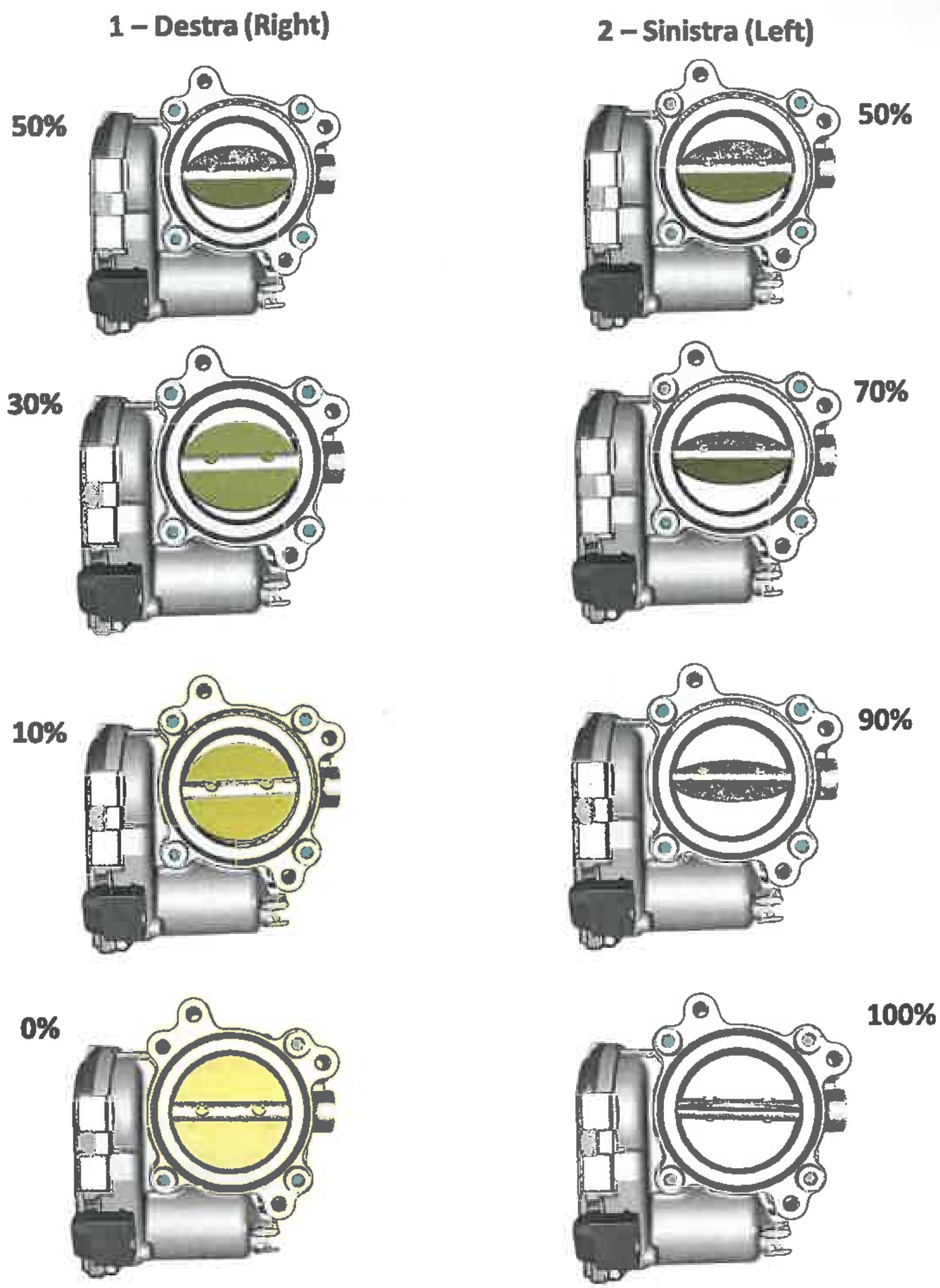
Deactivation time is kept at 100 seconds and not longer to prevent the catalytic converter temperature going below the limits of its proper operation.

In conditions where the engine only works with the left bank, the engine only takes air in from the latter. Thus the effective need for two separate calculation models for air intake.

Disabling the function can be decided by the '$ECM_1$ Master even during its normal duration (≈100s). If the user-vehicle presses the accelerator pedal requiring more performance, the $ECM_1$ Master module deactivates the function and restores operation at 6 cylinders.

The $ECM_1$ Master module, before starting to drive the OCV solenoid valves to collapse the hydraulic tappets, implements a progressive "unbalancing" of the engine torque towards the left bank. This strategy is to "prepare" the ground for deactivating the cylinders. It is an obligatory step to ensure the vehicle driver and any occupants don't perceive a sharp cut in torque delivery.

**NOTE:** **By way of example**, to give an idea of what happens in the management of the throttle bodies, the following page shows a diagram where the progressive opening of the right throttle and the progressive closure of the left throttle can be seen. The percentages given next to each figure represent the torque delivered by both banks. It starts from a position of equal opening of the two throttles. The positions the throttles gradually assume are emphasised to show their movement. In reality, the left throttle must reach an opening percentage that can make the left bank deliver 100% of the torque required by the operating map.




The progressive unbalancing of the torque towards the left bank is implemented by the $ECM_1$ Master progressively closing the throttle of the right bank intake system and simultaneously progressively opening the throttle of the left bank intake system (via the $ECM_2$ Slave module).

Starting from an opening condition of the two throttle bodies at 50%, the torque delivered by the engine is equally supplied by the two banks (50% of the torque given by the right bank and 50% given by the left bank). We progressively switch to a condition where the right bank throttle closes, delivering approximately 30% of the total torque, while the left bank throttle opens delivering approximately 70% of the total torque. We progressively reach a condition where the right throttle is in a position that allows only 10% of the total torque to be delivered, while the left throttle has an opening such that allows 90% of the total torque to be delivered. In the latter situation, the $ECM_1$ Master module has reached optimal conditions to deactivate the cylinders of the right bank.

Deactivation does not take place instantly on all cylinders, but the strategy follows the order of ignition. For the cylinder that has to fire at that moment, injection is deactivated, along with the command to the (ignition) coils, and lastly the solenoid valves are driven to collapse the intake and exhaust tappets. This same process will then apply to the second cylinder that has to fire and then the third.

In summary, it can be said that once the required conditions are met, the $ECM_1$ Master follows the steps below for each cylinder in the right bank:

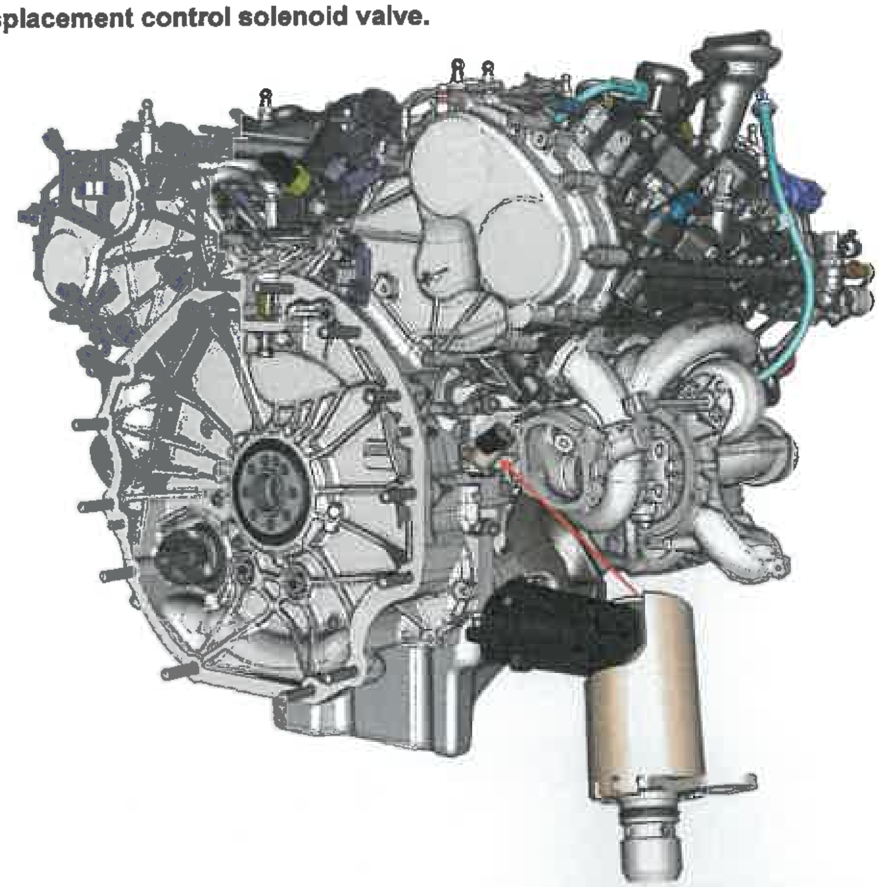
- Unbalance the torque towards the left bank.
- Deactivate the injection command to the injector of the cylinder to be deactivated.
- Deactivate the ignition command of the cylinder to be deactivated.
- Solenoid valve command to collapse the intake and exhaust tappets of the cylinder to be deactivated.

After deactivating the right bank, the engine goes from operation with 6 cylinders with ignition order 1-6-3-4-2-5, to operation with 3 cylinders with ignition order 6-4-5.

Once the 100 seconds elapse, the $ECM_1$ Master module reactivates the cylinders following a strategy opposite the one used for deactivation:

- Reactivate the tappets of the cylinder to reactivate.
- Restore the injection and ignition command of the same cylinder.
- Reactivate the tappets of the two remaining cylinders
- Restore the injection and ignition command of the remaining cylinders.
- Progressively realign the torque between the right and left banks.

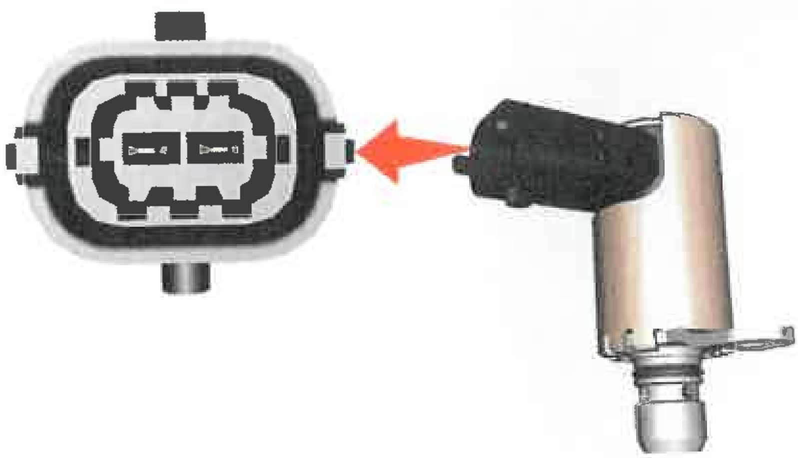
**Oil pump displacement control solenoid valve.**



The oil pump is the variable displacement type. Depending on the load and engine rotation speed, the $ECM_1$ Master manages the solenoid valve to vary the pump's displacement. The pump is configured at minimum displacement if current goes through the solenoid valve coil. It is configured at maximum displacement if instead there is no current going through it.

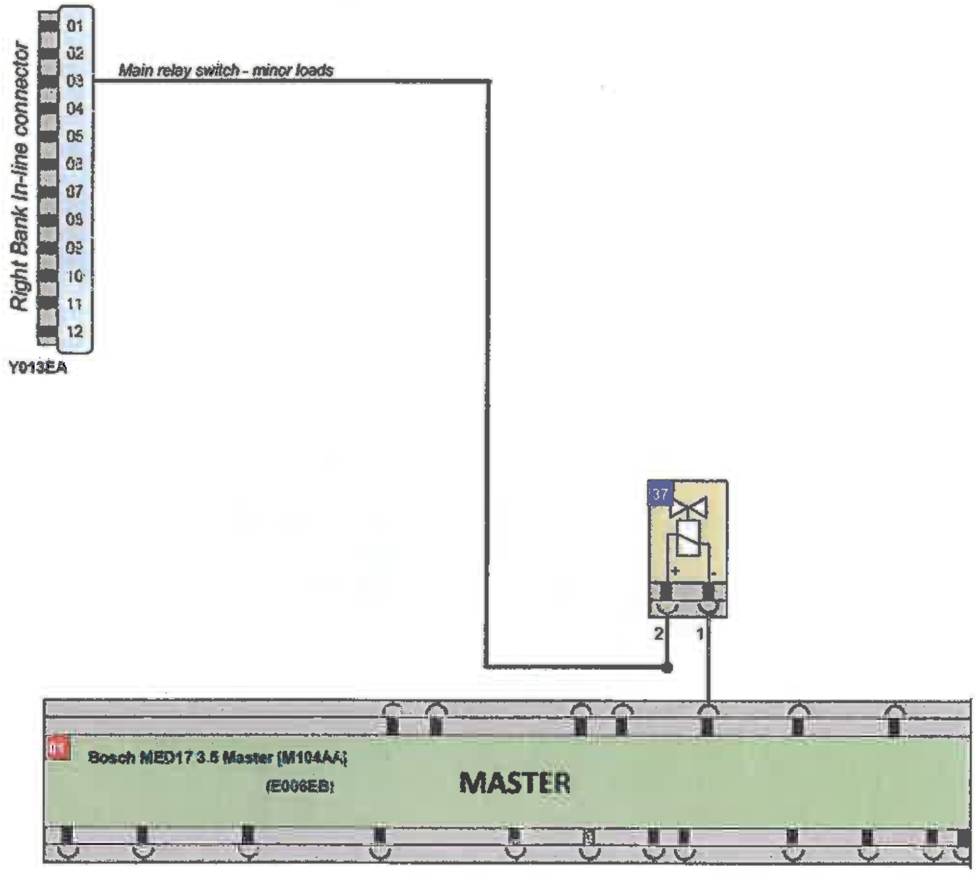
At maximum displacement, the supply oil pressure is approximately 4.5 bar. At minimum displacement, the oil pressure is approximately 1.5 bar.

The solenoid valve is type On/Off. It is earth commanded by the $ECM_1$ Master module and receives 12V power supply from the main relay.



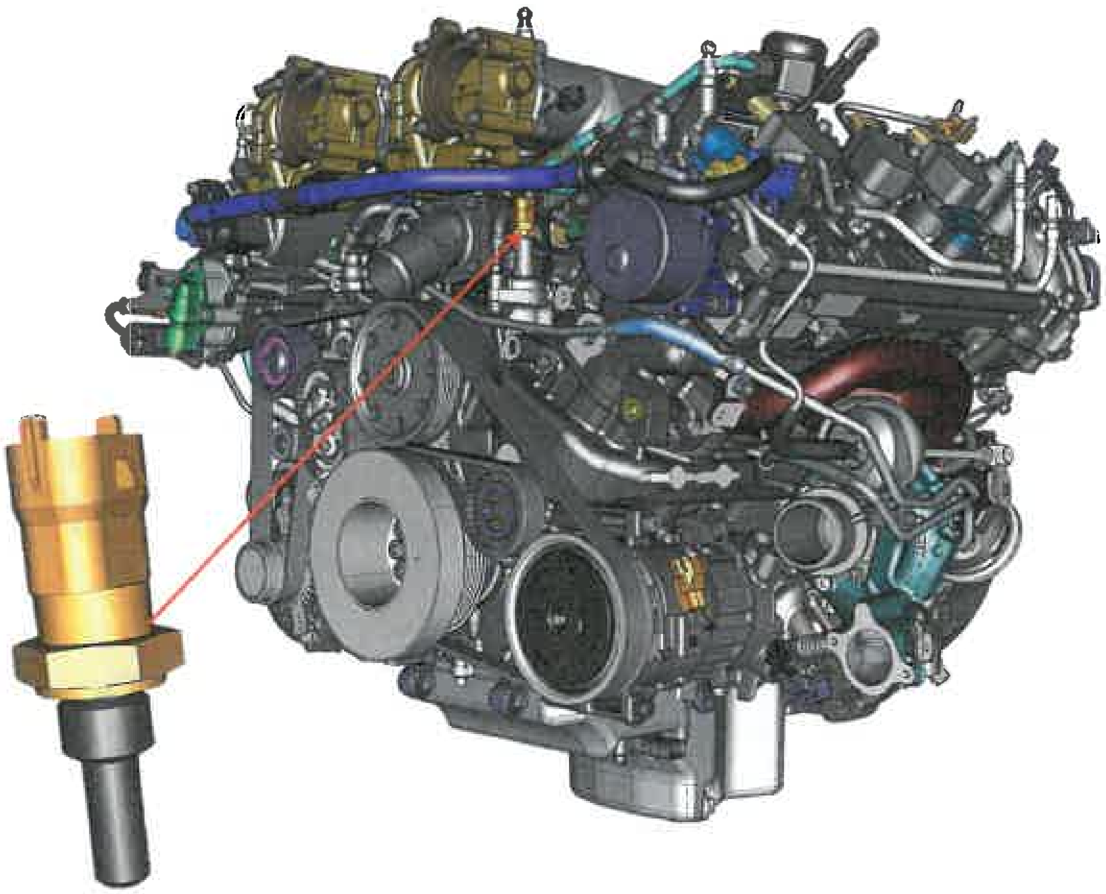
Pinout
1 – Earth command by $ECM_1$ Master.
2 – 12V power supply from main relay.

*Oil pump displacement control solenoid valve wiring diagram.*



**Coolant temperature sensor.**

The coolant temperature sensor is fitted near the thermostat.

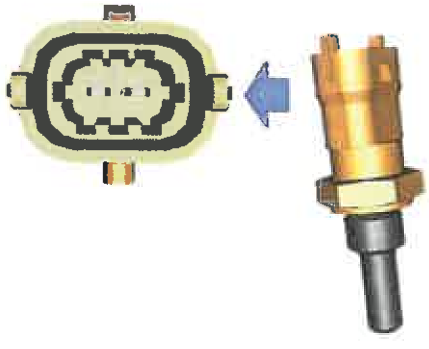


The temperature sensor is electrically connected to the $ECM_1$ Master module. The latter shares information with the $ECM_2$ Slave module.

The temperature sensor signal is used by the ECMs as one of the parameters based on which injection times are calculated.

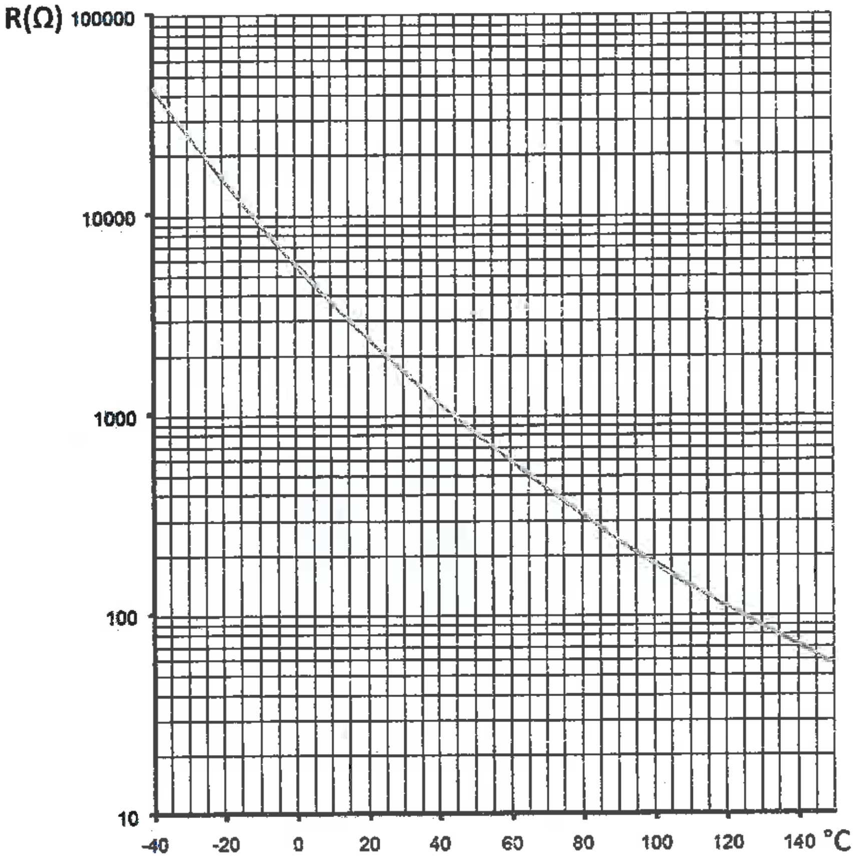
The engine coolant temperature value also allows the ECMs to understand whether the thermal conditions to enable the Stop&Start function exist.

Pinout



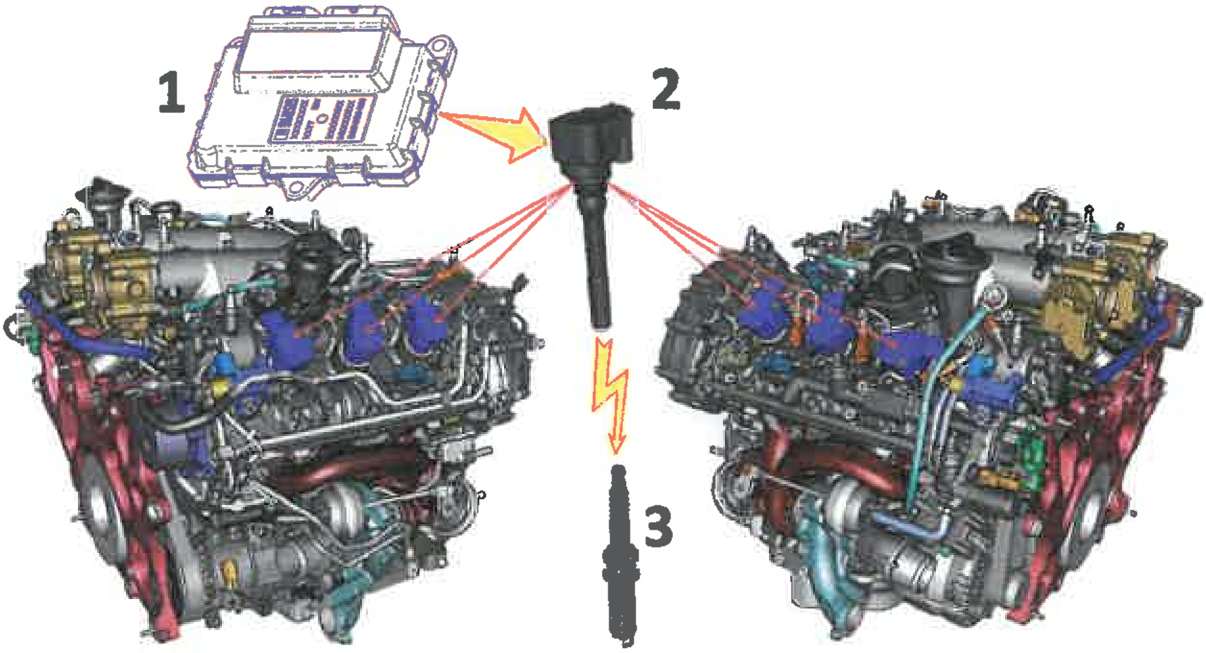
Key:
1 – Earth
2 – Voltage signal.

Temperature-Electrical Resistance diagram.




The sensor's sensitive probe is type NTC: as the temperature increases, the resistance value of the sensitive probe.

**Ignition system management components.**
The components through which both ECMs manage and implement the engine ignition stroke are the following:




Key:

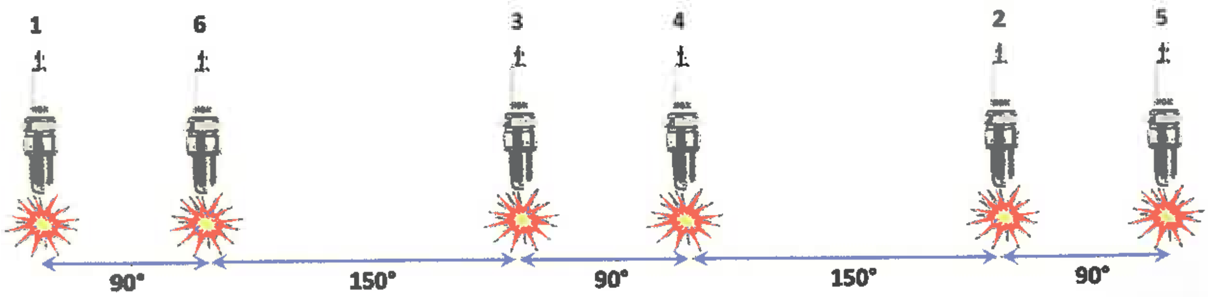
1 – ELDOR electronic module

2 - Ignition coils (ELDOR)

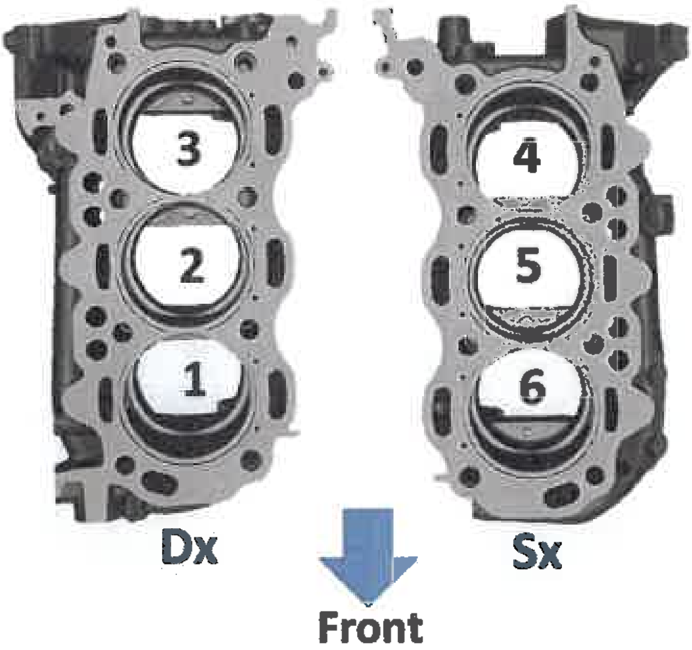
3 – Spark plugs.

**Introduction**

The 2.9 V6 turbo engine has the characteristic of working with odd firing. The firings follow one another every 90° and every 150°. This gives the engine a distinctive noise due to a less regular pace of the drive torque compared to firings that follow one another every 120°.



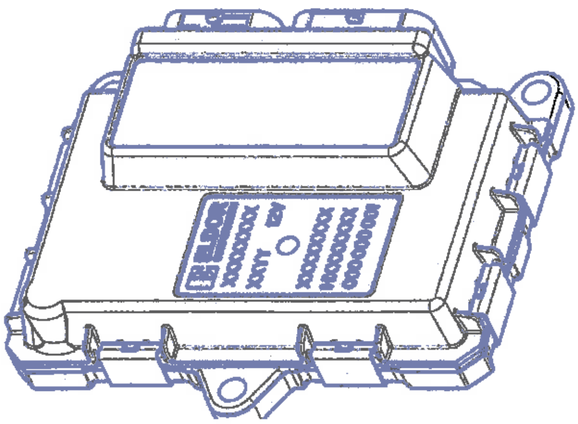
**Firing order**




The cylinders are numbered according to the order shown in the figure. "Front" means the front of the vehicle (front bumper).

The firings come in the following succession: 1-6-3-4-2-5.

**ELDOR electronic module.**



The ELDOR electronic module is designed to run diagnostics of misfires. The need for a specific module for this function is due to the engine's characteristic of having some firings very close to one another. The proximity of the fires does not allow the ECMs (Master and Slave) to accurately diagnose the misfire.

The ELDOR module detects the ionization current to the spark plug electrode heads using the ignition coil as a sensor: The ELDOR module detects the value of the current in the secondary winding of the coil and based on this, using a special algorithm, it calculates the ionization of the air-petrol mixture present between the spark plug's electrodes. The value of the current present in the primary winding of the coils the moment the spark is fired is influenced by the degree of ionization of the air-petrol mixture present between the spark plug's electrodes.

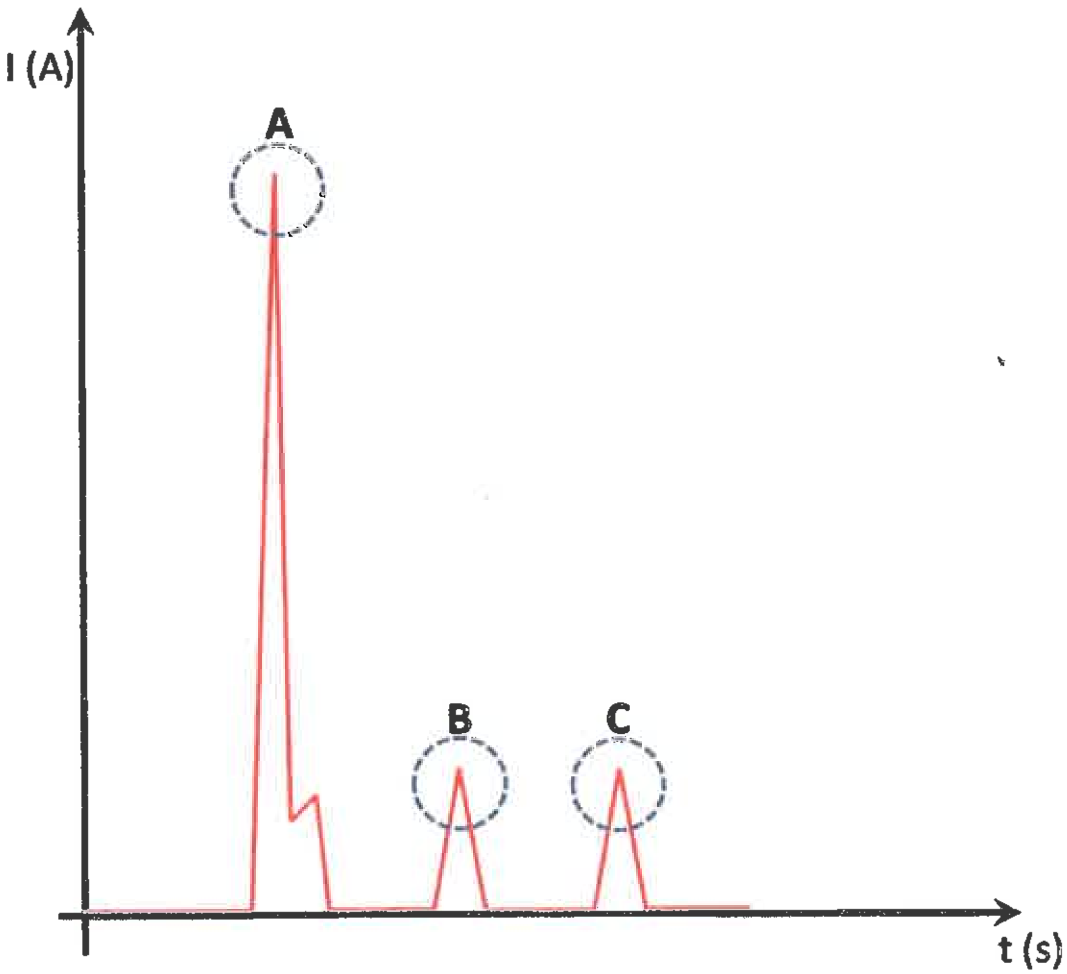
The ELDOR module receives the signal of the motor revolutions from a specific pin of the $ECM_1$ Master module.

The diagnostics present in the ELDOR memory allow it to analyse the current present in the secondary winding of the coils. If the current has certain values, the ELDOR module can establish:

1 – Whether there was a spark at the spark plug electrode head.

2 – Whether there is combustion.

The graph below shows the trend of the current in the coil's secondary winding. (The graph is a reconstruction and is representative of the true trend. The goal is to highlight the concept in which the ELDOR module runs diagnostics.)



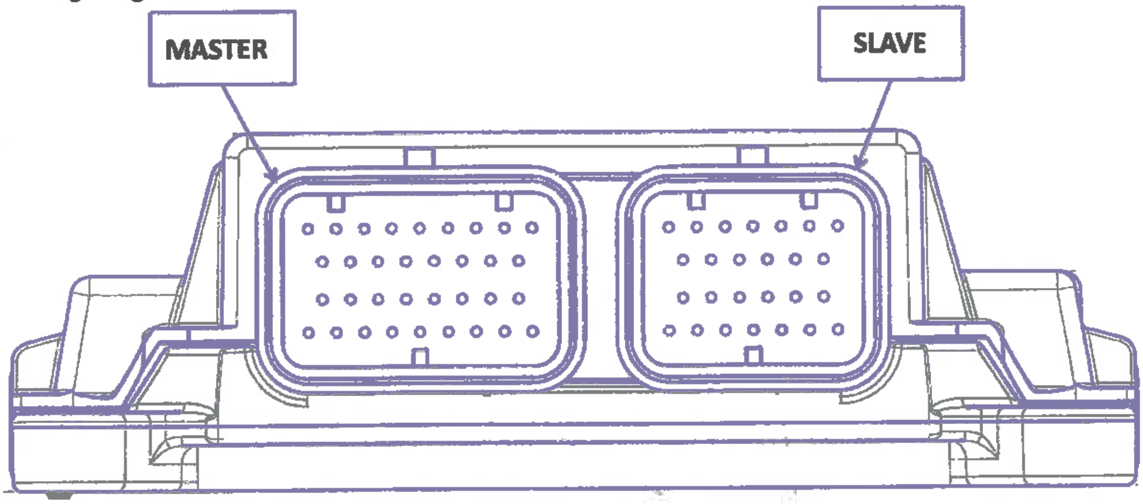

The ELDOR module can understand whether the spark at the spark plug's electrode heads was fired by the presence of the peak in current A. Obviously, if the spark was not fired, the peak in current is practically absent as the ionization in the air between the electrodes is nil.

The second peak in current B occurs when oxidation of the chemical species present in the air-petrol mixture begins.

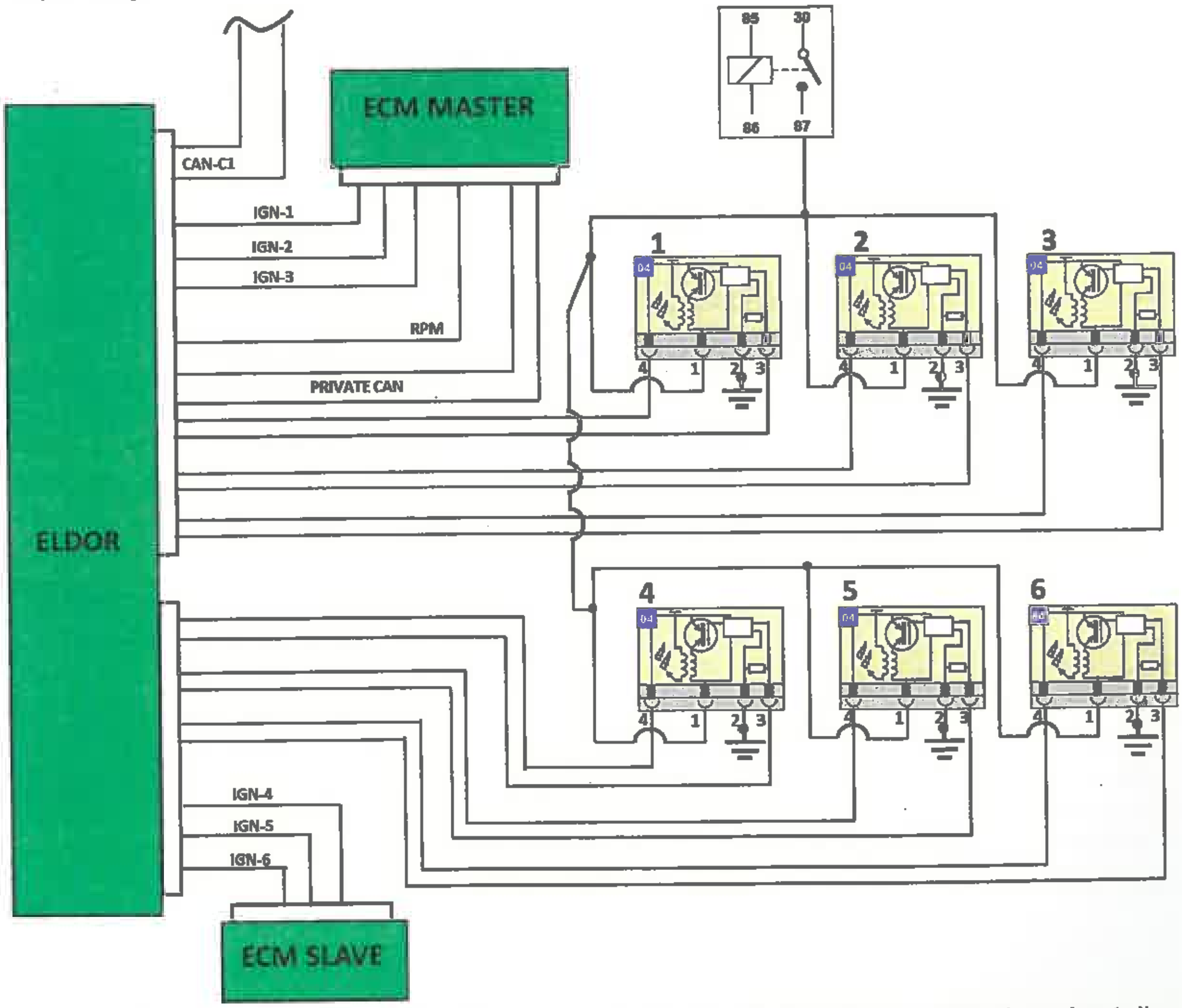
The peak in current C occurs when there is an increase in the release of heat (the moment the flame develops).

Between the two peaks in current B and C, the ELDOR module can understand whether the injection of petrol occurred and whether combustion is taking place.

**Wiring diagram.**




The ELDOR module has two connectors through which it interfaces with ECM Master and Slave respectively.

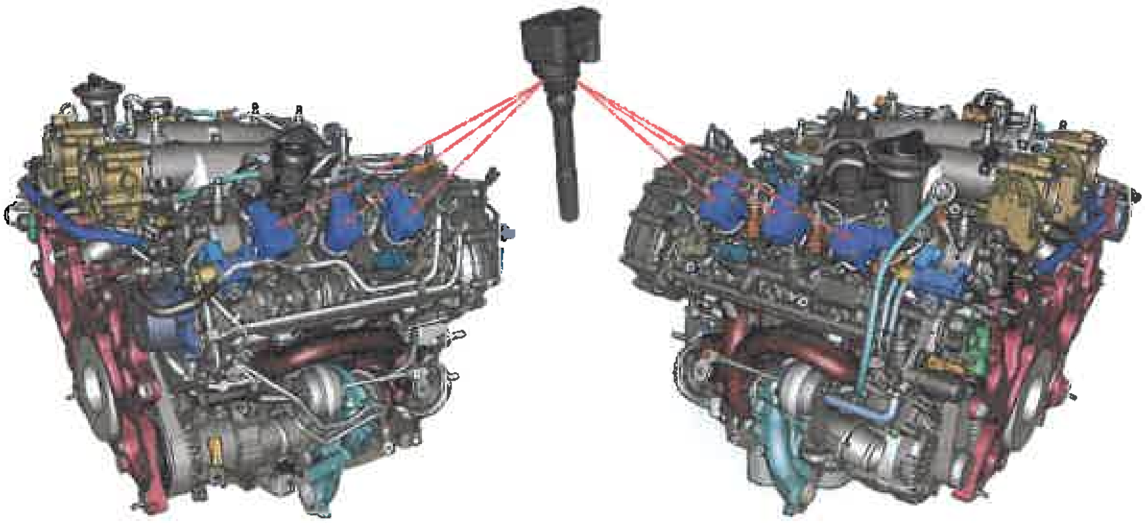



Ignition coils 1, 2, 3, 4, 5, 6 are indirectly commanded by the ECMs (Master e Slave), and not directly. The $ECM_1$ Master module sends ignition commands (IGN-1; IGN-2;IGN-3) to the ELDOR module, which in turn sends to pin 2 of coils 1, 2 and 3 the ignition command (to load the primary winding).

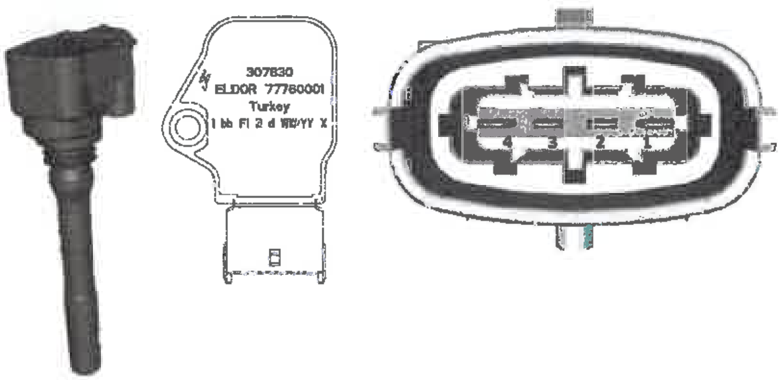
Similarly, the $ECM_2$ Slave sends the ignition commands (IGN-4; IGN-5; IGN-6) to the ELDOR module, which sends the commands (load the primary winding) to coils 4, 5, 6. The commands the ELDOR module sends to the coils follow one another in a sequential timing mode, in compatibility with the ignition order.

The two ECMs exchange data on the ignition commands given via the private CAN that connects them.

**Coils.**

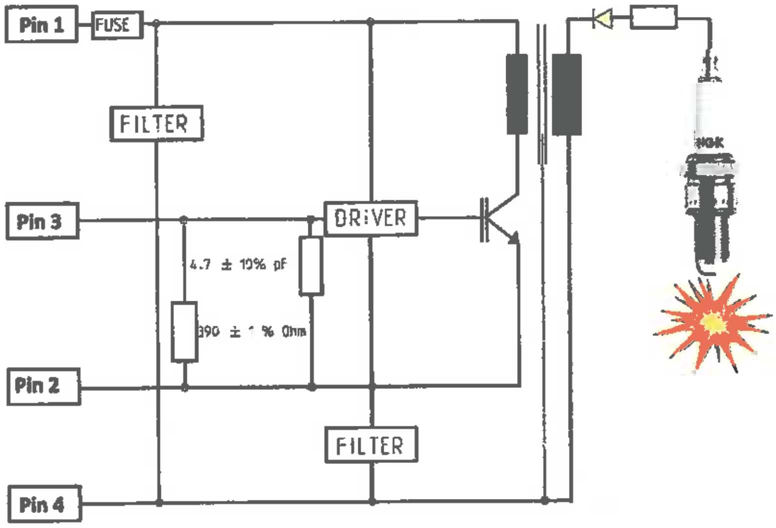


The coils of the 2.9 V6 engine are produced by ELDOR




Pinout
1 – 12V power supply from main relay.
2 – Vehicle chassis earth
3 – Command by ELDOR module (ignition)
4 – Ionization signal (for ELDOR).

## ELDOR coil wiring diagram.




To pin 3, the ELDOR module sends a threshold current to saturate the transistor allowing it to conduct current. Under this condition, the transistor connects the primary winding of the coil to pin 2 of the coil (chassis earth). From this moment, the primary winding loading stage begins. After about 2ms, the ELDOR module removes the command to pin 3, creating the variable magnetic flux that induces high tension in the secondary winding.

**Technical data.**

| | |
|---|---|
| Primary winding current. | 8.5 A ±0.1A |
| Ignition signal | 4 V ± 0.1V |
| Loading duration of primary winding | 2.0 ms ± 0.2ms |
| Voltage of secondary winding | 35 Kv |

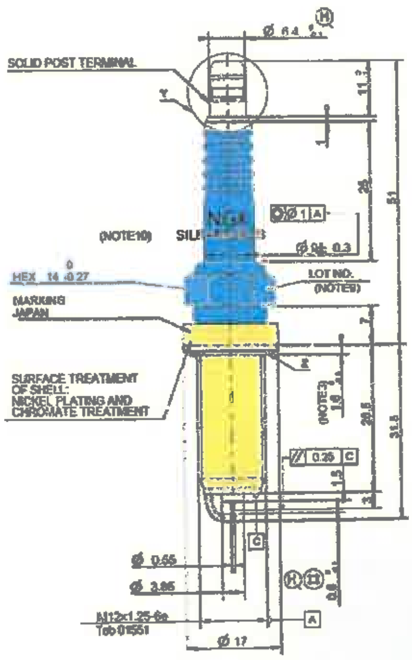
**Spark Plugs.**

The spark plugs are manufactured by NGK (design no. SILKAR8C6DS) and have the characteristic of a Nickel-Platinum surface treatment.

*Electrical features.*

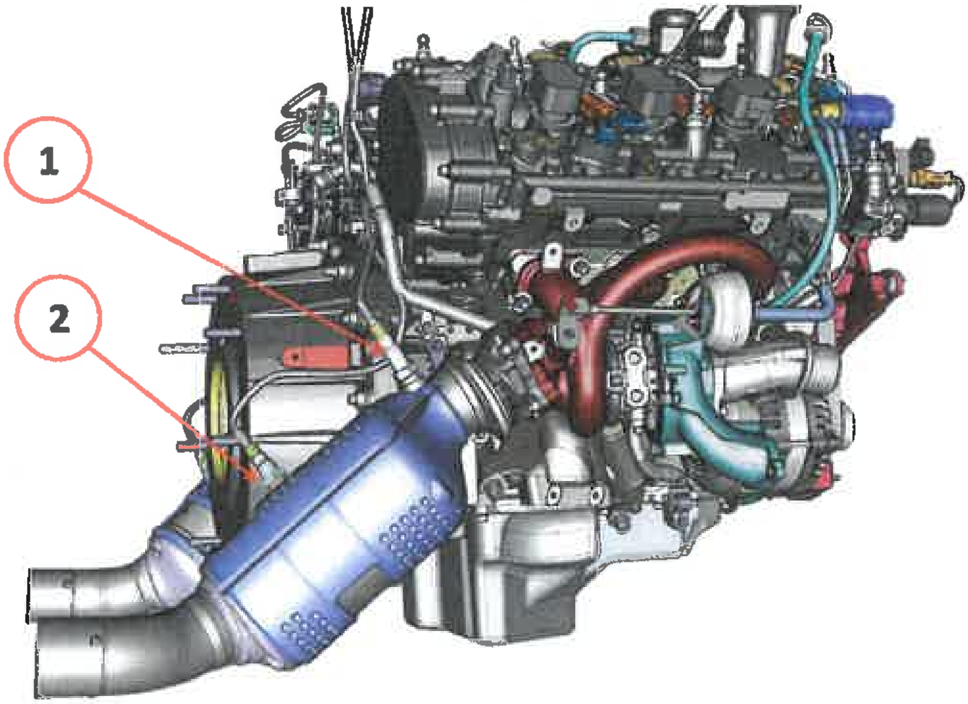
Maximum resistance: 7.5 KΩ

Miinimum resistance: 3 KΩ

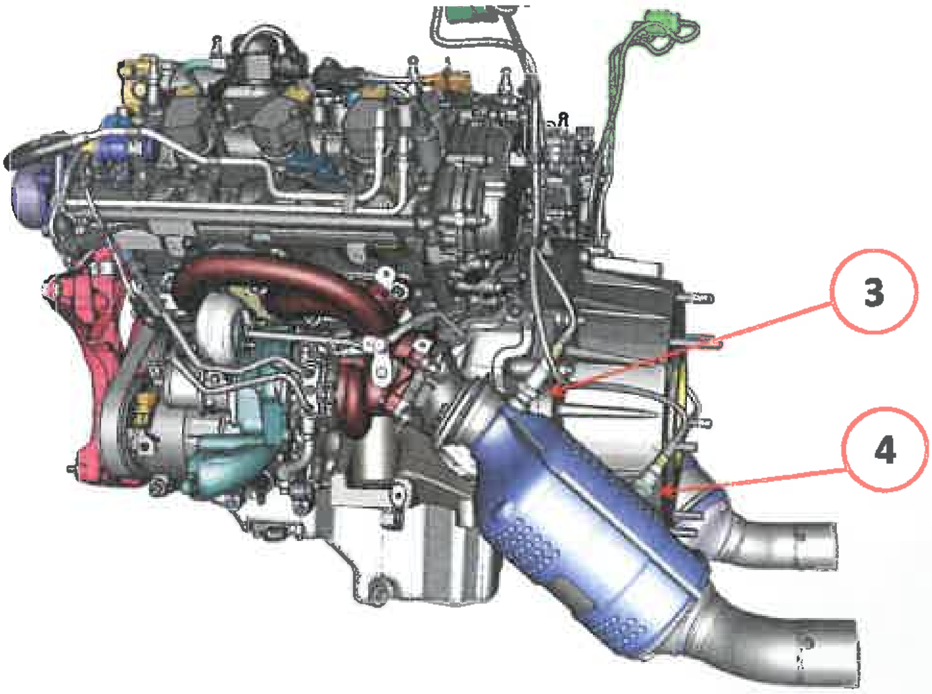


**NOTE:** To remove/reinstall the spark plugs, a socket wrench with the following characteristics is necessary:

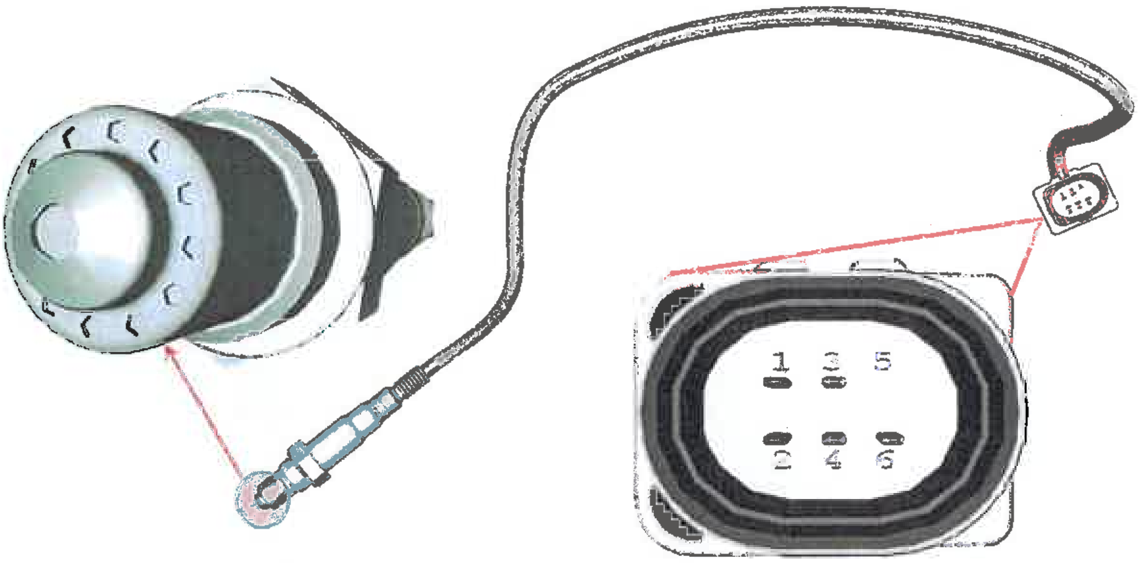
**Mixture ratio control and management components.**
The ECMs (Master and Slave) use lambda sensors to measure the quantity of oxygen contained in the exhaust gas and to run diagnostics on the correct operation of the catalytic converter. As seen in the previous section on the description of the exhaust system, the 2.9 V6 engine has two catalytic converters (one per bank) and the lambda sensors are located upstream and downstream of each individual catalytic converter.




Key.
1 – Upstream lambda sensor (right bank)
2 – Downstream lambda sensor. (right bank)
3 – Upstream lambda sensor (left bank)
4 – Downstream lambda sensor (left bank)



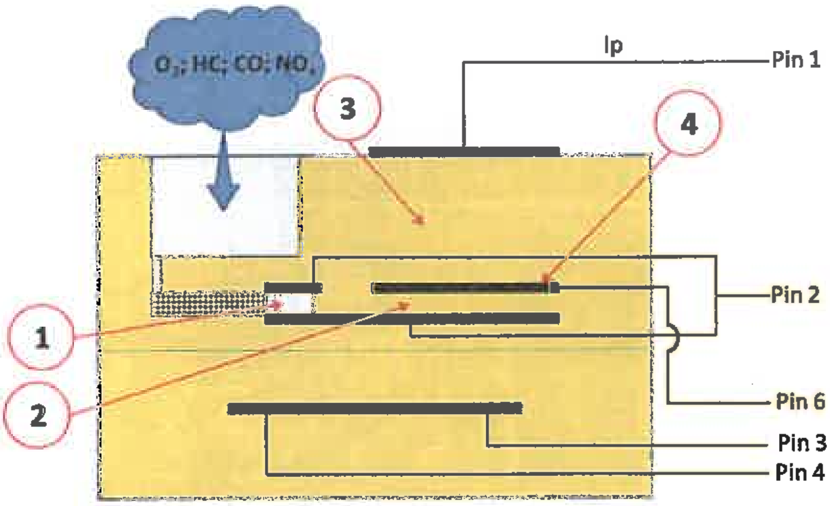
**Lambda sensor upstream of the catalytic converter.**



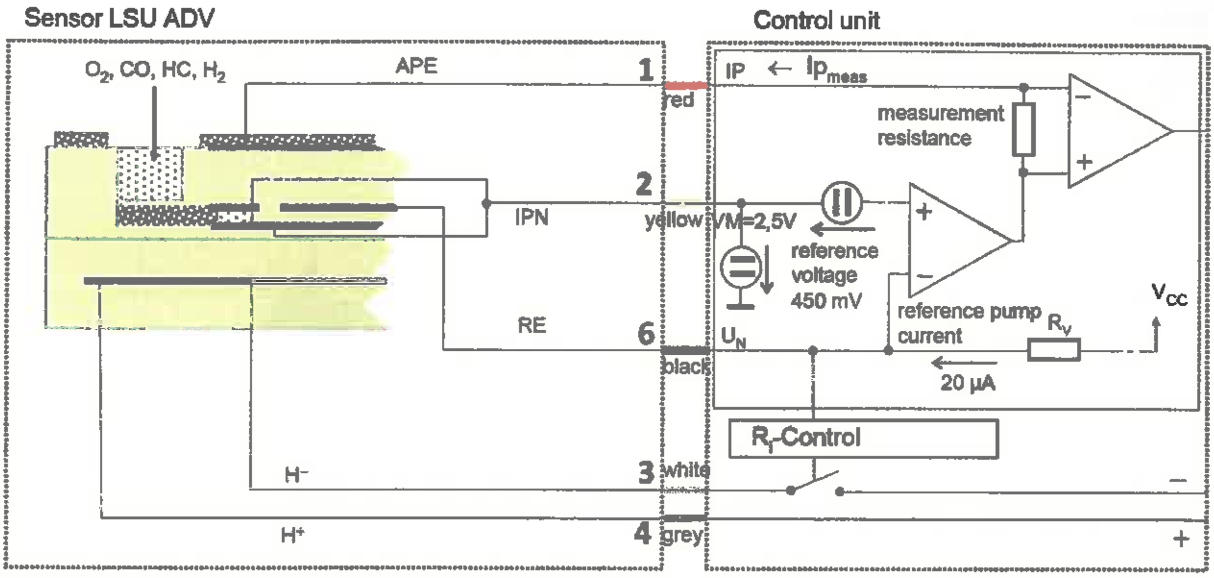

Pinout
1 - Ip pumping current
2 – Virtual earth
3 – Earth for heater
4 – 12V power supply for heater
5 – Closed. Absent.
6 – Nernst cell voltage signal.

The Bosch LSU ADV upstream lambda sensor is specifically for petrol engines. The function of the sensor is to allow the ECM to estimate the quantity of oxygen contained in the exhaust gas. Depending on the latter parameter, the ECM calculates the mixture ratio combusted in the engine and, if the ratio deviates from the stoichiometric value, it corrects the injection times.

The Bosch LSU ADV sensor has no trimming resistor. The sensors with trimming resistors have 6 pins. In the case of the 2.9 V6 engine, the lambda sensor upstream of the catalytic converter only has 5 connected pins.

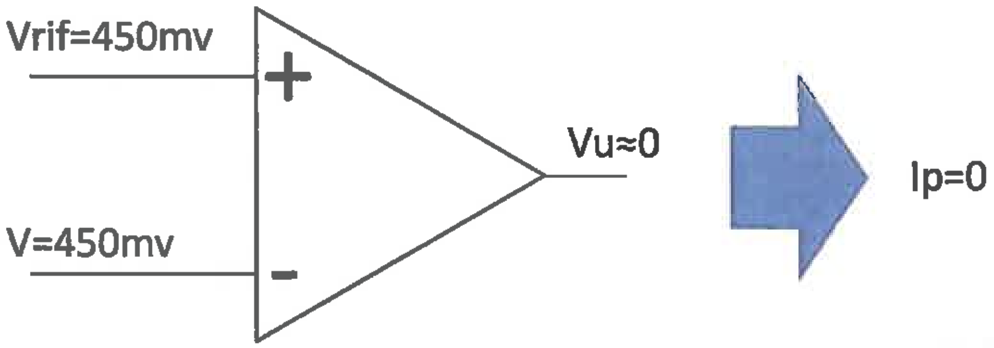



Key.
1 – Measuring cell.
2 – Nernst cell.
3 – Pumping cell.
4 – Reference electrode.

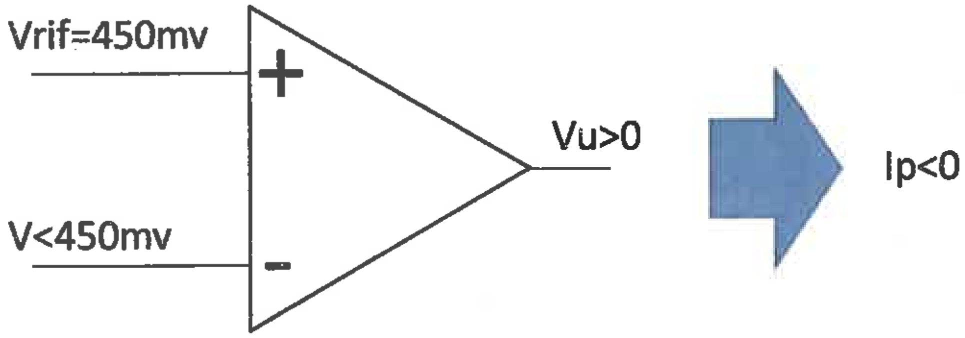



From the diagram it is possible to make the following analyses.
the exhaust gases, consisting of various substances ($O_2$, HC, CO, etc.), enter the measuring cell, which is connected to two electrodes. The latter are connected to a virtual earth supplied by the ECM (yellow wire). The sensor receives a current (20µA) at pin 6 whose purpose is to provide the electrode connected to it a reference voltage comparable to the voltage level the electrode would have if it were in contact with ambient air. Between the reference electrode and the measuring cell there is a porous conductive material (zirconium dioxide, $ZrO_2$; yellow part of the sensor) that constitutes the Nernst cell. The line where the current and reference voltage are present is connected to the negative inlet of the operational amplifier present in the ECM. If the exhaust gases contained in the measuring cell have an oxygen level typical of a stoichiometric mixture combusted by the engine, the voltage in the reference electrode is 450 mv. This voltage value is due to the fact that between the reference electrode and the electrodes of the measuring cell, there is a flow of current (oxygen ions) such to lead the reference electrode to a voltage of 450 mv. The operational amplifier in the ECM has two inlets. In the (negative) inlet is the voltage of the reference electrode, and in the other inlet is the fixed voltage of 450mv.

*Stoichiometric mixture*
If the mixture is stoichiometric in both inlets of the operational amplifier, the value is 450 mv. This means the output voltage of the operational amplifier is at the low level and the ECM sends a pumping current of zero to pin 1 of the lambda sensor.

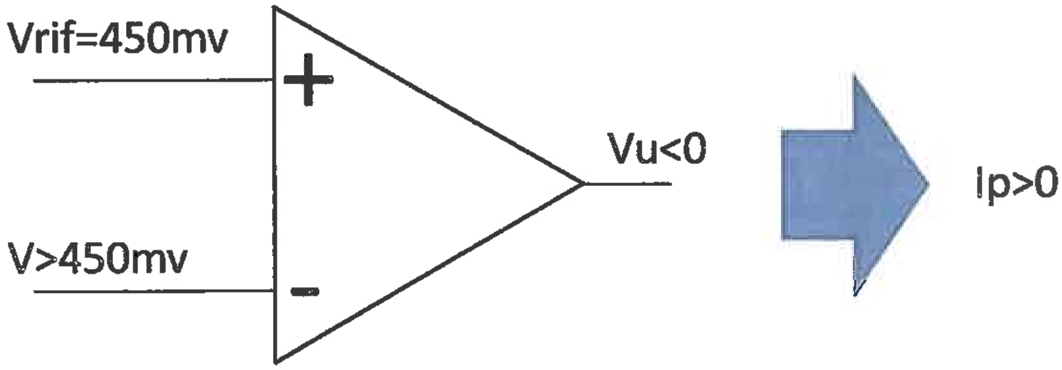


*Rich mixture*
If the mixture is rich, there is very little oxygen inside the measuring cell. An oxygen level this low triggers a greater flow of current from the reference electrode to the measuring cell electrodes. It follows that the voltage of the reference electrode is lower than 450mv.




In this case, the ECM, to restore the voltage value of the reference electrode to 450mv, has to send Ip current to the pumping cell of the lambda sensor (pin 1). The value of the current in this case is negative.

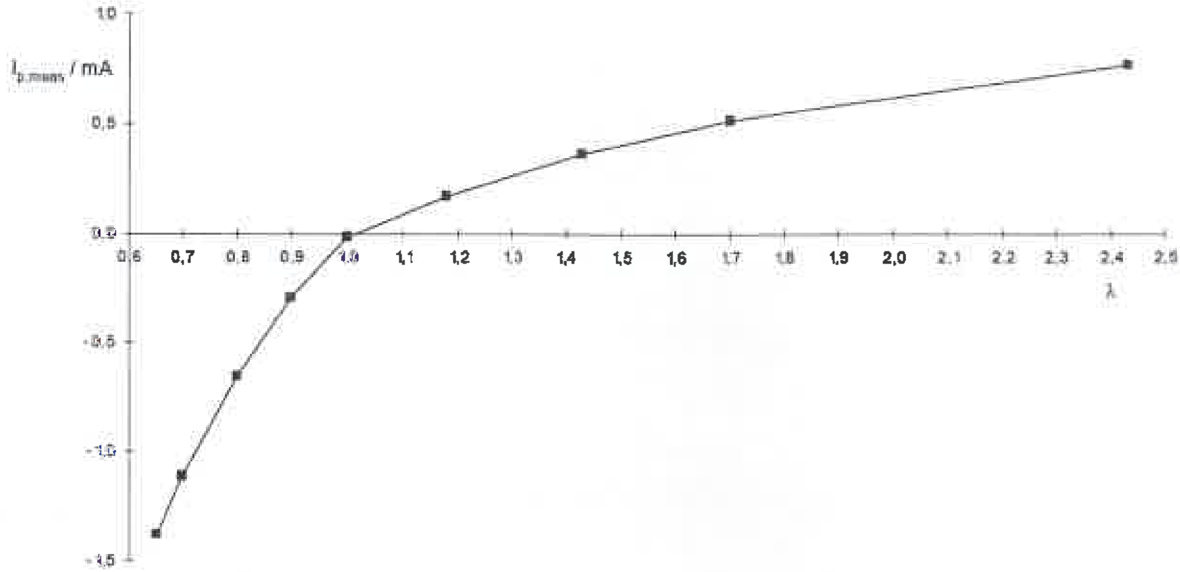
*Lean mixture*
If the mixture is lean, there is a lot of oxygen inside the measuring cell. An oxygen level this high triggers a flow of current from the measuring cell electrodes to the reference electrode. It follows that the voltage of the reference electrode increases, surpassing 450mv.



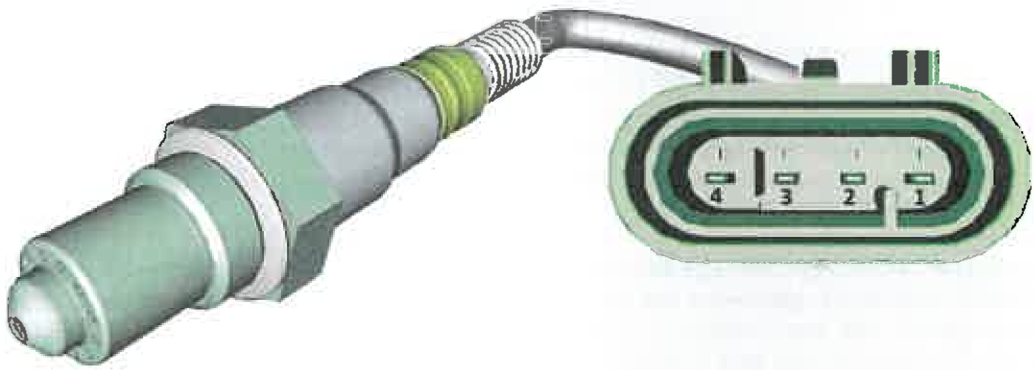

In this case, the ECM, to restore the voltage value of the reference electrode to 450mv, has to subtract Ip current from the pumping cell of the lambda sensor (pin 1). The value of the current in this case is positive.

The ECM can deduce the exact mixture ratio in function of the value and direction of the pumping current. The ECM can deduce not only whether a mixture is lean or rich, but especially "how lean" or "how rich".

Graph of Ip pumping current.

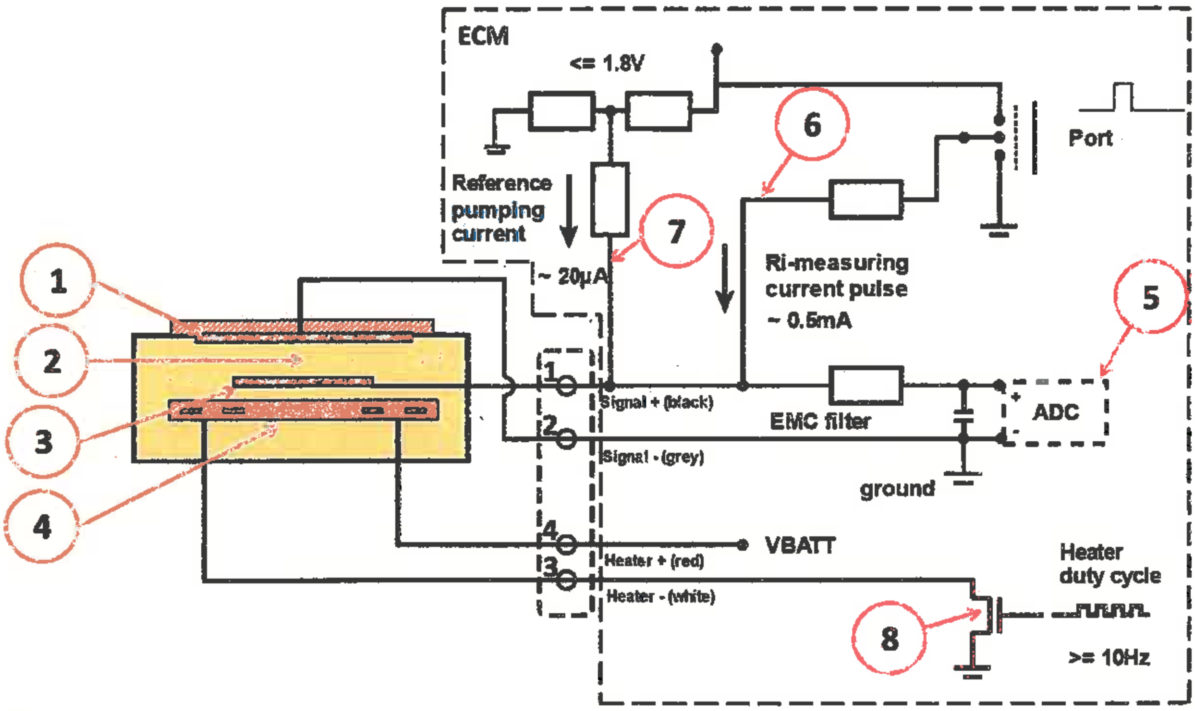



**Lambda sensor downstream of the catalytic converter.**




Pinout
1 – Positive probe signal (Nernst cell – black wire)
2 – Negative probe signal (Nernst cell – grey wire)
3 – Negative heater command
4 – Positive heater command

The lambda sensor downstream of the catalytic converter is made by Bosch and is type LSF Xfour TSP. The TSP acronym stands for Thermo Shock Protection. The sensor is type On/Off. This means that depending on the voltage of the Nernst cell (sensor signal), the ECM can understand whether the mixture is lean or rich, but cannot deduce how lean or how rich it is as the sensor located upstream of the catalytic converter can.




Key:
1 – Nernst cell electrode (+).
2 – Nernst cell.
3 – Nernst cell electrode (-).
4 – Sensor heater.
5 – ECM module controller
6 – ECM internal circuit to measure the resistance of the Nernst cell.
7 – Pumping current internal circuit (reference air simulation).
8 – Terminal for PWM command to heater.

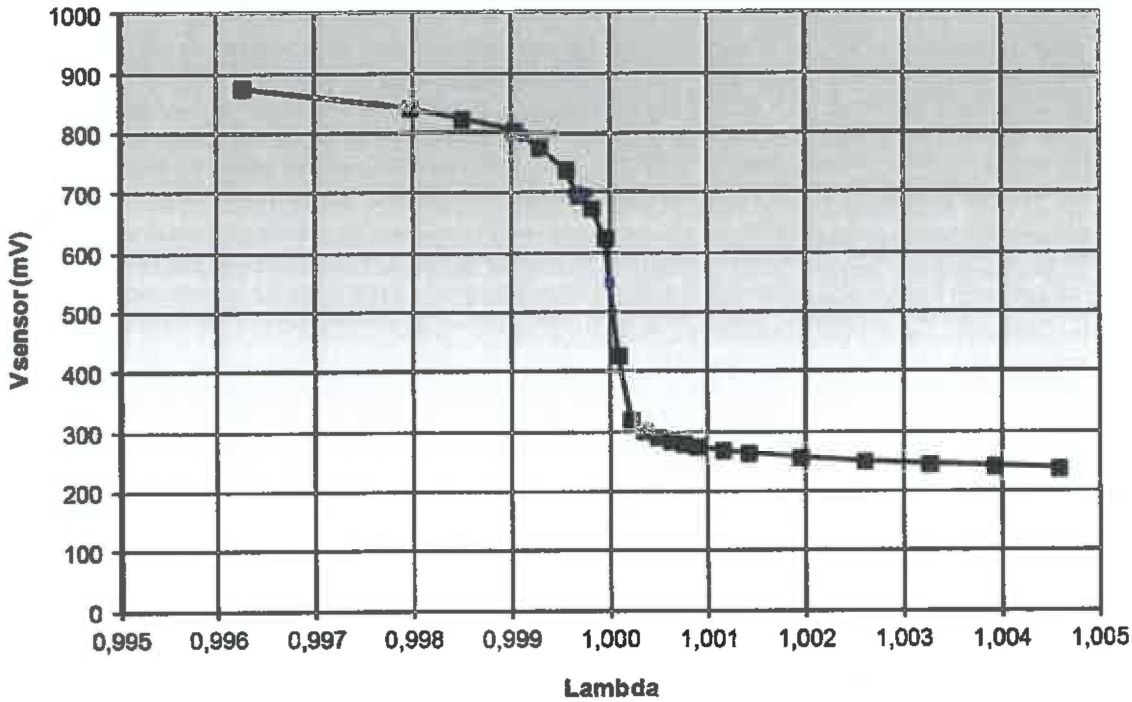
The Bosch LSF Xfour TSP lambda sensor consists of a Nernst cell (2) which, via two electrodes enslaved to it (1) and (3), generates the voltage signal in proportion to the concentration of oxygen in the exhaust gases. The probe does not contain a chamber with air for reference. The electrode (3) is powered by a current of ≈20µA in order to bring it to the reference voltage level similar to the one it would have in case it was in contact with a chamber with ambient air.

*Stoichiometric mixture.*
When the mixture combusted in the engine has a stoichiometric ratio (λ=1), the oxygen content in the exhaust gas is such that the flow of current (oxygen ions) triggered between the two Nernst cell electrodes subjects the electrodes themselves to a potential difference (sensor voltage) of ≈450mv.

*Rich mixture.*
When the mixture combusted in the engine has a ratio lower than the stoichiometric value (λ<1), the oxygen content in the exhaust gas is very low and is such that the flow of current (oxygen ions) triggered between the two Nernst cell electrodes subjects the electrodes themselves to a potential difference (sensor voltage) of <450mv.

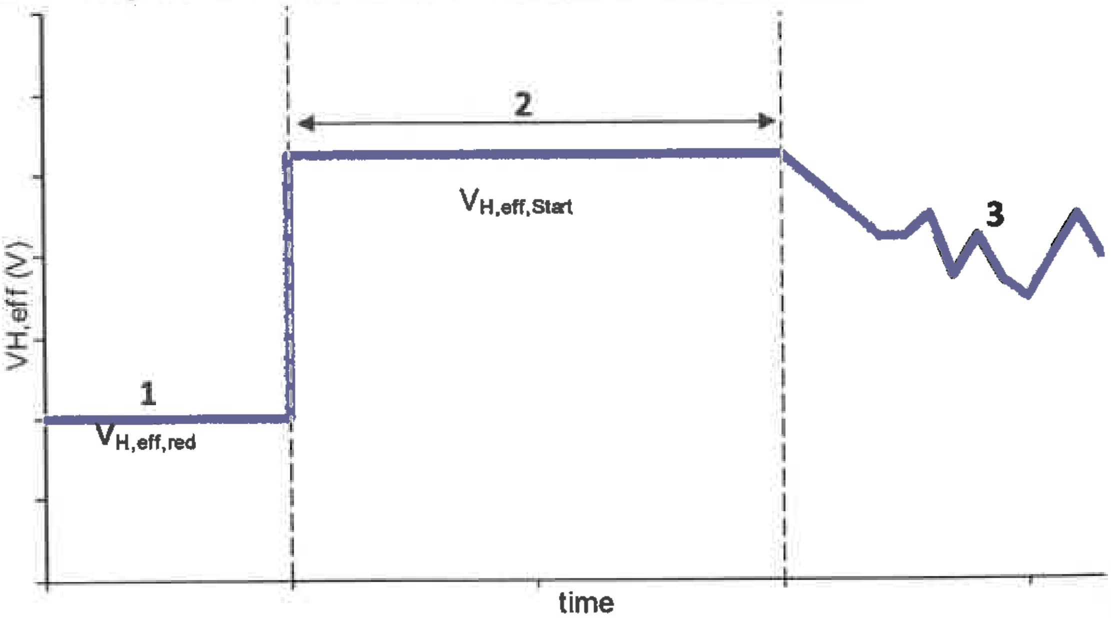
*Lean mixture.*
When the mixture combusted in the engine has a ratio higher than the stoichiometric value (λ>1), the oxygen content in the exhaust gas is very high and is such that the flow of current (oxygen ions) triggered between the two Nernst cell electrodes subjects the electrodes themselves to a potential difference (sensor voltage) of >450mv.

**Sensor signal graph.**




**NOTE:** The sensor signal graph shown above was obtained from bench tests in the laboratory using a gas-test. With engine exhaust gases, the graph's values could be more or less different.

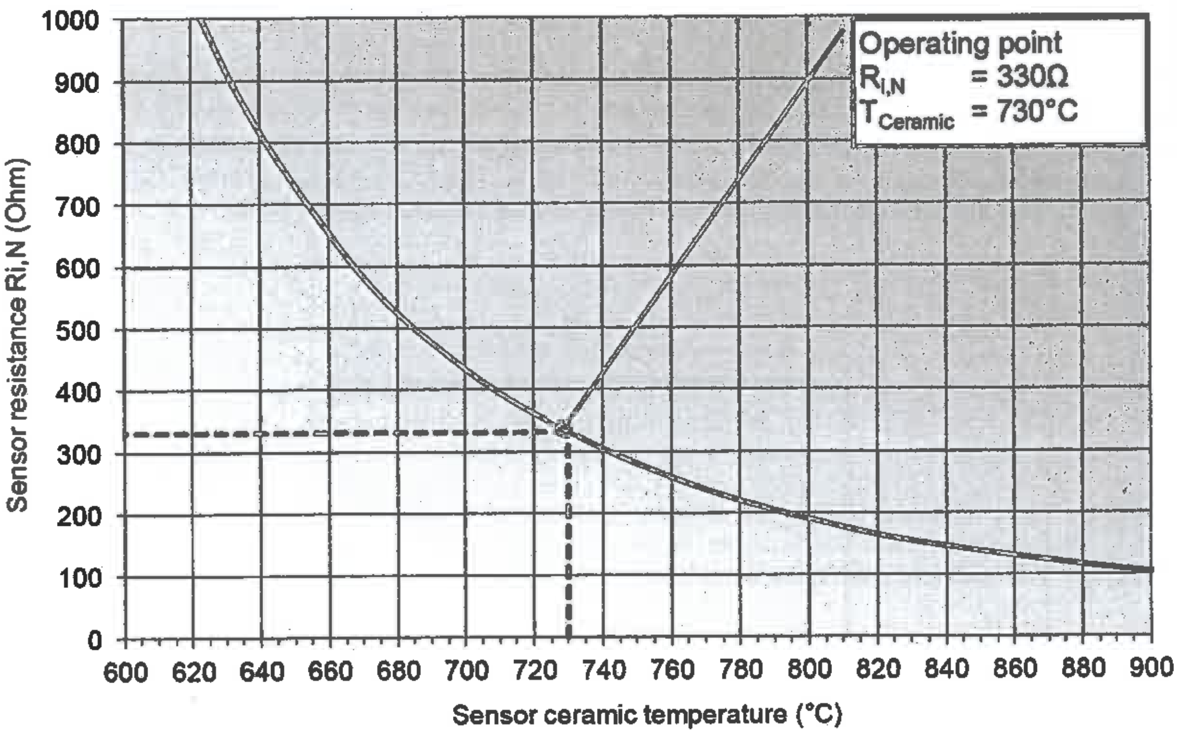
The Bosch LSF Xfour TSP sensor starts operating when the Nernst cell reaches its operating working point, which corresponds to a temperature of 730°C. The ECM module powers the heater inside the sensor to bring the latter to the thermal regime of operation in a shorter time.



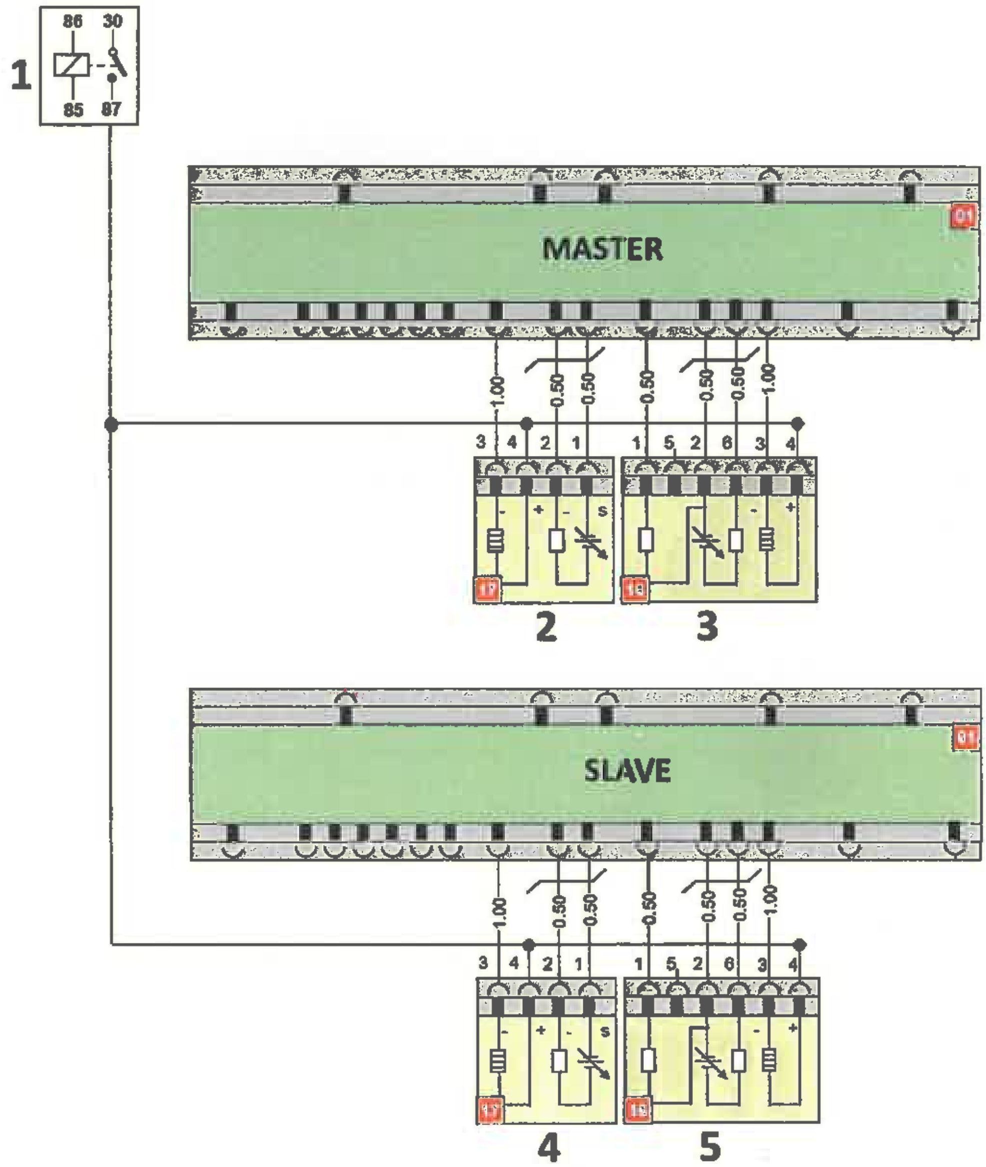

Key:
1 – Power supply to heater during the transient period (first moments after engine ignition).
2 – Operating power supply of heater to reach operating working point (730°C)
3 – Control power supply to maintain operating temperature (730°C).

The graph shows the trend of the effective voltage (command is in PWM) that the ECM module sends to the sensor's heater.
During the first moments of engine operation after ignition, the ECM module powers the heater with a minimum safety voltage (<4V) (1). The reason why it cannot increase the power supply ramp during this interval is because of the presence of condensed water vapour (droplets) in the exhaust gases (and therefore inside the sensor as well). If, hypothetically, the ECM did start the heater power supply ramp-up from the outset, the presence of droplets in contact with the hot ceramic of the sensor would create, with a high degree of probability, a thermal shock such that it would damage the ceramic of the probe itself. For this reason, during the transient period (1), the ECM module sends a very low effective voltage in order to evaporate the water droplets. Once the transient period has elapsed, it starts up the real power supply ramp that has to make the probe's Nernst cell reach the temperature of 730°C (interval 2 in the graph). After reaching the operating working point of the sensor, the ECM module shifts the heater's effective power supply voltage to lower maintenance level values (interval 3 in the graph).

**NOTE**: The switch from power supply regime 2 to maintenance power supply regime 3 is commanded by the ECM the moment the temperature of 730°C is reached. The ECM module uses its own internal circuit (6) to calculate the temperature of the Nernst cell. At regular intervals, the ECM, via the circuit (6), sends a current of ≈0.5mA to the electrode (3) of the Nernst cell. Through the voltage value generated at the heads of the Nernst cell, the central unit estimates the cell's resistance value. The resistance value is associated with a temperature value according to the graph below.

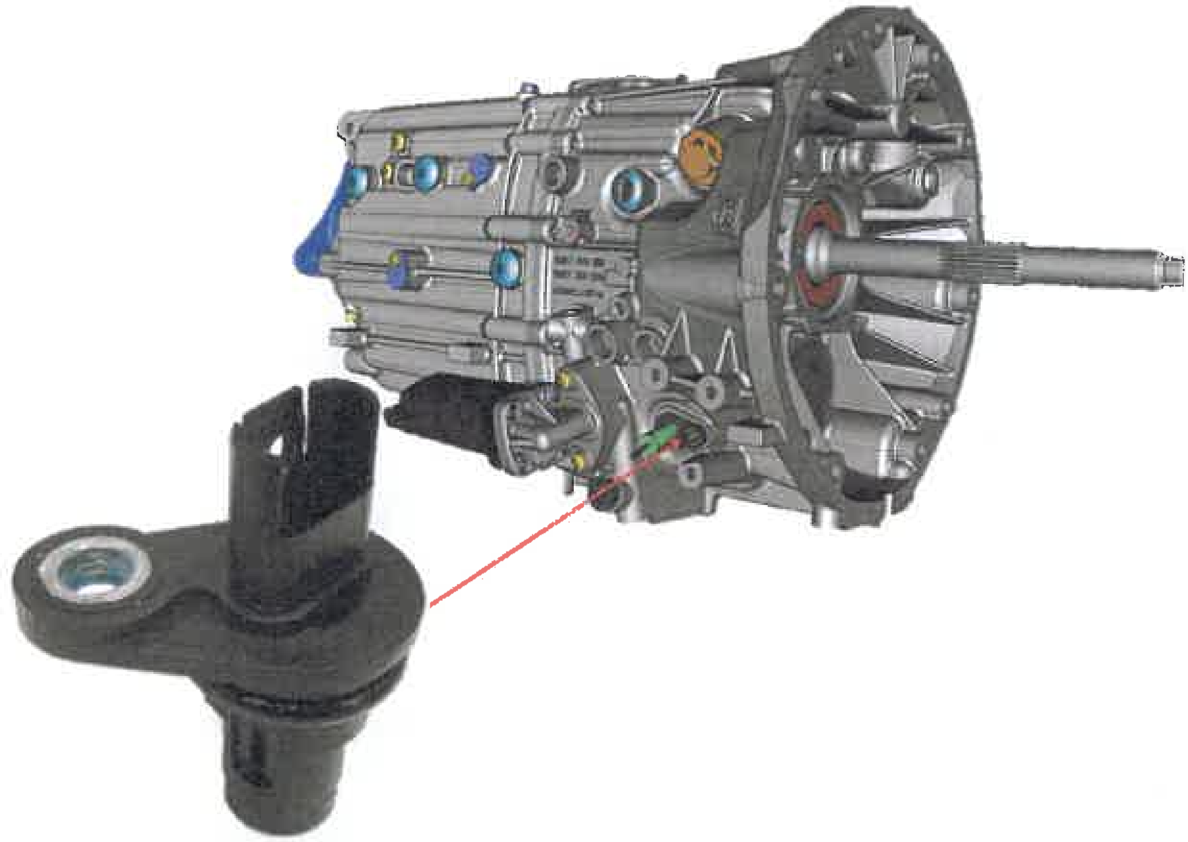


**Lambda probes wiring diagram (upstream and downstream of the catalytic converter).**




Key
1 – Main relay
2 – Lambda sensor downstream of catalytic converter, right bank.
3 – Lambda sensor upstream of catalytic converter, right bank.
4 – Lambda sensor downstream of catalytic converter, left bank.
5 – Lambda sensor upstream of catalytic converter, left bank.

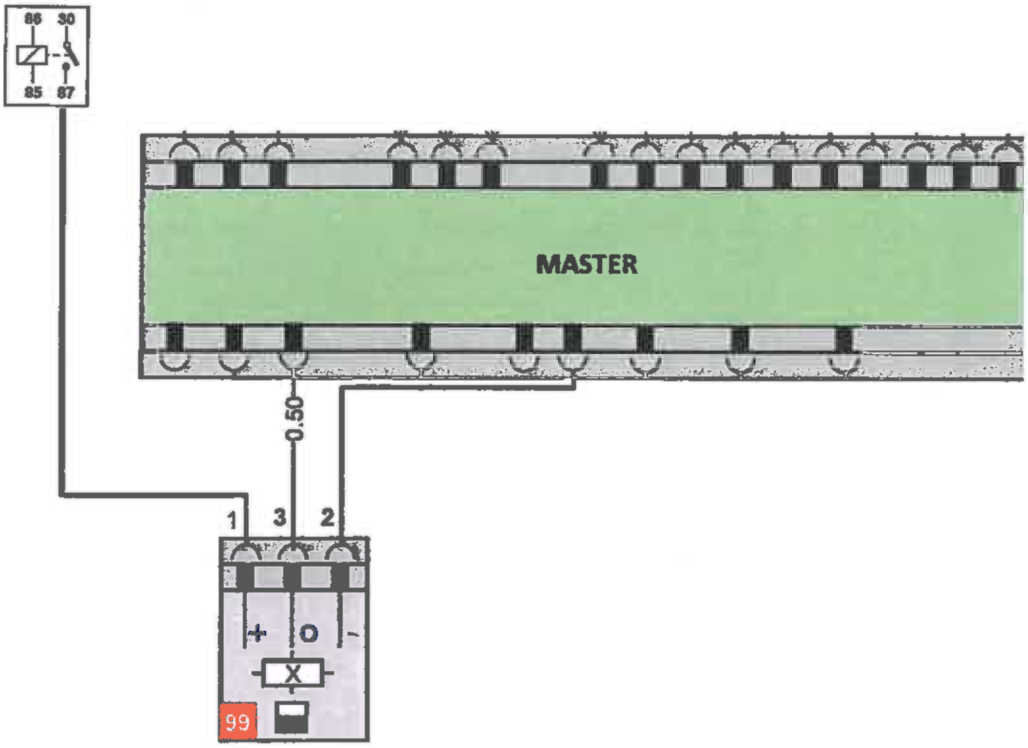
### Gearbox input speed sensor (MT only)



The revolution sensor is mounted on the semi-box of the manual gearbox connected to the engine. The sensor detects the rotation speed of the gearbox main shaft.

The sensor is type Hall effect and is electrically connected to the $ECM_1$ Master module.

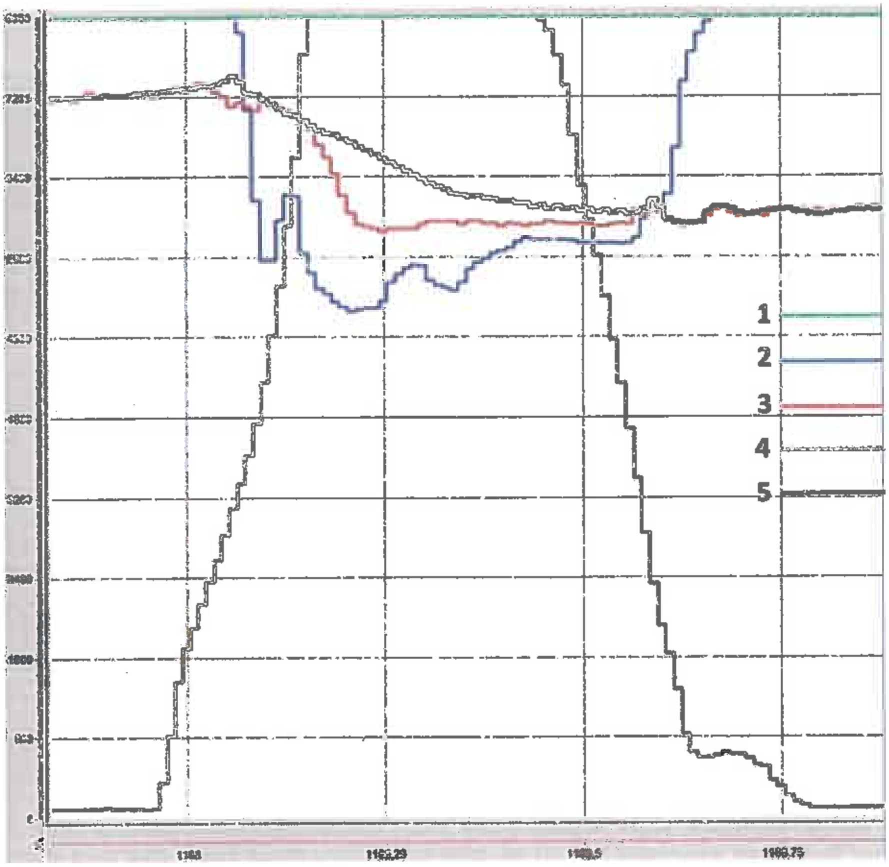
Pinout
1 – Power supply from main relay.
2 – Earths
3 – Gearbox main shaft speed signal




The $ECM_1$ Master control module requires information on the speed of the gearbox input shaft in order to trigger the strategies for limiting engine revolutions during gear changes.

By virtue of the sensor's information, the $ECM_1$ Master module can manage in the most optimal manner the fast gear changes typical of sports driving; drive gear changes more comfortable, and gear change downs with accelerator pedal released. These various gear change situations are managed by the $ECM_1$ Master module synchronising the engine revolutions and gearbox input shaft revolutions in order to facilitate gear engagement and limit clutch disc slipping.

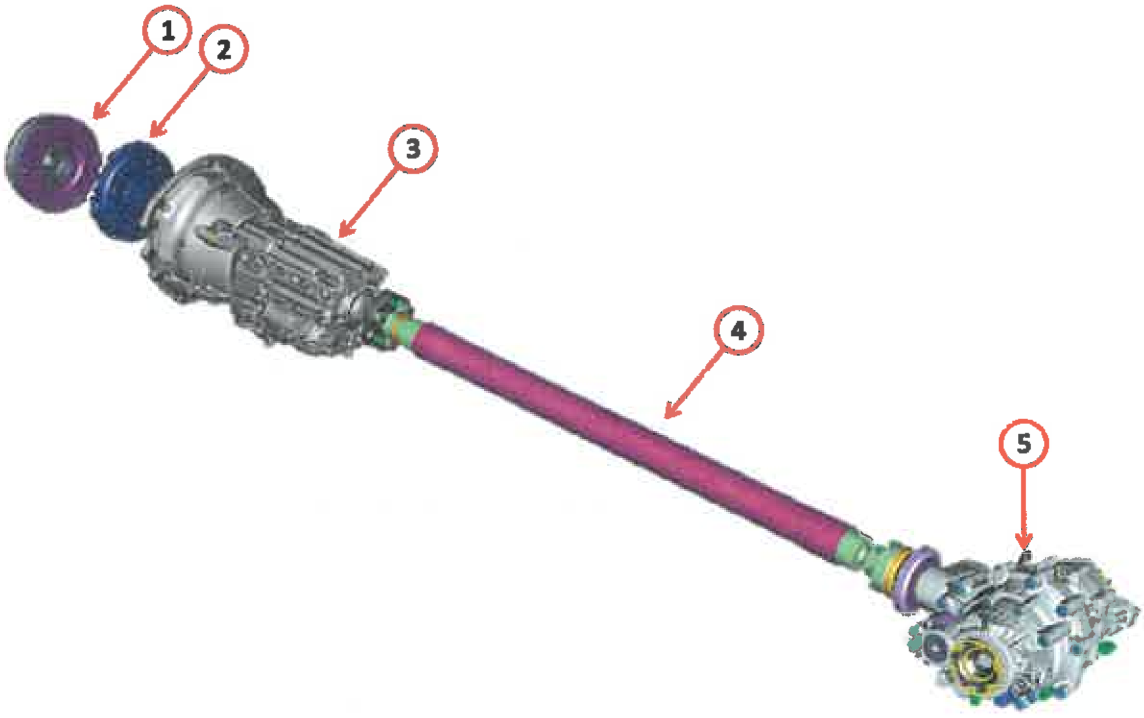
In the graph below, it is possible to see the Powershift type fast gear change strategy.




Key:
1 – Accelerator pedal position.
2 – Throttle position.
3 – Gearbox input shaft revolutions
4 – Clutch pedal position
5 – Engine revolutions.

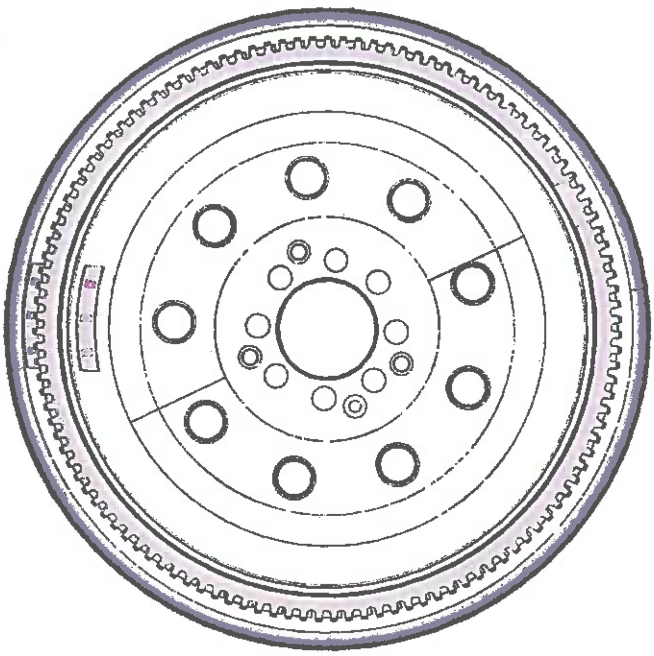
The graph shows that we are looking at a case where the accelerator pedal is completely pressed down and a gear change is taking place without releasing it. The moment the clutch pedal is pressed, the engine revolutions would tend to rapidly increase. The $ECM_1$ Master module "cuts" the torque to keep the engine revolutions as close as possible to the gearbox input shaft revolutions. This way, gear engagement is facilitated and clutch slipping is limited.

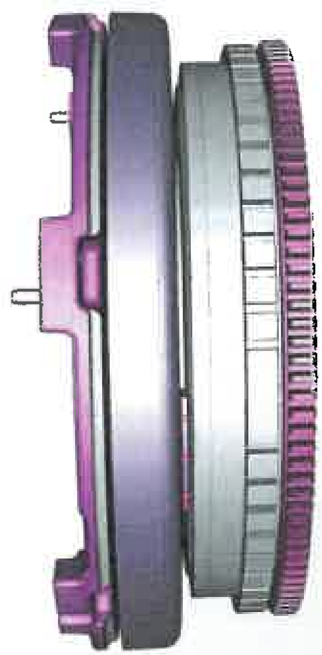
## QUADRIFOGLIO VERSION TRANSMISSION




1. Dual mass flywheel
2. Clutch kit
3. Mechanical transmission ZF 6S-53
4. Propeller shaft
5. Rear Torque Vectoring differential

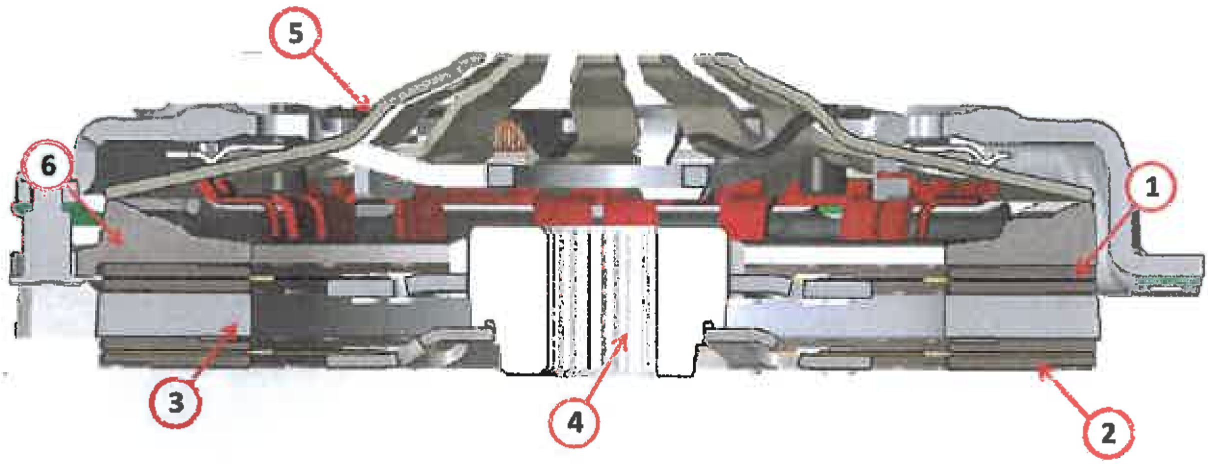
**Flywheel and clutch unit for the ZF mechanical transmission 6S-53 model Quadrifoglio version**





The flywheel is a dual-mass type with a vibration absorption system.
It has a total weight of about 19 kg and is produced by the supplier, LuK.

The clutch used is the type with automatic recovery of wear and is produced by the supplier, LuK.
The uniqueness of the clutch unit lies in the use of two friction discs.




Key:

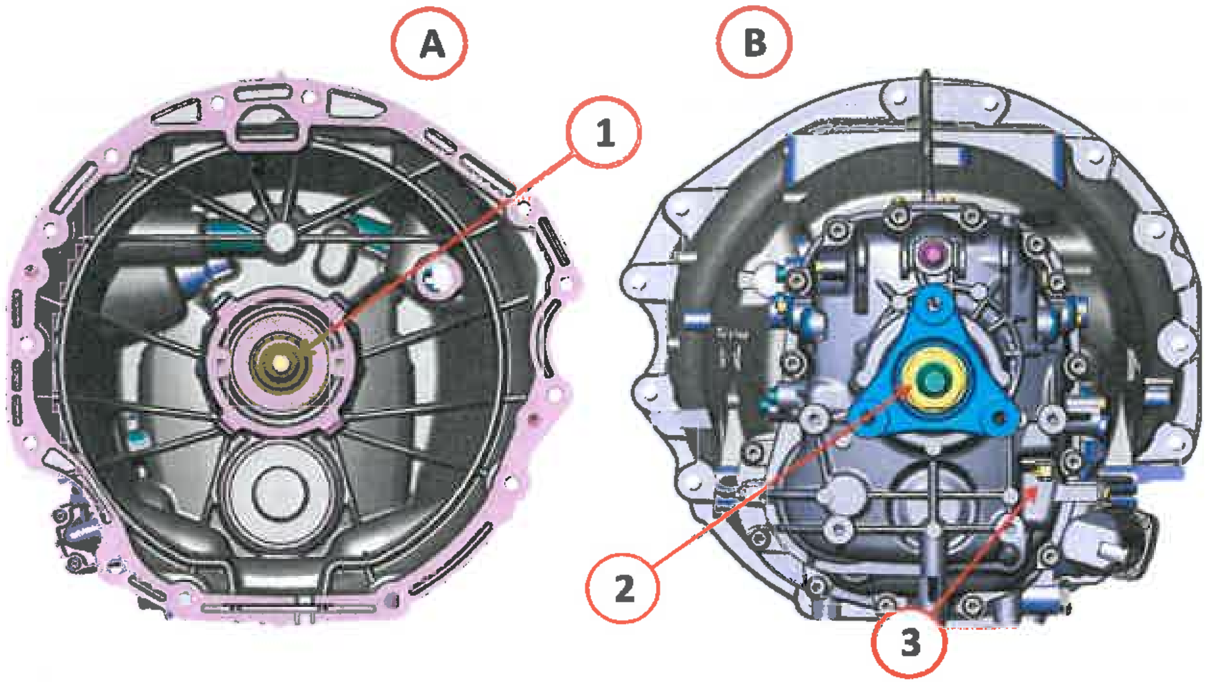
1 - Second clutch disc
2 - First clutch disc
3 - Intermediate flywheel
4 - Joint
5 - Cup spring
6 - Pressure plate

On the body of the first clutch disc, a joint with an external grooved profile and one with an internal grooved profile are installed.
The teeth of the outer grooved profile join with the teeth of the body of the second friction disc so as to join the two discs into a single piece.
The teeth of the inner grooved profile serve to join the two discs with the gearbox main shaft.
The intermediate flywheel is inserted between the two clutch discs.

**ZF Mechanical transmission 6S-53 model for the Quadrifoglio version**

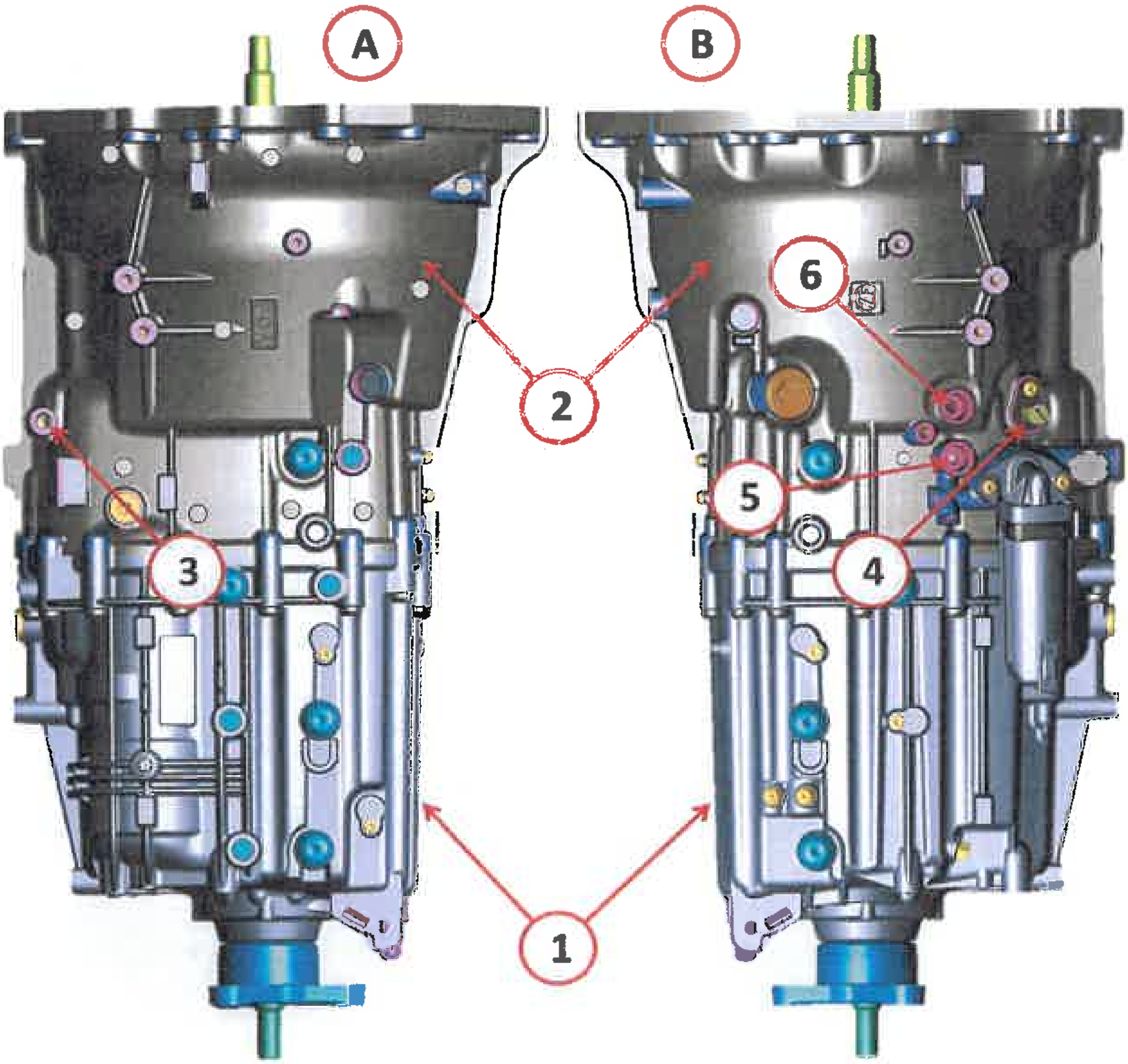
The ZF S6-53 transmission involves the use of synchronisers for the six forward gears and for reverse.
It is longitudinally mounted and has a maximum capacity of input torque of about 600 Nm. The housing and bell of the transmission are made of die cast aluminium. The bell of the transmission is fixed to the front of the crankcase and to the rear part of the gearbox casing by means of screws.
On the gearbox casing, the following are installed:

- Transmission input rpm sensor
- Transmission oil temperature sensor
- Reverse engagement sensor
- Neutral sensor
- Electrical lubrication pump



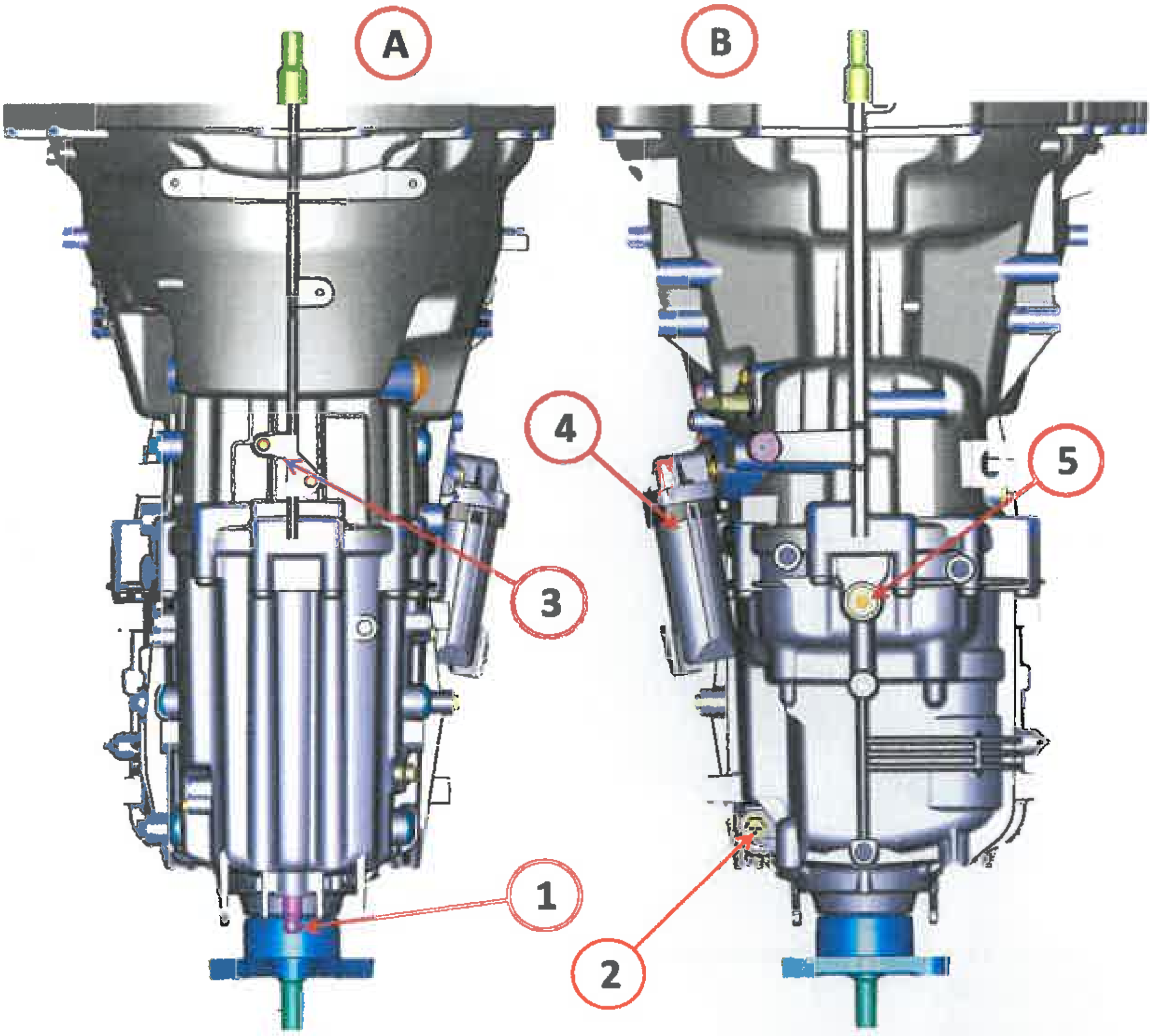

Key:

A. Front view
B. Rear view
1 - Input shaft
2 - Layshaft
3 - Reverse engagement sensor housing




Key:

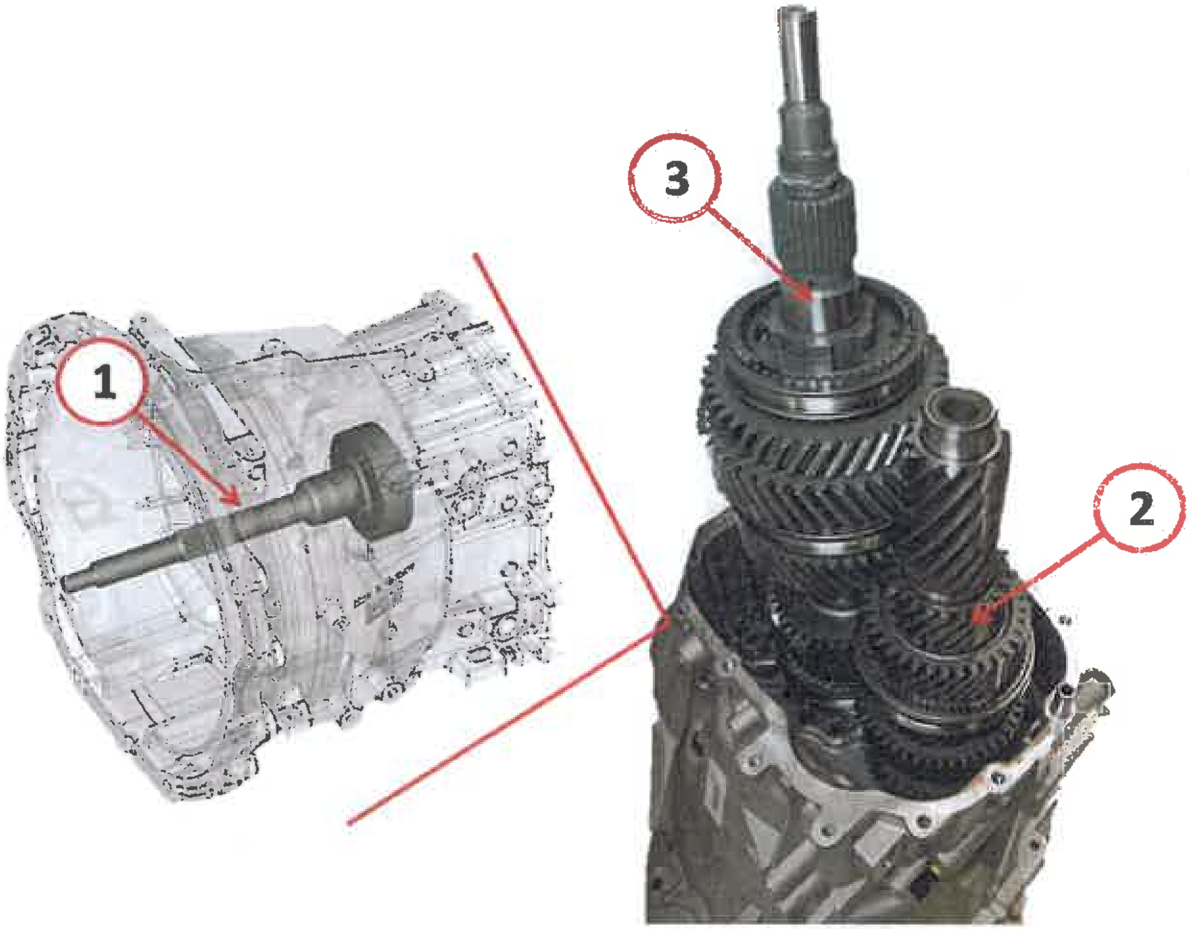
- A. Left side view
- B. Right side view
- 1 - Gearbox casing
- 2 - Gearbox bell
- 3 - Transmission oil temperature sensor housing
- 4 - Gearbox rpm sensor
- 5 - Oil outlet for heat exchanger
- 6 - Oil return from heat exchanger




Key:

A. Upper view
B. Lower view
1 - Selector lever and gear engagement
2 - Reverse engagement sensor housing
3 - Neutral sensor housing
4 - Electrical lubrication pump
5 - Oil drain plug

## Transmission architecture




The transmission architecture involves the use of three shafts for the power flow:

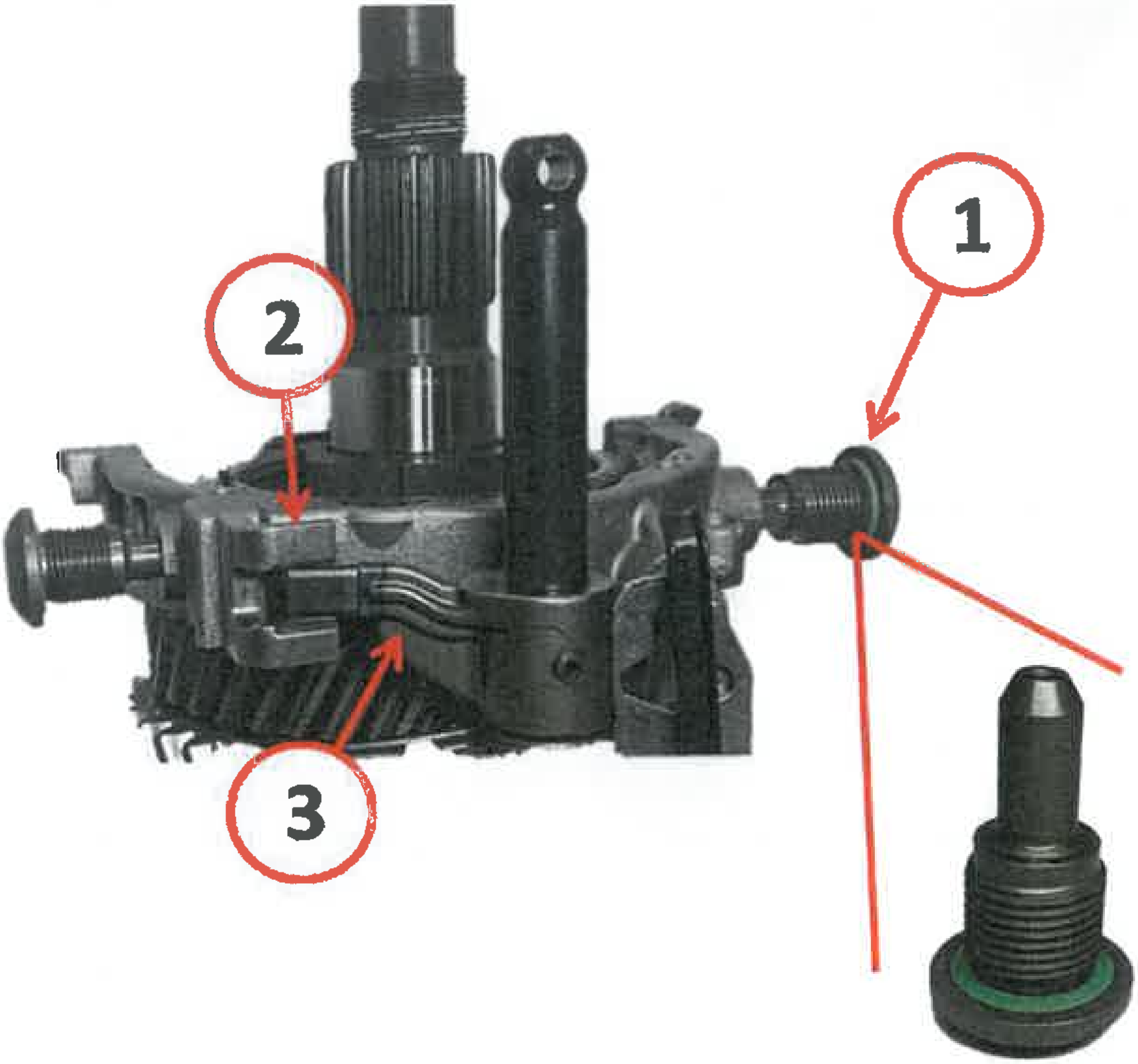
1 - Input shaft

2 - Main shaft

3 - Layshaft

The idler gears of the 1st, 2nd, 6th and reverse gear are found on the layshaft, while the idler gears of the 3rd and 4th gear are found on the main shaft. The coupling gears are built into the opposite shaft.
The main shaft and the layshaft are hollow to reduce weight.
The 5th gear is direct drive.
The weight of the gearbox is about 50Kg.

Gear selection and engagement architecture




Key:

1 - Fixing screw
2 - Fork
3 - Selector

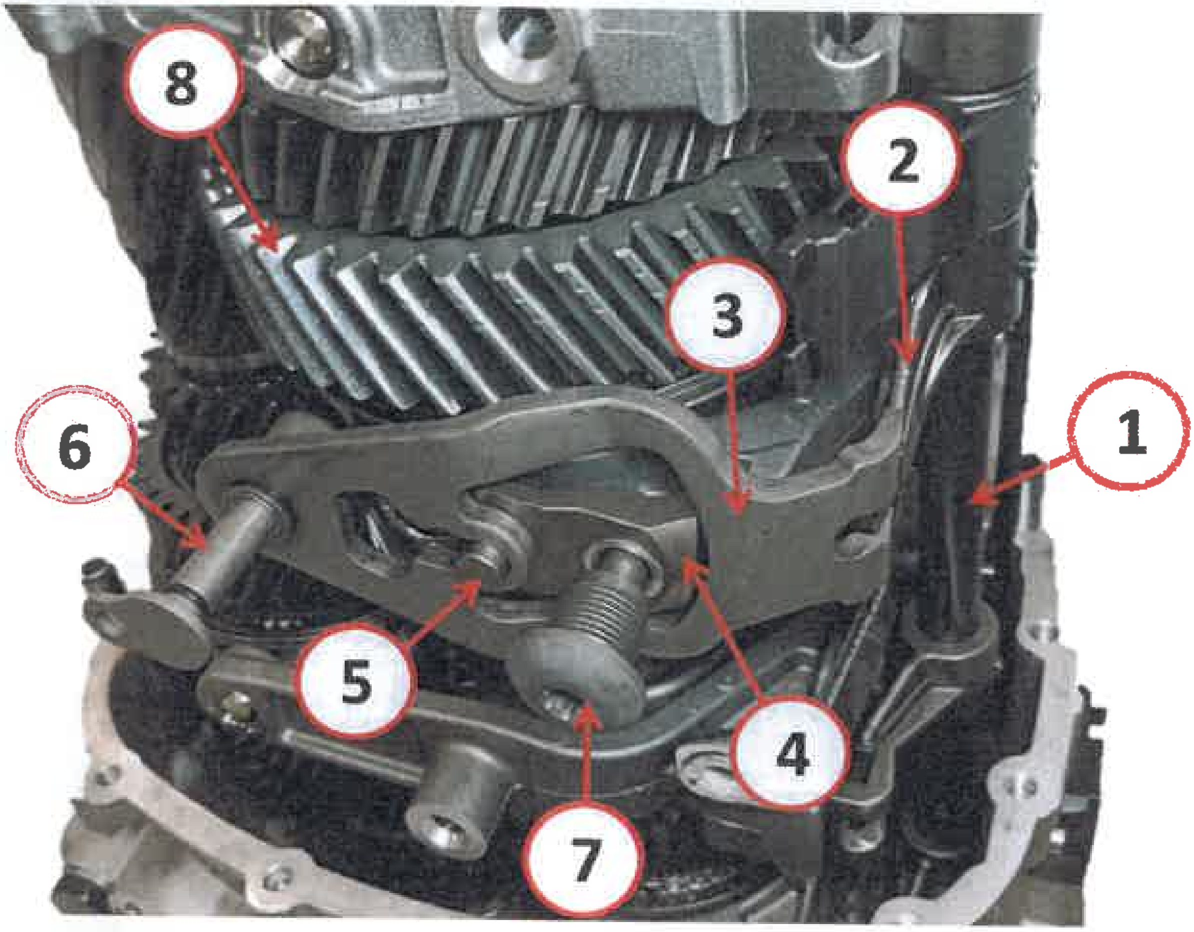
Unlike a traditional manual transmission, RWD (rear wheel drive), where generally there are forks supported by two rods with a third rod (gear shift) for the selection and engagement of gears, the ZF S6-53 transmission uses a single rod to select and shift gears and the forks are kept in position by two screws, one for each leg, screwed to the gearbox casing. The forks are made of die cast aluminium. The transmission uses four forks to effect $1^{st}/2^{nd}$ - $3^{rd}/4^{th}$ - $5^{th}/6^{th}$ and reverse gear changes; this reduces the friction in the selection system and internal gear changing.

Two screws, one for each leg, hinged with the forks, allow the sliding sleeve to move forward or backward depending on the movement received by the fork from the selector.

Two pads, mounted on each leg of the fork, engage with their respective sliding sleeve allowing the sleeve to rotate.

The forks, which can tilt, push on the sliding sleeve, which will engage the sprocket opposite to the direction of movement of the gear selection and engagement rod.

1st gear fork

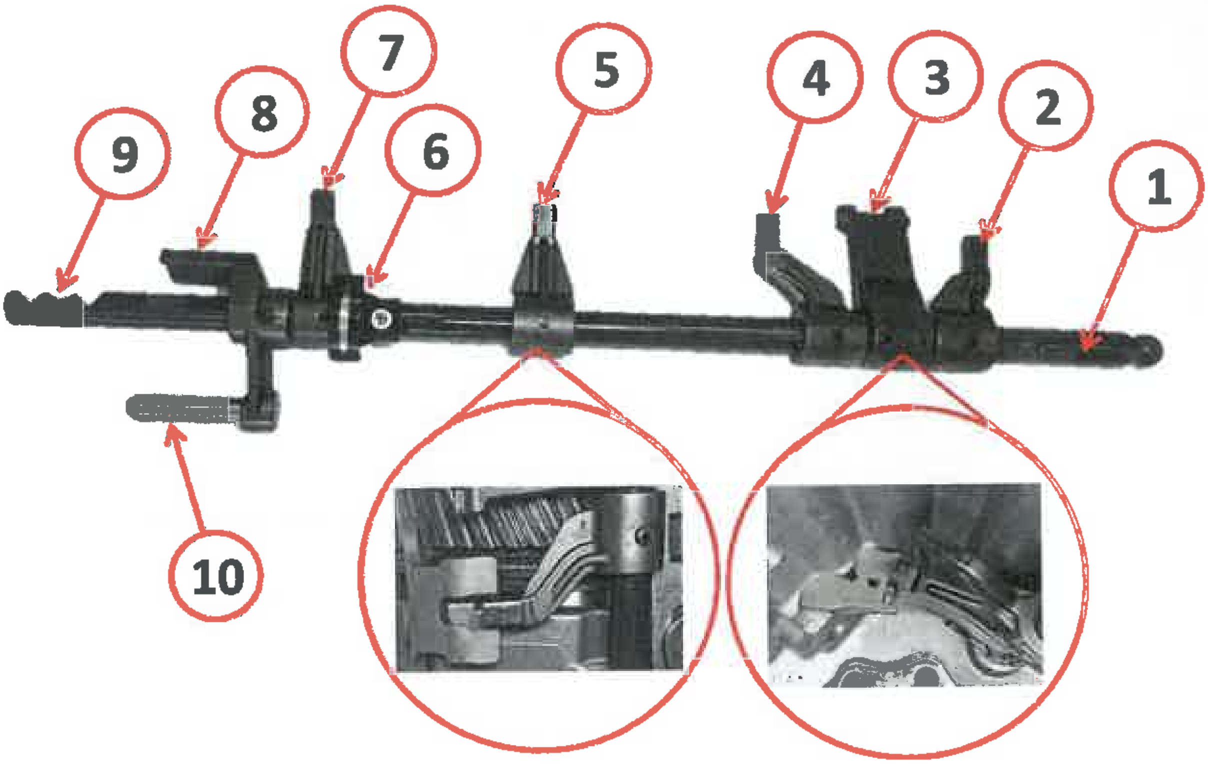



Key.

1. Selection and engagement rod
2. Selector
3. Oscillating return
4. 1st/2nd gear fork
5. Reaction pin
6. Fixing pin
7. Fixing screw
8. Idler 1st gear

The fork of the 1st/2nd gear is not put directly in contact with the selector but uses a return to engage the two gears. When the selection and engagement rod is pushed or pulled, the selector presses or pulls the engagement with the oscillating return. The latter, by means of the reaction pin of the fork, allows the same to move in the same direction as the selection and engagement rod.

## Gear selection and engagement lever

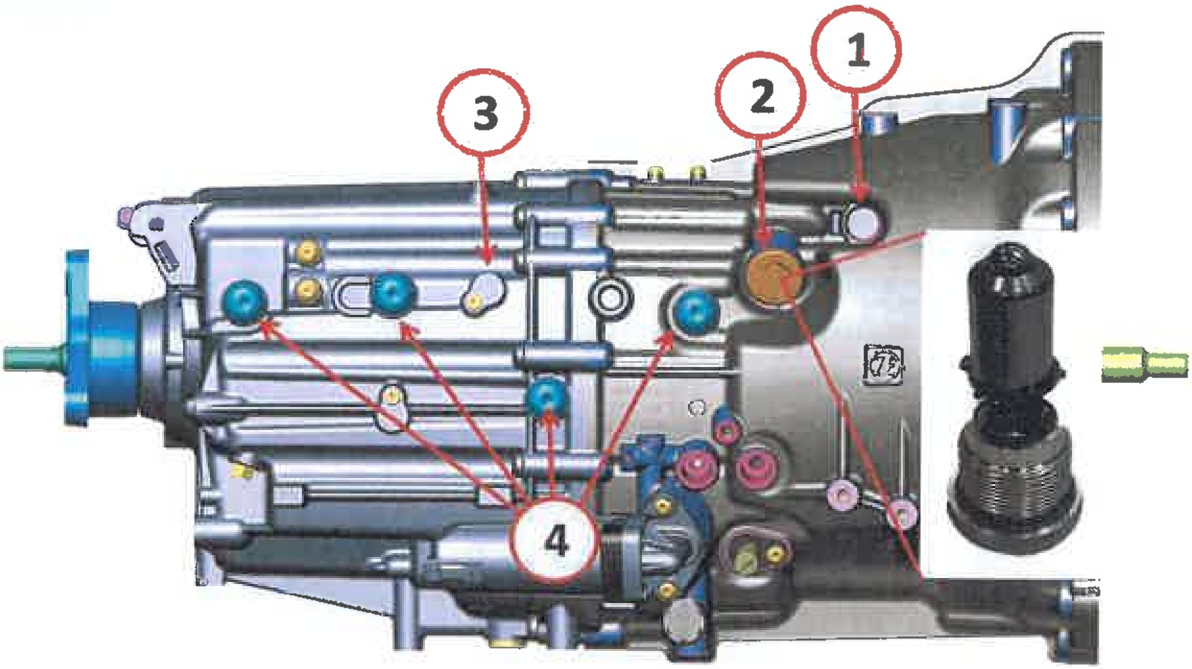



Key:

1 - Gear selection and engagement rod
2 - Reverse gear selector
3 - Gear drive selection (1st/2nd - 3rd/4th - 5th/6th and Reverse)
4 - 1th/2th Selector
5 - 3th/4th Selector
6 - Magnet for neutral position sensor
7 - 5th/6th Selector
8 - Reverse gear brake reaction point
9 - Selection and engagement lever stability brake reaction points
10 - Reaction pin to return rod to central position.

On the selection and engagement rod, selectors are inserted at different angles. The repositioning of the transmission lever in the passenger compartment, for gear selection (for example, 1st/2nd), creates a rotation of the selection and engagement rod. The rotation of the rod allows only a single selector to engage with one single fork. The moment the driver engages or disengages a gear, the selector pushes the fork in one direction or the other.

## Brakes of the selection and engagement lever



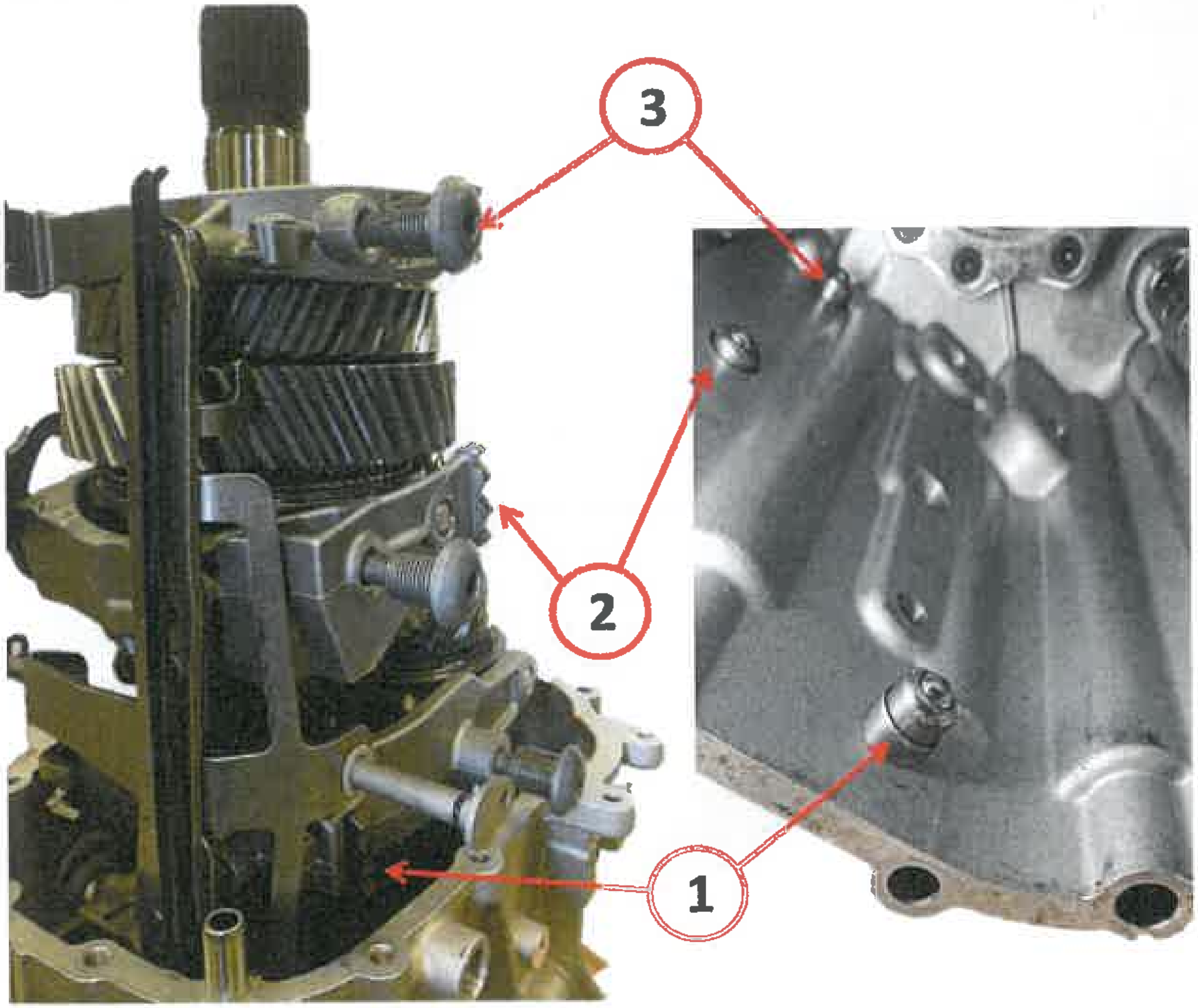

Key:

1 - Brake position for the selection and engagement rod
2 - Brake for reverse engagement
3 - Fixing pin for mechanical brake of forks
4 - Fixing screws for forks

On the selection and engagement rod, two brakes are present, made of one spring and one ball:

- A brake prevents the selection and engagement rod of the fork from unintentionally selecting the reverse gear.
- A brake provides the selection and engagement rod with stability in its position.

## System for locking forks

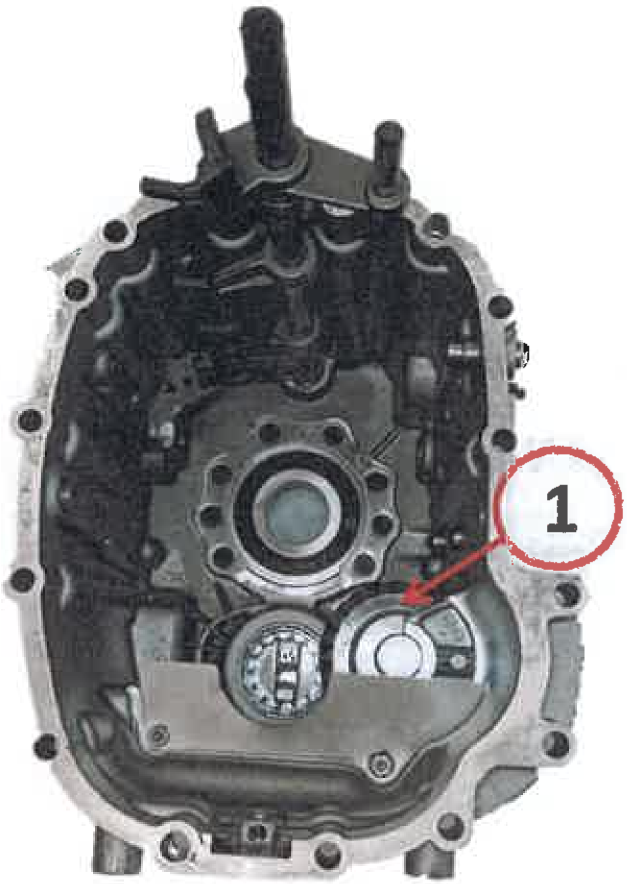



Key:

1 - Brake reaction point of 3$^{st}$/4$^{nd}$ fork
2 - Brake reaction point of 1$^{st}$/2$^{nd}$ fork
3 - Brake reaction point of reverse gear fork

During gear engagement, only one fork is involved with the selector while the other 3 are free. In order to prevent any movement of the forks, four brakes are inserted, one per fork, made with a spring and a ball. The brakes press on each fork ensuring their stability.

## Reverse gear idler

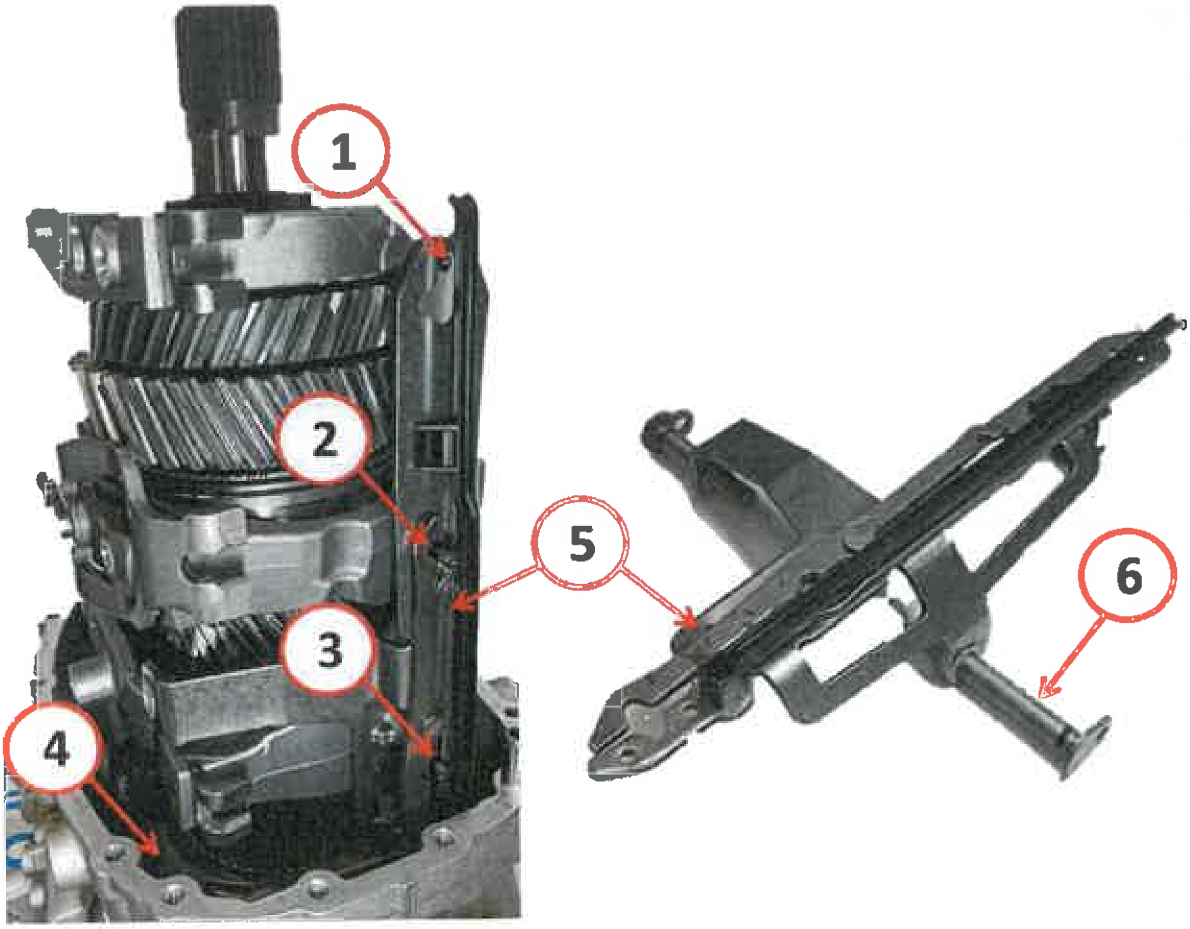



Key:

1 - Reverse gear idler

The change in rotation for reverse gear is obtained with the assistance of an intermediate gear located between the main shaft and the layshaft inside the gearbox.

## Mechanical locking system for the forks




Key:

1 - Reverse fork pin
2 - 1rd/2th fork pin
3 - 3rd/4th fork pin
4 - Fork, 5rd/6th
5 - Locking system for forks
6 - Fixing pins

To provide even more stability. for the forks that are not controlled, a simple but effective mechanical system is used to keep the free forks in position.

For each fork, a PIN is installed. When a fork is used, its PIN is moved, pressing on a lever that mechanically prevents the other three PINs from moving.

The locking system is maintained in position by two fixing pins installed on the gearbox casing.

### Synchronisers

The ZF S6-53 transmission uses various types of synchronisers depending on the gear:

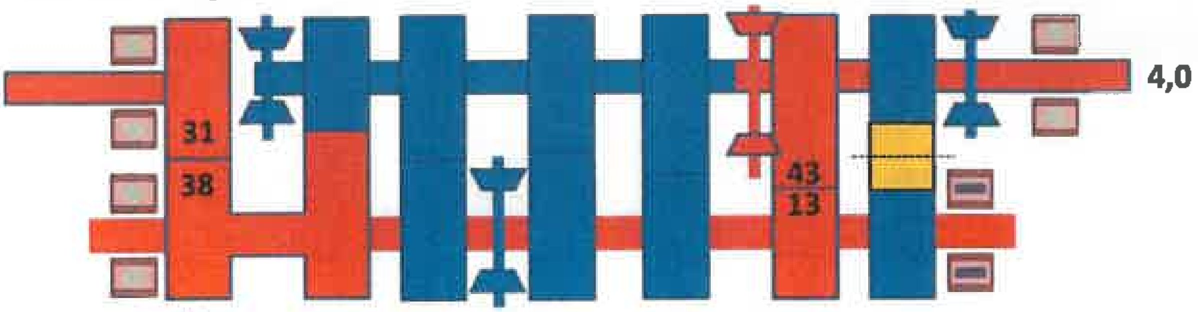
| Gear | Type of synchroniser |
|---|---|
| 1° | Triple cone |
| 2° | Twin cone |
| 3th / 4th | Twin cone |
| 5th / 6th | Single cone |
| Reverse gear | Twin cone |

### Bearings

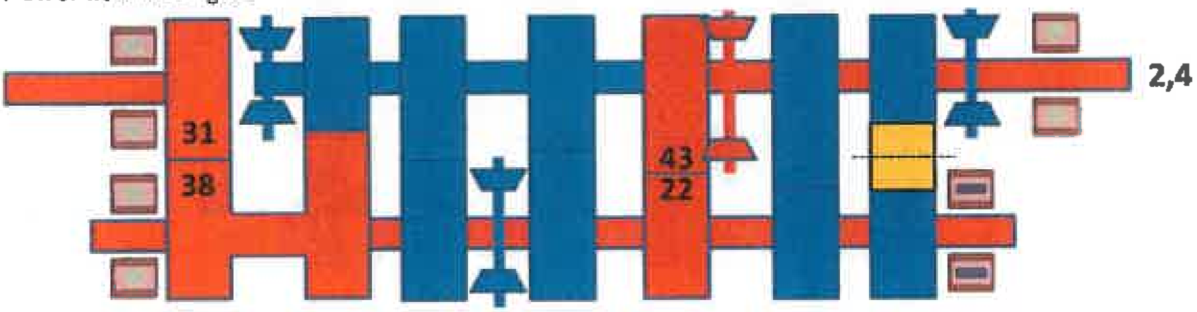
| Position of the bearings | | Type of bearings |
|---|---|---|
| Input shaft | Gearbox bell | Ball bearings |
| Main shaft | Gearbox bell | Ball bearing |
| | Gearbox housing | Roller bearing |
| Layshaft | On the input shaft | Roller bearing |
| | Gearbox housing | Ball bearings |
| Sprocket gears | | Roller bearing |

## Power flow

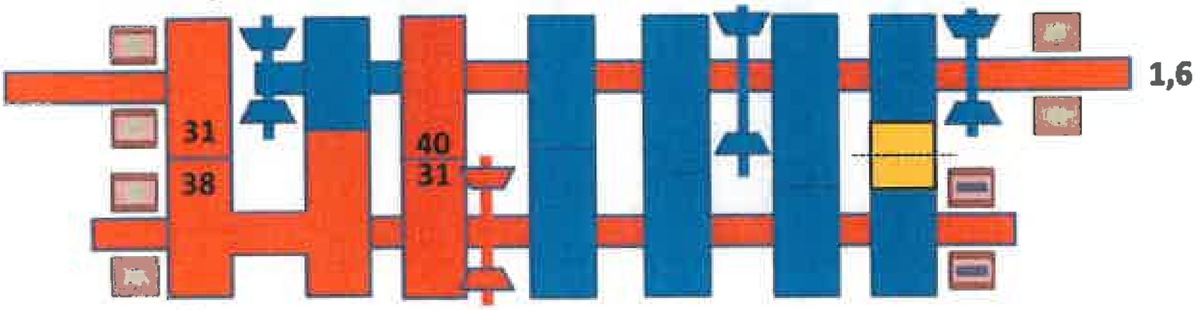
Power flow in 1th gear



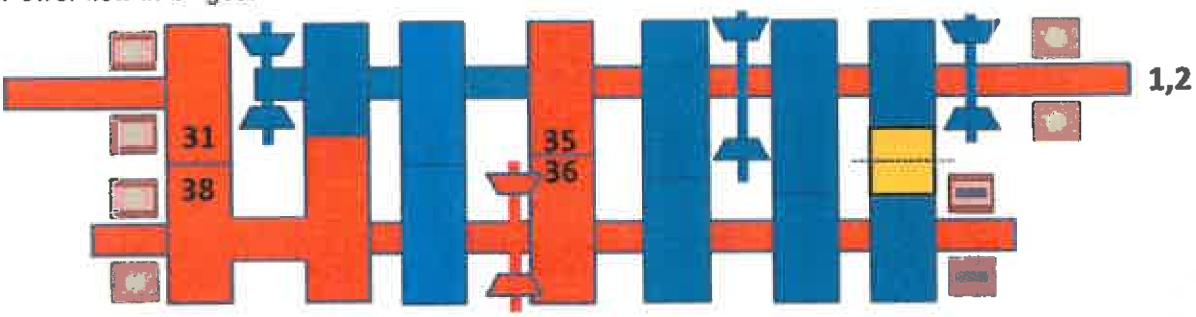

Power flow in 2th gear



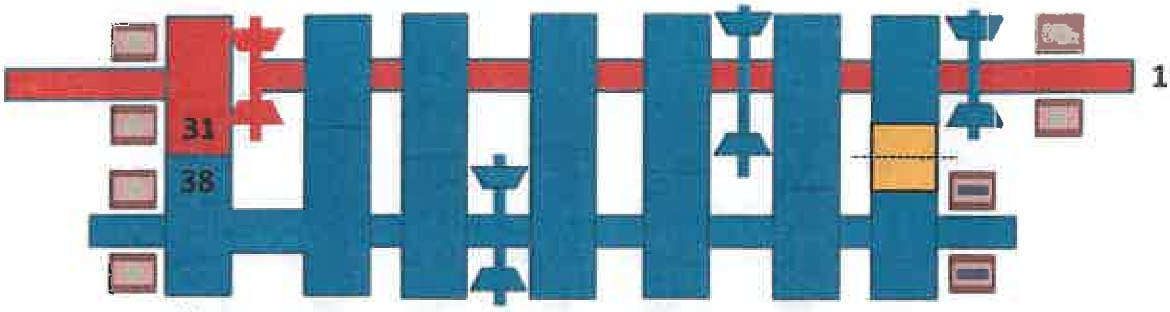

Power flow in 3th gear



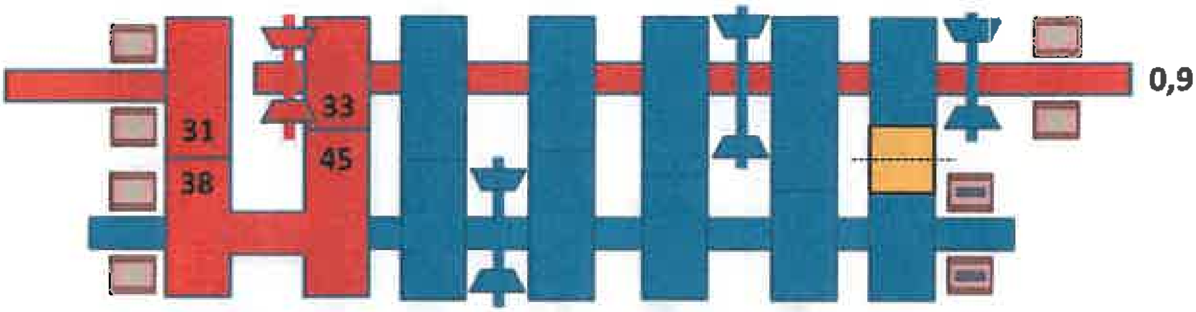

Power flow in 4th gear



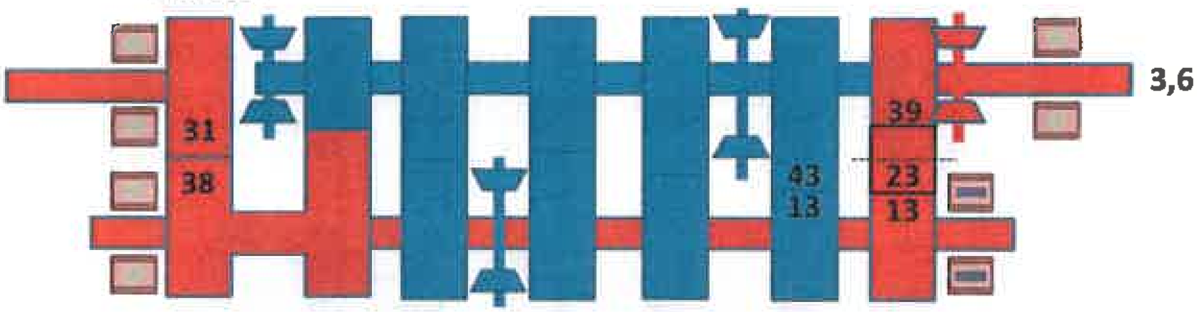
Power flow in 5th gear



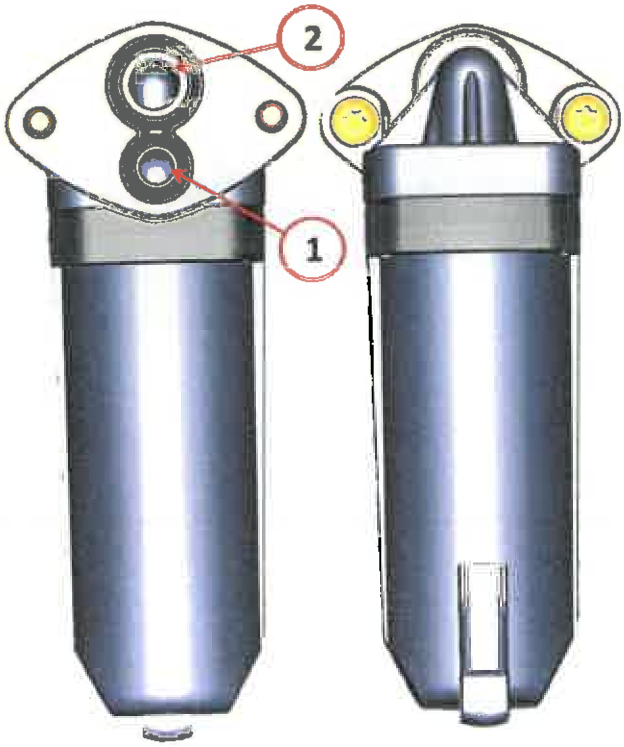

Power flow in 6th gear




Power flow in reverse



## Electrical lubrication pump



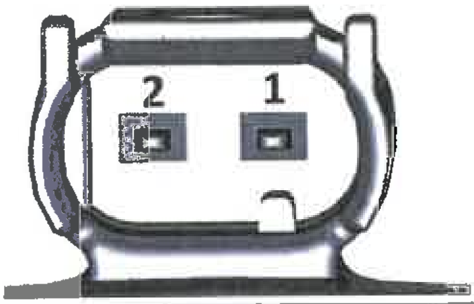

Key:

1 - Pump oil outlet

2 - Pump oil inlet

On the right side of the gearbox, the pump for lubricating the gearbox is fixed and activated by the ECM Master.

The pump draws the oil from the lower part of the gearbox, it passes through the filter and then reaches the pump. The pump sends it to the heat exchanger for cooling and finally it returns to the gearbox to lubricate the bearings.

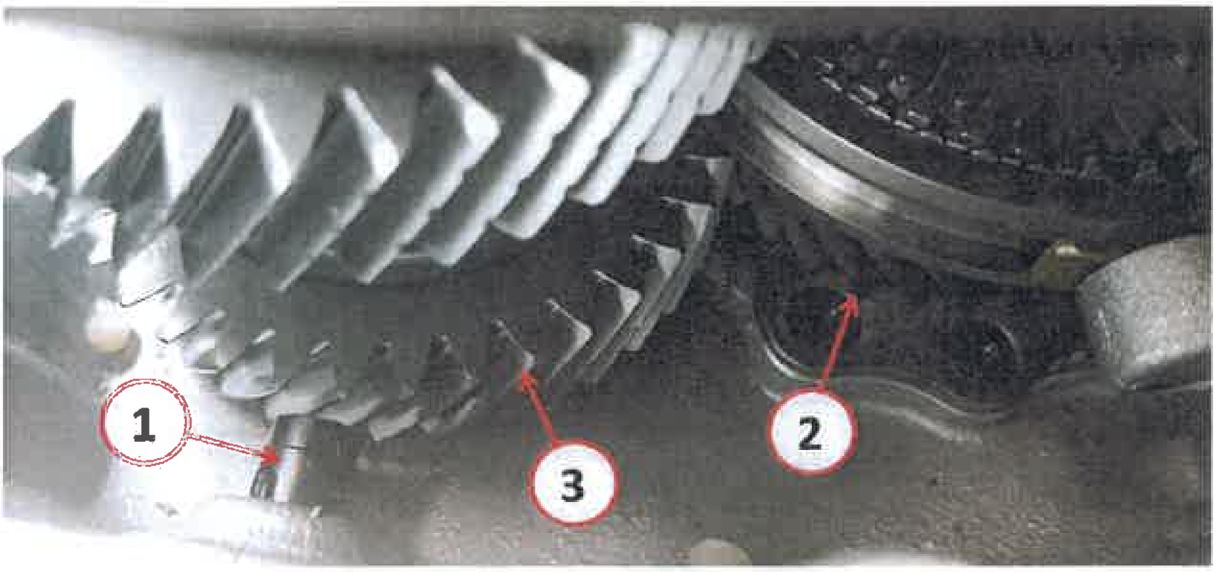



| Pin | Function |
|---|---|
| 1 | Power supply |
| 2 | Earth |

Technical specifications

| | |
|---|---|
| Maximum working temperature | 130°C |
| Maximum capacity: | 10 L/h |
| Oil pressure | 0.3 Bar |
| Power supply | 12 V |

**Gearbox rpm sensor**




Key:

1. Gearbox rpm sensor
2. Sprocket on the input shaft
3. Sprocket on the main shaft

The gear rpm sensor is a Hall effect sensor. The ECM control unit receives information on rpm at input at the gearbox to implement the correct motor management strategy during the starting phase and during gear changes.

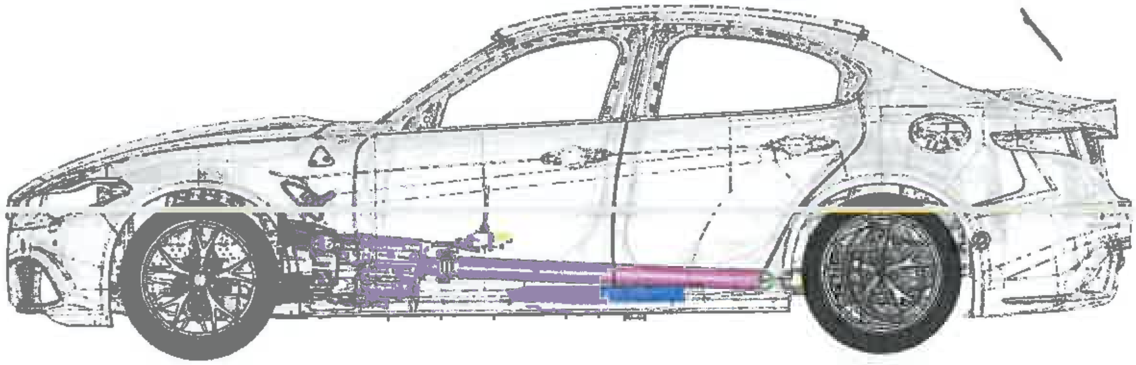
**Transmission oil temperature sensor**

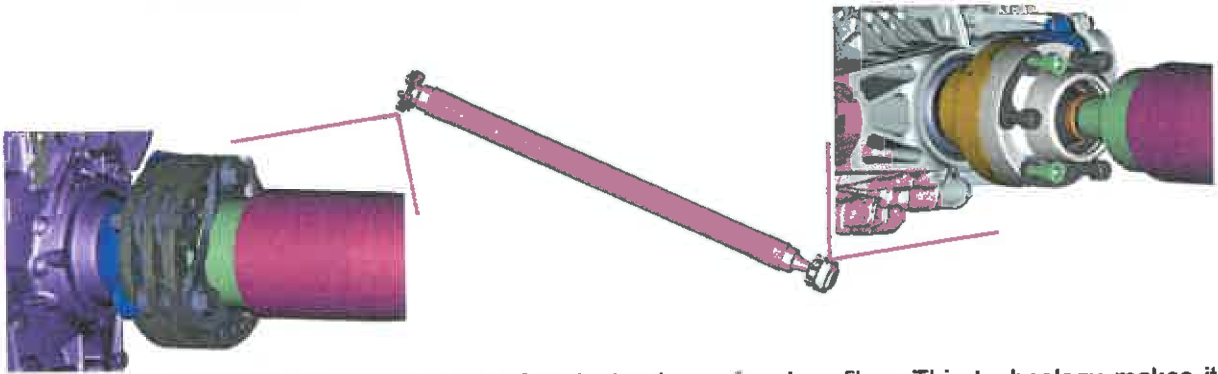
The ECM control unit receives transmission oil temperature information to activate the lubrication pump in order to prevent possible failure of the gearbox components.

**Oil filter change**

Before the oil is drawn by the electric pump, it is passed through a filter.
The filter has the function of retaining the larger solid particles and is constituted by a wire mesh.

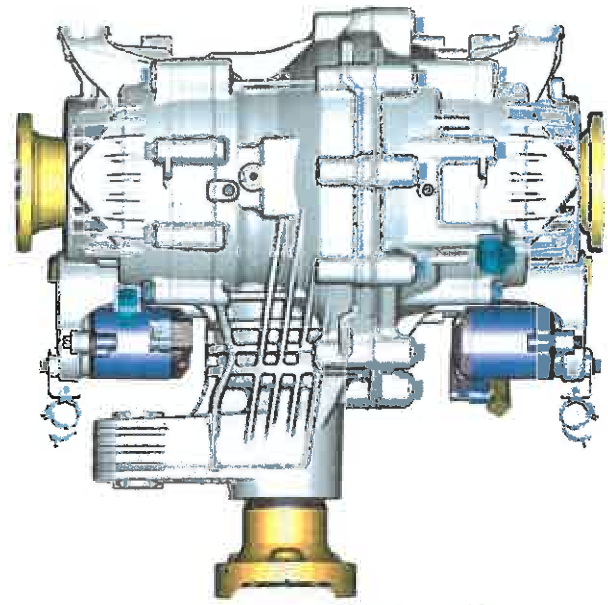
## Propeller shaft, Quadrifoglio version

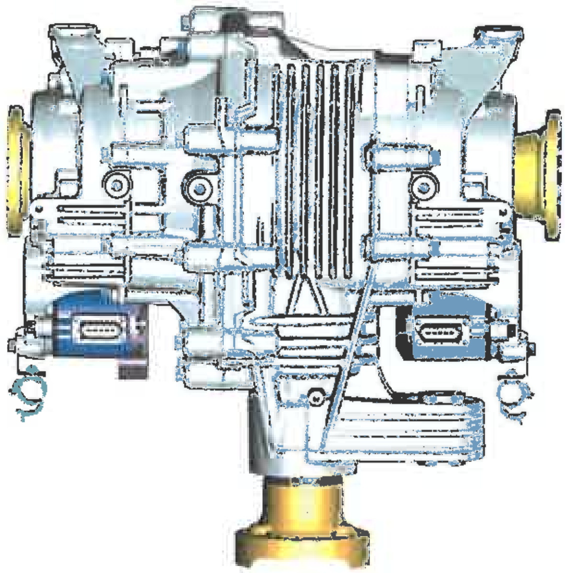


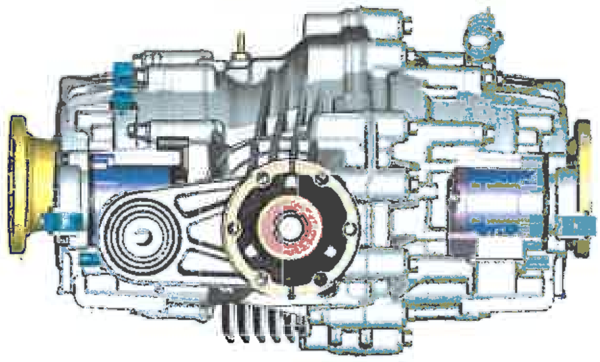


The body of the propeller shaft is made of a single piece of carbon fibre. This technology makes it possible to limit the weight of the component and to maintain the total weight at about 7Kg.
The component is supplied by the manufacturer, Hitachi.
On the shaft there are two flanges to join:

- The joint in rubber elements and steel discs, for joining the shaft to the transmission.
- The junction with a steel disc, to join the shaft to the Torque Vectoring differential.



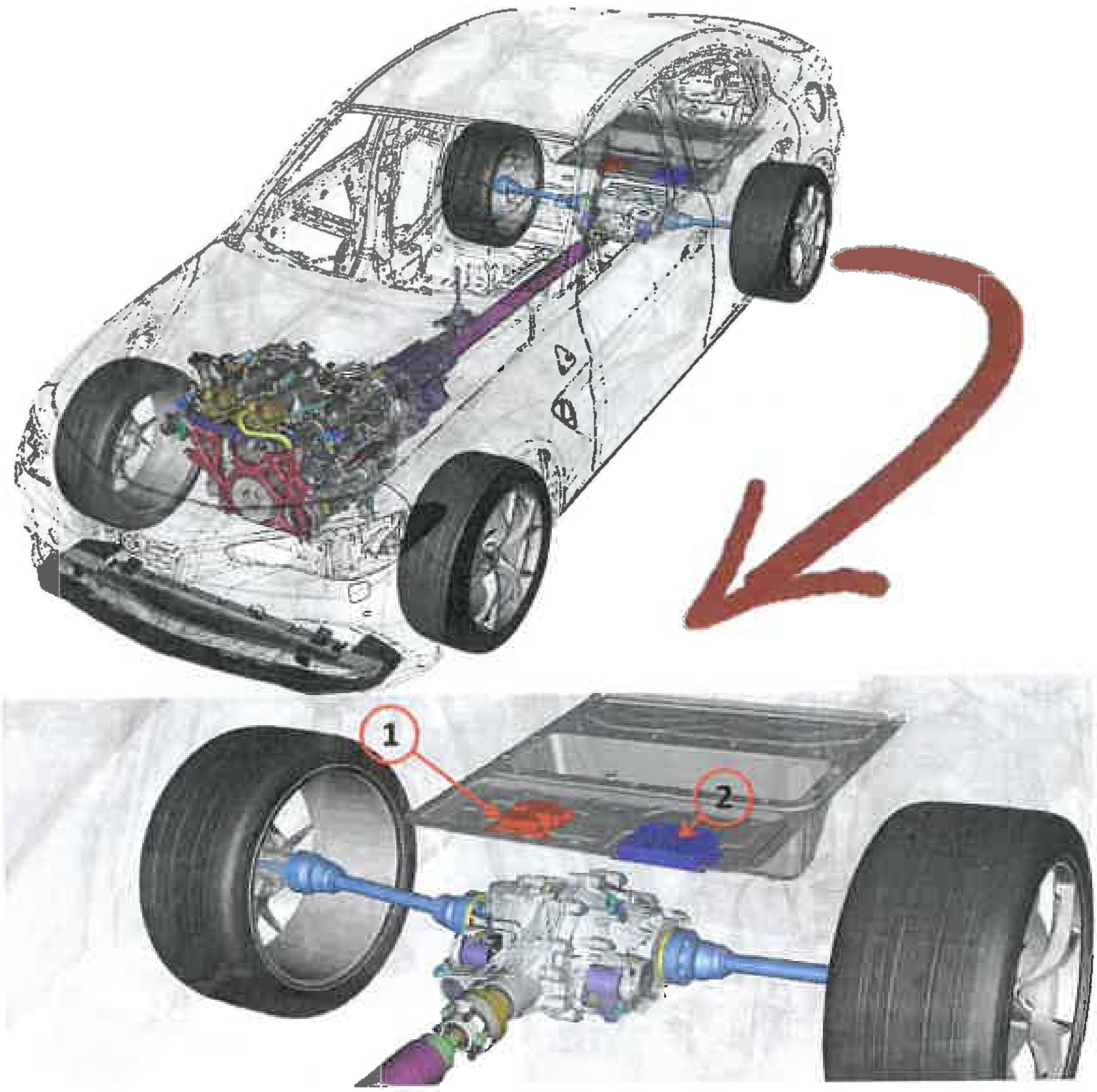




The characteristics of this differential are:

- The outer box of the differential is made of five aluminium elements
- It includes two epicyclic units
- It includes two clutch packs
- It includes two small electric motors
- The total weight is of about 53Kg.
- The transmission ratio is 3.09
- It uses 0.75 litres of 75w85 oil for the bevel gear.
- It uses a specific oil for the sides, where the clutches are present

The CDCM module communicates with the electronic TVM module (Torque Vectoring Module) for the purpose of requesting of the latter to differentiate the distribution of the torque between the two rear wheels. The TVM module manages, from the electronic point of view, the rear differential Torque Vectoring TV.

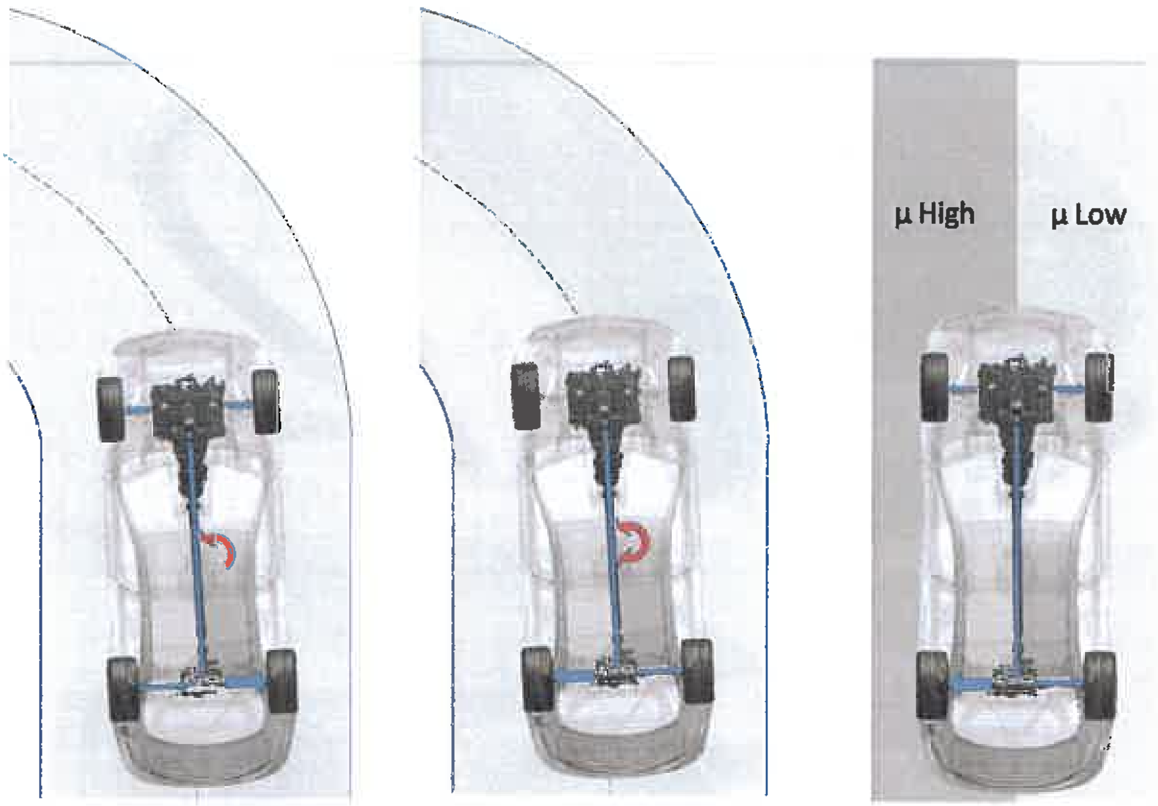



Key:
1 – CDCM module
2 – TVM module

The CDCM module requests of the TVM module to distribute, in different mode, the torque between the rear wheels in order to:

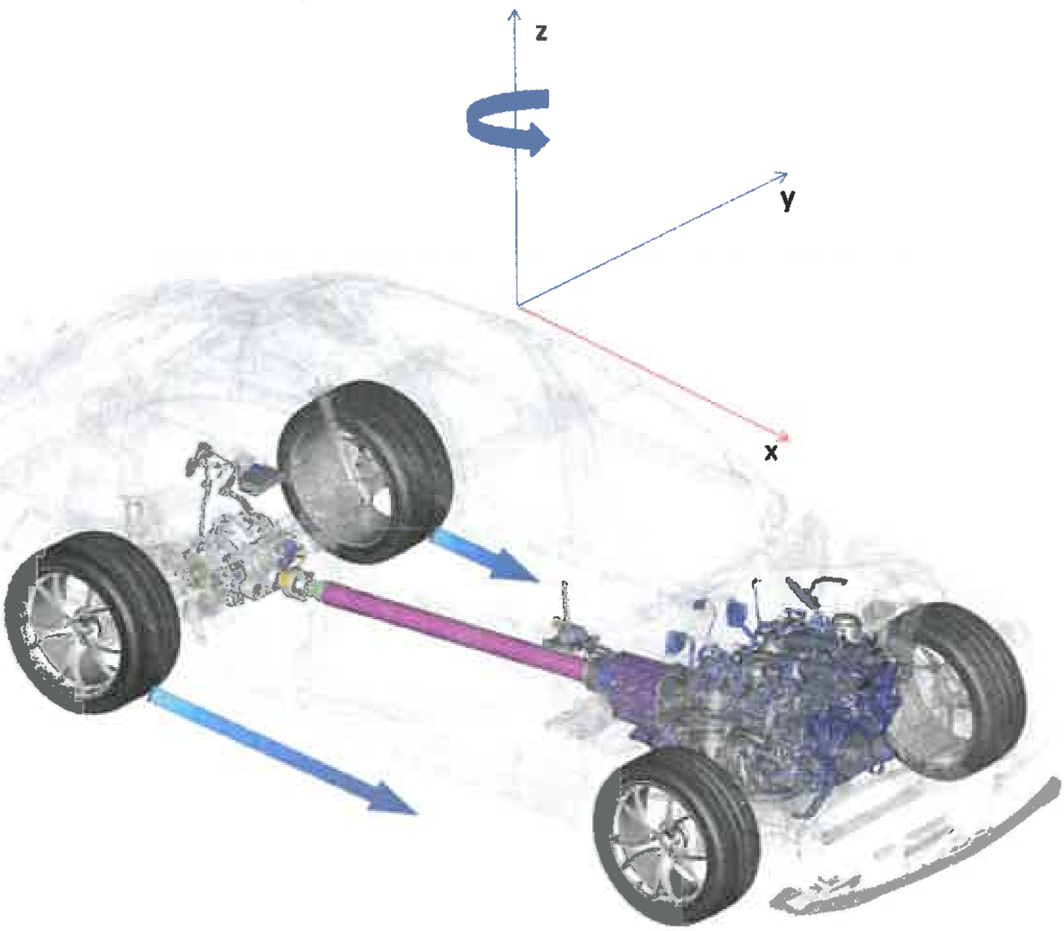
a) Improve the manoeuvrability of the vehicle incrementing the torque on the external wheel on entering a curve.
b) Increment the safety of the vehicle. For example. if the vehicle slips outwardly during the travel on a curve, the TV is able to increase the torque of the inside wheel.
c) To provide more traction in function of the friction coefficient μ, wheel-ground.

a) b) c)



The CDCM module continually monitors the "actual" dynamic state of the vehicle with the "desired" dynamic state and intervenes to minimize the deviation existing between the two states.

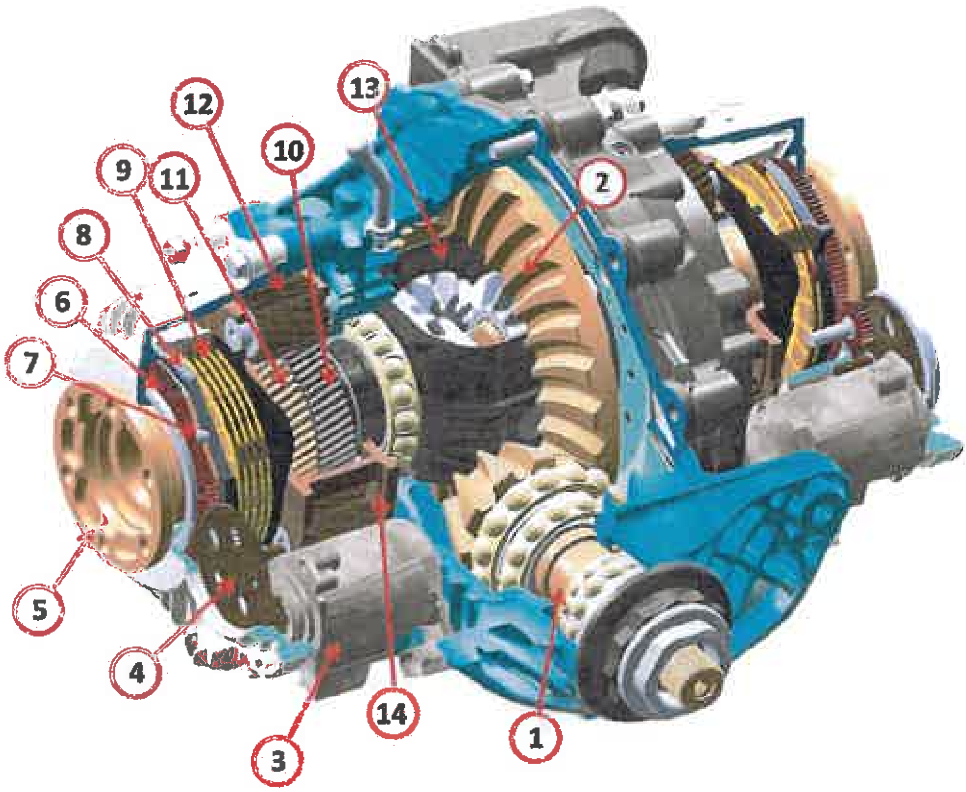
The reduction in deviation takes place through the generation of a "corrective" yaw moment that is calculated by the CDCM module on the basis of the difference between the "actual" and the "desired" state of the level of yawing of the vehicle. The CDCM module effectuates the calculation on the basis of information coming from three accelerometers present within it. The three accelerometers provide the values of acceleration, longitudinal (y) lateral (x), and yawing (z) in function of which it is able to estimate the level of the pitching and of rolling of the vehicle.




The yaw "corrective" moment is generated from a different distribution of torque between the rear wheels that the CDCM module requests of the TVM control module of the Torque Vectoring.

**NOTE:** Refer to the chapter relating to the rear differential full discussion of the manner in which the Torque Vectoring differential is able to achieve the requested torque distribution.

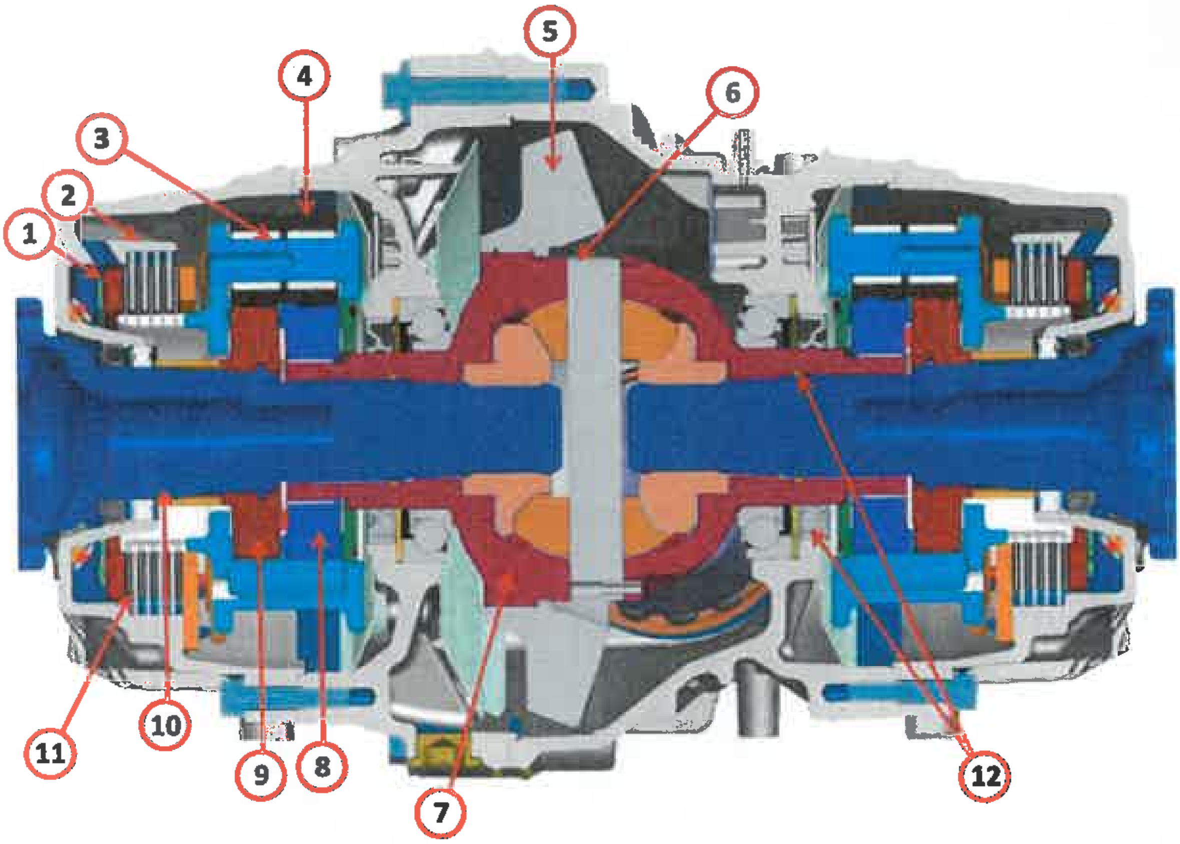
### Torque Vectoring differential composition




Key

1 - Pinion
2 - Crown wheel
3 - Electric motor
4 - Reduction gear
5 - Drive shaft joint
6 - Thrust ring (input)
7 - Ball
8 - Thrust ring (output)
9 - Clutch pack
10 - Differential casing sun gear
11 - Drive shaft sun gear
12 - Planet gears (epicyclic unit)
13 - Differential casing (open type differential)
14 - Satellite carrier (epicyclic unit)

Rear view of the differential in section




1 - Thrust rings and ball unit
2 - Fixing element to the clutch disc casing
3 - Satellite carrier
4 - Planet gears
5 - Crown wheel
6 - Satellite carrier shaft of open differential
7 - Differential casing
8 - Differential casing sun gear
9 - Drive shaft sun gear
10 - Drive shaft
11 - Clutch discs coupled to the satellite carrier
12 - Gaskets

Below, the components used to implement the Torque Vectoring strategies are shown

**Electric motors**

There are two electric motors: their function is to activate their respective clutch group when the TVM Torque Vectoring management module requests it.


Key

1 - Power connector

2 - Position sensor connector

Technical specifications

- Asynchronous electric motor
- Brushless
- High Resolution Digital Position Sensor

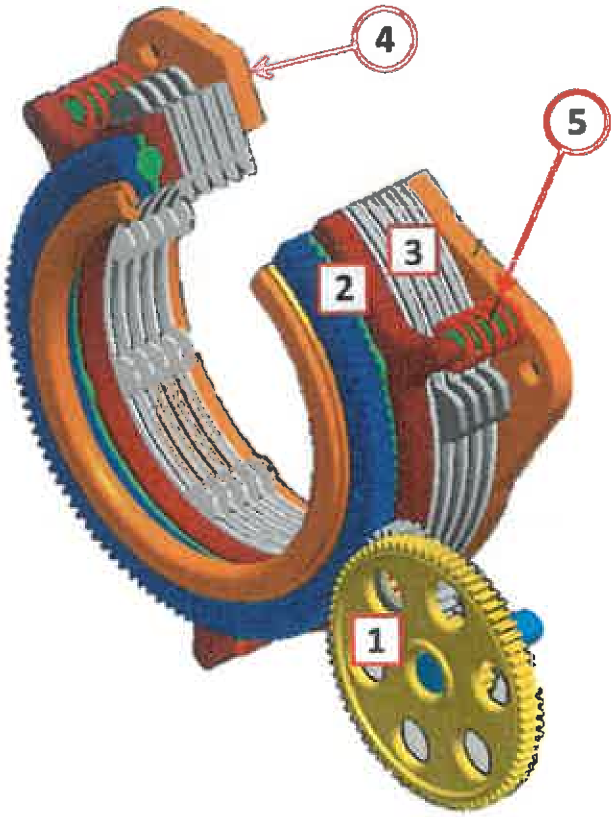
Position sensor connector

| Pin | Function |
|---|---|
| 3 | Position sensor earth |
| 4 | Position sensor power supply |
| 5 | Position sensor signal |

Power connector

| Pin | Function |
|---|---|
| 1 | Small motor 1 power supply |
| 2 | Small motor 2 power supply |
| 3 | Small motor 3 power supply |
| 4 | Small motor temperature sensor power supply |
| 5 | Small motor temperature sensor earth |

## Clutch assembly



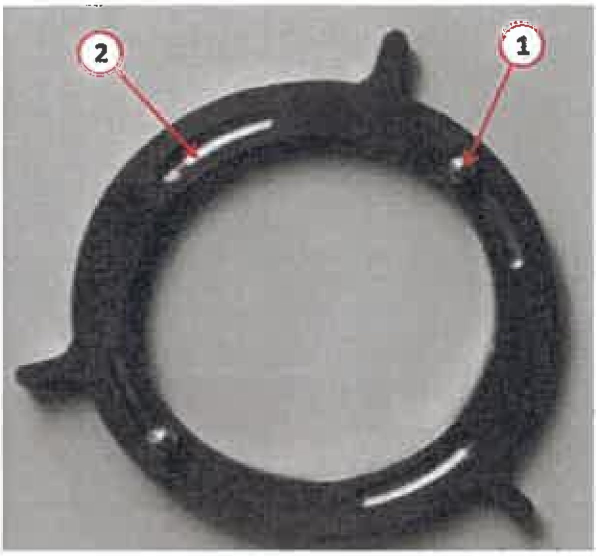

Key

1 - Reduction gear
2 - Thrust ring (input)
3 - Clutch discs
4 - Clutch support unit
5 - Reaction spring

The clutch unit consists of a support, the friction rings, two thrust rings, steel balls and a series of reaction springs in order to open the clutch when the small electric motor is not driven.

The function of the clutch unit is to slow down the satellite carrier.

## Reaction ramp on the thrust rings




Key

1 - Ball

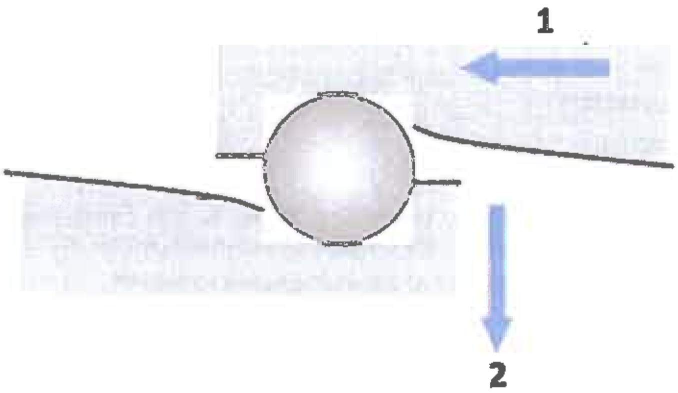
2 - Ramp

Among the thrust rings, there are balls that run within specific ramps formed on the thrust rings.

The actuation of the small electric motor by the TVM module causes the rotation of the thrust ring in input. The thrust ring in output is tied to the clutch support; it cannot rotate.

The balls sliding along the ramps, transform the rotary movement of the input ring into an axial movement of the output ring.

The axial movement of the output ring squeezes the clutch pack.

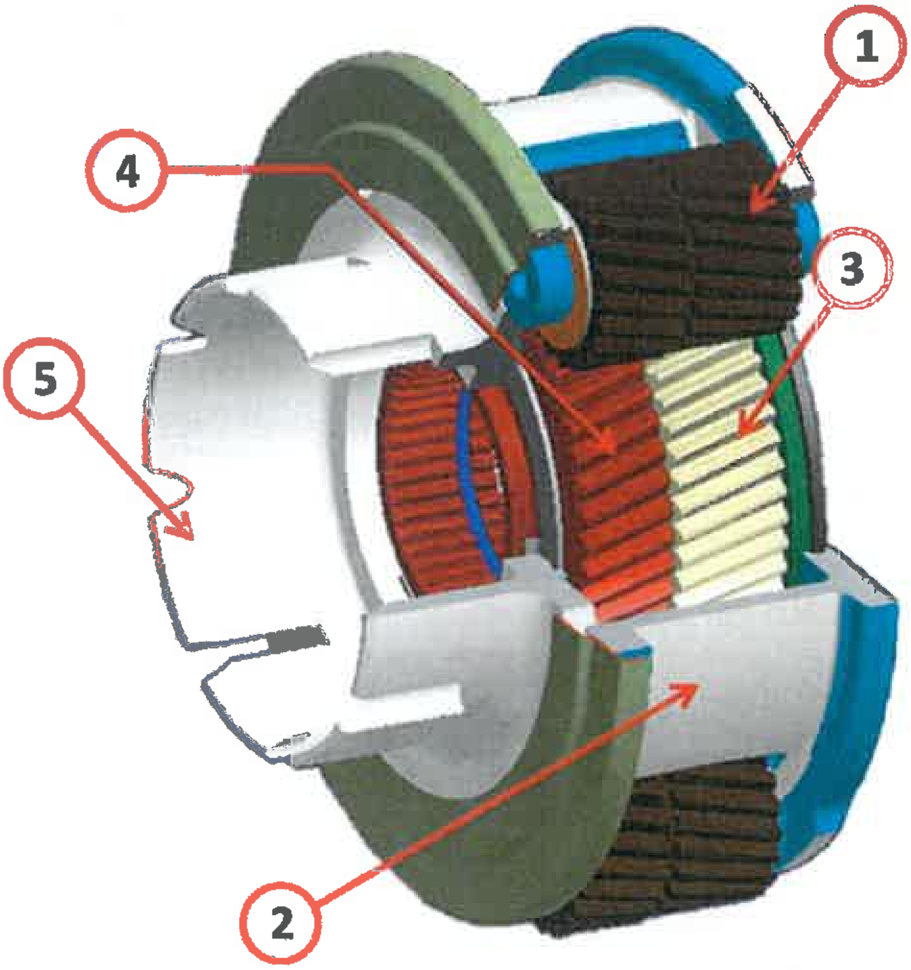



Key:

1 - Rotation input ring

2 - Shifting output ring

## Epicyclic gear set

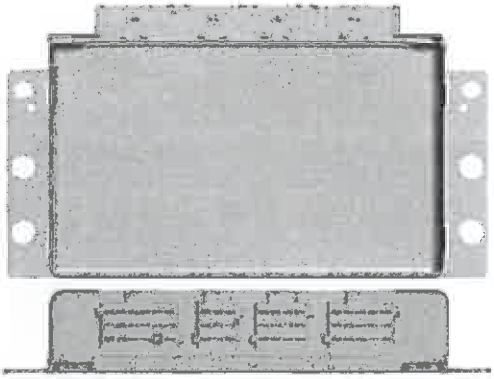



Key

1 - Planet gears
2 - Satellite carrier
3 - Differential casing sun gear
4 - Drive shaft sun gear
5 - Joint

The two sun gears do not have the same number of teeth and the transmission ratio is around 0.9. The planet gears are constructed as one piece and are in contact with the teeth of both sun gears. The satellite carrier is joined to the clutch discs by means of a joint.

## TVM Torque Vectoring Module



The operational strategies of Torque Vectoring are controlled and managed by the TVM module.

The TVM module receives over the CAN line:

- From the CDCM module, the request for torque distribution
- From the ABS module, it receives information on lateral acceleration data, the activation status of the ESC/ASR function and wheel rpm.
- From the EPS, the steering wheel angle
- From the ECM module, information on the accelerator pedal position and engine rpm.
- From the BCM module, the ignition status

The TVM module transmits via the CAN line:

- To the CDCM module, the status of the small electric motors and confirmation of torque distribution.
- Data on its own operational status and torque implemented.

The TVM module receives information directly from the:

- Small electric motor temperature sensors.
- Clutch oil temperature sensors
- Small electric motor position sensors

The TVM module sends activation commands directly:

- To the two small electric motors.

***Remarks***

If the ABS module should require the ASR function, the TVM module freezes the request for torque split, coming from the CDCM module, to implement the strategies for the ASR function.

**TVM Initialization procedure**

For each Key On, the TVM needs to know the reference point of the small electric motors (the "zero"). For each Key On, the TVM commands, at the same instant, the small electric motors and controls the implementation time of the demand for current and the signals from the position sensors.

**Estimate of clutch wear**

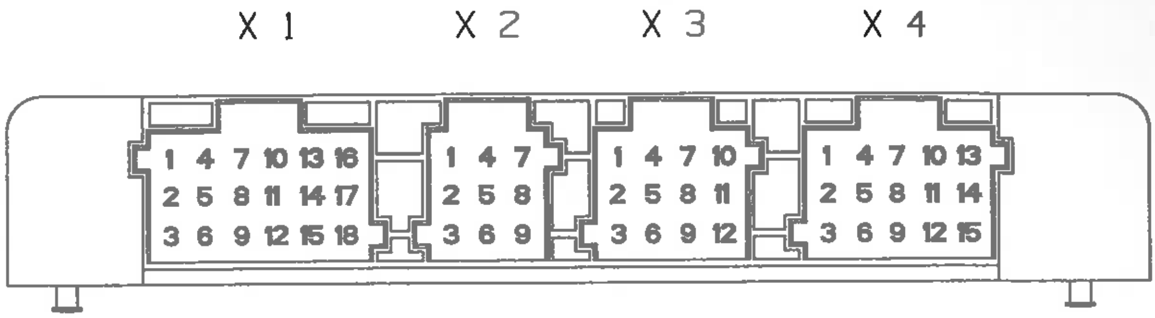
In order to properly command the clutch packs in the most correct manner, the TVM needs to know their wear. To know the wear of clutches, it commands the small electric motors to open and close the clutches. The current drawn by the small electric motors can reach peak currents of approximately 20A.

The process of ascertaining clutch wear takes about 45 seconds.

When the status of ignition and of the motor pass: from "ON" to "OFF" and the values of temperature and battery voltage allow it, the TVM starts the clutch wear estimation procedure and then turns Off.

The first 1,000 adaptations occur after the first switch-off, after which it will carry it out only after the second shutdown.

**TVM Pinout**

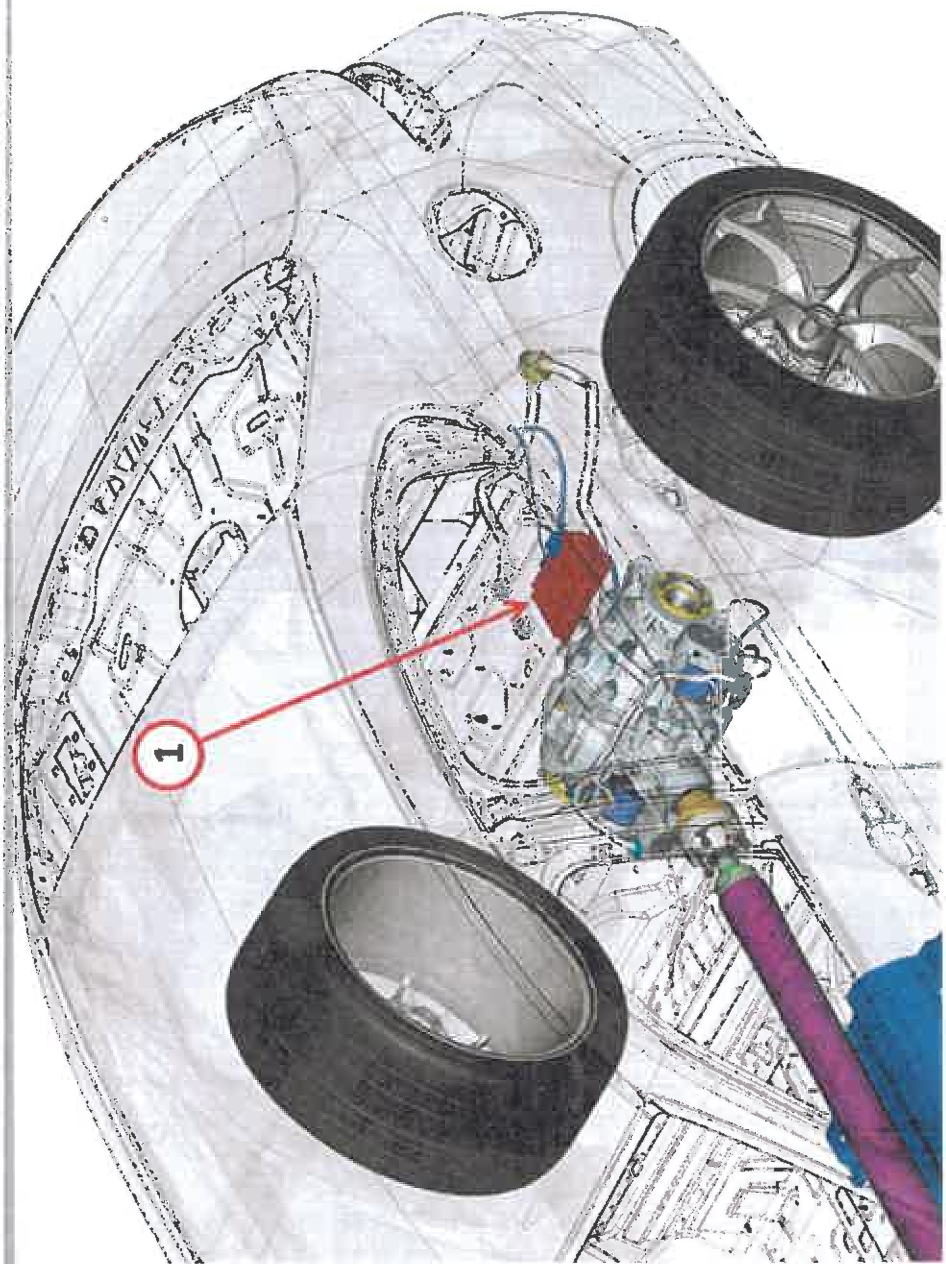



| Connector X1 | |
|---|---|
| **Pin** | **Function** |
| 1 | Small motor 1 power supply |
| 2 | Small motor 2 power supply |
| 3 | Small motor 3 power supply |
| 7 | Left temperature sensor power supply |
| 8 | Left temperature sensor earth |
| 9 | Shielding |
| 10 | Small motor temperature sensor power supply |
| 11 | Small motor temperature sensor earth |
| 16 | Position sensor power supply |
| 17 | Position sensor signal |
| 18 | Position sensor earth |

| Connector X3 | |
|---|---|
| **Pin** | **Function** |
| 2 | C-CAN2 H |
| 3 | C-CAN2 L |
| 7 | Earth |
| 9 | +30 electronic |
| 10 | +30 power |
| 12 | +15 |

| Connector X4 | |
|---|---|
| **Pin** | **Function** |
| 1 | Position sensor power supply |
| 2 | Position sensor signal |
| 3 | Position sensor earth |
| 4 | Small motor temperature sensor power supply |
| 5 | Small motor temperature sensor earth |
| 7 | Right temperature sensor power supply |
| 8 | Right temperature sensor earth |
| 9 | Shielding |
| 13 | Small motor 1 power supply |
| 14 | Small motor 2 power supply |
| 15 | Small motor 3 power supply |

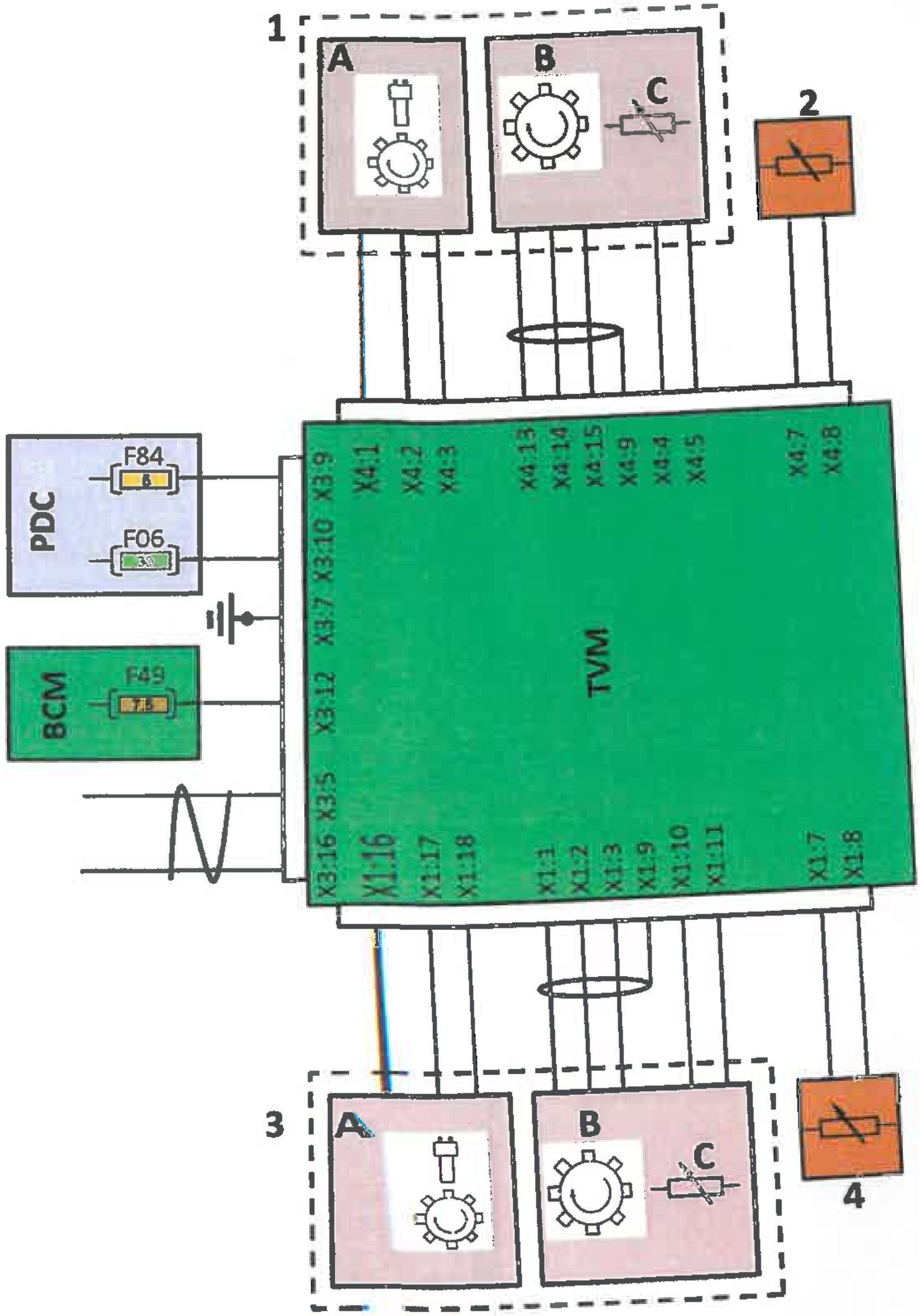
## Location of TVM module




Key

1 - TVM module

## Torque Vectoring wiring diagram




Key
1 – Right side electric actuator assembly.
2 – Right temperature sensor
3 – Left side electric actuator assembly
4 – Left temperature sensor.
A – Position sensor.
B – Electric motor
C – Temperature sensor.

### Torque Vectoring Operation

The operational principle of the Torque Vectoring system is based on the ability of the latter to divide in a differentiated way the total torque available on one wheel or the another.

In order to achieve this result, the Torque Vectoring differential uses two sprockets installed (per side): one on the drive shaft and the other on the differential casing. These two sprockets are the sun gears of the epicyclic gear set.

Meshing with the teeth of both sun gears, are the planet gears. The latter are inserted in the satellite carrier.

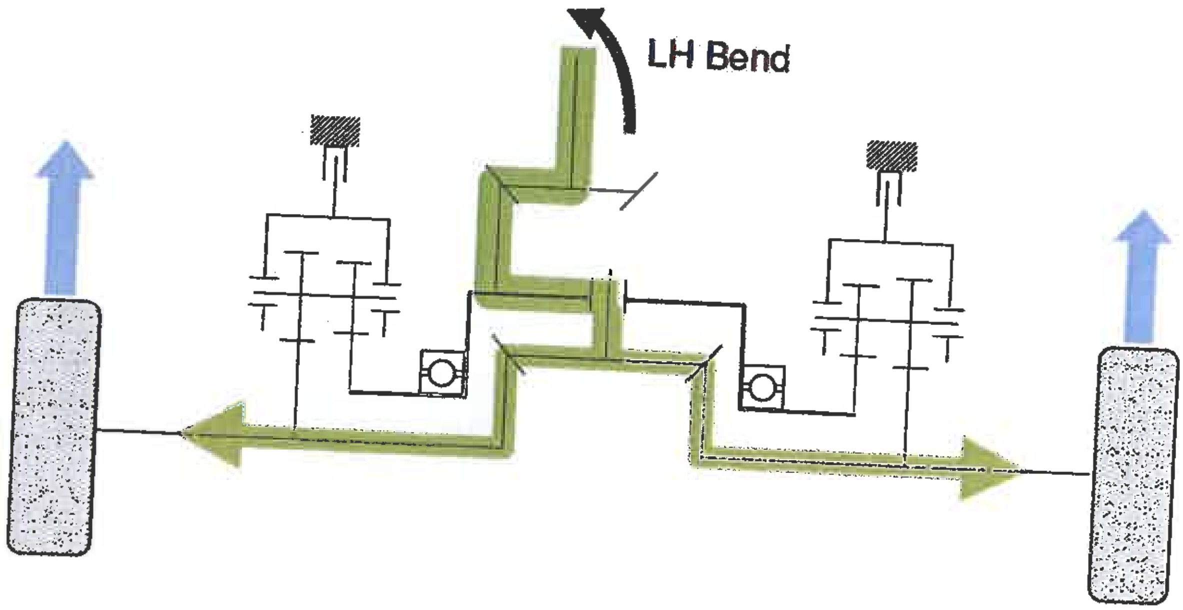
The satellite carriers on one side have a joint that serves to engage with the clutch discs.

The discs of two clutch packs, one for each satellite carrier, engage partly with the joint of the satellite carrier and partly with the support of the clutch fixed to the casing outside the differential.

For each clutch unit there is a small electric motor. The purpose of the small electric motor is to activate the clutches so as to slow down the satellite carrier to create a resisting torque.

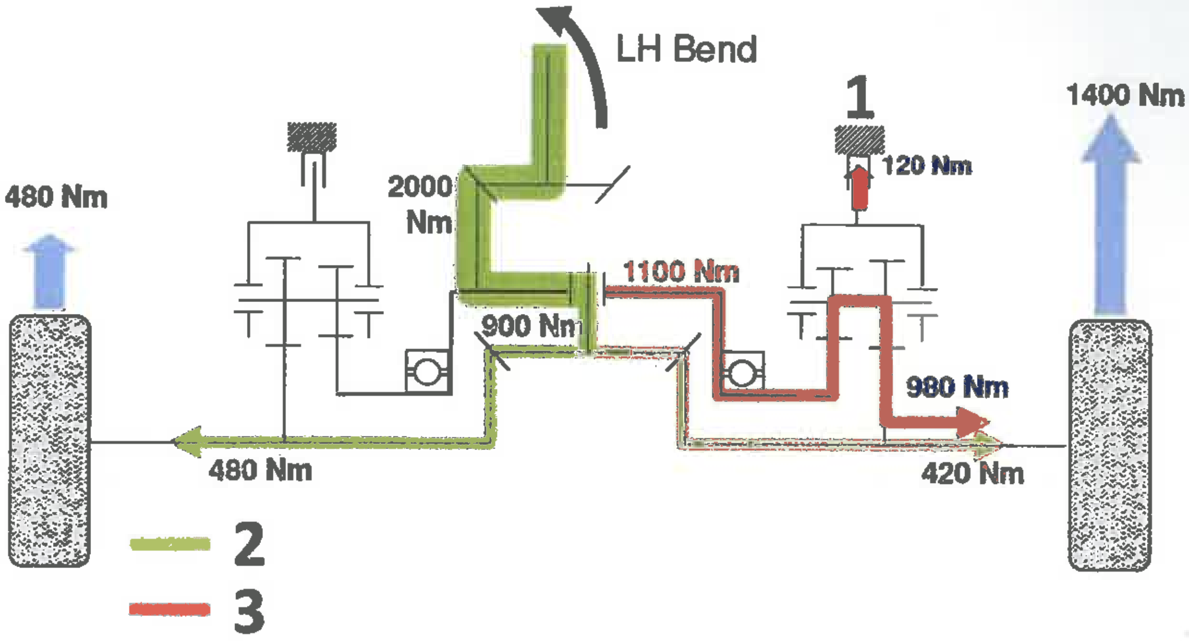
Below, are examples of operation of the Torque Vectoring differential:

**Flow of torque without activation of the small electric motors**




In green, the flow of torque during a left turn is shown. The torque is split in equal measure by the open differential of the torque vectoring.

**Flow of torque with activation of the right hand actuator**




1 - Activation of the right hand actuator
2 - Flow of torque through the differential
3 - Flow of torque through the satellite carrier and planet gears

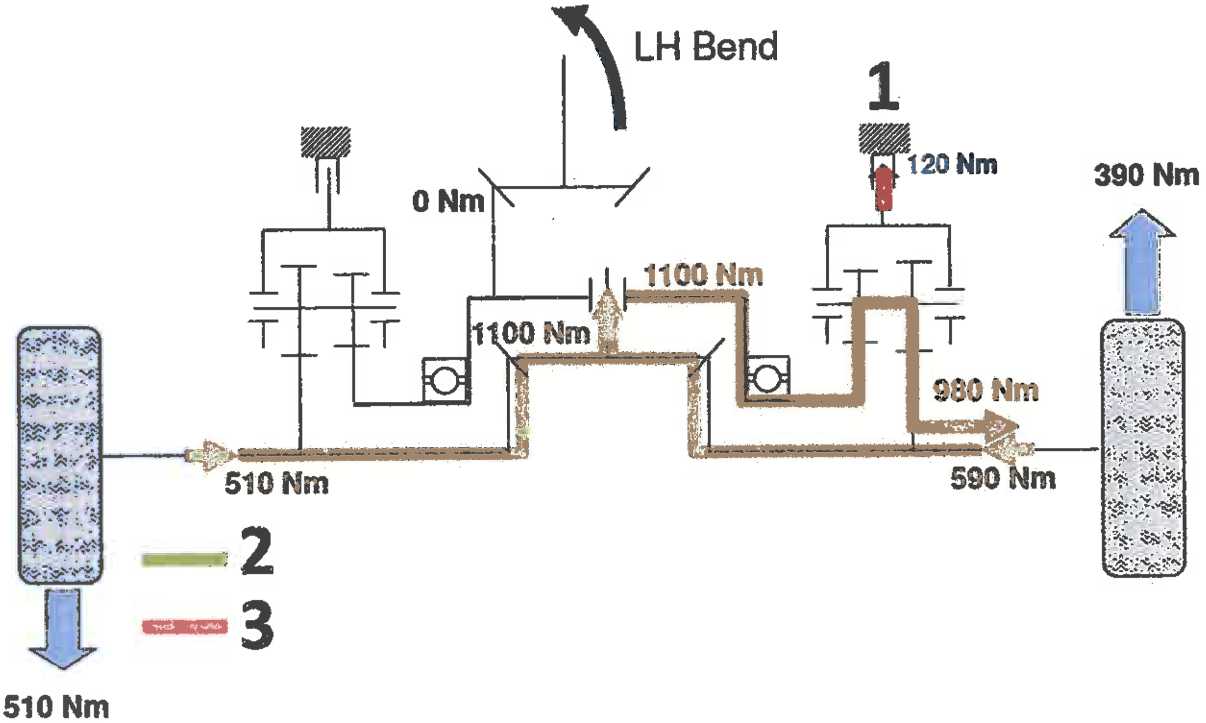
The Torque Vectoring differential can improve the input/output of curve by acting on the small electric motor external to the direction of the curve.

The above example illustrates the operation of torque vectoring during a curve (left) and with the presence of the motor torque at input to the differential.

The TVM module, in order to improve entry into a curve, activates the right hand small electric motor in order to create a resisting torque to slow the satellite carrier by means of the clutch discs.

The slowing of the satellite carrier, in part, draws torque from the differential casing which, by means of the planet gears, arrives at the drive shaft thus acting to unbalance the torque that arrives at the wheels.

**Flow of torque without application of the torque motor and activation of the right hand actuator**

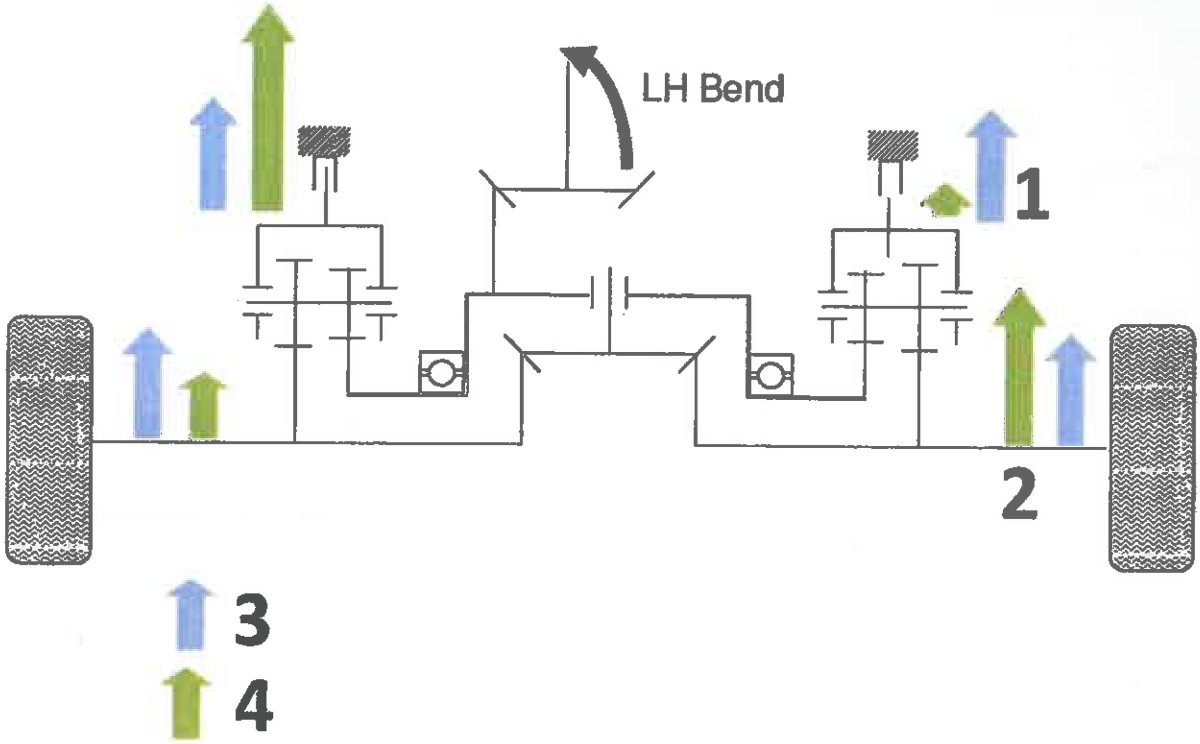



1 - Activation of the right hand actuator
2 - Flow of torque through the differential
3 - Flow of torque through the satellite carrier and planet gears

The above example illustrates the operation of the Torque Vectoring during a curve (left) and with the absence of the torque at input to the differential.

The TVM module activates the small electric motor external to the direction of the curve to create a resistant torque. The torque that arrives at the differential casing is generated by the movement of the wheels in contact with the ground surface and not from the motor; consequently the torque that arrives at the differential casing is partly absorbed by the slowdown of the satellite carrier and by means of planet gear input to the drive shaft. The result is that on the two wheels there is an unbalance of torque that acts to improve the input/output of the curve.

**Comparison between rotation speeds**



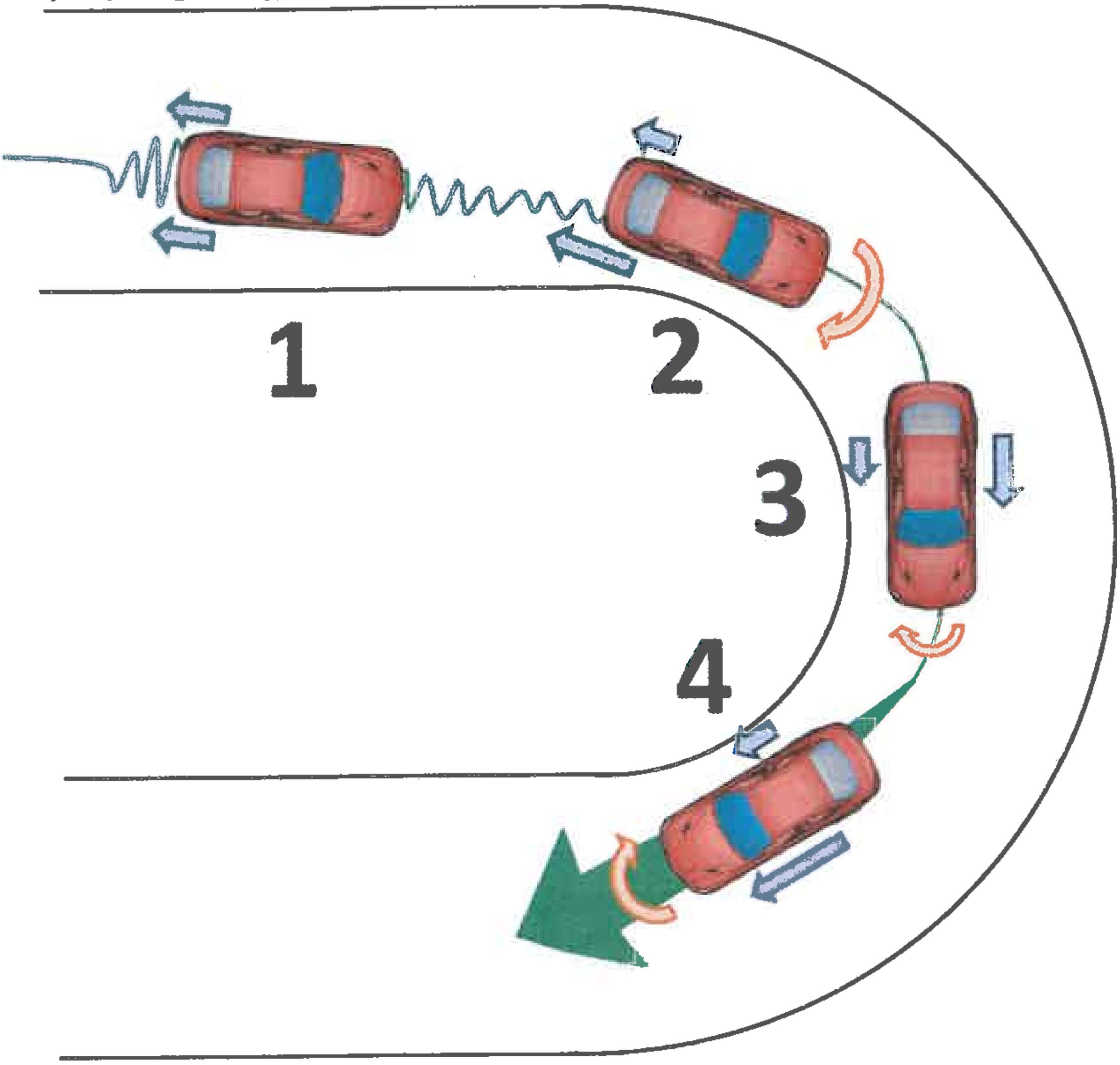

Key:

1 - Speed satellite carrier
2 - Wheel rpm
3 - Straight run
4 - Driving on curve (left)

The above example shows the trend of the wheels' rpm and of the satellite carrier while travelling in a straight line or in a curve (left) in the torque vectoring differential.

When driving straight ahead, the epicyclic gear set rotates as a single assembly.

## Torque splitting strategy of Torque Vectoring




Key:

1 – Upon entering a curve, without torque delivered by the motor, a negative torque of equal intensity is applied to both drive wheels to stabilize deceleration.

2 – As the driver turns the steering wheel to arrive at the apex, a negative torque is smoothly transferred to the internal drive wheel to help the car turn.

3 – During the rotation of the steering wheel, next to the apex, as soon as the engine restores torque, more torque is transferred to the outside driving wheel of the curve to increase stability.

4 – With the increase in power, more torque is transferred to the external driving wheel to speed up the exit of the car from the curve.