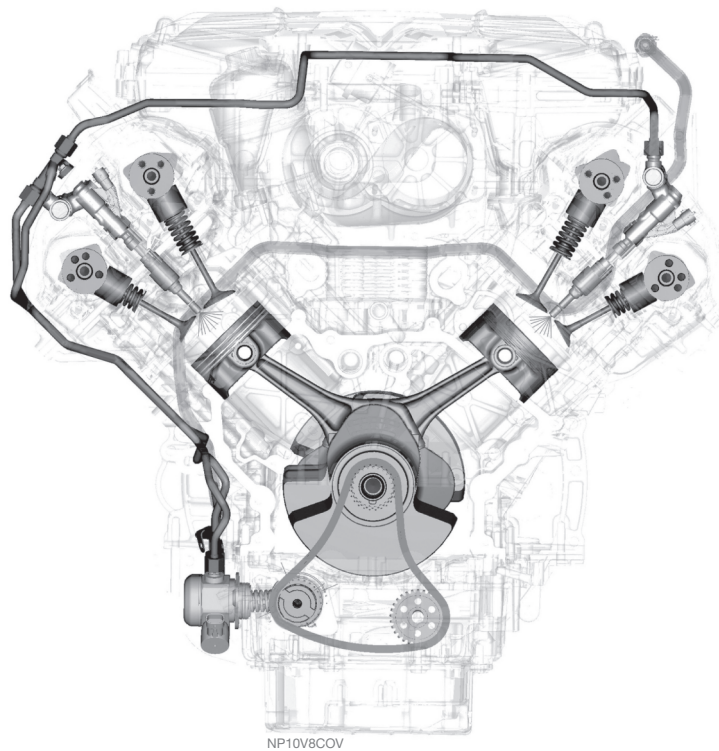


Technical Training
Technical Introduction

NP10-V8JLR: AJ133 5.0-Liter DFI V8 Engine



NP10V8COV



NP10-V8JLR 04/2009
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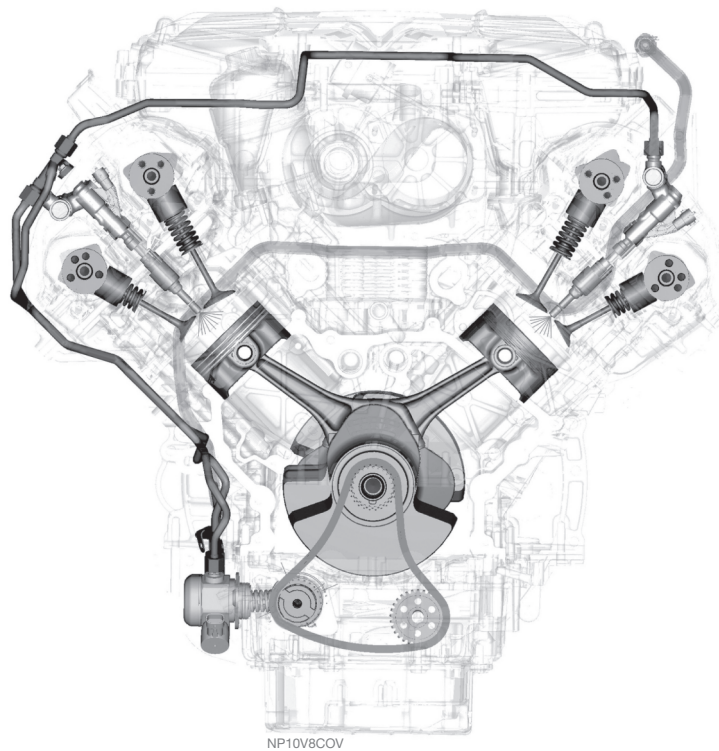
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Technical Training
Technical Introduction

NP10-V8JLR: AJ133 5.0-Liter DFI V8 Engine



General Information



NP10-V8JLR 04/2009
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ONLINE COURSE EVALUATION

Class participants are encouraged to fill out an on-line evaluation for this course.

The Jaguar evaluation is available at the following web link:

<http://www.fordtechservice.dealerconnection.com/vdirs/training/classsurvey/jagsurvey.asp>

The Land Rover evaluation is available at:

<http://www.fordtechservice.dealerconnection.com/vdirs/training/classsurvey/landrover/survey.asp>

The information provided in the evaluations is kept confidential and will only be used to improve Jaguar / Land Rover training activities. Your prompt response will be appreciated.

Your feedback is extremely important to us!

TRAINING COURSE CONTENT AND OBJECTIVES**Course Content**

1. General Information
 - Overview
 - Jaguar and Land Rover Variants
 - Special Tools
 - Features and Benefits
2. Engine Components and Systems
3. Engine Management

Course Objectives

At the end of this course technicians will be able to:

- Identify and describe the main components of the AJ133 engine
- Carry out service repairs in line with Jaguar / Land Rover Policy
- Correctly use special tools
- Understand operating principles of the engine systems:
 - Lubrication System
 - Torque-actuated Variable Camshaft Timing (VCT)
 - Camshaft Profile Switching (CPS)
 - Air Intake System
 - Fuel System

ACRONYMS, ABBREVIATIONS AND SYMBOLS

The following acronyms, abbreviations and symbols are used in this course book. The majority of them conform to J1930 standards.

Acronym, Abbreviation or Symbol	Definition or Description
A/C	Air Conditioning
AAT	Ambient Air Temperature (sensor)
APP	Accelerator Pedal Position (sensor)
ATDC	After Top Dead Center
BTDC	Before Top Dead Center
CJB	Central Junction Box
CKP	Crankshaft Position (sensor)
CMP	Camshaft Position (sensor)
COP	Coil-On-Plug
CPS	Camshaft Profile Switching
DC	Direct Current
DFI	Direct Fuel Injection
DMTL	Diagnostic Monitoring of Tank Leakage
DTC	Diagnostic Trouble Code
ECM	Engine Control Module
ECT	Engine Coolant Temperature (sensor)
EEC	European Economic Community
EJB	Engine Junction Box
EMS	Engine Management System
EVAP	Evaporative Emission
FEAD	Front End Accessory Drive
FPDM	Fuel Pump Driver Module
HO2S	Heated Oxygen Sensor
IAT	Intake Air Temperature (sensor)
IDS	Integrated Diagnostic System

Acronym, Abbreviation or Symbol	Definition or Description
LH	Left Hand
MAF	Mass Air Flow (sensor)
MAP	Manifold Absolute Pressure (sensor)
MIL	Malfunction Indicator Light
MRE	Magneto-Resistive Element
NTC	Negative Temperature Coefficient
NVH	Noise, Vibration, and Harshness
OBD	On-Board Diagnostics
PCV	Positive Crankcase Ventilation
PVD	Physical Vapor Deposition
PWM	Pulse-Width Modulated
RFI	Radio Frequency Interference
RH	Right Hand
SC	Supercharged
SG	Spheroidal Graphite
TCM	Transmission Control Module
TMAP	Temperature and Manifold Absolute Pressure (sensor)
TP	Throttle Position (sensor)
UHEGO	Universal Heated Exhaust Gas Oxygen (sensor)
ULEV	Ultra Low-Emissions Vehicle
VCT	Variable Camshaft Timing
VIS	Variable Intake System
WERS	Worldwide Engineering Release System
WOT	Wide-Open Throttle

OVERVIEW

The all new AJ133 V8 engine is a 5.0-liter all-aluminum unit, featuring four overhead camshafts and four valves per cylinder and is available in both Normally Aspirated (NA) and Supercharged (SC) variants. Both utilize state-of-the-art 'torque-based' engine management system (EMS), 'drive-by-wire' throttle control and an industry first, camshaft torque-actuated dual independent variable camshaft timing system – achieving optimum power, efficiency, and emissions.

JLR's first application of Direct Fuel Injection (DFI) and Camshaft Profile Switching (CPS) (NA only), coupled with a variable intake manifold system (NA only) and a supercharger produce a major improvement in the torque curve across the speed range.

The supercharger is a high-helix positive-displacement supercharger, driven from the crankshaft, with the ability to produce large amounts of boost while spinning at very low speeds. This makes the majority of the engine's torque available from 2000rpm to maximum engine speed, giving an instant linear response.

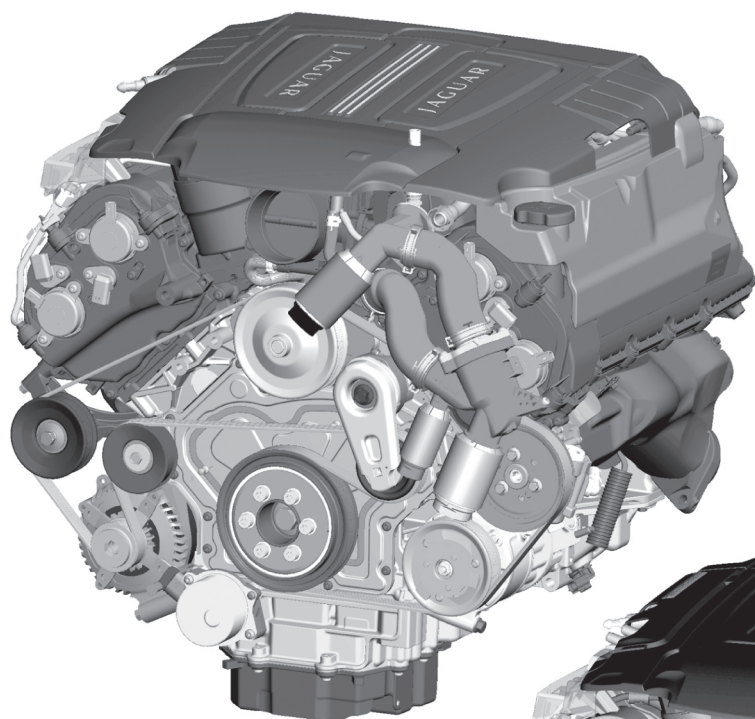
The efficiency of the new engine ensures that emissions are among the leaders in its class, achieving EU5 and ULEV2 standards.

Historically, motor manufacturers have focused on reducing the level of engine acoustics within the cabin. Development engineers have deliberately accentuated the acoustic feedback into the cabin in an effort to further increase the driving experience. An integral part of this development, and a first for JLR, is the introduction of a symposer into the engine air intake system of the SC engine. The symposer accentuates V8 engine acoustics and then feeds them into the cabin.

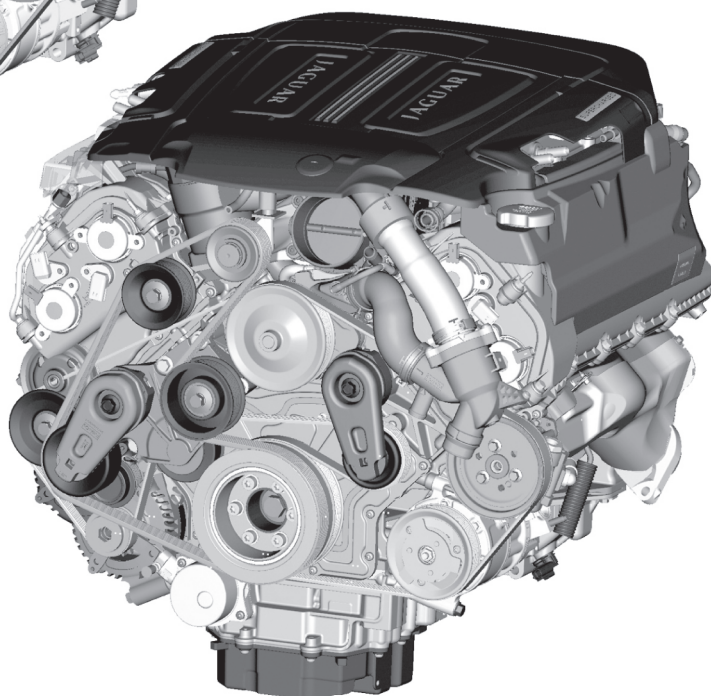
The new 5.0-liter V8 engines are produced at Bridgend, UK, and are unique to Jaguar and Land Rover.

The all new Castrol SLX A1 5W-20 is a dedicated engine oil that has been co-engineered with JLR specifically for the 5.0-liter V8 engine.

JAGUAR VARIANTS



NORMALLY ASPIRATED



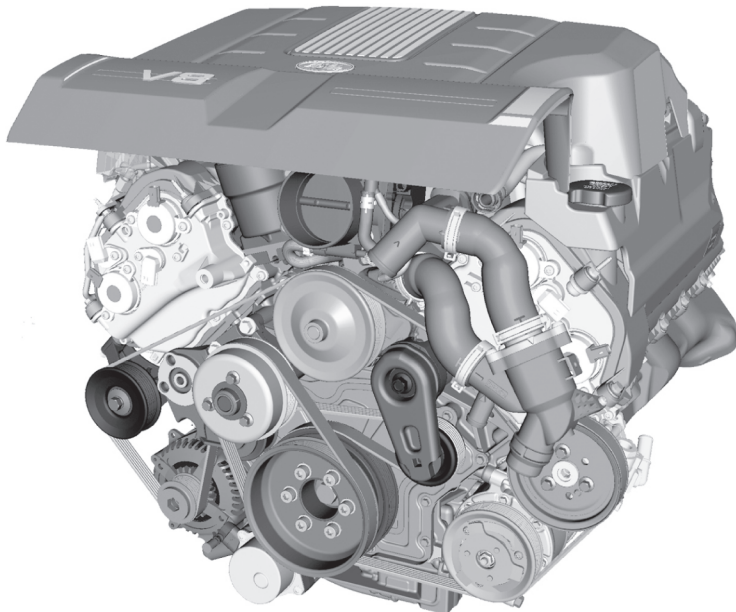
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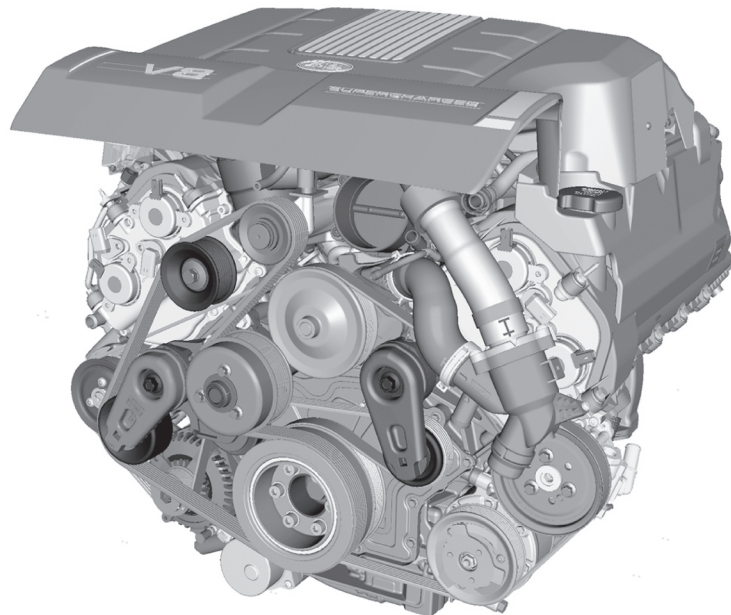
Technical Data

Specification	XK (X150)		XF (X250)	
	NA	SC	NA	SC
Capacity (liters)	5.0	5.0	5.0	5.0
Compression ratio	11.5 : 1	9.5 : 1	11.5 : 1	9.5 : 1
Bore/stroke (mm)	92.5/93.0	92.5/93.0	92.5/93.0	92.5/93.0
Power (kW)	283	375	283	375
Power (SAE bhp)	385	510	385	510
Torque (Nm)	515	625	515	625
Torque (SAE lb-ft)	380	461	380	461
0 – 60 mph (sec)	5.2	4.6	5.4	4.7
0 – 100 km/h (sec)	5.5	4.8	5.7	4.9
Service Intervals (miles/months)	15,000/12	15,000/12	15,000/12	15,000/12
Emissions rating	EU5/ULEV2	EU5/ULEV2	EU5/ULEV2	EU5/ULEV2
Oil capacity (service fill with filter change) (liters/quarts)	7.25/7.7	7.25/7.7	7.25/7.7	7.25/7.7

LAND ROVER VARIANTS



NORMALLY ASPIRATED



SUPERCHARGED

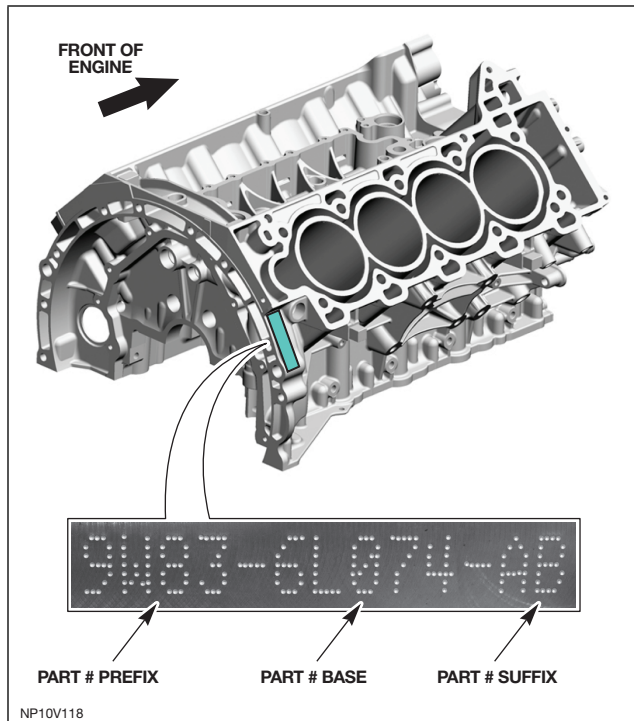
NP10V8002

Technical Data

Specification	LR3	Range Rover Sport		Range Rover	
	NA	NA	SC	NA	SC
Capacity (liters)	5.0	5.0	5.0	5.0	5.0
Compression ratio	11.5 : 1	11.5 : 1	9.5 : 1	11.5 : 1	9.5 : 1
Bore/stroke (mm)	92.5/93.0	92.5/93.0	92.5/93.0	92.5/93.0	92.5/93.0
Power (kW)	276	276	375	276	375
Power (SAE bhp)	375	375	510	375	510
Torque (Nm)	510	510	625	510	625
Torque (SAE lb-ft)	375	375	461	375	461
0 – 60 mph (sec)	7.2	7.2	5.9	7.2	5.9
0 – 100 km/h (sec)	7.6	7.6	6.2	7.6	6.2
Service Intervals (miles/months)	15,000/12	15,000/12	15,000/12	15,000/12	15,000/12
Emissions rating	EU5/ULEV2	EU5/ULEV2	EU5/ULEV2	EU5/ULEV2	EU5/ULEV2
Oil capacity (service fill with filter change) (liters/quarts)	8.0/8.5	8.0/8.5	8.0/8.5	8.0/8.5	8.0/8.5

ENGINE DATA LABELS

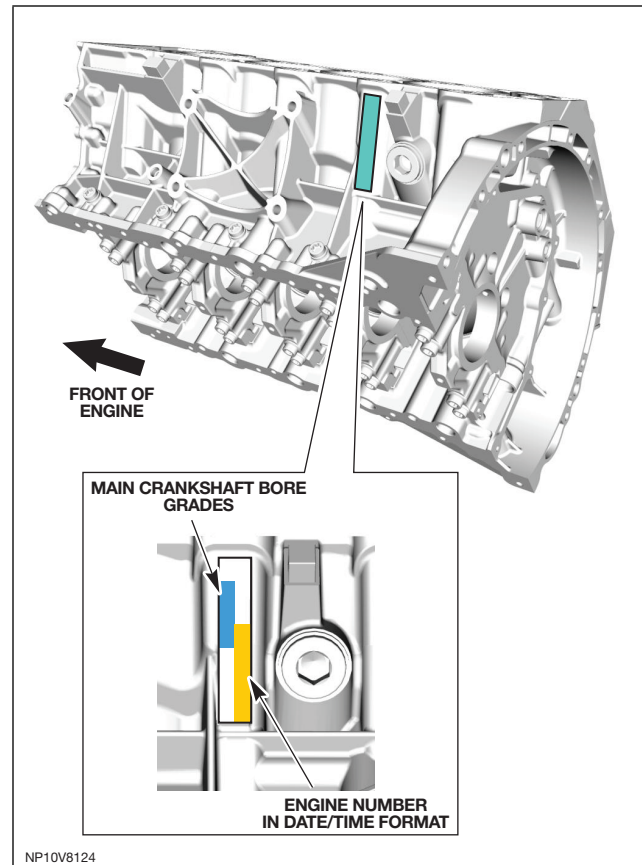
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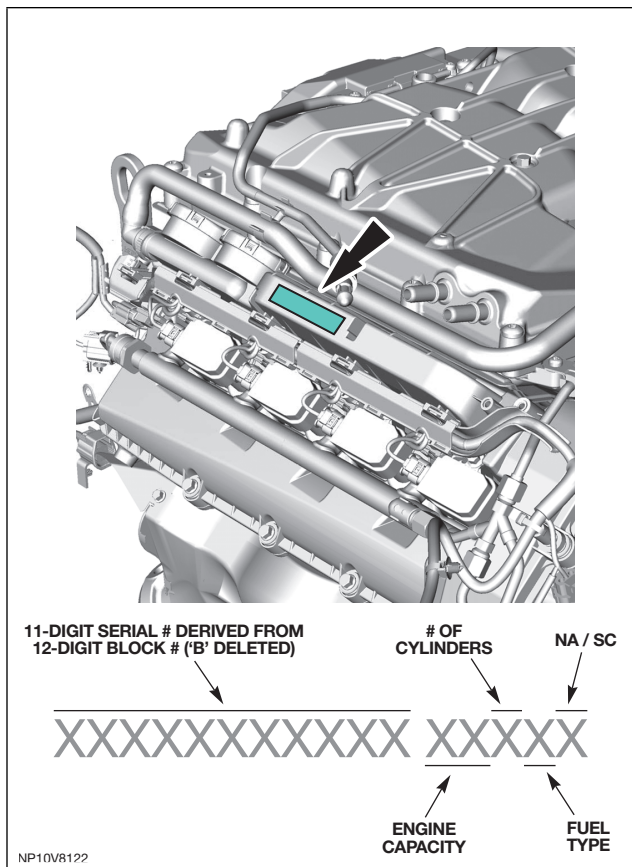
Part # Prefix:

- 8W93 = Jaguar N/A
- 9W83 = Jaguar S/C
- 9H23 = T5 NA
- 9H33 = T5 S/C
- 9H43 = L322

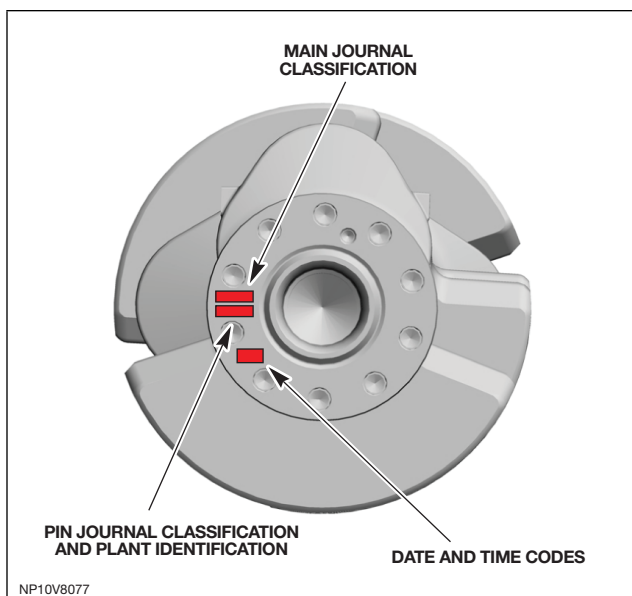
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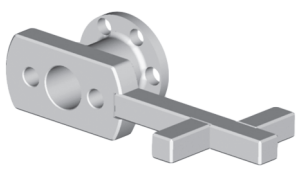
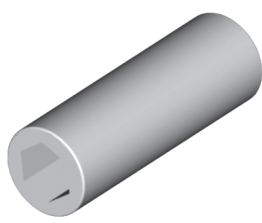
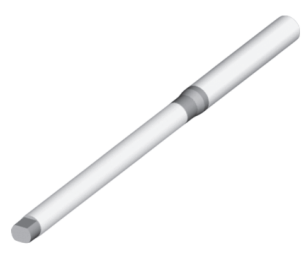
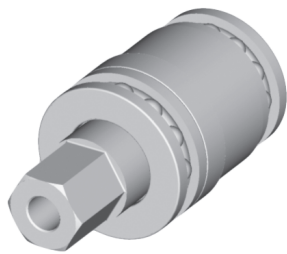
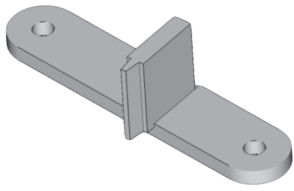
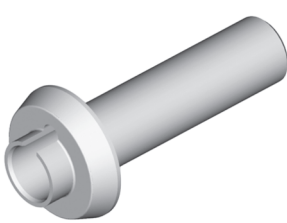
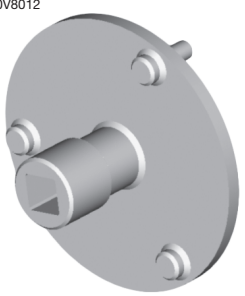
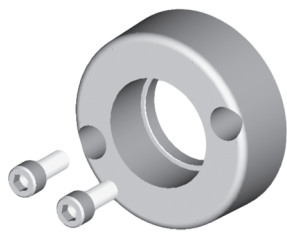
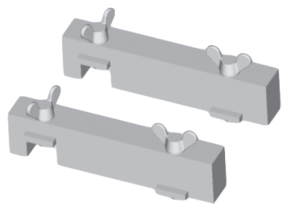
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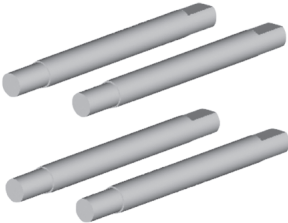
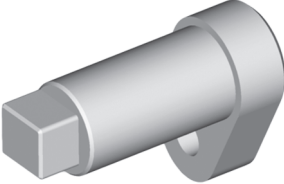
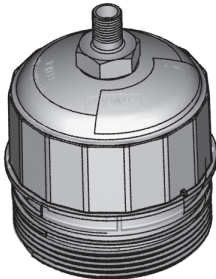
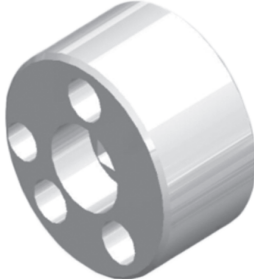


Crankshaft Identification



SPECIAL TOOLS

NP10V8003  303-1435 Engine Lifting Brackets (Rear)	NP10V8004  303-1436 Engine Lifting Brackets (Front)	NP10V8005  303-1437 Crankshaft Damper Removal / Installation Reaction Tool	NP10V8006  303-1438 Crankshaft Damper Fixing Removal / Installation Socket (long)
NP10V8007  303-1439 Crankshaft Damper Removal Plate	NP10V8008  303-1440 Crankshaft Damper Removal / Installation Center Stud	NP10V8009  303-1441 Crankshaft Damper Removal / Installation Body	NP10V8010  303-1448 Crankshaft Damper Setting Ring Gear Locking Tool
NP10V8011  303-1433 Front Crankshaft Seal Cover Aligner	NP10V8012  303-1434 Front Crankshaft Seal Remover / Installer	NP10V8013  303-1442 Rear Crankshaft Seal Guide / Splay Tool	NP10V8014  303-1443 Rear Crankshaft Seal Cover Aligner
NP10V8015  303-1444 Exhaust Manifold Installation Guide Pins	NP10V8016  303-1445 Camshaft Alignment Timing Tool	NP10V8017  303-1446 Camshaft Cover Longitudinal Alignment Tool	NP10V8017  310-197 Injector Removal Tool

NP10V8018  310-198 Injector Teflon Seal Installer Guide	NP10V8019  310-199 Injector Teflon Seal Sizing (Calibration) Tool	NP10V8020  303-1484 Engine Oil Extraction Kit	NP10V8021  303-1484-01 Engine Oil Extraction Kit Adaptor
NP10V8022  303-1449 Supercharger Installation Alignment Guide Pins	NP10V8023  303-1447 Flywheel Alignment Timing Tool	NP10V8024  310-200 Fuel Rail Installation Alignment Pins	NP10V8025  303-1450 Spark Plug Removal / Installation Socket
NP10V8026  310-121 HO2 Sensor Removal / Installation Socket	NP10V8027  303-1451 Oil Pressure Test Dummy Cap	NP10V8028  303-1452 Camshaft Rotating Tool	NP10V8125  303-1482 Timing Chain Tensioning Tool

FEATURES AND BENEFITS

Feature/Attribute	Benefit	Technologies
High Performance Output	Increased combustion efficiency	- High compression ratio: - Enabled by direct injection technology – increased charge cooling mitigates knock and allows more optimal combustion phasing
	Increased volumetric efficiency and torque throughout the speed range	- Direct fuel injection (JLR first): - Increases the charge air cooling resulting in a higher charge density
	Reduced SC parasitic load and increased volumetric efficiency	- High efficiency supercharger (JLR first): - High helix angle and new air entry/porting - Design optimized indirect charge air cooling (air to water to air – SC only): - Intercooler cools down the air heated up in the SC, which increases charge density and hence reduces SC parasitic load, but also allows more optimal combustion phasing
	Improved performance responsiveness	- Design optimized indirect charge air cooling (air to water to air – SC only): - Due to high heat capacity of cooling medium and hence temperature inertia
Flat torque curve/high low speed torque/responsiveness	Improved performance responsiveness through transients	- Central spray-guided direct injection system (JLR first): - Fuel injected directly into cylinder allows more precise fuelling control through transients
	Increased volumetric efficiency and torque throughout speed range	- Variable geometry intake manifold (NA only) (JLR first for variable geometry manifold on V8): - Two different geometries (intake tract lengths) allow volumetric efficiency to be optimized for both low to mid speeds and high speeds
	Increased torque across speed range	- High efficiency supercharger (JLR first): - Higher volumetric and thermodynamic efficiency of new design
	Good fuel mixing across the speed range	Direct injection combustion system
	Optimized low speed volumetric efficiency leading to excellent low speed torque	- Camshaft Profile Switching (CPS) (NA only): - Typically low speed performance is compromised to meet power requirements. In this case the two profiles allow both low speed and high speed performance to be optimized simultaneously – Best in Class relative torque at 1500rpm (torque at 1500rpm as % of max torque)
	Optimized volumetric efficiency and minimized pumping losses across speed range	- Dual independent variable camshaft timing (VCT) – intake and exhaust (JLR first): - Intake and exhaust camshaft timing can be independently optimized at each speed and load condition to maximize volumetric efficiency and minimize pumping work

Feature/Attribute	Benefit	Technologies
Flat torque curve/high low speed torque/responsiveness (continued)	Minimized engine pumping losses	• Dual independent VCT (JLR first): – Valve timing is optimized for every operating point of the engine to achieve the desired level of residuals and minimize pumping work • Camshaft Profile Switching (CPS) (NA only): – Increased low speed torque delivered by CPS allows the transmission to lock-up at lower speeds and higher gears to be selected which shifts the engine into a more efficient operating region • Asymmetric exhaust camshaft profile (JLR first): – Asymmetric profile enables more valve overlap area for a given piston to valve clash constraint resulting in optimized residual levels and hence reduced pumping work
Engine efficiency/ specific fuel consumption	Maximized combustion efficiency	• Optimized charge motion in combustion chamber via intake port design: – Optimized charge motion to ensure balance between optimum air-fuel mixing and minimum pumping losses for good volumetric efficiency
	Reduced parasitic losses	• High efficiency supercharger (JLR first): – SC parasitic losses significantly lower than on outgoing engines
	Minimized SC parasitic load at part throttle conditions	• Increased SC bypass valve size: – Increased by-pass valve size results in reduced pressure drop and hence reduced SC pumping work
	Maximized combustion efficiency	• Central spray-guided direct injection system with multi-hole injectors (JLR first): – Central injector position coupled with optimized design of fuel sprays results in minimized deposition of fuel on combustion chamber and piston leading to low emissions levels and high combustion efficiency • High compression ratio: – Higher compression ratio enabled by direct injection technology – increased charge cooling mitigates knock and allows more optimal combustion phasing
	Reduced engine friction – particularly at lower oil temperatures	• Lower oil viscosity specification (5W20 vs. 5W30) (JLR first)
	Maximized oil pump efficiency	• Smart oil pump pressure relief valve (JLR first): – Oil pressure controlled to oil gallery rather than pump outlet pressure • Camshaft torque actuated VCT (Industry first): – Uses energy from positive and negative cam torques to change cam timing rather than oil pressure – hence much lower oil demand required leading to optimized oil pump sizing
	Minimized piston and fuel pump parasitic losses	• Low friction coatings (diamond-like carbon coating on fuel pump tappets, solid film lubricant coating on piston skirt)

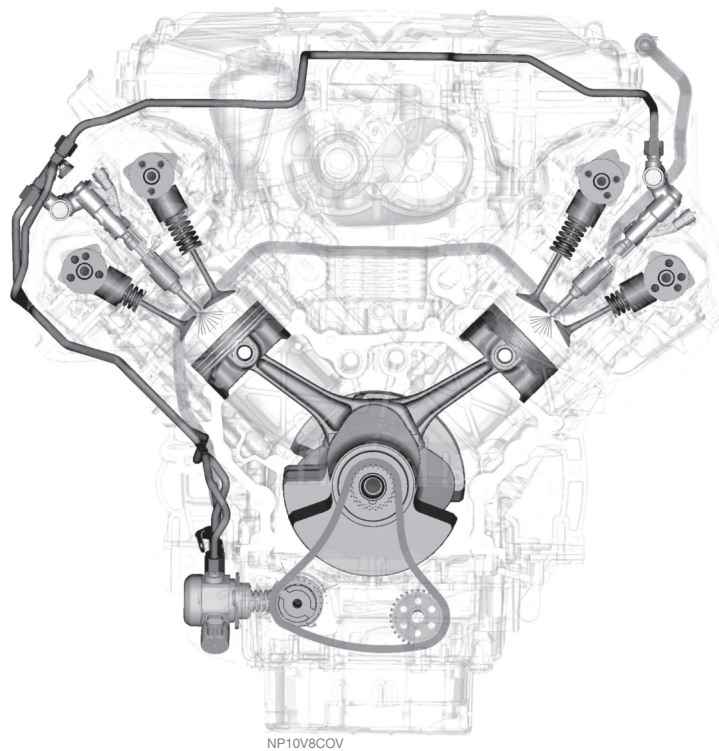
Feature/Attribute	Benefit	Technologies
Engine efficiency/ specific fuel consumption (continued)	Reduced engine parasitic loss	- Detailed component and system design optimization for minimized friction: - Sub-system and component level target setting and new process for predicting effect of very small friction changes on fuel economy employed to optimize design – very low engine friction given the size of engine, some sub-systems best in class
	Lower parasitic losses during warm-up	- Engine internal oil-coolant heat exchanger: - During warm-up heat is transferred from coolant to oil increasing oil temperatures and hence reducing viscosity and parasitic losses - Design optimized high flow cooling system with low volume cylinder head and block cooling passages
	Delivers clean oil at the correct temperature and pressure to every part of the engine	- Small single stage oil pump: - Less demand from the new VCT system
Lubrication system	Reduced oil foaming	Structural baffle plate
	Improved economy	Gallery pressure feedback
	Top-down servicing	- Oil evacuation tube located under the oil filler cap - Oil filter accessible from the top of the engine
	Soot removal	Highly efficient filter
	Accurate oil level monitoring	Electronic dipstick
	Reliable, continuous high-load operation	- Plate type oil-to-water cooler: - Removes heat from oil into main cooling circuit
Oil specification and cooling	Increased reliability and improved efficiency	Dedicated low-viscosity synthetic Castrol SLX A1 5W-20 oil
Emissions performance achieving demanding European EU5 and Federal ULEV2 emissions standards	Reduced level of hydrocarbons released into the atmosphere	Evaporative emission control system intake and exhaust VCT (JLR first)
	Improved mixture preparation for improved combustion	Direct injection (JLR first)
Low radiated noise	Good foundation for reduced noise output	- Stiff, strong cast aluminum engine structure - Cast iron, cross bolted main bearing caps
	Excellent fuel preparation and controlled in-cylinder pressure rise	ECM (engine control module) and injection system
Intake system	Low noise and high efficiency	- Variable intake geometry system (NA) (JLR first for variable geometry manifold on V8) - Mechanically-driven, high helix rotor supercharger (Jaguar first)
	Accentuated acoustic feedback to further increase the driving experience	- Bark tube (NA) - Symposer (SC) (JLR first)

Feature/Attribute	Benefit	Technologies
Fuel injectors	Optimum combustion conditions both at cruising speeds as well as during acceleration	High-pressure centrally mounted injectors (JLR first)
Cooling system	- Reduced cold-start emissions and fuel consumption - Durable - Faster cabin warm-up	High flow cooling system with low volume cylinder head and block cooling passages
	Controlled radiator coolant flow	Multi-stage thermostat
Long service intervals	Low cost of ownership	- Timing chain with oil pressure-controlled hydraulic tensioners avoids requirement for costly belt replacement - Maintenance free primary ancillary belt - Maintenance free camshaft and auxiliary shaft drive chain - Generous air filter area - Oil cooling and synthetic oil reduces rate of oil degradation 15,000 mile service intervals

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Technical Training
Technical Introduction

NP10-V8JLR: AJ133 5.0-Liter DFI V8 Engine



Components and Systems



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FRONT END ACCESSORY DRIVE

A new front end accessory drive (FEAD) belt system powers the engine accessories: the generator and air conditioning (A/C) compressor as well as the engine cooling pump, power steering pump and – if equipped – the supercharger and the Dynamic Response pump.

The accessory drive belts are automatically pre-loaded by mechanically-sprung tensioners and routed over a series of idler pulleys to help control belt run, and wrap around the accessories (the power that can be transmitted to each pulley depends on how far around it the belt is wrapped). The idler pulleys also help control belt noise, by limiting the length of belt that can vibrate freely. This ensures slip-free drive of the accessory components.

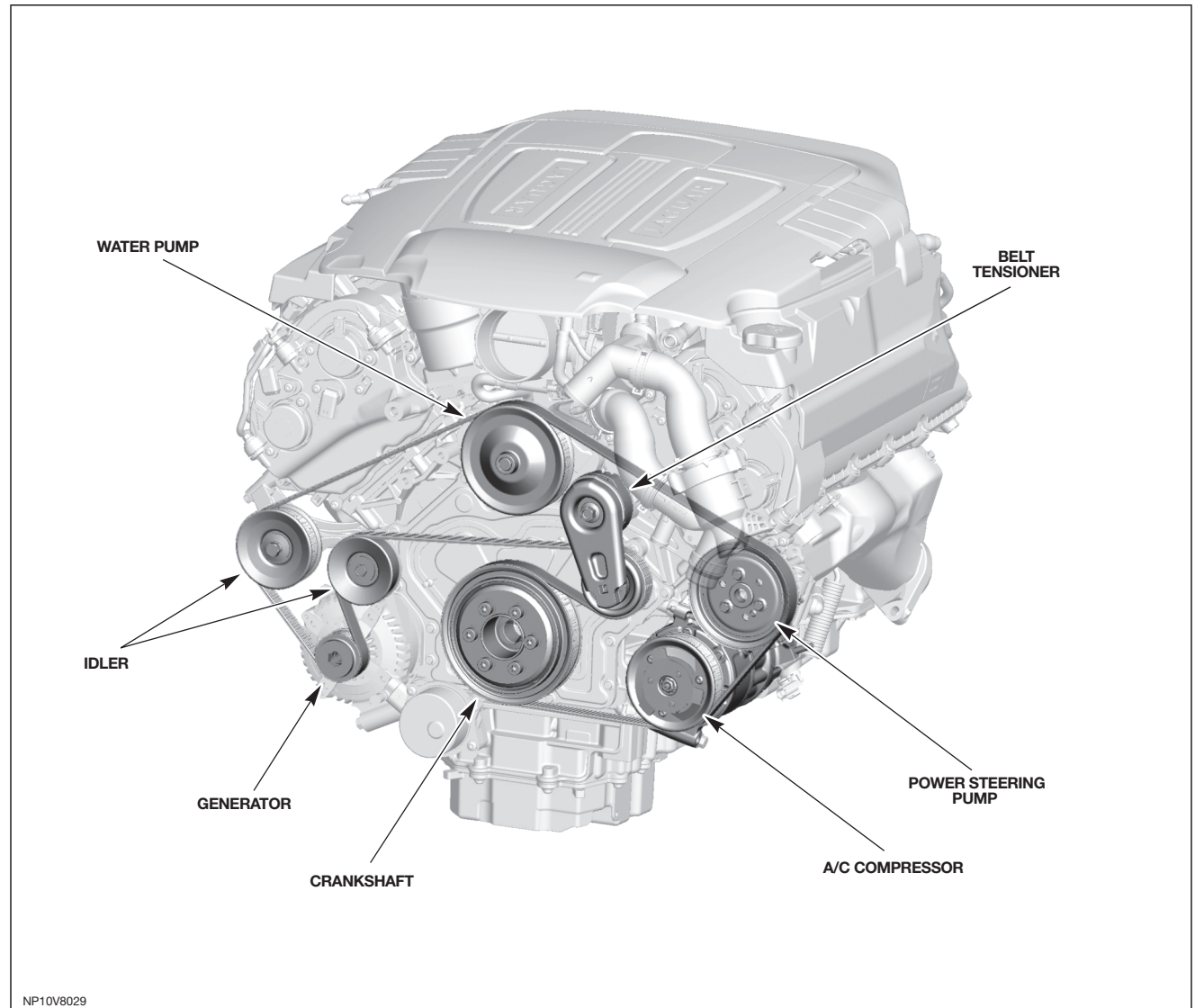
The crankshaft pulley drives the primary and secondary belts, and incorporates a torsional vibration damper to absorb vibration from the engine firing loads.

All accessories are mounted directly to the base engine structure to reduce vibration and weight.

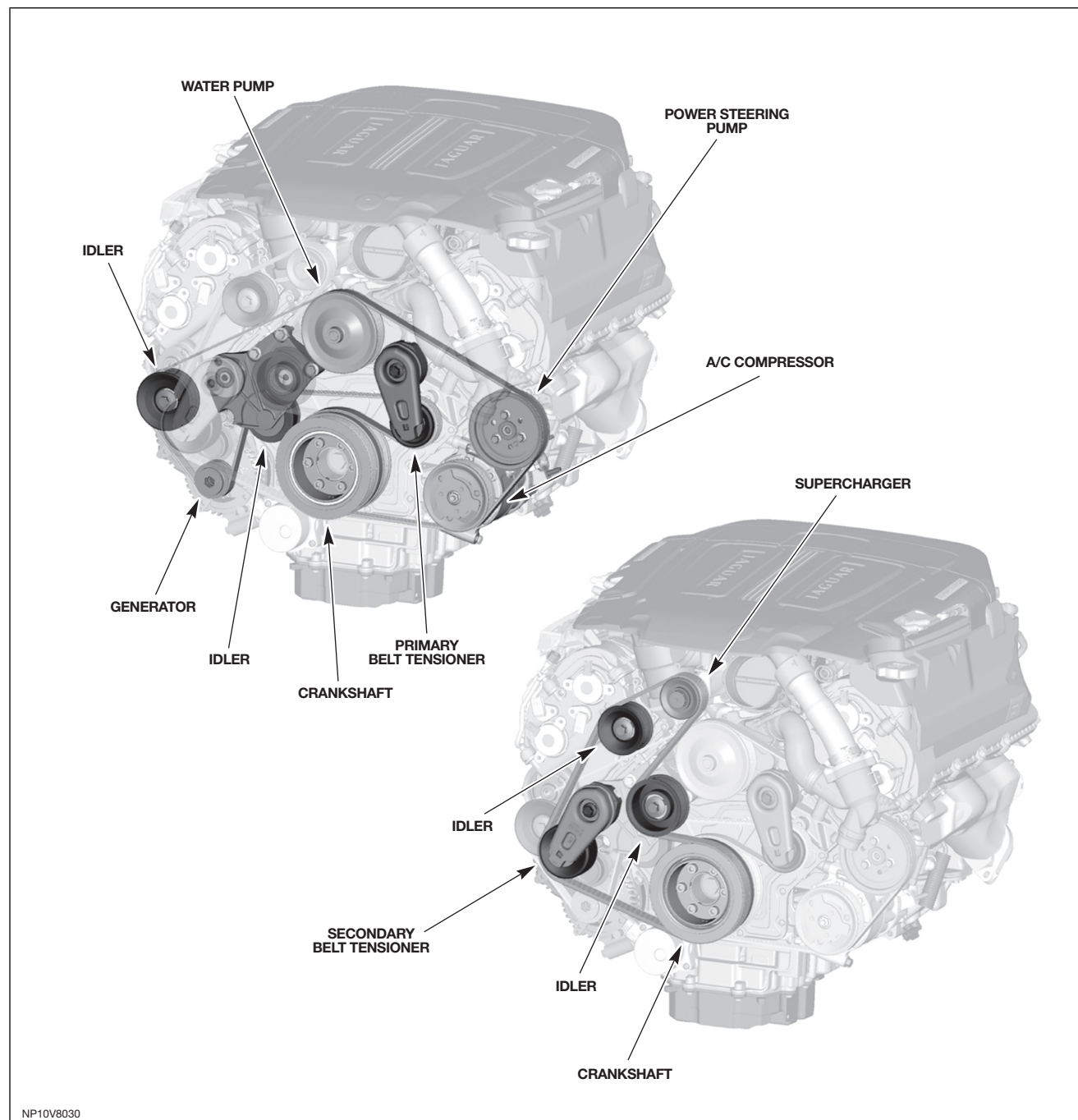
Jaguar Variants

The maintenance-free primary belt drives all of the engine-mounted accessories. The secondary belt drives the supercharger.

Jaguar Naturally Aspirated Layout



Jaguar Supercharged Layout

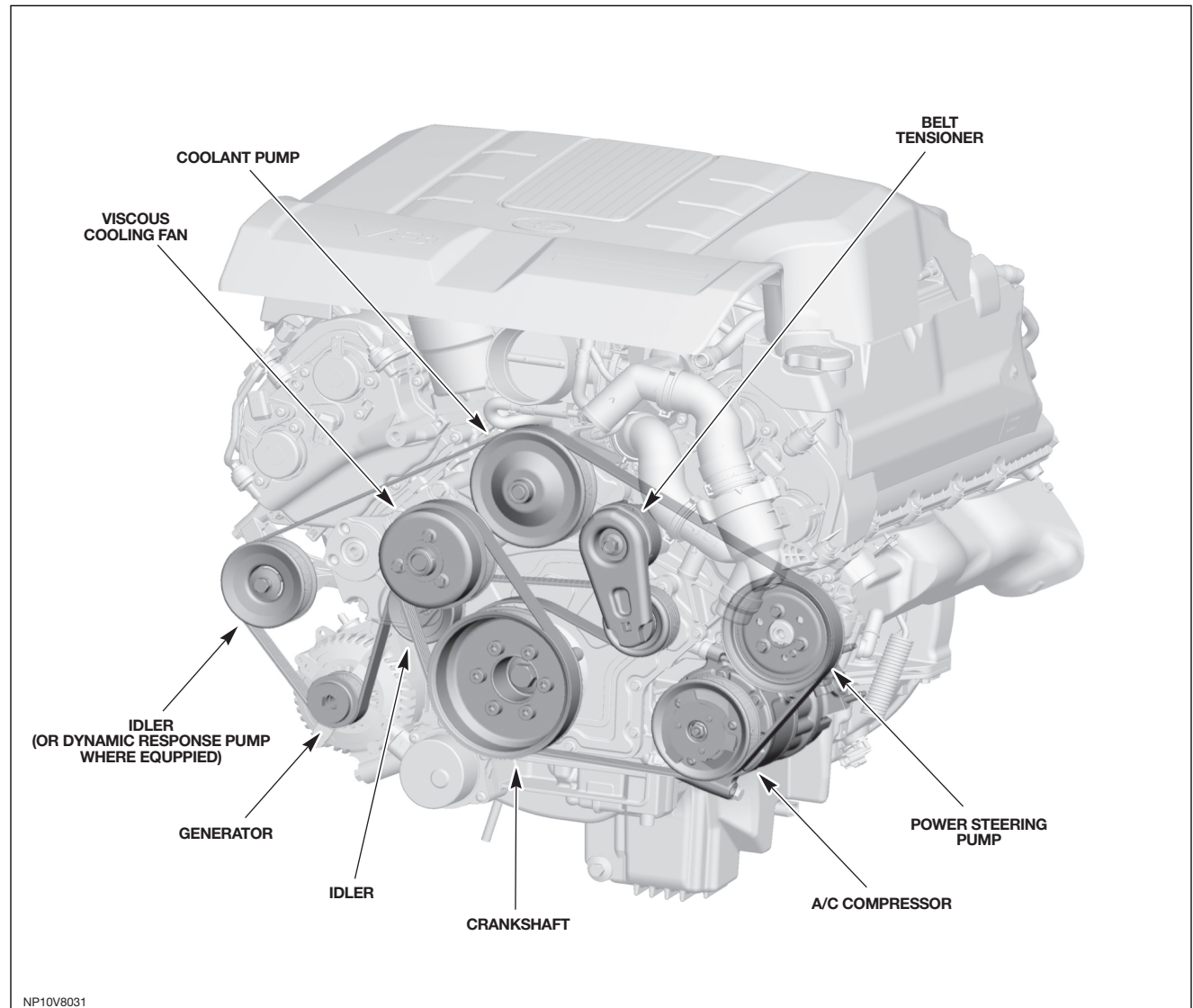


NP10V8030

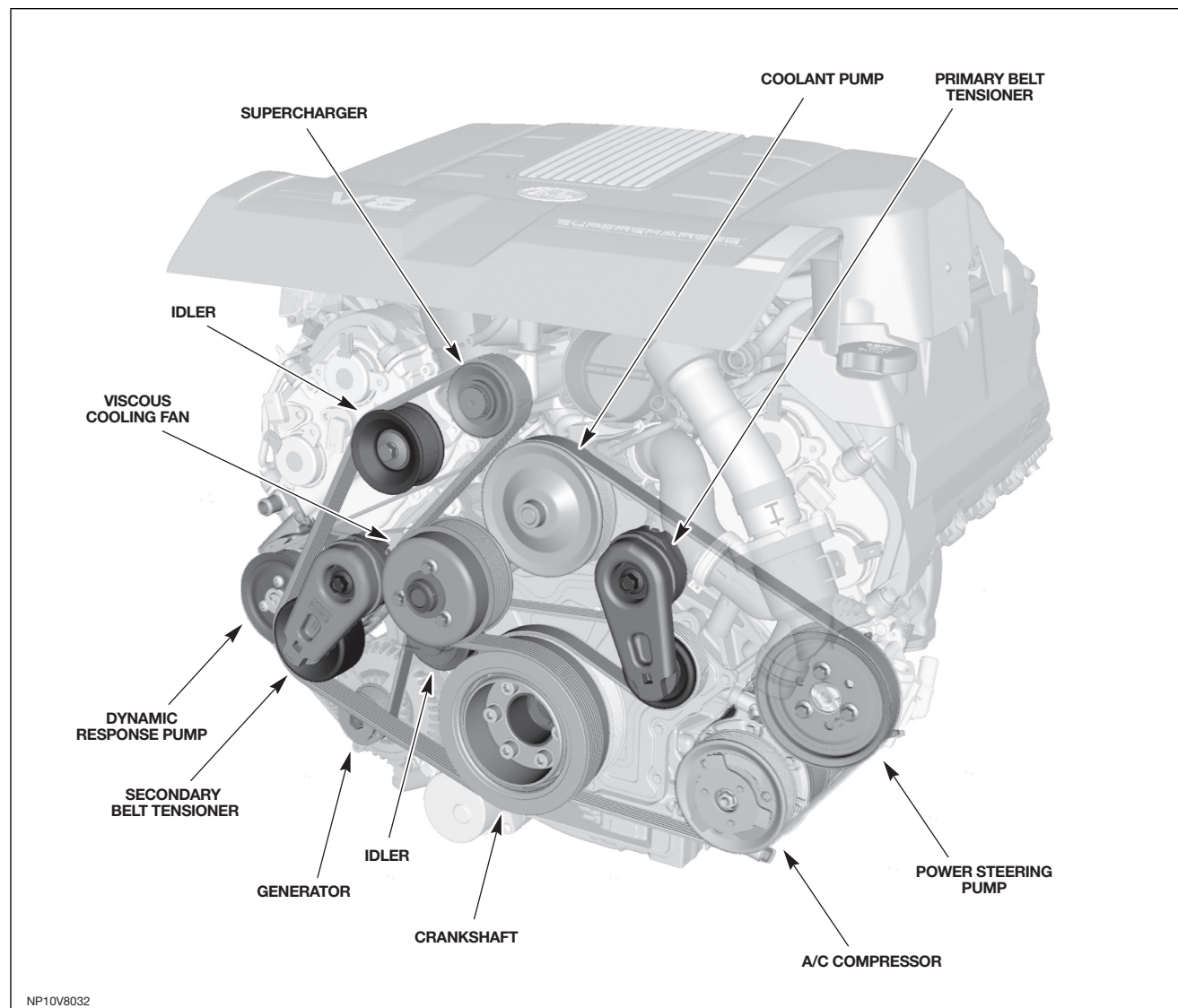
Land Rover Variants

The primary belt drives all of the engine-mounted accessories. The secondary belt is manufactured from an elastic/stretchy material to minimize weight and drives the viscous cooling fan and, on supercharged variants, the supercharger. Where equipped, the Dynamic Response pump is mounted on a die-cast aluminum bracket on the right hand side of the engine; otherwise, this bracket supports an idler.

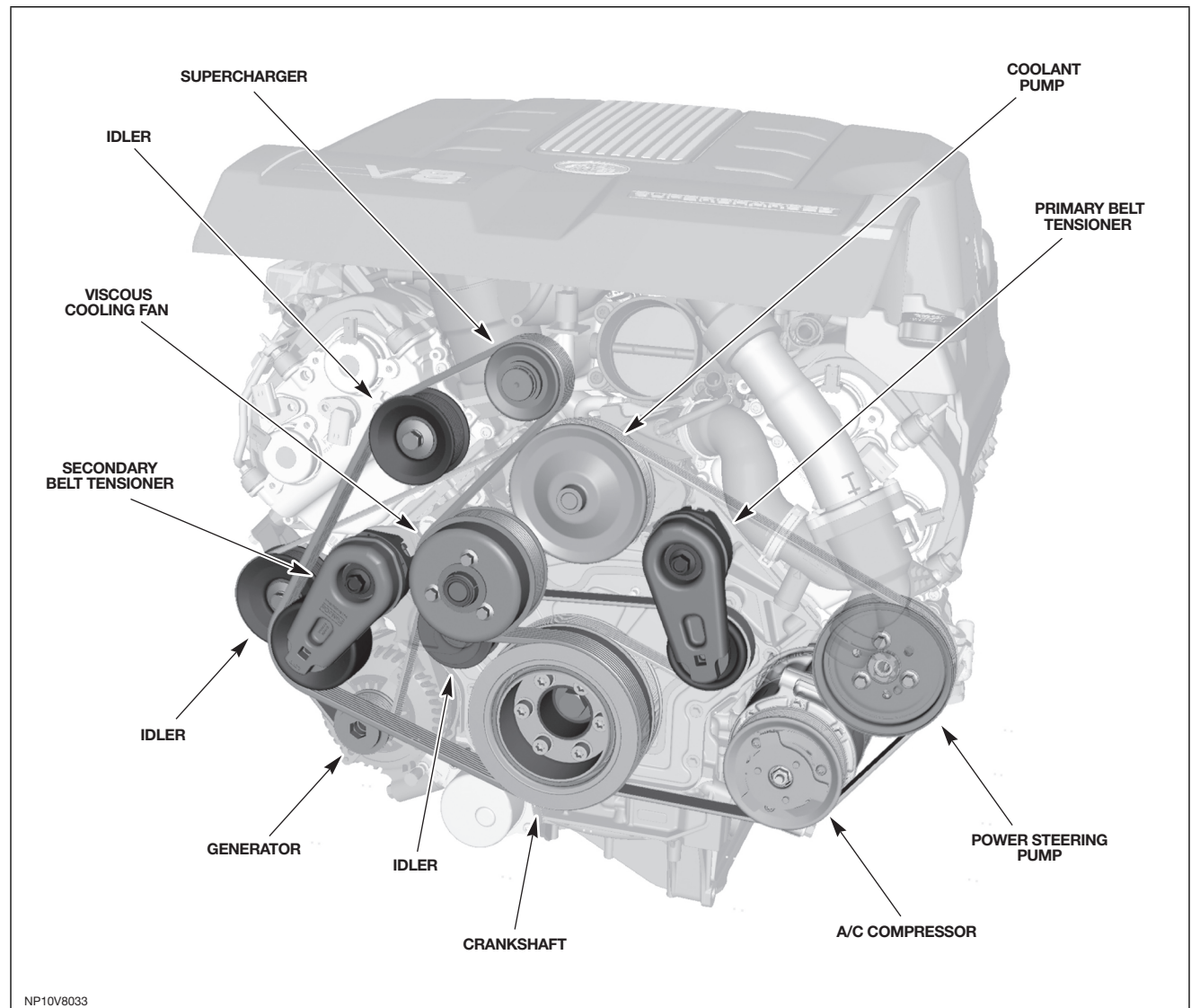
Land Rover Naturally Aspirated Layout



Land Rover LS Supercharged Layout



Land Rover LM Supercharged Layout



ENGINE COOLING SYSTEM

Overview

The primary function of the cooling system is to manage the heat generated by the engine at all operating and environmental conditions. The cooling system must protect the engine from overheating by keeping the combustion chamber surrounding metal temperatures within specified limits. To achieve this, the coolant pump, thermostat, and radiator provide the required flow, control and heat rejection.

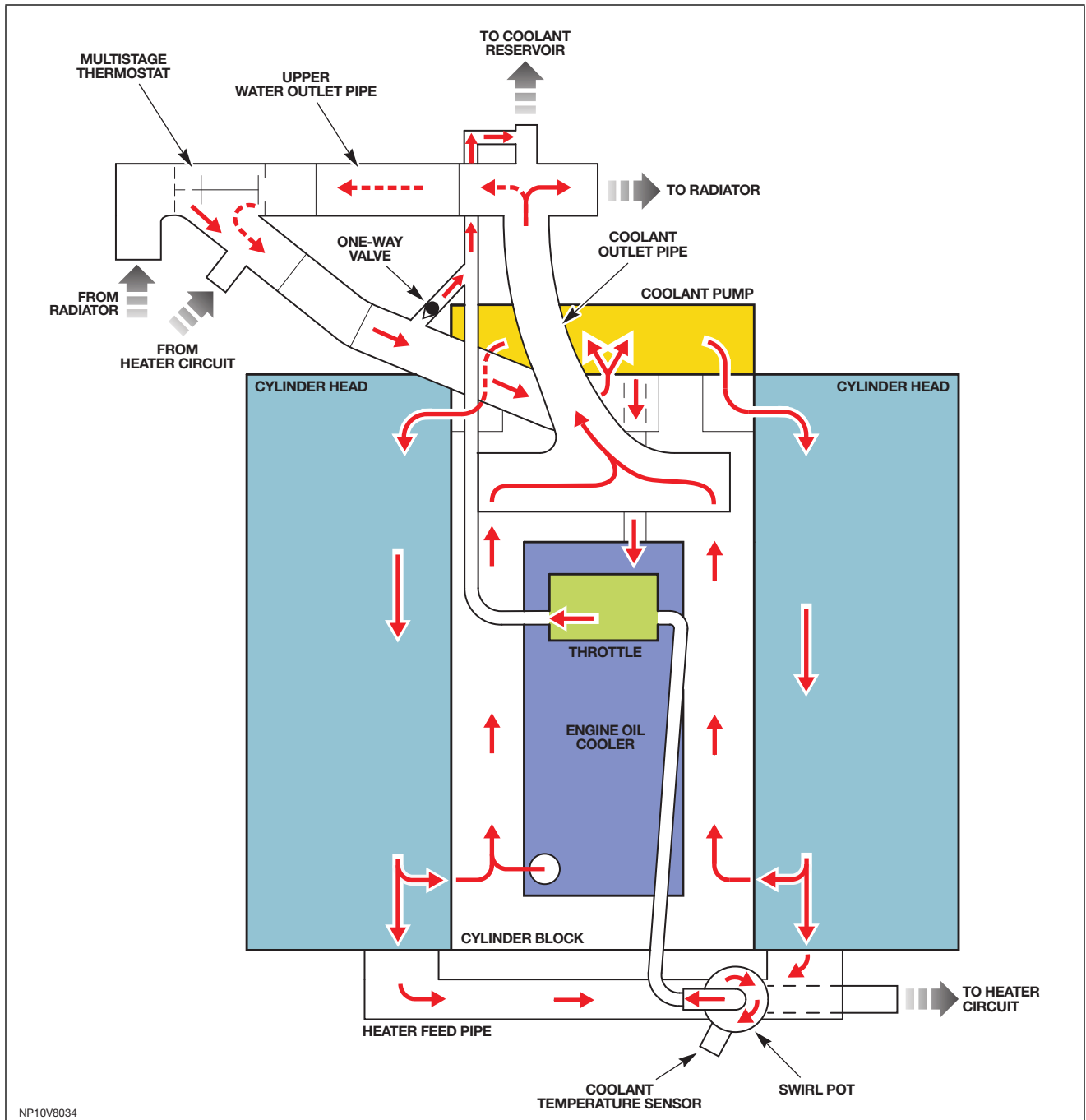
The 5.0-liter V8 engine cooling system is also designed to provide all the benefits of rapid warm-up:

- Less wear
- Reduced emissions and fuel consumption
- Fast cold weather cabin warm-up
- Robust throttle operation with cold weather heating

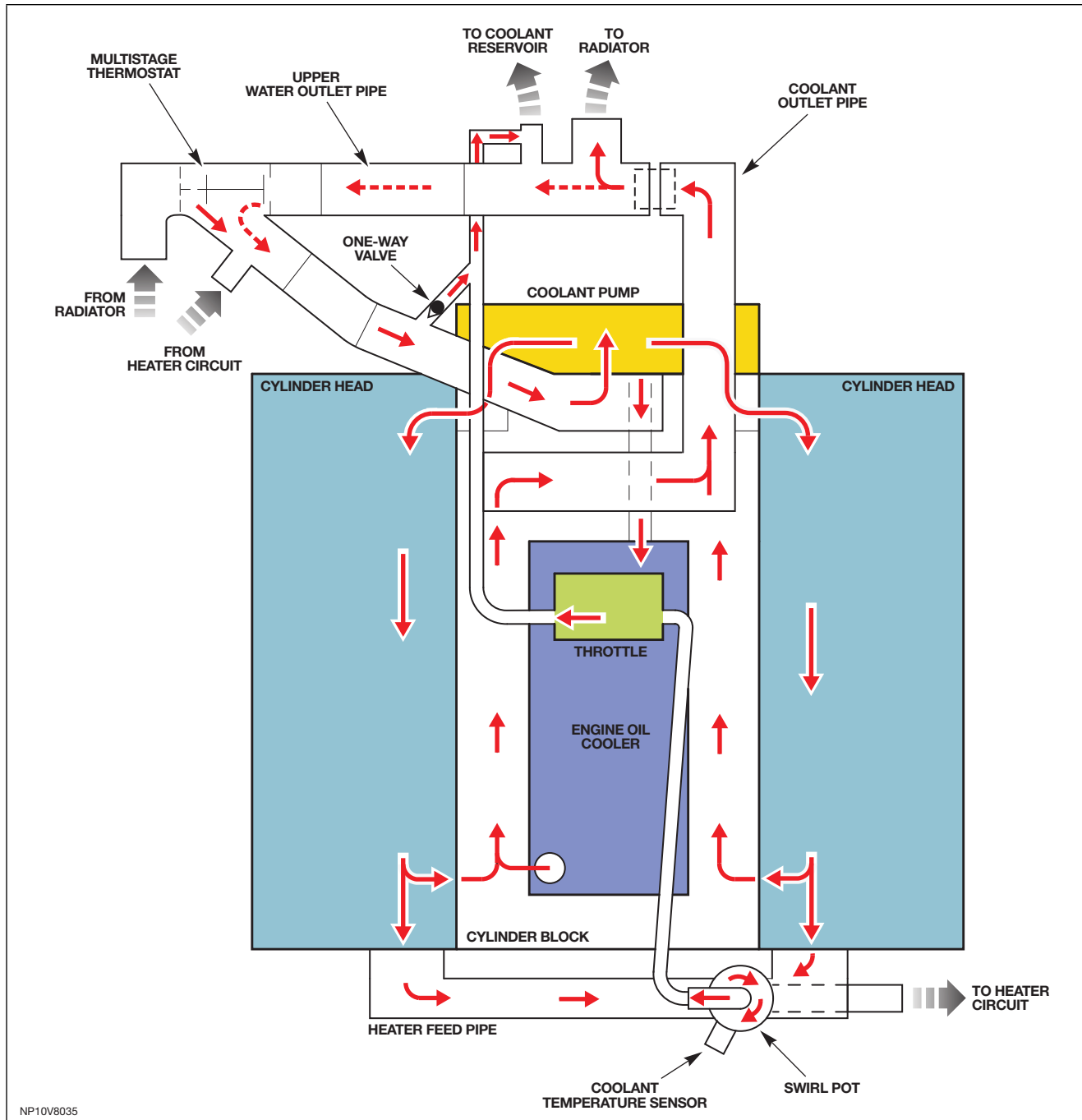
Once warm, the cooling system thermostat modulates flow through the engine and radiator to maintain the coolant temperature at its ideal operating range for efficiency and durability.

Cooling Circuits

Naturally Aspirated Cooling Circuit



Supercharger Cooling Circuit (Charge Air Cooler Circuit Not Included)



Coolant Flow

From the coolant pump, coolant flows into the oil cooler and each cylinder head, where the most heat is available for rapid coolant warm-up. The thermostat controls flow through the engine and the heater circuit until optimum temperature is achieved. At the rear of the cylinder heads the flow splits between the cylinder block and the heater circuit. The cylinder block coolant then flows forwards to the outlet ports and merges with the heater return flow at the coolant pump inlet. When the thermostat is closed, the coolant returns directly to the pump through the bypass on the thermostat housing. When the thermostat is open, the coolant returns to the pump via the vehicle's radiator. A coolant drain plug is installed on the rear left side of the cylinder block.

Cold, low-pressure coolant is drawn from the radiator by a belt-driven water pump. This is distributed through a coolant circuit that includes the engine, oil cooler, cabin heater, and coolant reservoir.

A multi-stage thermostat is located on the water pump inlet side to provide good response and control for the engine outlet temperature. When the coolant temperature varies, the thermostat reacts by changing its opening position to control radiator coolant flow.

The operational benefits of the multi-stage thermostat are:

- Closed position during warm-up contains the coolant flow to the engine and heater circuit for rapid warm-up
- During warm-up and at engine speeds above 1800 rpm, a bypass valve opens to control flow and pressure, protecting engine components
- When the thermostat opens 6mm and the coolant is approaching optimum temperature, the bypass flow is shut off
- When the thermostat opening exceeds 6mm, the radiator coolant flow is further controlled up to the point where the thermostat is fully open. At this point maximum cooling is required, so maximum radiator flow is achieved

AIR INTAKE SYSTEM

Overview

The air intake system has been designed to make available the appropriate air supply to the engine.

There are two rigid injection-molded air cleaner housings located inside the engine compartment. Each air cleaner housing is supported on elastomer mountings to minimize noise transmission to the vehicle's body structure and contains a replaceable paper filter element.

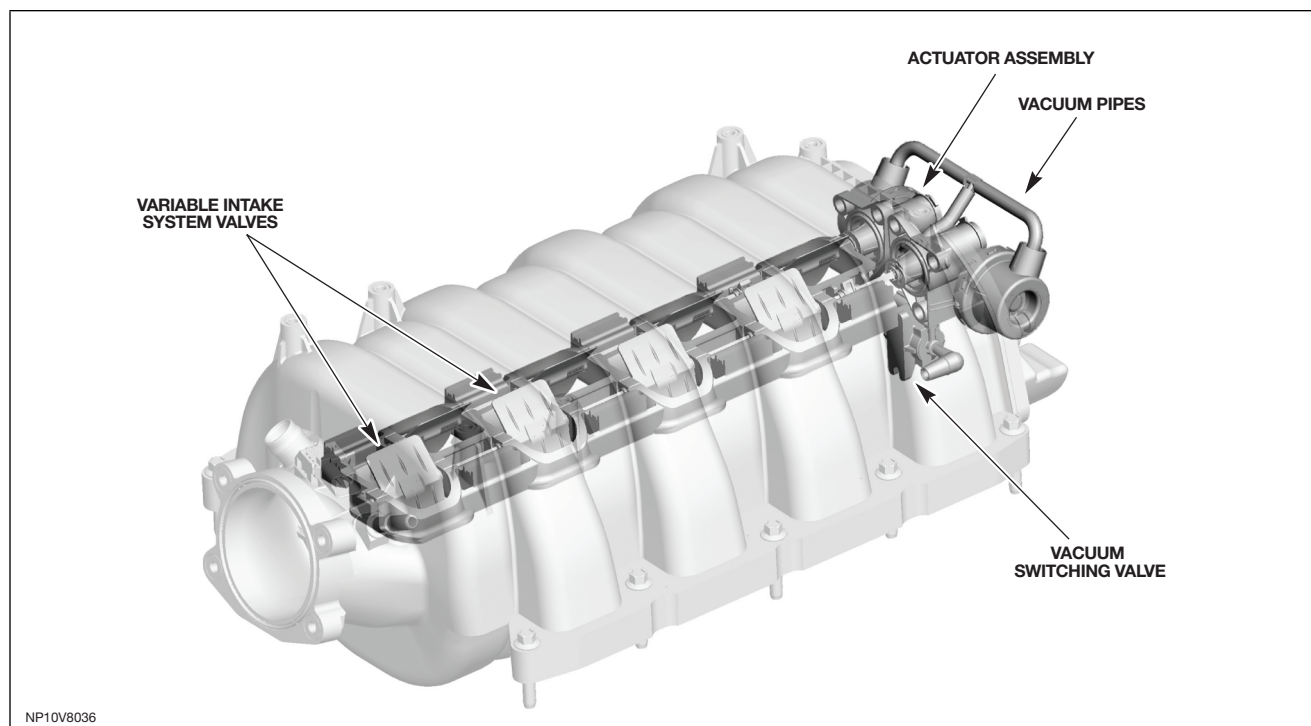
A poly-fiber duct designed to reduce intake noise directs dirty air into the air cleaner housings and through the filter elements. The clean air duct then passes the filtered air over the mass airflow sensor, through the electronic throttle and up to the intake manifold where it is distributed to the individual cylinders.

The clean air duct of the normally aspirated (NA) engine features a feedback tube and diaphragm device to enhance engine sound quality. A symposer system is mounted on the rear of the supercharged engine and is connected directly to the right hand intake manifold to enhance engine sound quality.

Variable Intake System (NA)

The NA engine employs an intake manifold, which is manufactured from a composite material with metal inserts and comprises a central chamber with eight runners leading to the intake ports on the engine.

Intake Manifold (NA)



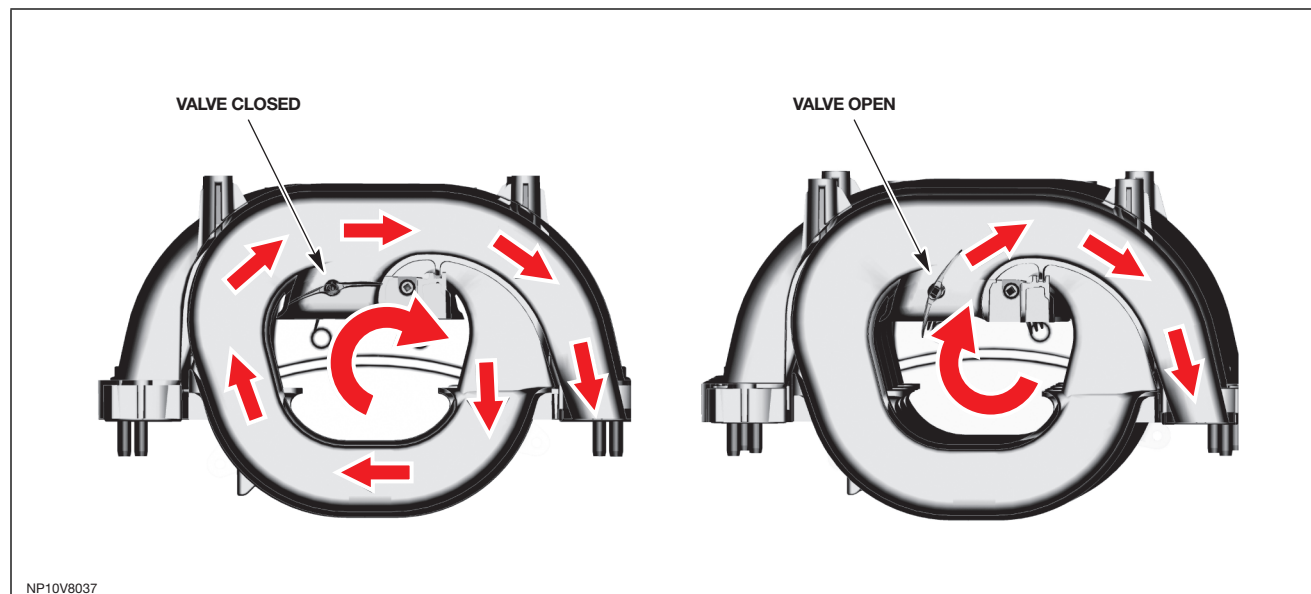
The Variable Intake System (VIS) varies the length of the intake tract in order to optimize power and torque and is engine speed dependent (approximately 4000 to 5000 rpm).

Varying the length of the intake runners for different engine and load conditions optimizes the filling of the cylinder and thus the engine's efficiency. At low engine

speeds, the rate of air flow is increased by directing the air down a longer path to provide optimum engine torque. The shorter path opens when engine speed increases so that a greater amount of air can enter the chamber to optimize engine power for the existing engine speed range.

Vacuum-operated actuators, located at the rear of the intake manifold, open and close the valves via a connecting rod. The actuators respond to signals received from the engine management system via a vacuum switching valve.

The variable intake system is a two-position system and is either fully open or fully closed.



The intake manifold tuning solenoid valve is the interface between the variable intake system unit and the engine control module (ECM). The variable intake system unit varies the intake manifold runner length to improve the engine's volumetric efficiency. Its basic construction is a vacuum switching valve, which is opened through the application of an electrical supply to the coil. When the electrical supply is cut, the vacuum switching valve closes, cutting off the air supply. The vacuum tank on the manifold is permanently connected to the vacuum pump in the vehicle, which supplies a constant level of 950mbar vacuum.

Valve Opening

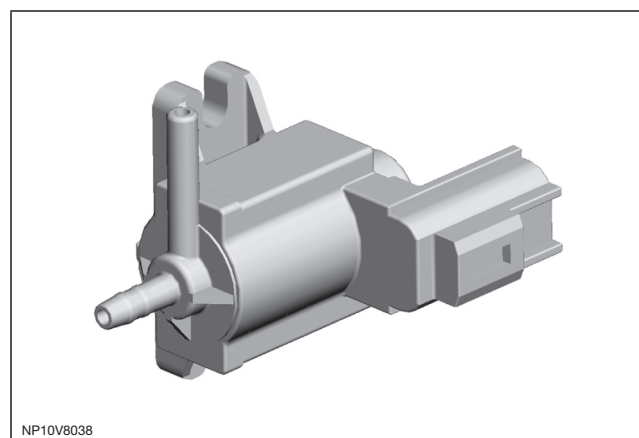
At a set engine map point, the ECM provides a signal to the solenoid, which energizes the coil. The valve opens, permitting the flow of the vacuum supply into the hose assembly and hence into the two actuators.

The vacuum pulls on the diaphragm inside the motor housing, compressing the spring and pulling in the actuator arm. The linear arm motion creates a rotation of the lever arm, which is connected directly to the drive shafts of the flap system. The complete flap assembly rotates to the stop position (flaps closed – long runner length) in the manifold runners.

Valve Closing

When the electrical signal is stopped, the needle valve inside the solenoid closes, shutting off the supply of the vacuum, and opens up the venting channel.

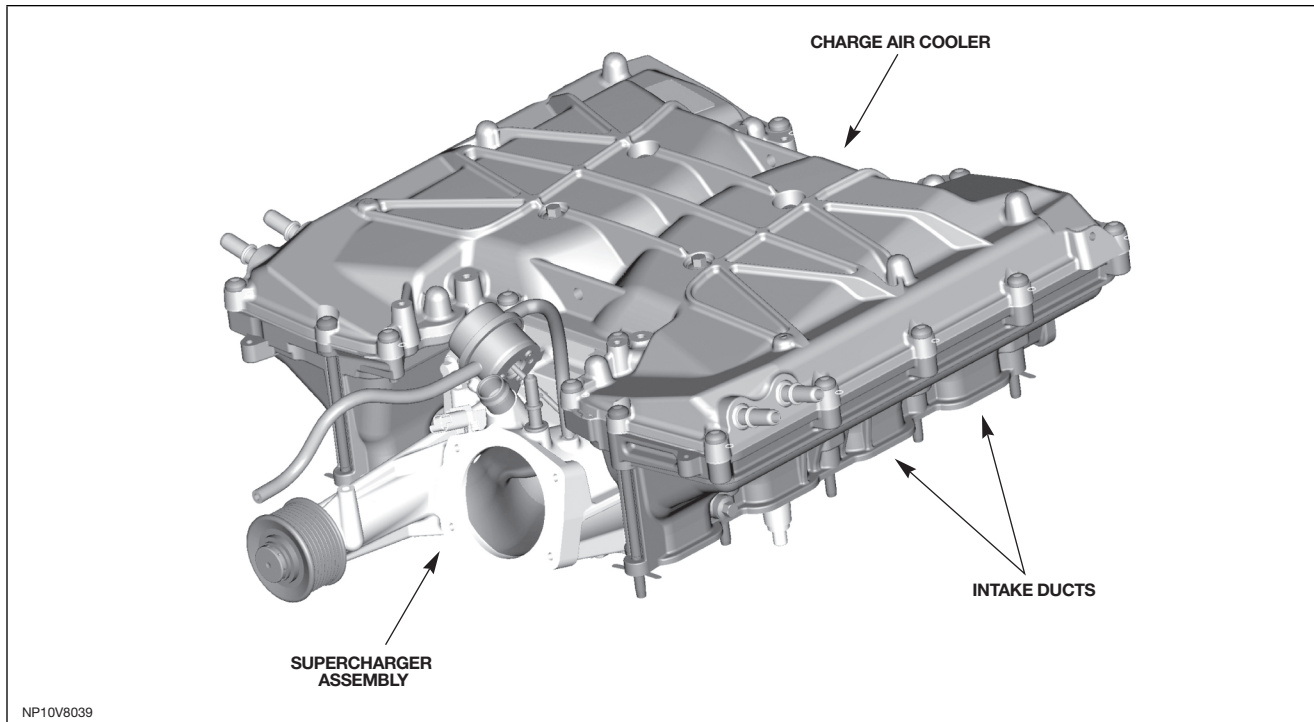
The vacuum air supply vents to atmosphere, restoring ambient pressure to the system. The springs in the actuator body push back the diaphragm and the arm, forcing the lever arm to rotate in the opposite direction. This (due to the direct drive on the shafts) rotates the flaps back to the open condition (short runner length) ready for the next signal.



The valve is mounted to the back of the intake manifold below the pneumatic actuators.

Supercharger

On supercharged (SC) engine variants the supercharger unit and two water-cooled charge-air coolers essentially replace the intake manifold of the naturally aspirated variant.



The Roots-type supercharger, manufactured by Eaton, with high helix angle rotors is used to pump air into the cylinder, which boosts the density of the air charge to create a more powerful combustion inside the cylinder. This increases cylinder pressure upon ignition and creates more power.

As the supercharger pumps the air, its temperature increases. This rise in air temperature reduces the potential for power gains. By employing water-cooled charge-air coolers, the air is cooled to increase the charge air density.

The supercharger delivers pressurized air to the charge-air coolers. The pressurized cooled air is then fed directly into each intake port.

The charge-air coolers are water cooled via a radiator and coolant pump.

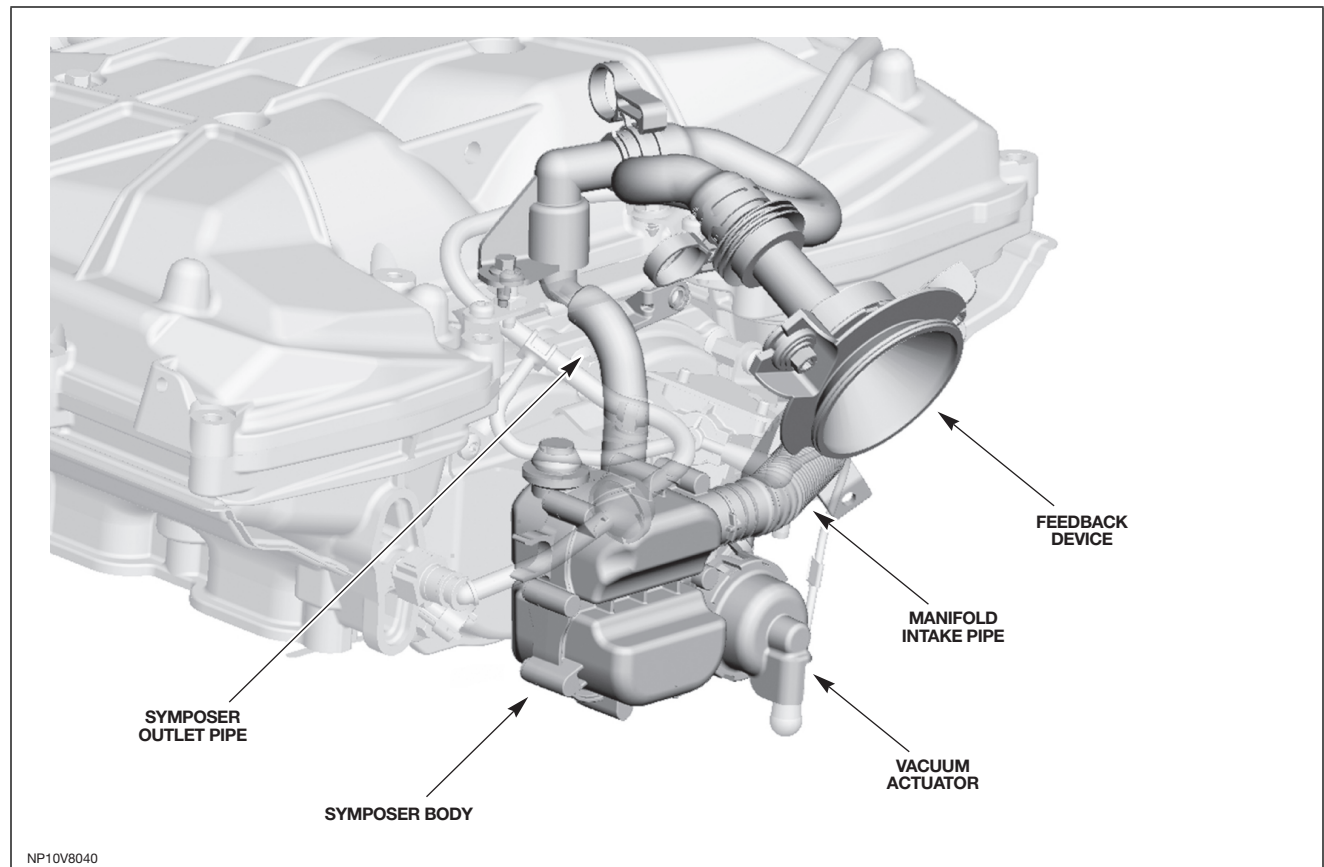
The supercharger has a fill-for-life internal lubrication system and is aligned with the secondary accessory drive belt. The belt drives the supercharger via the crankshaft at 2.1 engine speed.

A mass air flow (MAF) sensor provides an input to the ECM pre-supercharger, and a temperature / manifold absolute pressure (TMAP) sensor provides an input to the ECM post-supercharger.

Symposer

Historically, automobile manufacturers have focused on reducing the level of engine acoustics within the cabin. With the introduction of the new 5.0-liter V8 engine, development engineers have deliberately accentuated the acoustic feedback into the cabin in an effort to further increase the driving experience.

An integral part of this development is the introduction of a symposer into the engine air intake system of the SC engine. The symposer is mounted on the rear of the engine and is connected directly to the RH intake manifold.



Engine order pulsations from the intake system are fed into the symposer, which picks out the pulsations that are within the target frequency range. These accentuated V8 engine acoustics are then directed into the cabin.

The symposer is a mechanical device that is operational when the engine is running. However, a vacuum operated valve, which is controlled by the ECM, only allows the acoustics into the cabin under certain conditions. This is to achieve the desired engine sound quality in the cabin.

FUEL INJECTION SYSTEM

Overview

One of the most important challenges facing car manufacturers today is to offer vehicles that deliver excellent fuel efficiency and superb performance while maintaining cleaner emissions and driving comfort. Increasing awareness of global warming as a threat to the environment has added another dimension to this challenge.

In response, a highly efficient low-emission direct-injection system has been developed, which controls the mixture formation under a wide range of engine operating conditions. This is essential in reducing smoke and particulate generation and optimizing fuel economy, and in doing so, demonstrates an ability to meet existing and future emission legislation.

The fuel is highly pressurized and injected directly into the combustion chamber of each cylinder, as opposed to conventional multi-point fuel injection that happens in the intake tract or cylinder intake port.

Combustion Requirements

In a direct -injection engine, the injectors supply fuel directly into the combustion chamber as streams of high-velocity atomized fuel. For ideal combustion, these must disperse to create a stoichiometric homogenous mixture of fuel vapor across the entire combustion chamber before the spark ignites the mixture.

This process of droplet dispersal and vaporization is especially difficult at high engine speeds, as there is very little time for vaporization to take place between the start of fuel injection and the onset of combustion.

Among the many factors influencing mixture preparation, two are particularly important:

- Fuel droplet size: the smaller the atomized droplets of fuel, the faster they can vaporize
- Gas motion within the combustion chamber: controlled, rapid gas movement helps disperse fuel droplets across the combustion chamber as they vaporize

By helping to address these issues, the new injection system is at the heart of the engine's competitive advantage. It offers an excellent balance between emissions, performance, and efficiency.

Fuel Preparation

The size of fuel droplets is affected by both fuel injection pressure and the size of the injector's nozzle holes. The smaller the nozzle, the finer the atomization of the fuel. Likewise, increased fuel injection pressure also helps to produce smaller fuel droplets.

There are clear limits to the amount of fuel that can physically be forced through the injector's fine orifices in a given period of time; the engine's demands for greater volumes of fuel at higher operating loads places practical limits on the extent to which orifice size can be reduced.

Fuel injection timing is critical too. Optimal injection timing on a homogenous charge direct-injection engine is primarily about achieving the right balance between volumetric efficiency, adequate mixing, and minimal fuel deposition on the piston/liner.

A stratified charge strategy is used for cold starts depending on climate conditions and engine temperature. The fuel delivery is timed with ignition at close to TDC on the compression stroke to give optimum driveability from start-up in all conditions. The timing strategy will vary depending on ambient air temperature and engine conditions. This strategy also aids catalyst warm-up.

The fuel system employs 6-hole injector nozzles and peak injection pressures of 150 Bar (2176 psi) to achieve these objectives.

The new engine's 32-valve layout has been configured with symmetrical inlet ports.

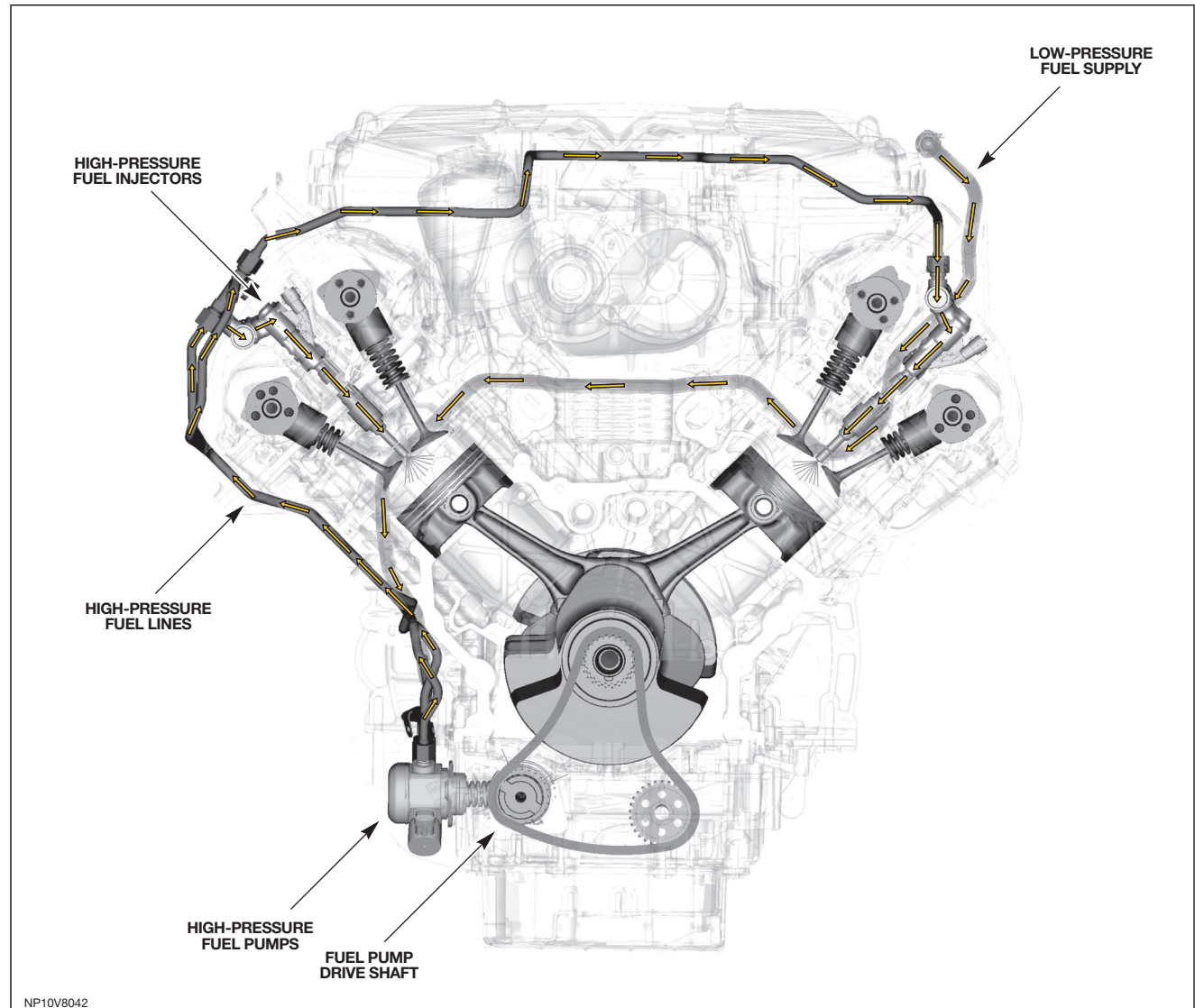
Mixture Requirements

To encourage rapid dispersal of fuel droplets throughout the combustion chamber across a broad range of engine speeds, the motion of air within the combustion chamber must also be carefully controlled.

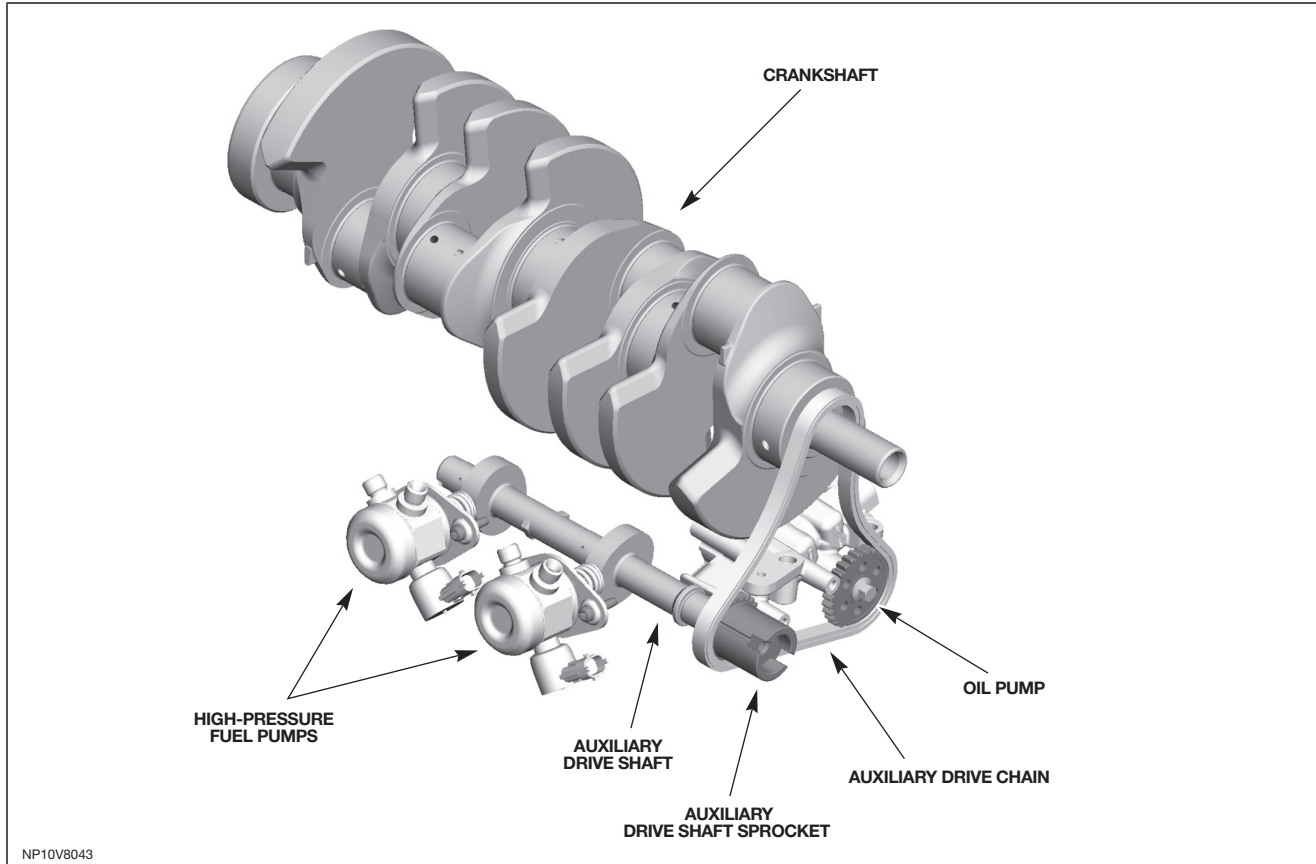
The 32-valve combustion system has been developed to create a repeatable 'tumble' motion of intake gas inside the chamber. 'Tumble' motion delivers the optimal balance between good mixing / combustion efficiency and optimal flow performance for good volumetric efficiency.

The new engine's Direct Fuel Injection (DFI) system has been specifically designed to achieve high standards of durability, combustion performance, and refinement.

Locating the fuel injectors into the cylinder head and spraying directly into the combustion chamber requires fuel pressures much higher than the 3 to 4 bar (44 to 58 psi) of conventional engines. This, in turn, demands a high-pressure fuel pump. The new direct-injection engine, which incorporates two auxiliary shaft-driven fuel pumps regulated by the engine management system, is capable of generating fuel delivery pressures as high as 150 bar (2176 psi).



A single-plunger design is used in the high-pressure injection pumps to provide high volumetric efficiency at low drive torque and at low cost. The pumps have a built-in electromagnetic control valve, and the control function varies the fuel delivery amount by adjusting the timing of the drive pulses sent to the valve. The drive torque and pulsation inside the high-pressure lines are minimal, since the pumps supply only as much fuel as the engine actually requires.



Ultra-precise machining of the high-pressure injectors helps ensure a fine, high-quality spray to achieve optimum combustion conditions both at cruising speeds and during acceleration.

The new engine uses stainless steel high-pressure fuel rails. The fuel pressure in the rail is detected by a high-pressure sensor, which controls flow into the rail by adjusting the electromagnetic fuel metering valve in the high-pressure fuel pump's outlet.

The pressure relief valve (located in the high-pressure pump) protects the high-pressure side of the system from excessive pressure if there is a failure of the fuel metering valve. If the pump delivery pressure increases to 195 – 204 bar (2828 – 2959 psi), the pressure relief valve opens and returns fuel to the inlet side of the plunger.

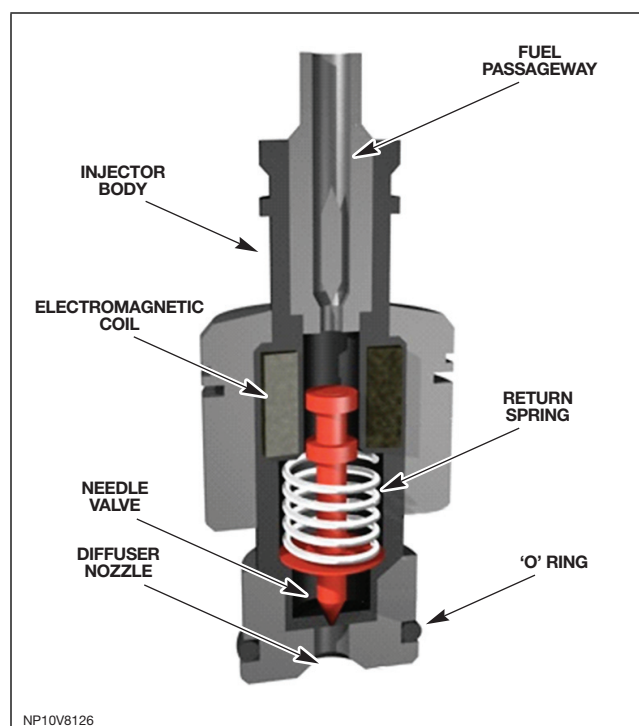
NOTE: The high-pressure fuel system can only be diagnosed using Jaguar Land Rover approved diagnostic equipment.

Like other fuel injection components, the fuel rails are used well below their design pressure limit of 350 bar (5076 psi).

Fuel Injectors

The nominal maximum operating pressure of the DFI system is 150 bar (2176 psi) absolute fuel pressure. The injectors deliver the fuel mass directly to the combustion chamber.

The injectors have 6 spray beams: 2 point below the spark plug, the other four distribute fuel to the rest of the cylinder.



The injectors are similar to traditional solenoid-based fuel injection injectors, however, they operate on a two-stage power supply from the ECM. For the initial trigger they require 65V; once the boost current of 11A is reached, the power supply is switched to battery voltage.

The fuel rail and fuel injectors have built-in non-serviceable filters.

Safety Precautions

⚠ WARNING: The fuel system on both NA and SC engines operates at a maximum nominal pressure of 150 bar (2176 psi). Do not begin work on the fuel system without consulting the service manual.

⚠ CAUTIONS:

- It is mandatory for the Teflon seals to be replaced if the injector is removed from the engine. The Teflon seals are part of the injector sealing to the combustion system.
- Do not contaminate the Teflon seals with oil. Do not use oil and grease to aid the assembly of the injectors to the engine.
- Always clean injector bores before fitting fuel injectors.
- Do not tamper with the electrical connections, as the voltage will reach 65V during operation and has a high current requirement.

Failure Modes

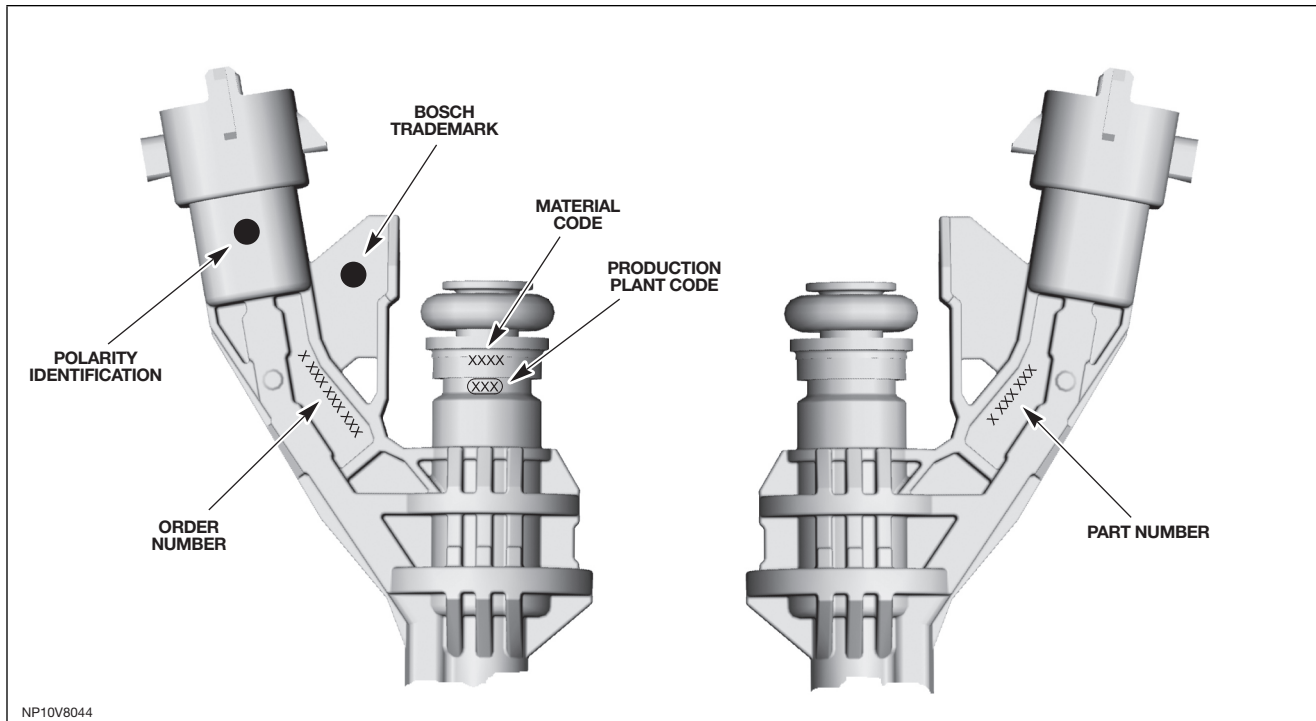
- Failed Teflon seal – major exhaust gas leakage
- Injector deposit buildup
- Injected fuel mass variability

Failure Symptoms

- Unstable idle
- Poor NVH characteristics
- Poor emission performance

Specification	Function
Power Source	65V $\pm$ 0.2V ECM 2-stage power supply
Resistance	1.5 ohms $\pm$ 5 percent
Booster current	11A
Holding current	2.5A
Pin 1	Supply (Positive Polarity)
Pin 2	Ground

Injector Identifying Marks



Fuel Injection Firing

Condition	Degrees (approx.)
Part load	270° – 300° BTDC
Full load	360° BTDC

For the majority of the part load operation, injection timing is between 290° and 300° BTDC, approximately one-third into the intake stroke. Any earlier and too much fuel is deposited on to the cylinder, resulting in increased smoke production. If the timing is any later, less time is available for mixing, which ultimately will result in higher emissions and poorer combustion efficiency.

For full load operation the basic behavior is similar, however, there are two additional considerations:

- There is the additional requirement to phase the timing to maximize volumetric efficiency and minimize knock sensitivity – at low speeds this generally results in the start-of-injection timings similar to that above
- As engine speed increases, the time to complete mixing dominates above all other requirements so that the start-of-injection timing has to move earlier. At peak power, the NA engine has a start-of-injection timing of 360° BTDC (on compression stroke); for SC, it is even earlier – around 400° BTDC

The fully mapped strategy is ECM controlled, depending on:

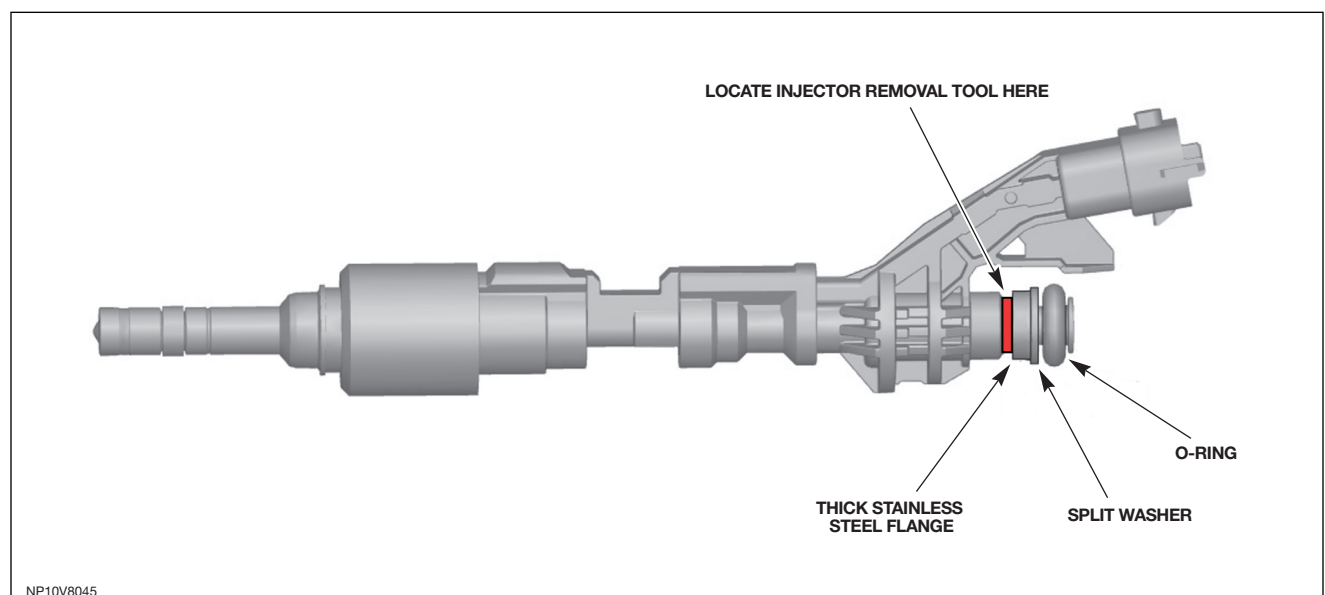
- Engine temperature
- Engine load
- Throttle position
- Engine speed

Injector Removal

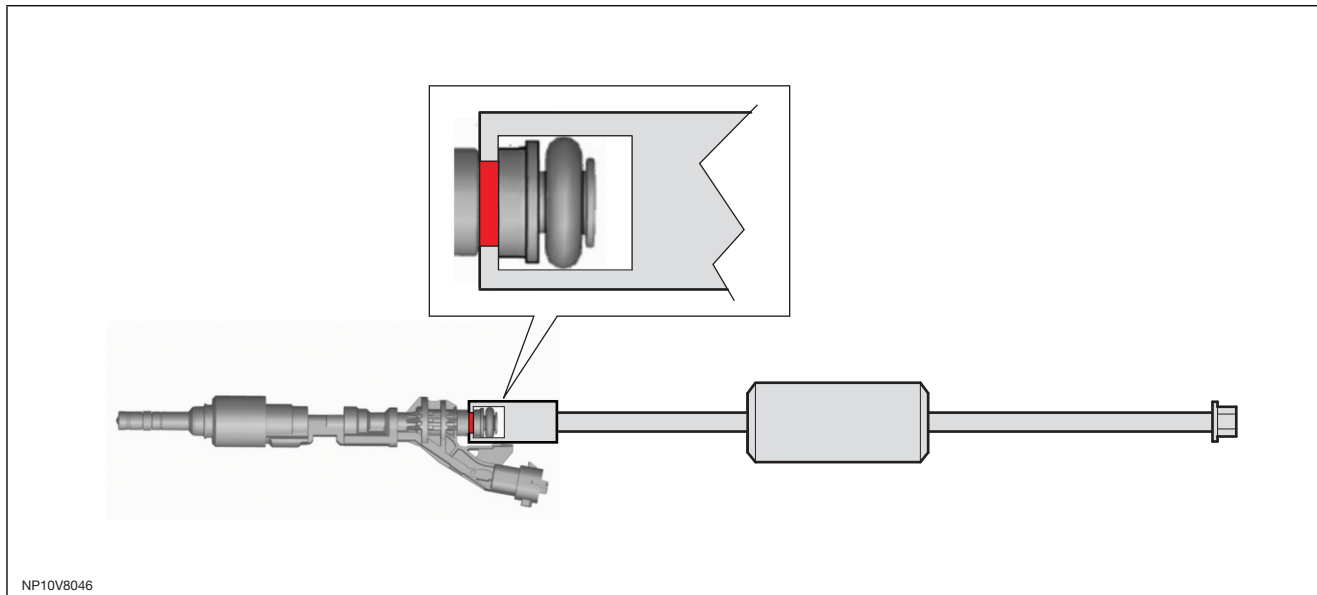
- ⚠ WARNING:** The direct injection fuel system can operate at a pressure up to 150 bar (2176 psi); there is danger of injury if the following precautions are not observed:
- Ensure that the fuel system is depressurized
 - Disconnect the union for the feed pipe to the rail; catch any fuel that leaks out. Position the pipes away from the rails to avoid damage to the threads during removal
 - Remove fuel rail bolts and remove rail by hand. Some or all injectors may also come out in the process; otherwise they will separate from the rail and remain in the head. Significant force, i.e. wiggling, is required to release the O-rings, but do not lever against the camshaft cover
 - Be prepared for a large quantity of fuel (200 ml) to escape from the rail as it is removed. Ensure that suitable protective equipment is worn (protective goggles, suitable filtered face mask, gloves, etc.)
 - Place fuel rail on a clean work bench. Ensure that dirt cannot enter the rail – for example, by capping the open holes

- ⚠ WARNING:** The spark plugs should have been removed prior to pulling out the injectors with the slide hammer tool. Otherwise, it is possible (especially if the engine has been turned over recently) for there to be a little compression pressure in a cylinder, and when the seal is broken with the cylinder head, the fuel that has collected around the injector in the head bore can be forcibly sprayed into the operator's face. Either remove the plugs or remove all the fuel from around the injectors to prevent this from occurring

Position the end of slide hammer injector removal tool carefully under the thick stainless steel flange located under the top O-ring and support washer.



⚠ CAUTION: Take care to ensure correct engagement of the tool to the flange, as engaging the tool under the grey plastic split washer may damage the washer, O-ring, and upper flange.



- Ensure that the tool is kept aligned to the center line of the injector during removal
- Hold the end of the tool to make sure that the engagement between the tool and the injector is maintained during slide hammer blows

An easy injector will only take 3 or 4 hammer blows to remove. A difficult injector may take several blows to extract. If a tight injector is experienced, use a gradually increasing force for the slide hammer blows

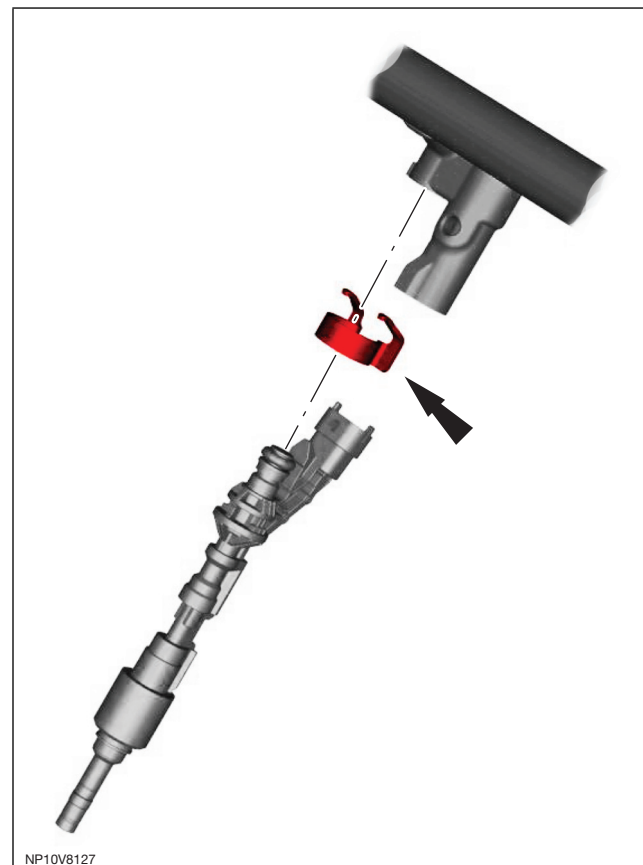
Once the injector is free from the cylinder head, take care when removing the injector from the end of the tool, as it is possible for fuel to flick into the face when the injector breaks free from the tool end. Ensure that the correct protective equipment is being worn.

Place a clean cap over the O-ring end of the injector to prevent contamination by dirt.

When installing injectors:

- Always reinstall injectors in the same location from which they were removed.
- Use new spring clips if injector location is changed or when installing new injector(s).
- Install and size a new teflon sealing ring whenever an injector has been removed.

Injector Spring Clip



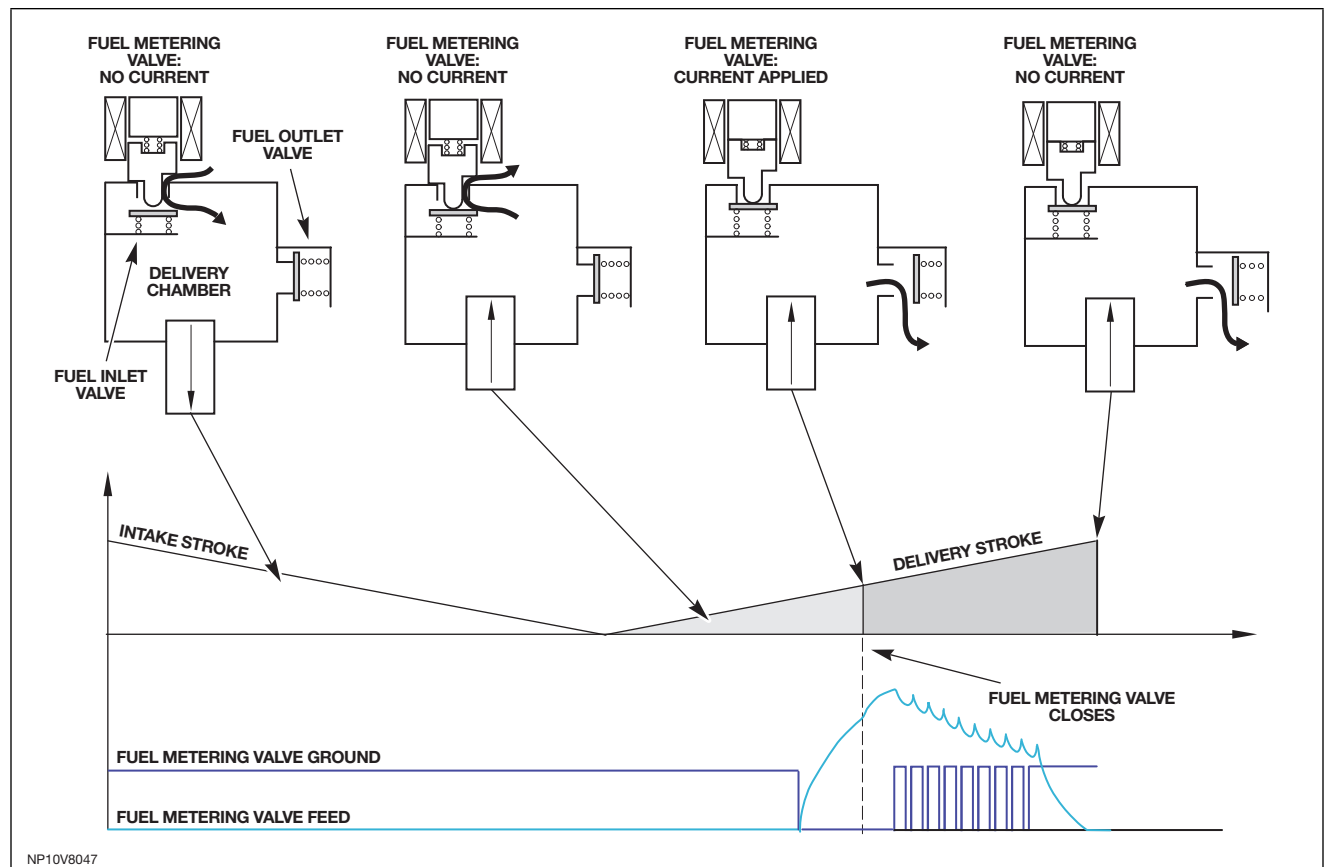
Direct Injection High-Pressure Fuel Pumps

To obtain the required fuel pressure for a direct injection system, additional high-pressure fuel pumps are required. The high-pressure pumps have three functions:

- Pressurized fuel
- Demand-controlled delivery
- Limited system pressure to ensure limp-home operation mode

There are two high-pressure fuel pumps on both NA and SC engines. The high-pressure fuel lines are connected together before they feed the RH bank rail. As such, one pressure sensor in RH bank monitors the pressure of both rails. Fuel pressure is controlled by the fuel metering valve.

The fuel pumps are mounted on the right (RH bank) side of the sump. Pump 1 is the most forward pump; pump 2 is the rear pump in vehicle installation.



The pump operates as per the principle shown. There are two high lift lobes per camshaft for both fuel pumps on the sump/windage mounted auxiliary camshaft, which rotates at crankshaft speed.

Safety Precautions

⚠ WARNING: The fuel system operates at a maximum nominal pressure of (150 bar (2176 psi), do not begin work on the fuel system without consulting the service manual.

⚠ CAUTION: The fuel metering valve has very low resistance. If connected directly to a power source (e.g. a battery), the fuel metering valve will be destroyed after a very short time.

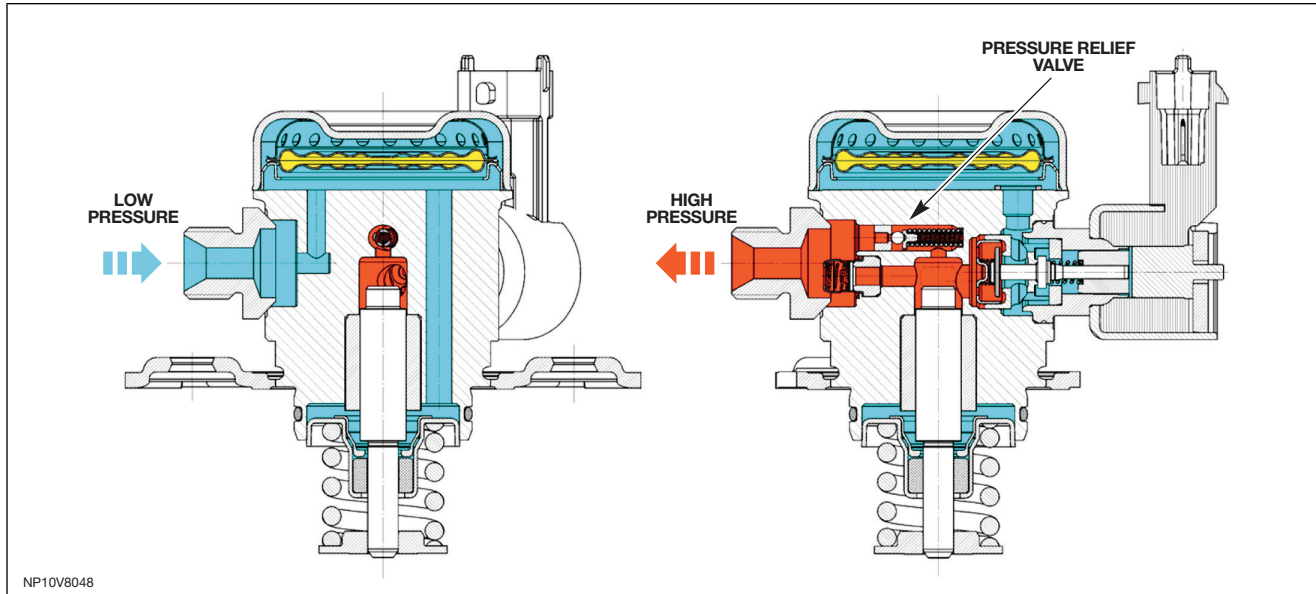
⚠ CAUTION: Do not test the functionality of the fuel metering valve by connecting directly to a power source, as there is a danger of major damage.

The start-up fuel pressure of 150 bar (2176 psi) is instantaneous on cranking and is mapped within the ECM for the supercharged engine.

Failure Symptoms

- No fuel pressure

High-Pressure Fuel Pump Cross-Section



NP10V8048

Specification (Fuel Metering Valve)	Function
Resistance	0.47 ohms
Min Voltage	10.8V
Max Voltage	18.0V
Pin 1	Power
Pin 2	Ground

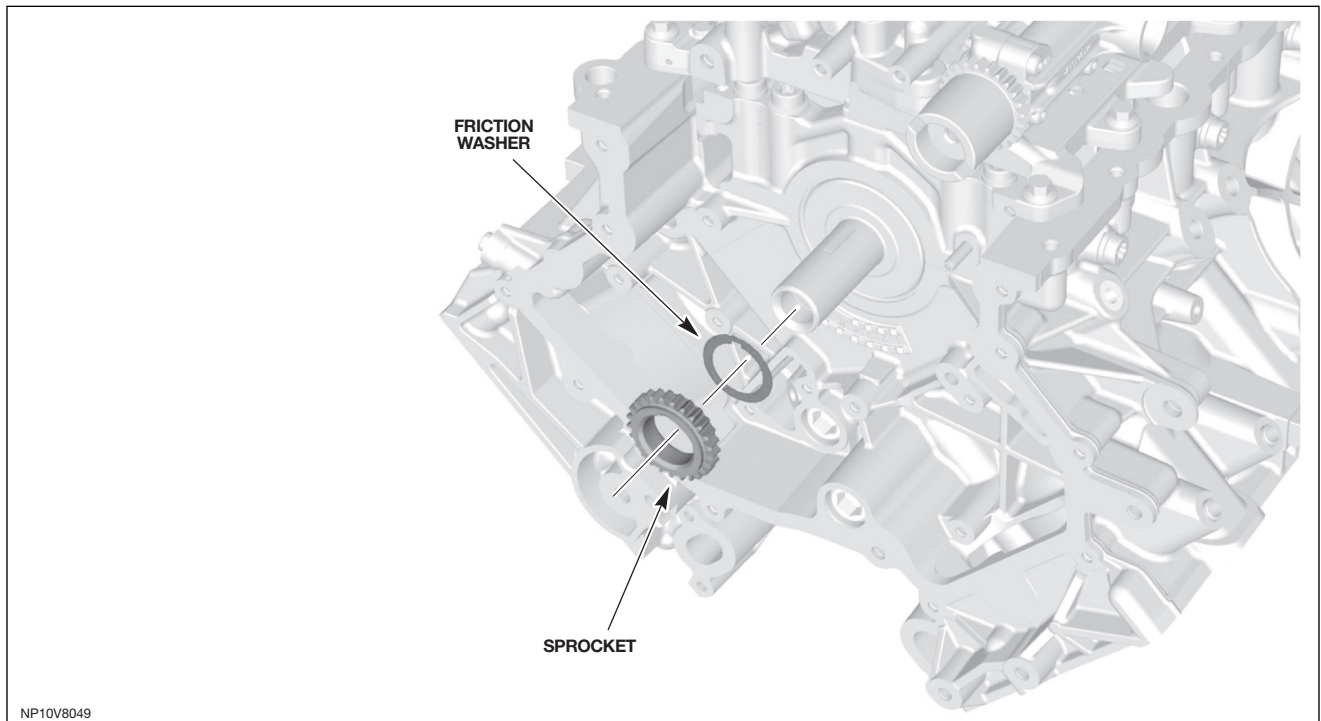
⚠ WARNING: Before any work is carried out on the high-pressure fuel system, the system must be depressurized. This is achieved by using IDS to disable the fuel pump and allowing the engine to run until it stops, while monitoring the fuel rail pressure using Datalogger to ensure that the fuel pressure has been depleted.

⚠ CAUTION: Great care must be taken when refitting the high-pressure pumps. The fuel pump fasteners **MUST** be tightened evenly. Failure to follow the set procedure will result in the mounting flange being stressed, which will lead to failure of the pump. Always use correct fasteners.

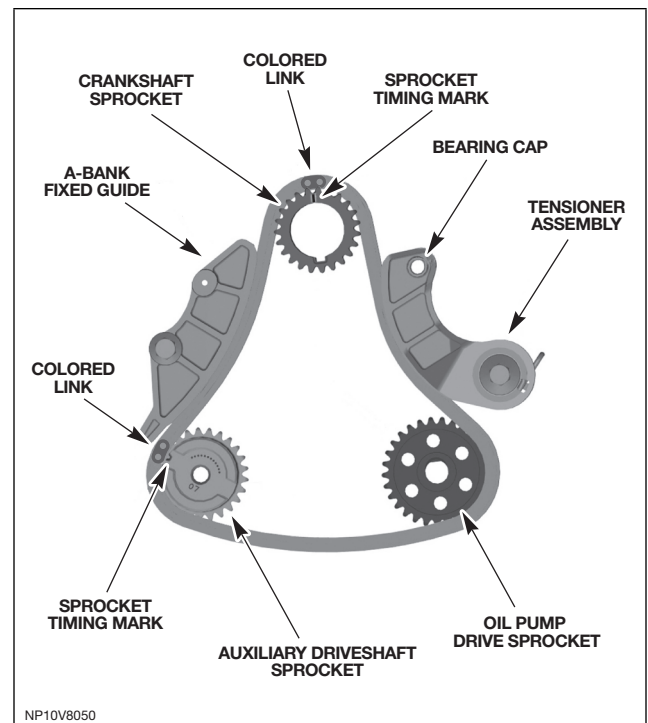
NOTE: The high-pressure pumps are noisy in operation. The noise is more pronounced when starting from cold – this is normal and does not require any action. To avoid unnecessary noise being transmitted, the pumps are equipped with covers, which must always be refitted correctly if removed.

Auxiliary Drive Chain Installation

The auxiliary shaft is timed for proper fuel pump operation. Failure to time the shaft properly will result in DTCs.



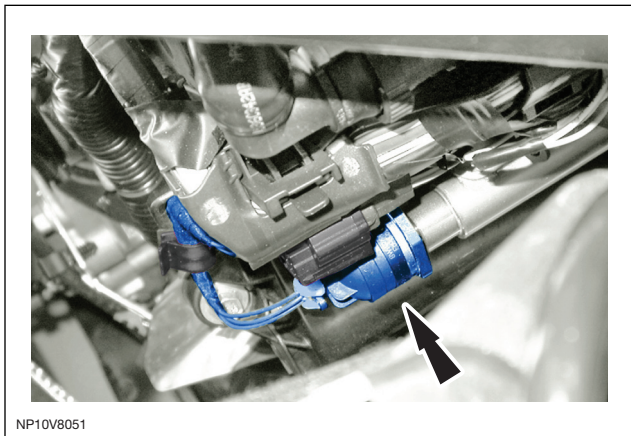
Align the auxiliary shaft to 45° ATDC using colored links and the timing tools.



Fuel Pressure Sensor (High Pressure Side)

The fuel rail high-pressure sensor is mounted in rear of the RH bank fuel rail and measures the fuel pressure in the fuel rail.

The pressure measurement is based on the expansion of a steel diaphragm, on which strain gauges in metal thin film technology are placed to form a Wheatstone bridge. The measured signal is proportional to the pressure and is processed in a custom-designed integrated circuit. This input is then used to deliver the correct quantity of fuel to the engine.



NP10V8051

Fuel Pressures (approx.)	
Start-up	Up to 150 bar (2176 psi)
Idle	30 bar (435 psi)
Maximum load	150 bar (2176 psi)

Specification	Function
Power Source	5V $\pm$ 0.25V
Response Time	< 2ms
Max Output Impedance	10 Ohms
Operating Range	0MPa – 20MPa
Pin 1	Ground
Pin 2	Signal
Pin 3	Power

⚠ WARNINGS:

- Do not remove the sensor while residual pressure is in the fuel rail.
- Always remove and clean away any fuel that has spilled onto engine components when working on the fuel system.
- Always wear prescribed personal safety equipment when working on the high-pressure system.

⚠ CAUTIONS:

- Fuel rail pressure sensors can be replaced (if failed) in service, but care must be taken to prevent dirt ingress.
- The high-pressure fuel lines must not be stressed if removed or replaced. The connecting unions must be lightly lubricated with engine oil when tightened and should not be forced. If resistance is felt, then new pipes must be fitted.
- If the fuel rails are removed, special tools must be used to align the fuel rail to injector when refitting. If this procedure is not carried out then the injector is subjected to excessive side-loading which can cause the injector seal to become overheated and burn. This will cause major damage to the cylinder head.
- DO NOT interchange injector spring clips, as this will have an impact on the loading force of the injector.

Failure Modes

- Operates on low pressure (fuel tank pump pressure), approximately 6.5 bar (94 psi)

Failure Symptoms

- Poor high-speed performance
- Default 3000rpm (limp-home)

NOTE: The high-pressure fuel system can only be diagnosed using Jaguar Land Rover approved diagnostic equipment.

Low-Pressure Fuel Pump

The engine has a returnless fuel system. The system pressure is maintained at a constant 4 bar (59 psi), with no reference to intake manifold pressure. The fuel is supplied to the high-pressure fuel pumps from a fuel pump fitted within the fuel tank.

The fuel system is pressurized as soon as the ECM is powered up; the pump is then switched off until engine start has been achieved.

Opening a vehicle door will cause the fuel pump relay to be activated for 3 – 5 seconds.

 **CAUTION:** When measuring fuel pressure, ensure that fuel is not sprayed onto hot components.

Failure Modes

- Relay drive open circuit
- Short circuit to vehicle supply or ground
- Component failure

Failure Symptoms

- Engine stalls or will not start
- No fuel pressure at high-pressure fuel pumps

Fuel Pump Driver Module

The fuel pump driver module (FPDM) receives a battery supply from the fuel pump relay. The relay is energized when a request is received from the ECM. Two wires connect the FPDM to the fuel pump motor and a ground through a body ground point.

The ECM outputs a pulse-width modulated (PWM) signal to the FPDM. The frequency of the signal determines the duty cycle of the FPDM, which subsequently controls the pump pressure output.

Engine Shutdown Under Vehicle Impact

The restraints control module communicates with the CJB via both a high speed CAN message and a dedicated PWM signal. These signals convey an Impact/No Impact status (an impact status is judged to require the deployment of airbags and pretensioners and to stop the engine).

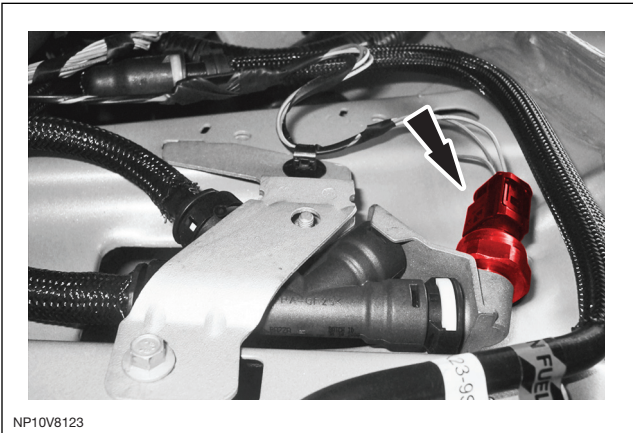
Should the CJB observe either of these signals at impact state, or if both signals are missing, the CJB will determine that an impact has occurred, and will immediately turn off the fuel pump relay. The ECM will log a 'Crash Input' DTC.

Fuel Pressure Sensor (Low Pressure Side)

The low-pressure sensor measures the fuel pressure in the fuel line from the in-tank fuel pump.

The measured signal is proportional to the pressure and is processed in a custom designed integrated circuit. This input is then used to deliver the correct quantity of fuel to the high-pressure fuel pumps. The sensor signal is used by the ECM as feedback for control of the fuel pump driver module, which in turn controls the electric fuel pump.

Fuel Pressure Sensor (X250 Shown)



Pin	Function
Pin 1	Ground
Pin 2	Output signal
Pin 3	5V reference

Safety Precautions

⚠ WARNING: Do not carry out any repairs to the fuel injection system with the engine running. The fuel pressure within the system can be as high as 150 bar (2176 psi). Failure to follow this instruction may result in personal injury.

⚠ CAUTIONS:

- Direct fuel injection equipment is manufactured to very precise tolerances and fine clearances. It is therefore essential that absolute cleanliness be observed when working with these components.
- Always carry out the cleaning process before carrying out any repairs to the fuel injection system components. Failure to follow this instruction may result in foreign matter ingress to the fuel injection system.
- Do not re-use the high-pressure fuel pipes under any circumstances if the fuel pumps have been disturbed.
- This engine uses high-pressure injection components. This will require care during service work on the high and low-pressure fuel circuits. Pay attention to cleanliness and tightening torques.

Preparation Before Starting Work

The work area must be clean, including the floor, hand tools and clothing. Ensure a dust-free environment. Bear in mind that the whole engine is built in a clean environment and when carrying out any repair work, common sense should be used as to the working conditions.

Any work on a dirty engine requires cleaning in the event of:

- Opening of the high-pressure circuits
- Removal of the cylinder heads

The use of high-pressure cleaning is prohibited. Protect the electrical components from any spillage. Clean each union to be opened and the parts using a suitable brush and approved degreasing agent. Use a vacuum machine to collect residue.

NOTE: Always refer to current workshop literature.

Instruction for Cleanliness During Removal

As soon as the high-pressure and low-pressure circuits are opened, plug the open pipes immediately using suitable plugs on the following parts:

- Pump supply pipe
- High-pressure pumps
- Fuel rails

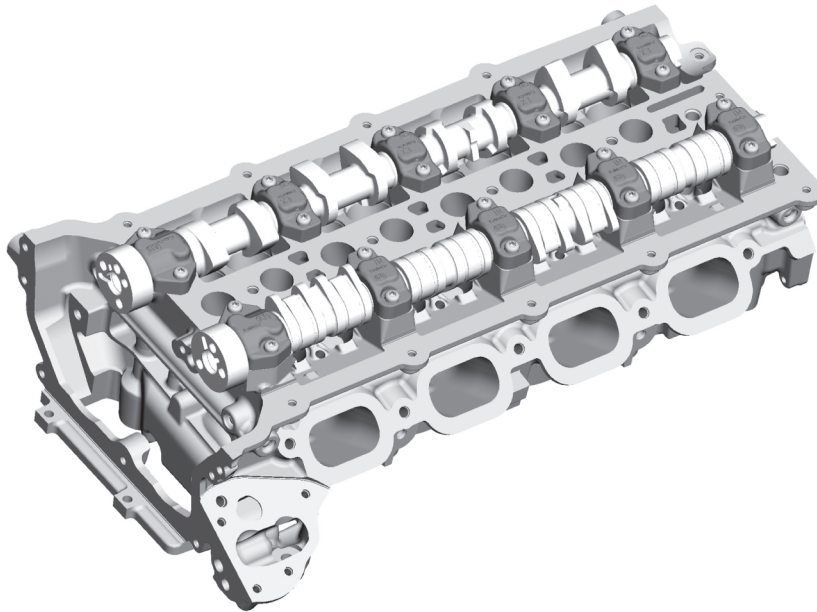
⚠ CAUTION: Dismantling the injectors for cleaning (even ultra-sonic cleaners) is not permitted.

⚠ WARNINGS:

- Do not begin work on the fuel system until it has been depressurized. This is achieved by using IDS to disable the fuel pump and allowing the engine to run until it stops, while monitoring the fuel rail pressure using Datalogger to ensure that the fuel pressure has been depleted.
- Do not smoke when working on the vehicle.
- Do not place your hands in the region of a suspected leak in the high-pressure fuel system.

CYLINDER HEADS

The cylinder heads are manufactured in cast aluminum alloy, and are unique for each cylinder bank. Deep-seated bolts reduce distortion and secure the cylinder heads to the cylinder block. Each cylinder head incorporates two overhead camshafts, operating four valves per cylinder. Graded tappets enable adjustment of valve clearances. The intake side incorporates hydraulic lash adjusters and Camshaft Profile Switching (CPS) for NA variants.



NP10V8052

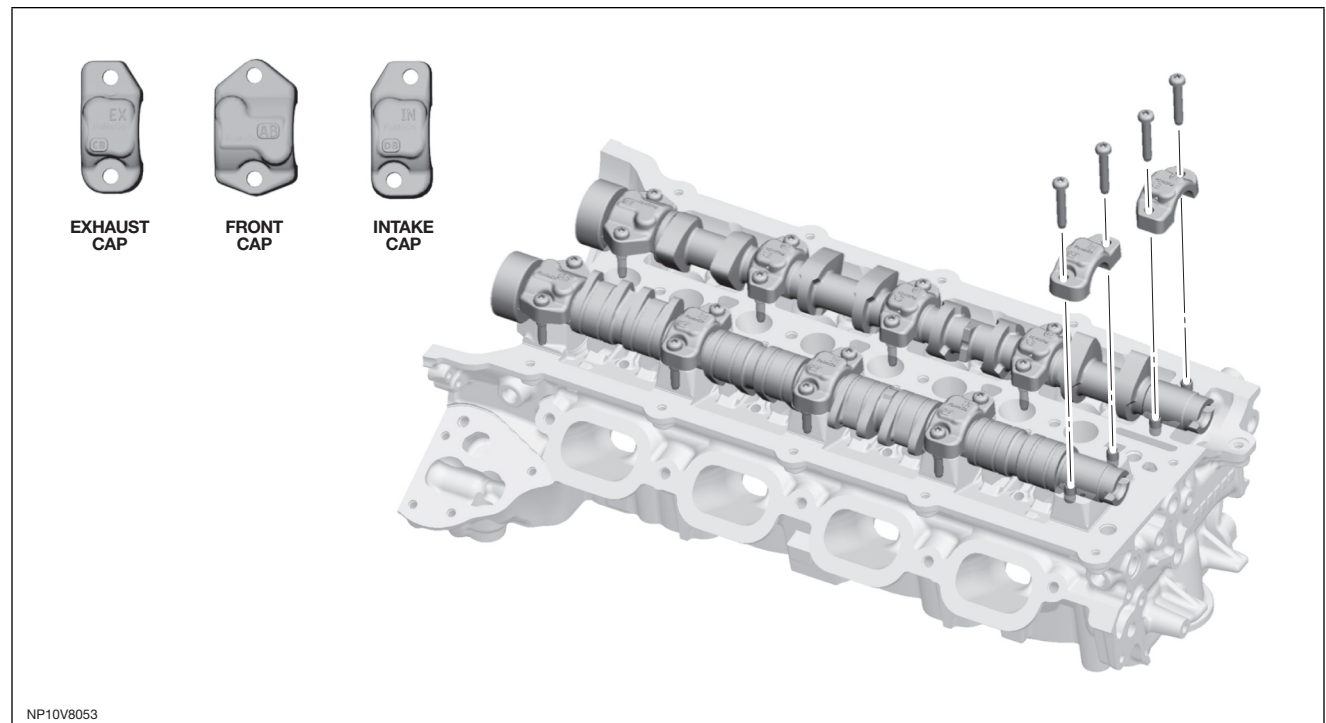
The lightweight valve gear provides good economy and noise levels and is chain-driven, via the crankshaft, for durability.

The design incorporates many refinements to help reduce maintenance and improve engine operation.

Each cylinder is served by four valves. Fuel is supplied to the combustion chamber via a centrally-mounted injector.

The cylinder head gasket is a multi-layer steel construction with excellent service life and sealing properties.

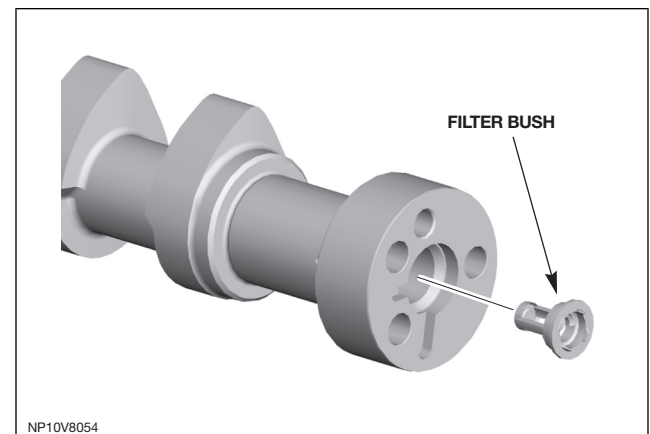
Camshaft Installation (RH Bank shown; LH Bank similar)



The camshaft caps must be maintained in their correct positions and orientation as marked on their outer faces, intake 0 – 4 from front, exhaust 5 – 9 from front. Ensure that the camshaft caps are marked prior to removal from cylinder head.

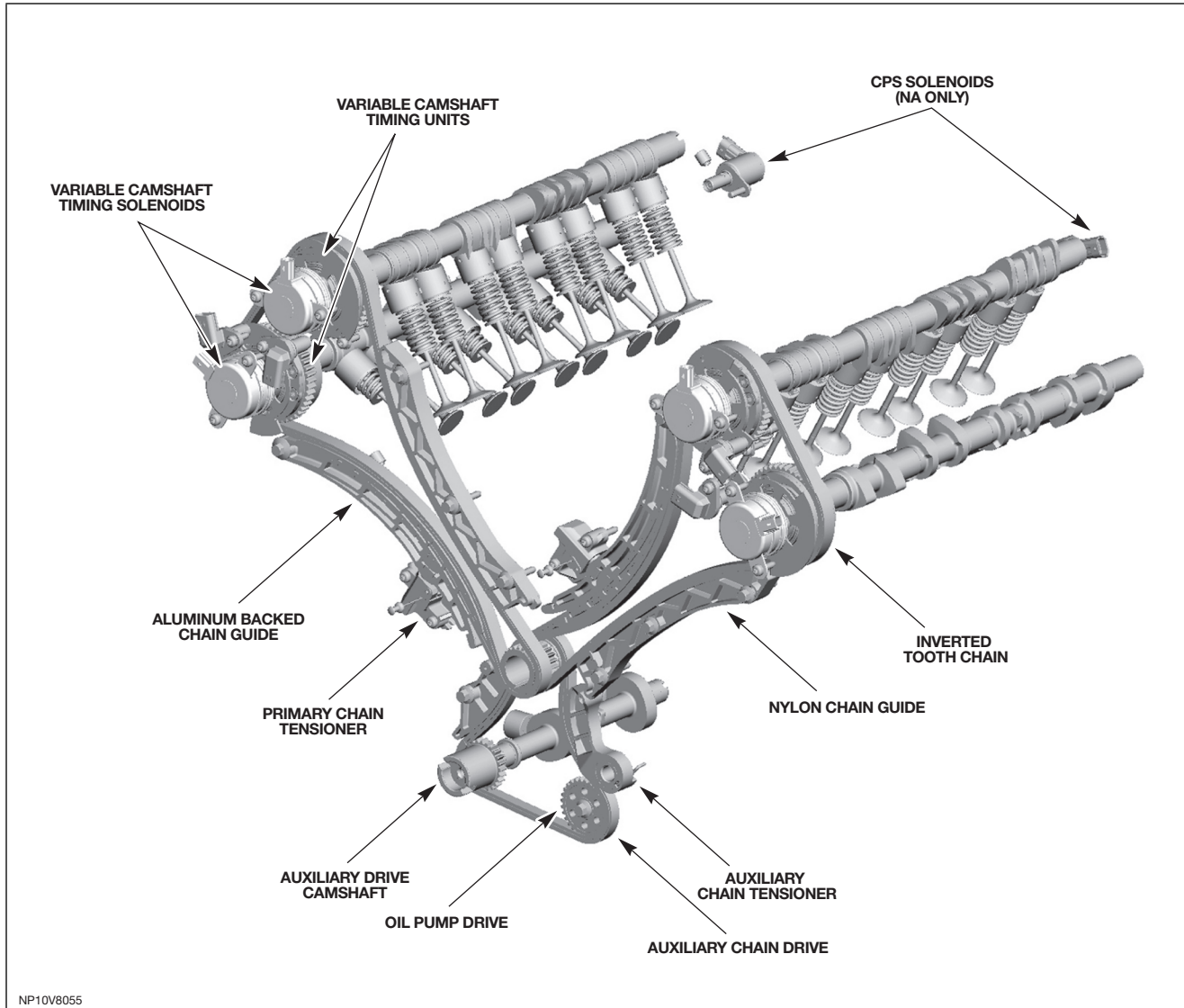
Camshaft End-Float	0.08 to 0.18mm
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Ensure that the filter bush is present in camshaft prior to assembly.



Valve Train

Twin overhead camshafts operate the engine's valves. A maintenance-free highly durable chain transfers drive from the crankshaft to the camshafts, via the variable camshaft timing (VCT) units. The oil pump is driven at 0.87 engine speed by a separate chain, also from the front of the crankshaft, for reduced friction.

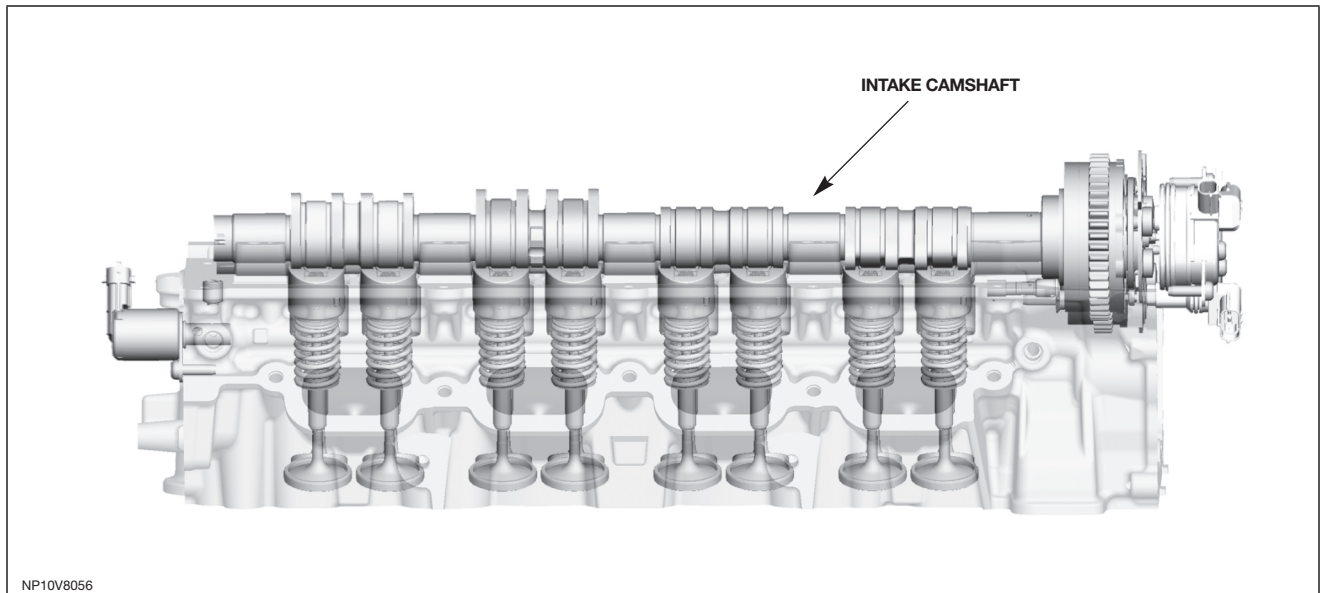


Each camshaft chain has a spring-assisted hydraulic tensioner operated by engine oil pressure. The chain tensioners also incorporate a ratchet mechanism to eliminate start-up noise. The chains are lubricated via oil squirt tubes located at the front of the engine block. Nylon chain guides control chain motion on the drive side.

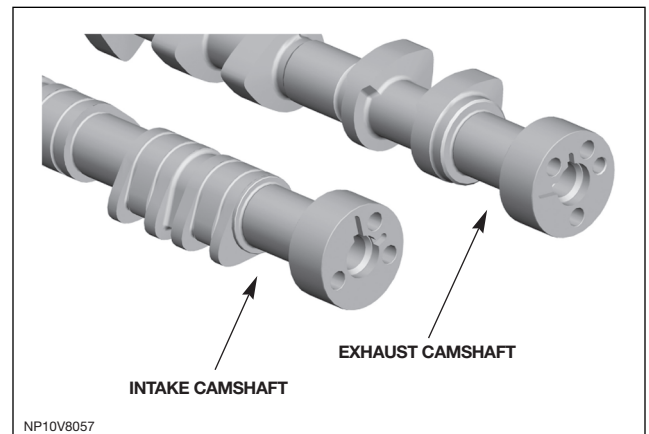
CAMSHAFT PROFILE SWITCHING

Overview

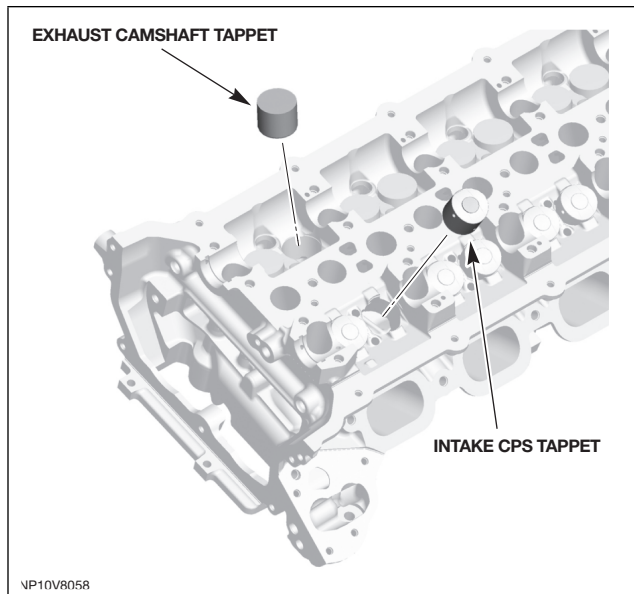
The Camshaft Profile Switching (CPS) system for the NA engine features two completely different intake camshaft profiles machined onto the same camshaft. The engine management system determines which camshaft profile to use, depending on the engine's running conditions and driver's torque demands. One profile is ideal for low-speed/low-load driving; the other, which gives higher valve lift, is better for higher speeds and loads. A two-piece hydraulic tappet arrangement alters the camshaft profiles.



The intake camshaft features three lobes per valve with two different profiles, one centrally located for low valve lifting height and two outer lobes for high valve lift. These are used by the CPS system to adjust the lift of the intake valves from 5.5mm to 10.53mm. Profile switching depends on the instantaneous engine running conditions and the driver's torque demands. The exhaust camshaft is a conventional design featuring a single lobe per valve, giving a set 9.36mm valve lifting height.

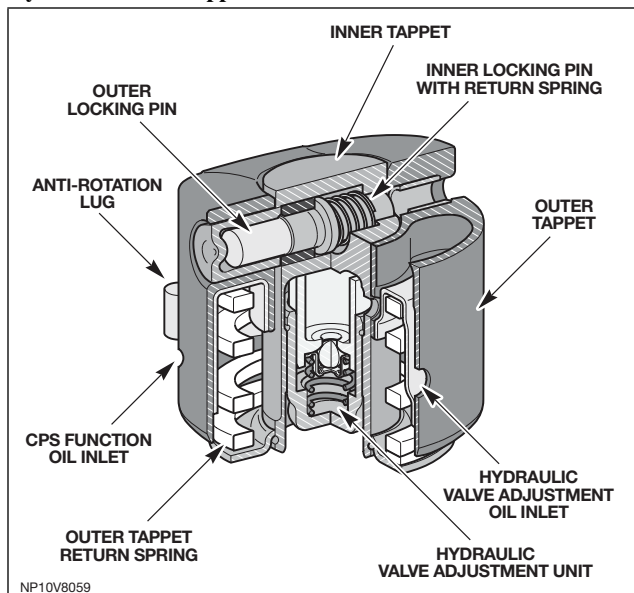


The tappets for the intake and exhaust camshafts differ from each other in their design and function. The exhaust tappets are mechanical with an adjustable valve clearance that is set using graded tappets. The intake camshaft tappets are hydraulic, which compensates for any wear – therefore the valve clearance is 0.



The intake tappets also feature a two-piece design which allows switching between the two intake valve lifting heights using an internal tappet locking mechanism.

Hydraulic Intake Tappet



CPS Operation

Varying the point at which the intake valve opens relative to the point at which the exhaust valve closes can yield a number of benefits. A high level of overlap (during which the exhaust and intake valves are both open simultaneously) encourages good cylinder charging at high engine loads as the incoming rush of air purges the cylinder of any residual exhaust gas.

While high overlap is good at high engine loads, the minimal cylinder charge and high intake vacuum at very low loads can lead to poor and unpredictable cylinder charging, as exhaust back-pressure means the cylinder will find it much easier to charge from the exhaust manifold than the intake system. This causes combustion instability, which manifests itself as uneven idle and hesitation under very light load conditions.

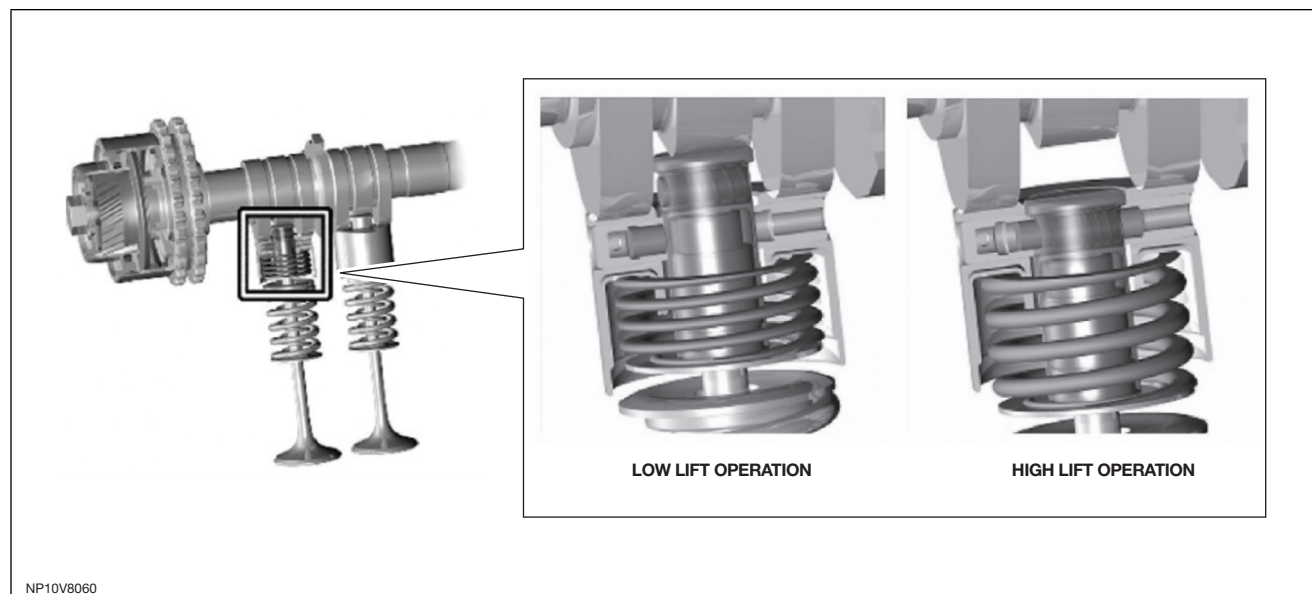
At moderate loads, overlap is beneficial, though for different reasons. Although the lower gas velocity eliminates any tendency for the incoming rush of charge air to purge the cylinder, the modest charge volumes and reduced manifold depression mean that a small volume of exhaust gas is drawn back into the cylinder. However, higher intake gas speeds ensure good mixing of this exhaust gas with the fresh charge, so combustion stability is not jeopardized.

This effect, known as internal exhaust gas recirculation (EGR), actually improves both the volumetric efficiency of the engine by reducing the work the engine has to do pumping a fresh air charge into the cylinder as well as its part-load emissions performance because the exhaust gas is inert, and does not interfere with the combustion process.

This conflict between low load stability and high power output means engines with fixed valve timing must operate compromised valve timing. This compromise attempts to balance the need for smooth and refined idle performance (demanding little or no overlap) with good high speed power and torque output (requiring significant overlap).

The new 5.0-liter V8 engine overcomes the need for compromise in two ways:

- The intake and exhaust camshafts are equipped with a continuous Variable Camshaft Timing (VCT) mechanism. The point at which the intake valve begins to open can be altered by up to 62° of crank rotation. The point at which the exhaust valve begins to open can be altered by up to 50° of crank rotation.
- Using the CPS system, the engine can choose between two completely different camshaft profiles that vary not only valve lift (between 5.5 and 10.53mm), but also the overall opening period of the intake valve over a range of approximately 175° to 310°. This capability provides exceptional control over intake valve operation and yields significant benefits in both engine response and fuel efficiency.



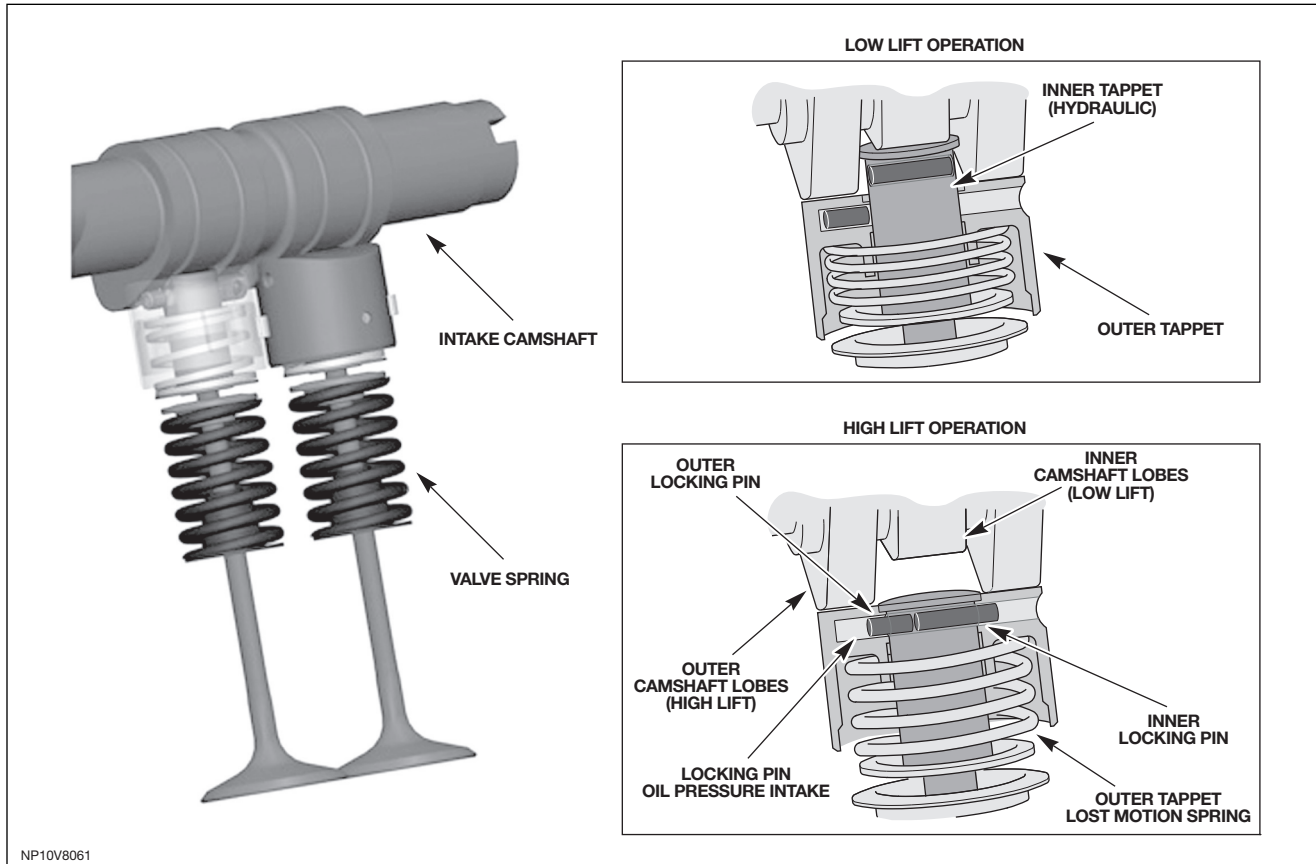
The CPS system controls the lifting height of the intake valves. At engine speeds from idle up to the range of 2,800 – 4,825 rpm (load dependent), the intake valves have a lifting height of 5.5mm. At speeds and loads outside of this range, the high lift cam (10.53mm) is used.

Lifting Height	Valve Opens	Valve Closes
Intake – 5.5 mm lifting height	27° BTDC to 35° ATDC	187° ATDC to 249° ATDC
Intake – 10.53 mm lifting height	37° BTDC to 25° ATDC	213° ATDC to 275° ATDC
Exhaust – 9.36 mm lifting height	244° BTDC or 194° BTDC	6° ATDC to 56° ATDC

NOTE: BTDC = Before Top Dead Center; ATDC = After Top Dead Center

When the CPS system is used in combination with the VCT function it is possible to control the cylinders' incoming air quantity in such a way as to optimize cylinder filling and apply the throttle as normal. The use of CPS and VCT allows larger than usual throttle openings during warm-up to gain heat from the exhaust and, hence, catalyst light-off.

At low engine speeds from idle up to the range of 2,800 – 4,825 rpm (load dependent), the center and outer sections of the tappet are not linked. Only the centrally located lobe on the camshaft acting on the center section of the tappet opens the valve. The outer camshaft lobes act on the outer section of the tappet, compressing the return spring ensuring the tappet is always in contact with the camshaft, but none of this movement is transferred to the valve, giving a valve lift height of only 5.5mm.



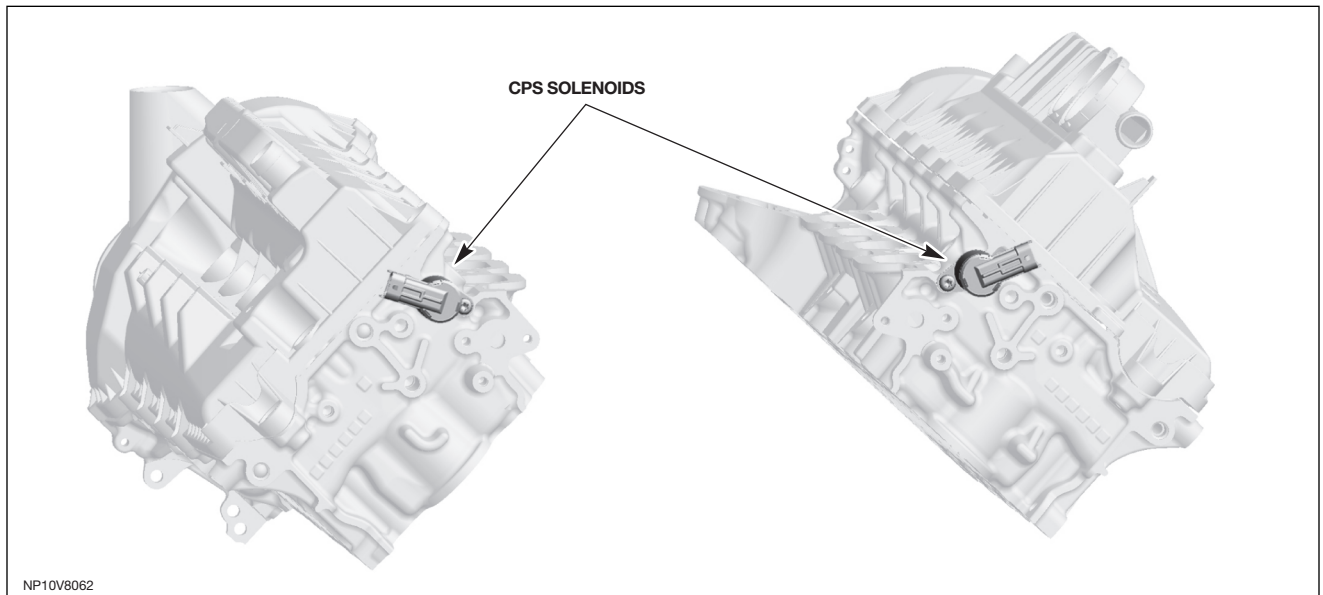
At engine speeds and loads outside of this range, the center and the outer sections of the tappet are joined by two hydraulically-controlled locking pins. The tappet has an anti-rotation lug to maintain alignment of the oil passages. The movement of the outer camshaft lobes is now transferred from the outer tappet section through the locking pins to the center tappet section, giving a valve lift of 10.53mm.

NOTE: Switching of all intake valves occurs within one complete camshaft revolution only when each tappet is in contact with the base circle of the camshaft lobes and the valves are closed.

To ensure that the switch from low lift (5.5 mm) to high lift (10.53 mm) is seamless, the switching speed is load-dependent to ensure that the volumetric efficiency of the engine is the same for low and high lift. Switching is only enabled at oil temperature above 20°C (calculated internally in the ECM). An engine speed limit of 5000 rpm is imposed in low lift (e.g., at oil temperatures below 20°C).

Camshaft Profile Switching Solenoids

The two CPS solenoids are located at each end of the cylinder head, adjacent to the intake camshaft.

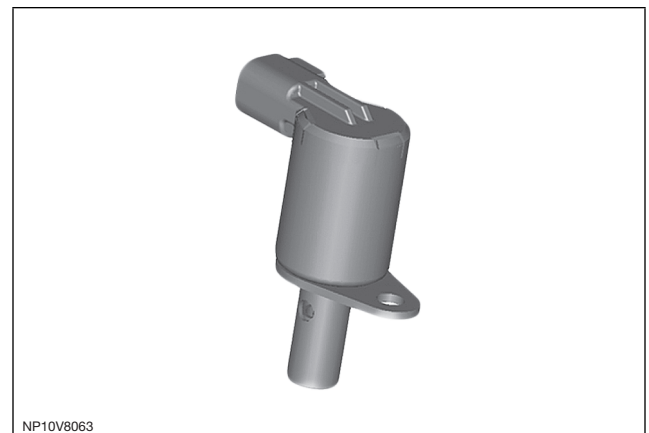


The CPS solenoids control the supply of oil pressure to the hydraulic tappet locking pins, allowing the camshaft profile to be changed to adjust the intake valve lifting height from 5.5 mm to 10.53mm.

The CPS solenoids receive a fused battery supply from the main relay. The ECM provides a ground for the solenoid, which actuates a valve within the solenoid allowing oil pressure to adjust the camshaft profile.

The ECM can diagnose the operation of the CPS solenoids and store fault related codes.

NOTE: If the CPS solenoids fail, high valve lift is disabled.

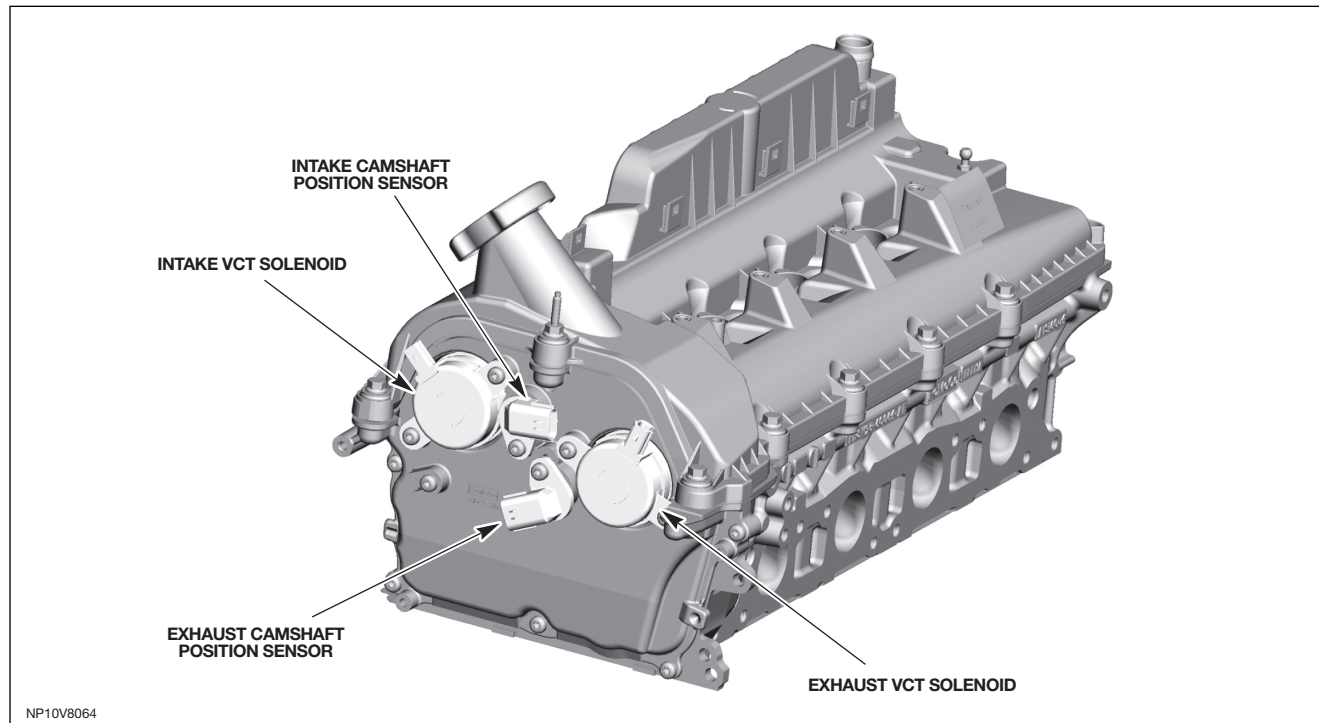


Specification	Function
Operating voltage	10.5 to 15V (normal: 13.5 ± 0.5V)
Supply current	0.8 to 1.85A
Functionality	On/Off
Resistance	8.5 ohms ± 0.5 ohms
Movement of magnetic valve	2mm

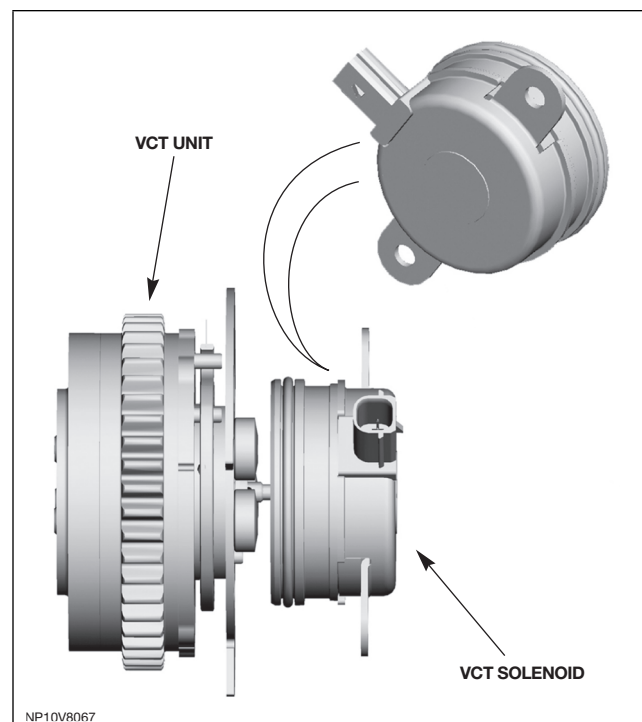
VARIABLE CAMSHAFT TIMING

Overview

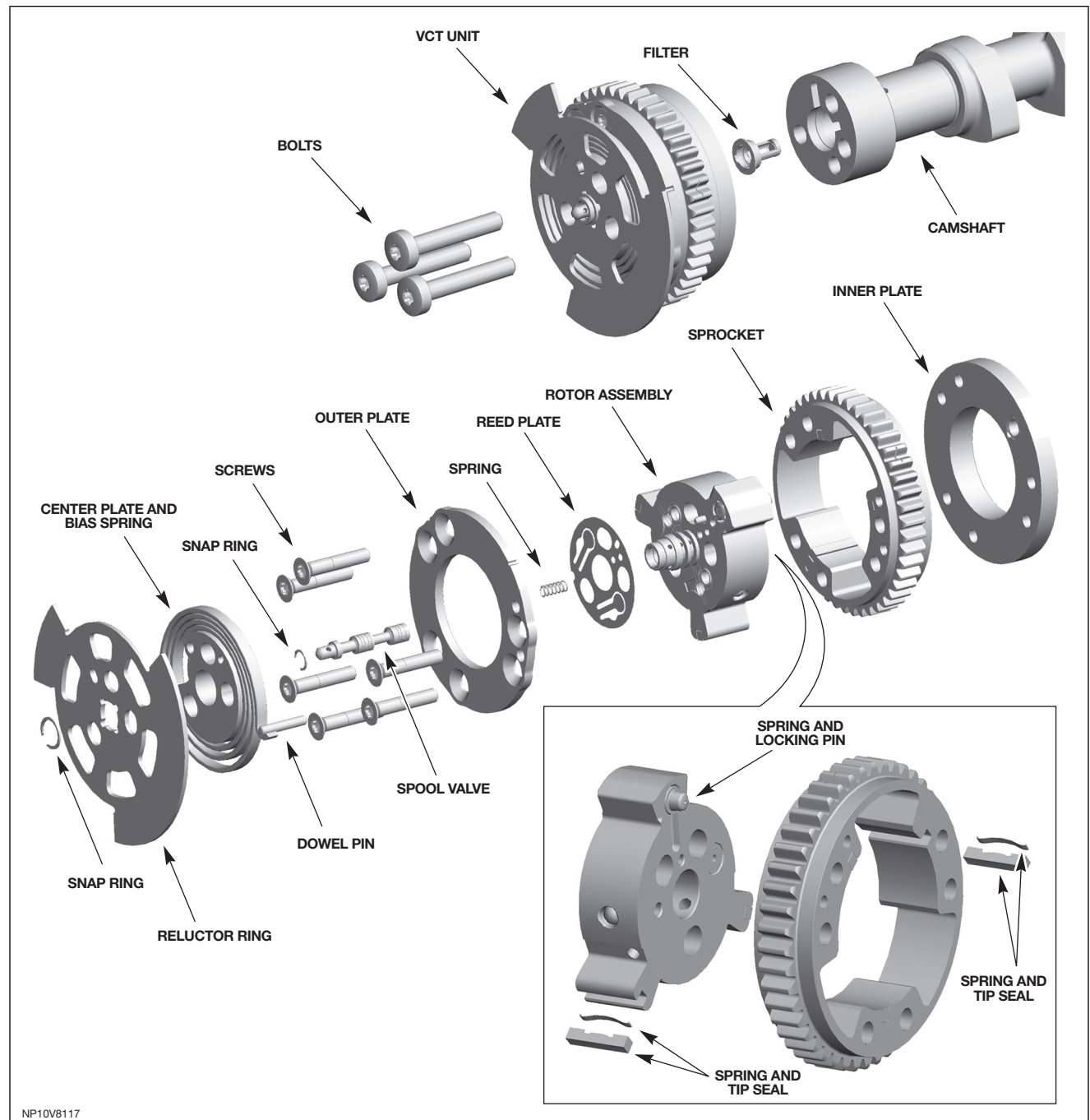
The camshaft torque-actuated, dual independent Variable Camshaft Timing (VCT) system constantly controls camshaft timing to deliver optimum power, efficiency, and emissions. With dual independent camshaft phasing, the intake and exhaust camshafts can be phased independently of each other.



The chain-driven camshaft timing units are mounted on the end of each camshaft, and advance or retard the camshaft timing to thereby alter the camshaft-to-crankshaft phasing. The control solenoids act on hydraulic control valves within each VCT unit to control angular position using camshaft torsional energy to alter the phase. This provides the most flexible method of camshaft phasing, allowing the overlap of exhaust valve closure and intake valve opening to be varied.



Variable Camshaft Timing Unit – Exploded View



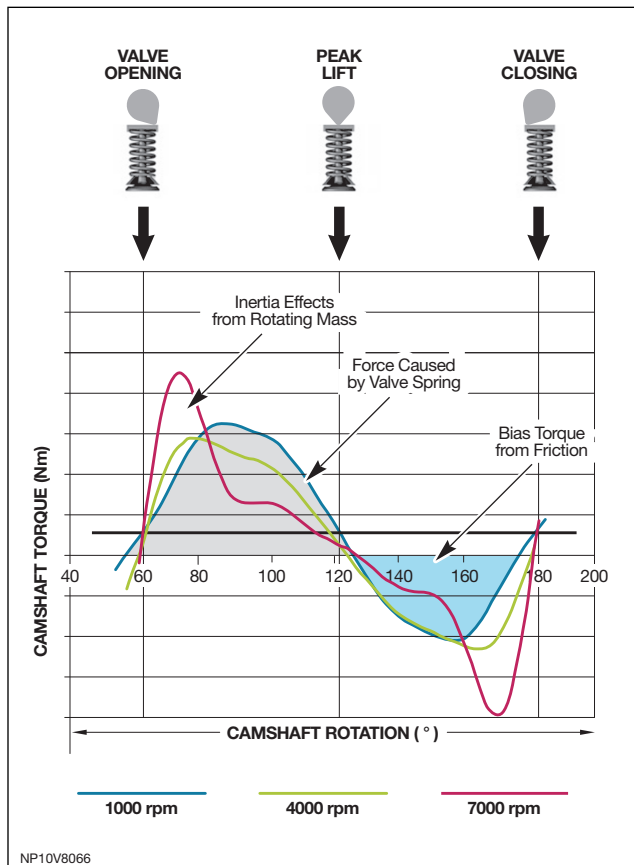
NP10V8117

CAUTION: Do not reuse the VCT units if they have been subjected to an impact (such as being dropped on the floor).

Camshaft torque-actuated VCT technology uses camshaft torsional energy generated by the camshaft lobes acting against the valve springs and inertia of the valve train components to phase the camshafts, rather than using oil pressure generated by the oil pump. Angular phasing is achieved by the internal transfer of oil between the chambers of the phaser, via check valves, controlled by a hydraulic control valve – in essence a controlled hydraulic ratchet device. As a result, camshaft torque-actuated VCT technology has a much lower oil demand than that of oil-pressure actuated VCT units (approximately 15%). The reduction in oil demand allows the engine oil pump capacity to be reduced, resulting in fuel economy benefits.

As camshaft torque-actuated VCT technology is not reliant on engine oil pressure to phase the camshafts, response rates at low engine speeds and high temperatures – where engine oil pressure is typically low – is significantly improved. This translates to improved transient performance and response (performance feel).

Camshaft Torsional Energy (for a Single Valve Event)



VCT Operation

The required position of each camshaft is controlled in closed-loop from the ECM, by actuation of a variable force solenoid against the VCT hydraulic control valve at the front of each unit, with reference to signals from the four camshaft position (CMP) sensors and the crankshaft position (CKP) sensor.

The VCT solenoid force is controlled with a pulse width modulated (PWM) duty cycle at battery voltage. When the VCT solenoid is not energized, the phaser pintle is fully extracted (via spring force), locking the camshaft in the base timing position.

The intake camshafts will be in full retard and the exhaust camshafts will be in full advance. Under operation, the intake camshafts can advance 62° crankshaft angle; the exhaust camshafts can retard 50° crankshaft angle.

To hold the camshafts in any other position other than the base timing lock position, the ECM partially energizes the solenoids – holding them in the ‘null’ position. To retard the intake camshafts, the opposite is true, where the VCT solenoid is powered with a lower duty cycle and then returns to the null position once the target angle is reached.

The exhaust camshafts operate in the opposite manner to the intake camshafts, where the solenoid is energized to retard the exhaust camshafts and underpowered to advance the camshafts.

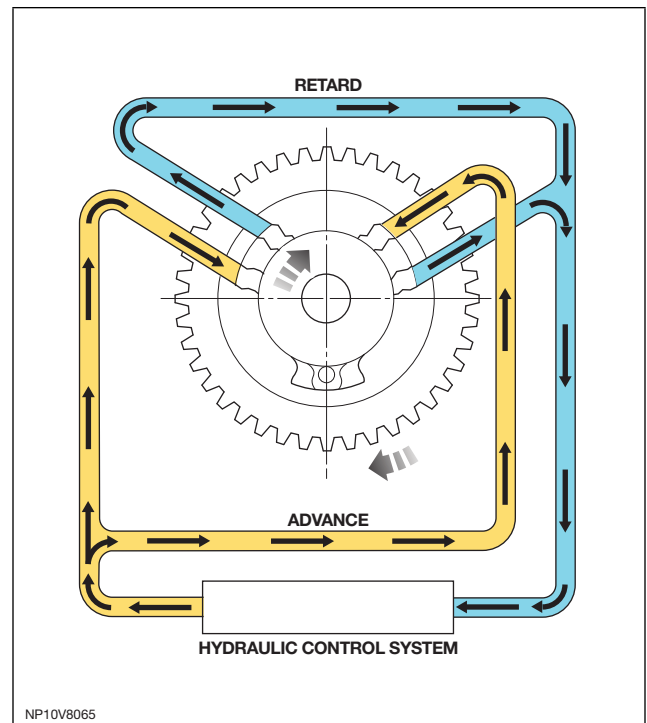
The control from the 'null' position is exponential, whereby the camshafts will advance or retard at a faster rate with a duty cycle displacing the pintle further from the 'null' position.

The major components within the system are:

- A single-source oil feed via a camshaft bearing through the camshaft to the VCT
- An inlet check valve to the VCT
- A common passage that always communicates with the center of the control valve and leads to the high-pressure check valves for the advance and retard hydraulic chambers
- A control valve that is used to control the direction and rate of oil flow from one hydraulic chamber to another and a mechanical spring loaded locking pin that is released on command by hydraulic oil pressure

The oil supplied to the VCT is necessary to fill the VCT initially and then supply a continuous amount of oil to replenish any oil that leaks back from the VCT.

Oil Recirculation



NOTE: By supplying source oil to both chambers via a common passage the force, due to oil pressure, is balanced on opposing sides of the vane. Therefore oil pressure does not cause the rotor to move relative to the housing.

After the initial filling the VCT is ready to actuate and control.

The first function of the control valve as it moves to the right is to selectively apply source oil pressure to the locking pin on command. In this control valve position, the locking pin has been commanded to release but the control valve has not reached the position where the VCT is being commanded to move yet. Therefore no force bias is applied to the VCT before releasing the locking pin.

Camshaft Advance

The camshaft torque-actuated VCT uses the camshaft torque energy to move while recirculating the oil within the VCT from one chamber to the other chamber. The control valve will continue to move to the right and open an exhaust port from the retard chamber to the common passage. During each valve-closing event, when negative camshaft torques are generated, the oil in the retard chamber is pressurized. By opening the exhaust port during valve closing events, oil is allowed to flow from the retard chamber, through the common passage past the advance chamber check valve, to the advance chamber via. The VCT advances an incremental amount with each valve-closing event. During valve-opening events, the advance chamber will be pressurized but no flow will occur because the advance chamber check valve is closed while the control valve has the advance chamber exhaust port blocked.

As a result, with each valve-closing event, oil from the retard chamber flows to the advance chamber, causing the VCT to advance. During the valve opening events when the camshaft torque is positive, the VCT holds position.

The control valve not only controls the direction of flow but also controls the rate of flow from one chamber to the other chamber by means of a variable size opening at the exhaust port.

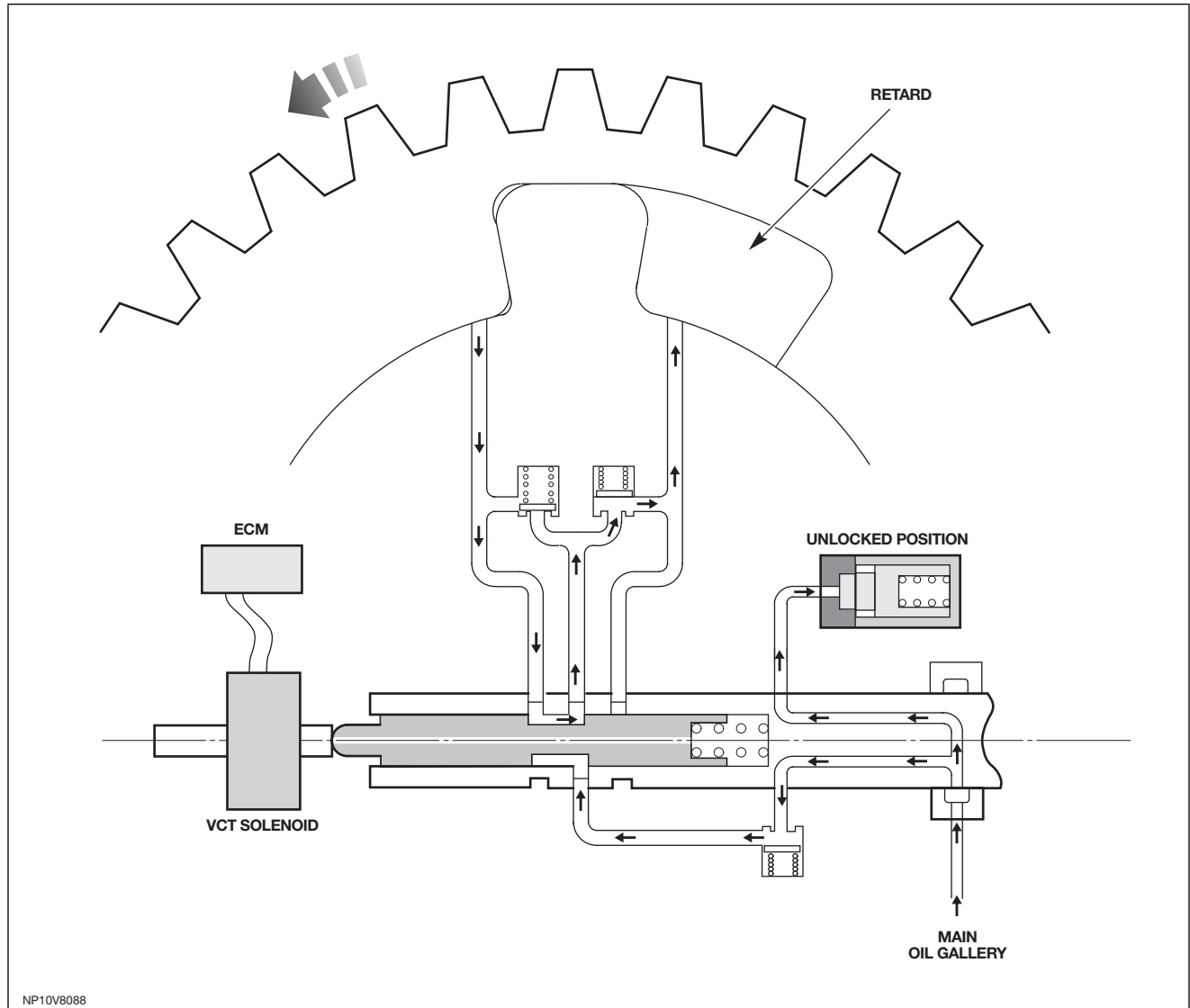
NOTE: When VCT reaches the advance stop, the control valve returns to the null or centered position.

Camshaft Retard

The VCT retards during valve-opening events by moving the control to the left and opening the exhaust port from the advance chamber. The VCT moves to retard with each valve-closing event and holds position during the valve-opening events. Since this VCT is operated under closed loop control motion, the VCT can be stopped at any moment and in any position by returning the control valve to the centered or null position. Even though there is pressure in both chambers from the positive and negative camshaft torque energy, the VCT is not moving because all exhaust ports from the hydraulic chambers are blocked by the high-pressure check valves and the centered control valve.

When the VCT is commanded to move to the fully retarded position, the control valve moves to the left. At the end of the VCT travel, the mechanical locking pin will align with its receiver and engage. The locking pin is allowed to engage because the control valve, when in the extreme left position, simultaneously blocks source oil pressure from reaching the locking pin and opens a vent to allow the oil in the locking pin passage to vent.

This is the default position for the VCT, which can occur by command, or can occur as a failsafe mode if power to the VCT control system is lost. This event can occur in less than 300ms from any phase position and at any engine speed.



The VCT solenoid is powered directly from V battery (Pin 2) through the ECM controlled relay, with a low side driver in the ECM connected to Pin 1 on the VCT solenoid.

Safety Precautions

⚠ WARNING: The VCT solenoids are heat generators, and can reach high temperatures.

Failure Modes

- VCT Solenoid Stuck
- VCT Phaser Stuck

Failure Symptoms

- No VCT Control

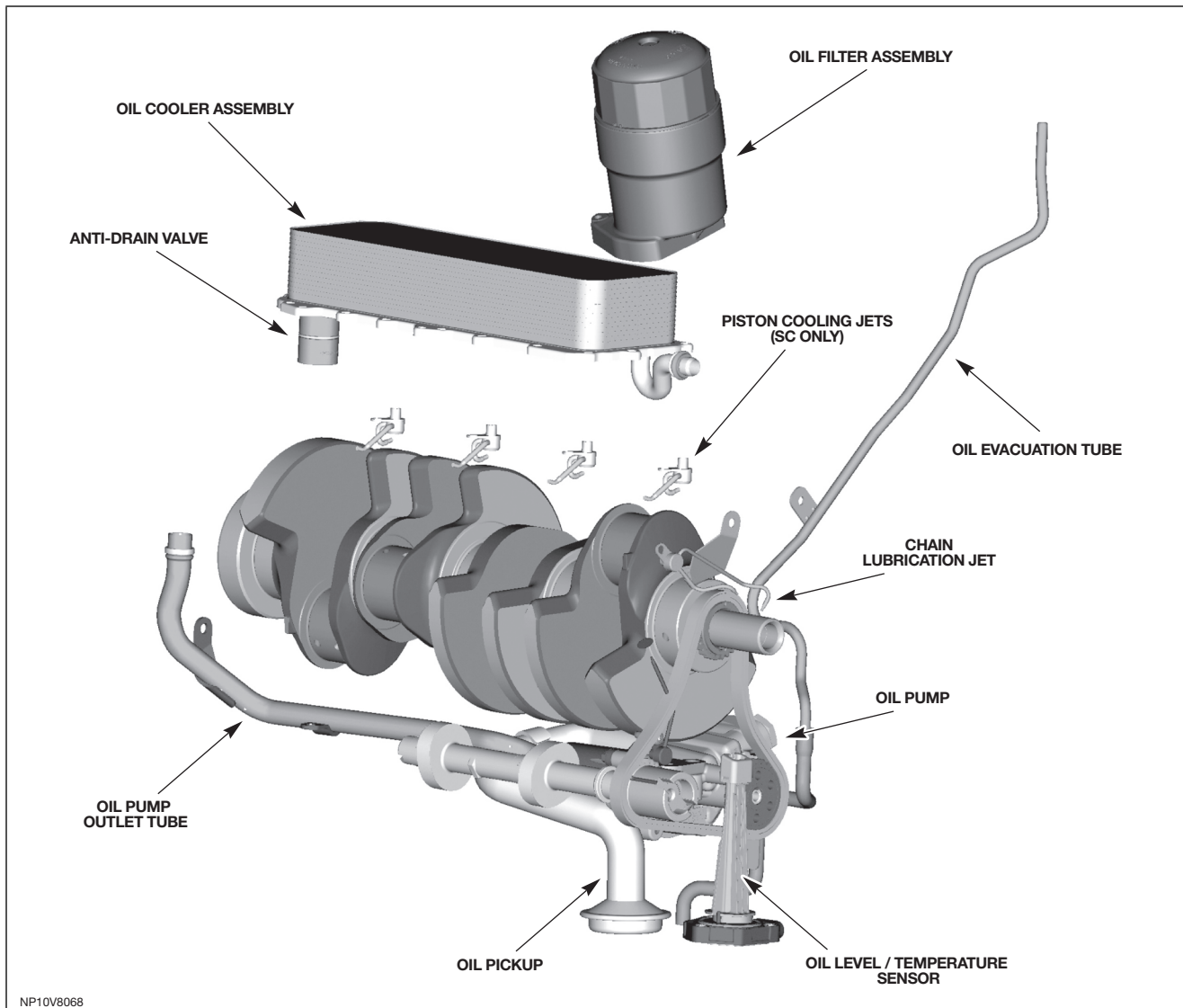
LUBRICATION SYSTEM

Overview

Castrol SLX A1 5W-20 is a dedicated engine oil that has been co-engineered with JLR. Its low viscosity and advanced additive package help to reduce engine friction and maintain engine cleanliness.

By running a cleaner, more efficient engine, the cost of ownership can be reduced and a saving on fuel can be made. With this improved efficiency the service intervals have moved to 15,000 miles / 12 months.

The oil pump is driven from the front of the crankshaft by the auxiliary chain. It draws oil from the aluminum sump via a centrally mounted pick-up. The oil pressure is regulated using gallery pressure feedback. Oil is then cooled by a plate-type oil-to-water cooler before being filtered by a replaceable element, accessible from the top of the engine.



The oil cooler is designed to ensure good control of engine oil temperature under all operating conditions. Cooled oil is distributed through a series of internal galleries to the engine's critical bearing surfaces before draining back into the sump.

Synthetic oil is specified; this is more resistant to temperature-related degradation than conventional mineral oil. It also has lower viscosity at low temperatures and improved lubrication performance at higher temperatures.

The specification of SLX Professional A1 5W-20 synthetic oil is an important part of new engine's oil change strategy as it permits longer oil-change intervals than conventional lubricants.

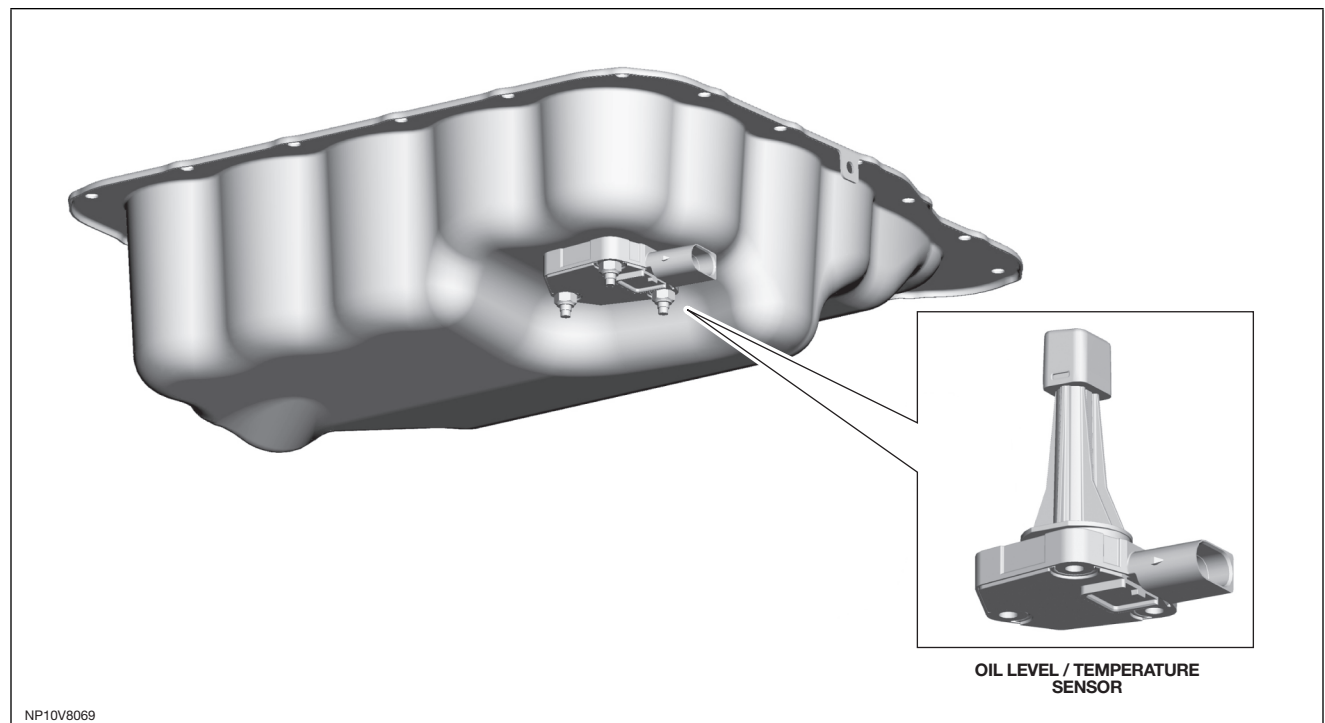
Oil Level / Temperature Sensor

The new ultrasonic sensor, a first for JLR, provides an electronic indication as to when the oil in the engines sump is low or high. This allows for the deletion of the mechanical dipstick.

The sensor maps the fill level of the oil continually during trips. An advantage in comparison with the static 'dipstick' method is that all marginal influences are compensated for by averaging. Marginal influences include the vehicle being on a slope, the oil flowing back at the end of a journey, lateral and longitudinal acceleration, or even dipstick tolerances.

The values determined can be used to signal that the minimum oil level has been reached or to display the current oil level if required.

NOTE: Jaguar Sump Shown



The continuous-mode sensor measures engine oil level and temperature. The oil level and oil temperature readings are taken and turned into a pulse-width modulated output signal.

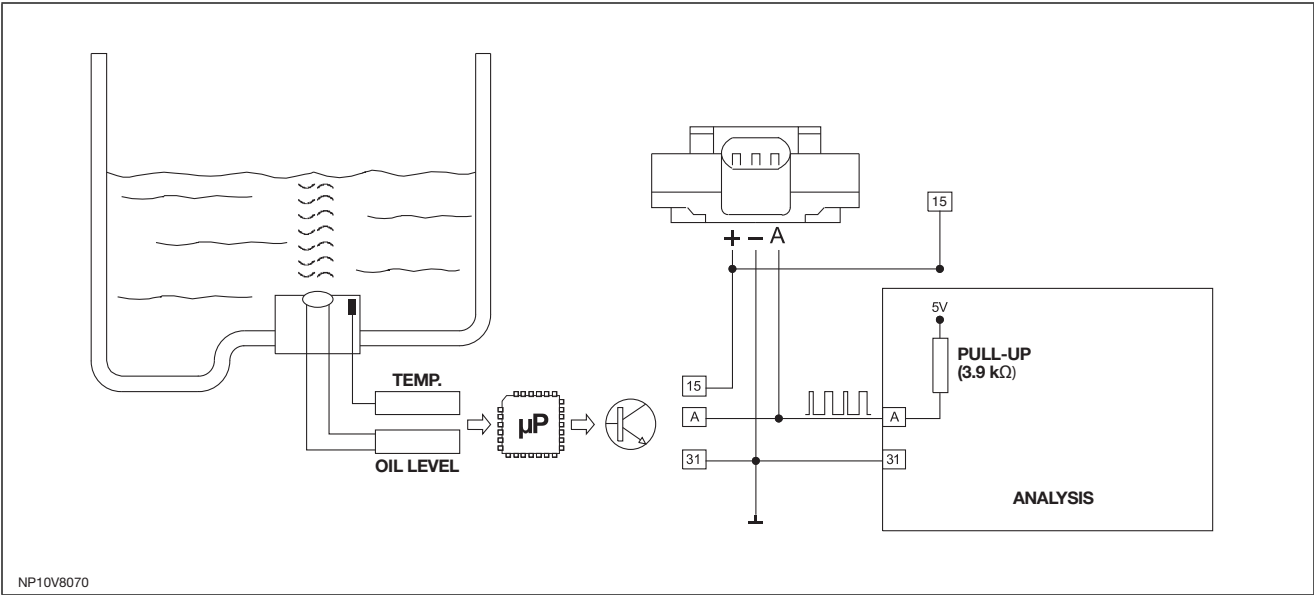
The measuring system consists of a flange, connector, electronic circuitry and the temperature and oil level sensor. Oil level metering is determined by the oil-to-air interface layer.

The oil level sensor has the following technical properties:

- Linear measuring range
- Continuous measuring under static and dynamic conditions
- Temperature signal and oil level signal 0.3s after switch-on
- Measuring frequency > 10 Hz
- Customer-specific output signal
- Installs at bottom of oil sump
- Temperature measuring

The sensor is mounted to the underside of the sump, from where it sends an ultrasonic pulse vertically upward (engine position). It then measures the time for the pulse to be reflected back from the top surface of the oil.

It compares this time period with a time period of a second pulse which travels within the sensor across a reference distance. With both time periods it can calculate the oil height from the sensor flange, negating the noise factors which affect the speed of the pulse through the oil.



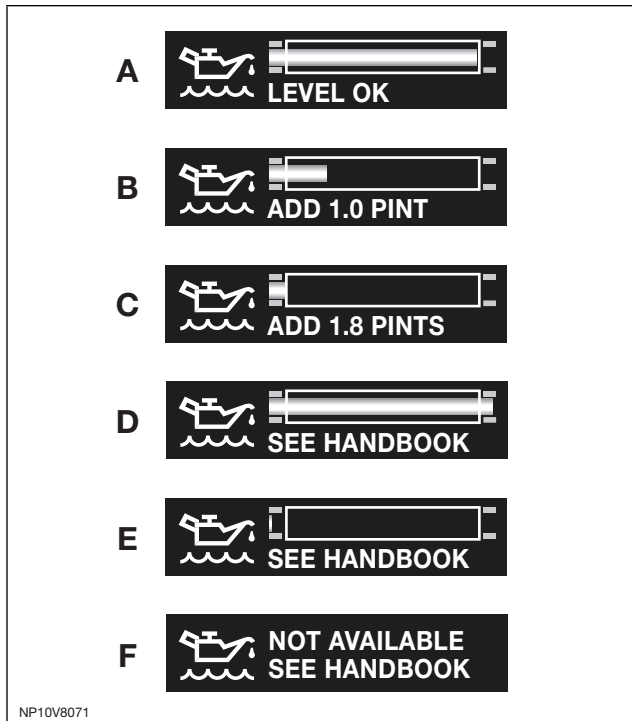
Specification	Function
Power source	Battery voltage
Level Accuracy	±2mm (±4mm < -30°C)
Temperature Accuracy	±2°C (35°F)
Operating Level Range	18mm – 116mm (Dynamic) 116mm – 147mm (Static)
Operating Temp. Range	-40°C – 160°C (-40°F – 320°F)
Pin 1	Power Supply
Pin 2	Ground
Pin 3	Output Signal

Oil Pressures

Engine Speed	Temperature	Pressure
Idle	20°C (68°F)	2 bar (29 psi)
1500 rpm	20°C (68°F)	6 bar (87 psi)
3000 rpm	40°C (104°F)	6.2 bar (90 psi)
3000 rpm	110°C (230°F)	5 bar (72.5 psi)
3000 rpm	130°C (266°F)	4 bar (58 psi)

Oil Level Check

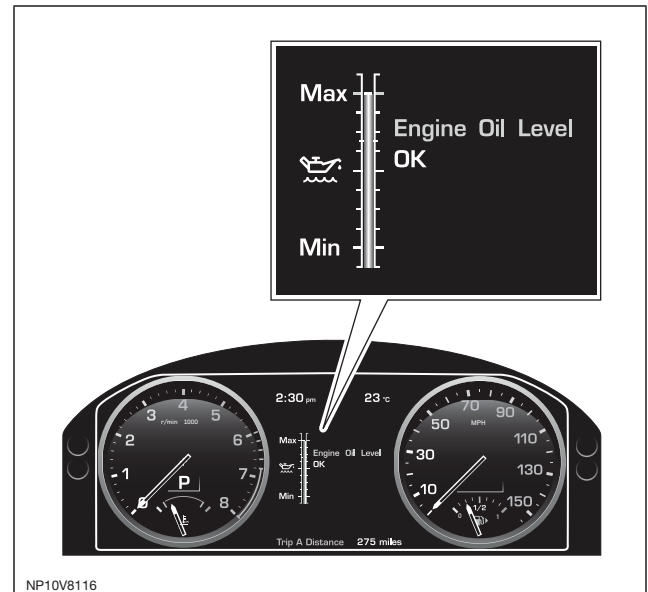
The engine oil level is automatically monitored and displayed in the trip computer area of the message center. The current oil level can be viewed by pressing the trip button with the ignition on, with the engine stopped and the transmission in park.



Key to illustration above:

- **A:** Oil level 50% to 100% of recommended level. No top-up required.
- **B:** Oil level 12.5% to 50% of recommended level. Add 0.5 liters of oil.
- **C:** Oil level 0% to 12.5% of recommended level. Add 1 liter of oil.
- **D:** Oil above maximum for safe operation. Do not drive vehicle. Seek qualified assistance.
- **E:** Oil level below minimum for safe operation. Add 1 liter of oil and re-check.
- **F1:** Oil drain in progress, oil level not available. Wait 5 minutes then re-check the oil level display.
- **F2:** If this display is accompanied by the warning message 'ENGINE OIL LEVEL MONITOR SYSTEM FAULT', a fault with the oil level monitor is indicated. Seek qualified assistance.

Land Rover LM Display



On the Land Rover LM display, messages to the right of the gauge advise of any action required.

- If the oil level is within the required operating range, the message 'Engine Oil Level OK' will be displayed. Do not add any additional oil to the engine.
- If the oil level is below the required operating range, a message will be displayed indicating the recommended quantity of oil to add (e.g. 'Add 0.5L'). Add the recommended quantity of oil then recheck the level.
- If the message 'Overfilled' is displayed, service may be required. Do not drive the vehicle as this will cause serious damage to the engine.

Oil Level Message Center Warnings

Warnings will be displayed in the message center if the oil level is not maintained within the safe operating levels (minimum and maximum). A warning will also be displayed there is a fault with the oil level monitoring system.

ENGINE OIL LOW (Amber)

The oil is at the minimum level for safe operation. Top-up with 1 liter of oil.

ENGINE OIL HIGH (Amber)

This warning is displayed when the engine is started, if the oil is above the maximum level for safe operation. Seek qualified assistance to have the engine oil drained before driving the vehicle.

ENGINE OIL CRITICALLY LOW (Red)

The oil is below the minimum level for safe operation. Stop the vehicle as soon as safety permits and top-up with 1.5 liters of oil. Wait for 5 minutes, re-check the oil level reading and top-up again if necessary.

ENGINE OIL LEVEL MONITOR SYSTEM FAULT (Amber)

A fault with the oil level monitoring system is indicated. Seek qualified assistance as soon as possible.

Service Interval Indicator

The service interval message will only be displayed when the vehicle has less than 3200 km (2000 miles) before the service is due.

When the ignition is switched on and the vehicle has started its service countdown, 'SERVICE REQUIRED XXXX km (XXXX miles)' is displayed in the message center. At the same time the display will glow amber. After approximately 5 seconds, the display reverts to show the preset requirements.

When the service distance has been reached, 'SERVICE REQUIRED' is displayed in the message center and the display will glow red. After approximately 5 seconds, the display reverts to show the preset requirements.

The distance countdown reduces in increments of 50 km or 50 miles, depending on which display units have been selected.

The distance countdown is controlled by the engine management system and is automatically adjusted to allow for driving style and conditions, which gauges when the service becomes necessary.

Time-Based Countdown

This element indicates to customers covering less than the set mileage in a year that the annual service is due. It works on a count-down from 365 days and will display 'SERVICE REQUIRED' in the message center 21 days before the end of the period. The countdown restarts from 365 days when the dealer resets the indicator as part of the service schedule. The time-based message will override the mileage-based message as appropriate.

Mileage-Based Countdown

'SERVICE REQUIRED XXXX km (XXXX miles)' is displayed in the message center only at key-on for about 4 seconds and starts at either 3,200 km or 2,000 miles (depending on market's measurement units) before service is required. When the counter hits zero, 'SERVICE REQUIRED' is displayed.

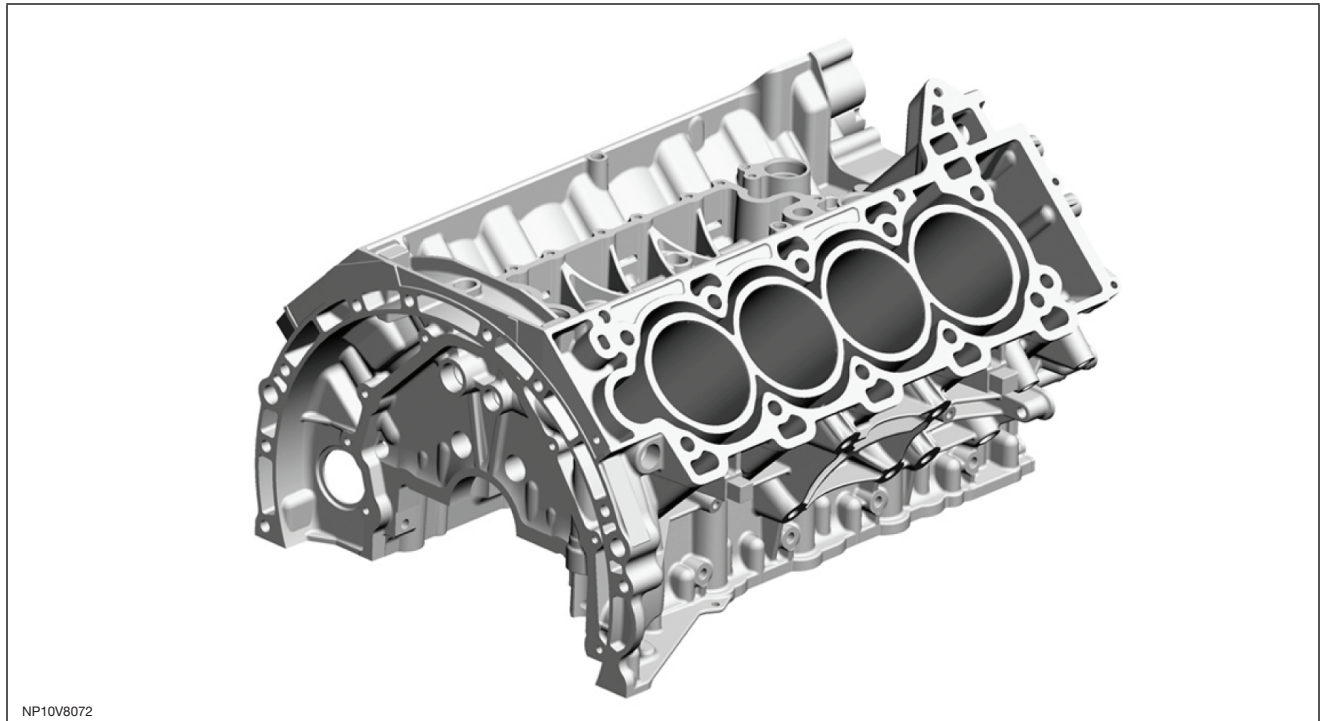
Duty-Cycle Algorithm

The remaining distance to service is determined based on either distance travelled or vehicle duty cycle. Both methods are calculated and the lower value is used. Therefore, if a customer drives in a manner that rapidly deteriorates the oil, thus requiring a service before the nominal distance is travelled, the service indicator would be based on the vehicle duty cycle calculation.

After the completion of each service, the dealer will reset the distance display to commence the countdown to the next service.

CYLINDER BLOCK AND SUMP ASSEMBLY

The new engine is built around a very stiff, lightweight, enclosed V-engine, deep skirt block. To achieve high strength and good noise, vibration, and harshness (NVH) attenuation, the cross-ribbed block is manufactured from high-pressure die-cast aluminum with cast-in iron liners and features cross-bolted and doweled cast iron bearing caps.



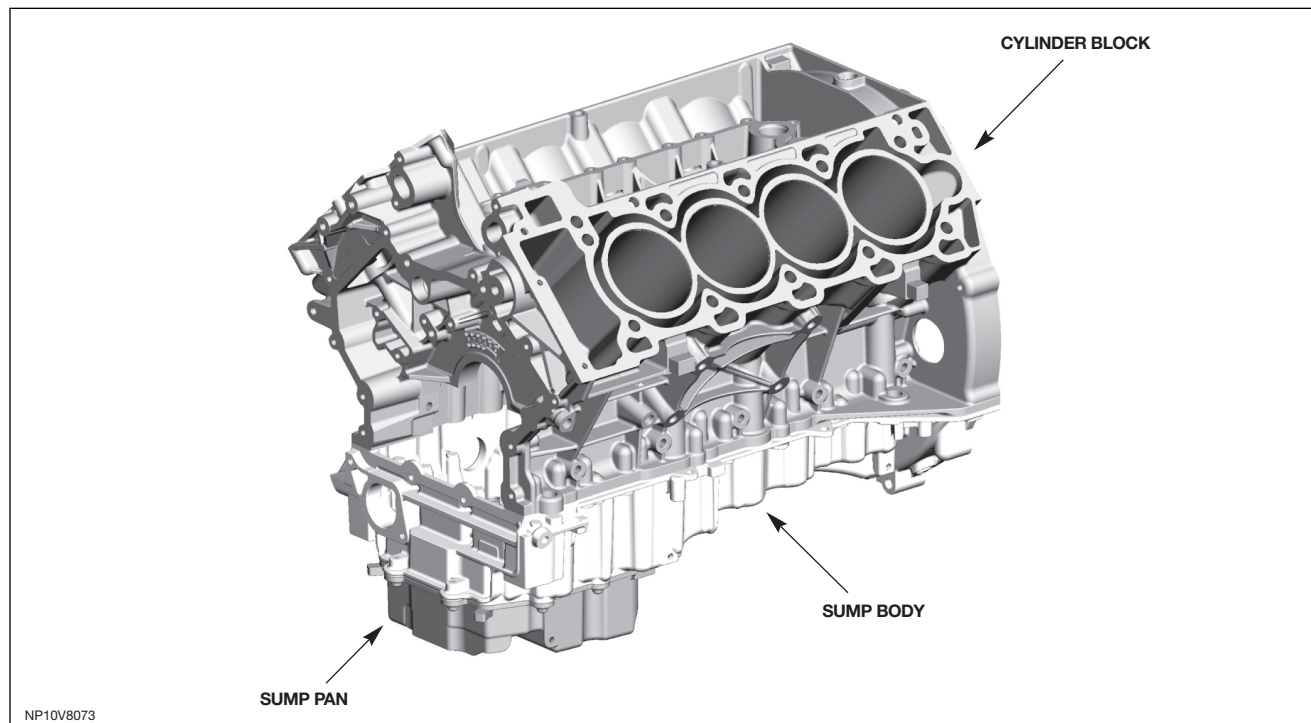
A low volume open-deck die-cast coolant jacket improves warm-up times and piston noise levels; the longitudinal flow design of the jacket, with a single cylinder head coolant transfer port in each bank, improves rigidity and head gasket sealing.

A high-pressure die-cast aluminum structural baffle plate is bolted to the bottom of the engine block to further improve block stiffness, minimize NVH, and help reduce oil foaming.

To further enhance the stiffness of the lower engine structure, a heavily ribbed aluminum sump body is employed. Manufactured from high-pressure die-cast aluminum, the body helps reduce engine noise.

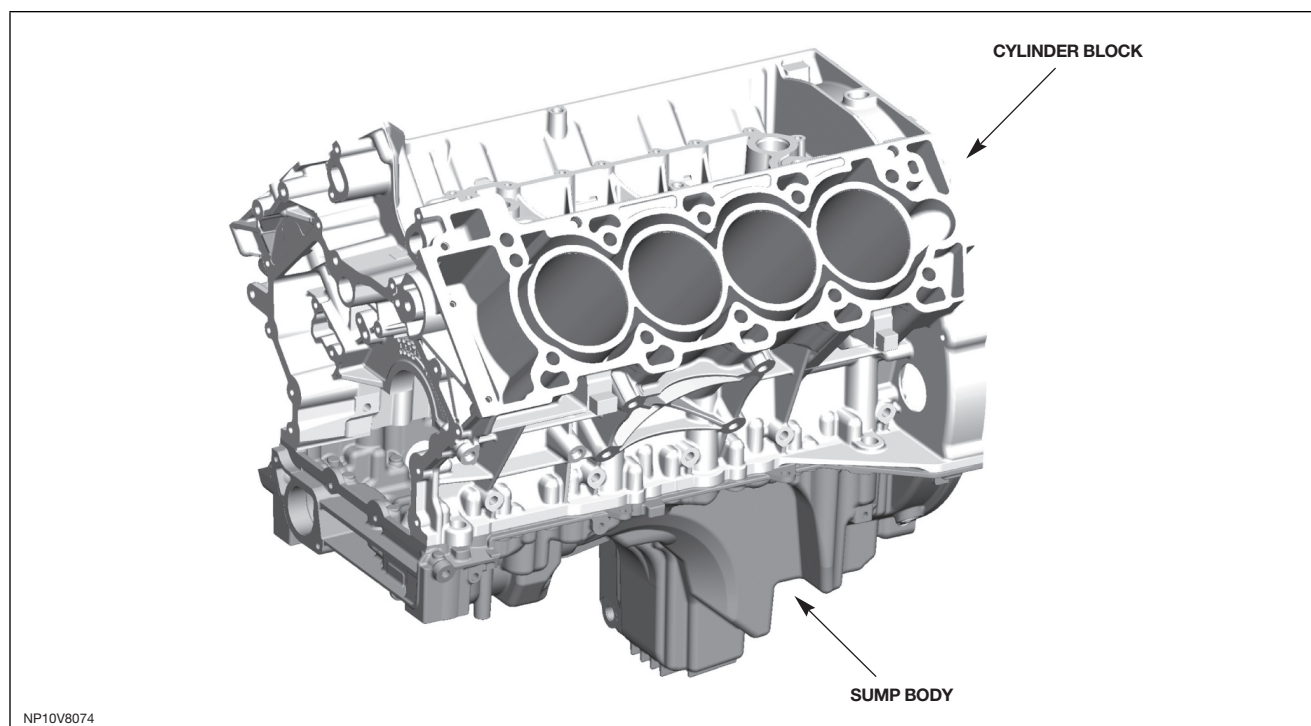
Jaguar Sump Assembly

A cast aluminum sump pan is bolted to the structural sump body.



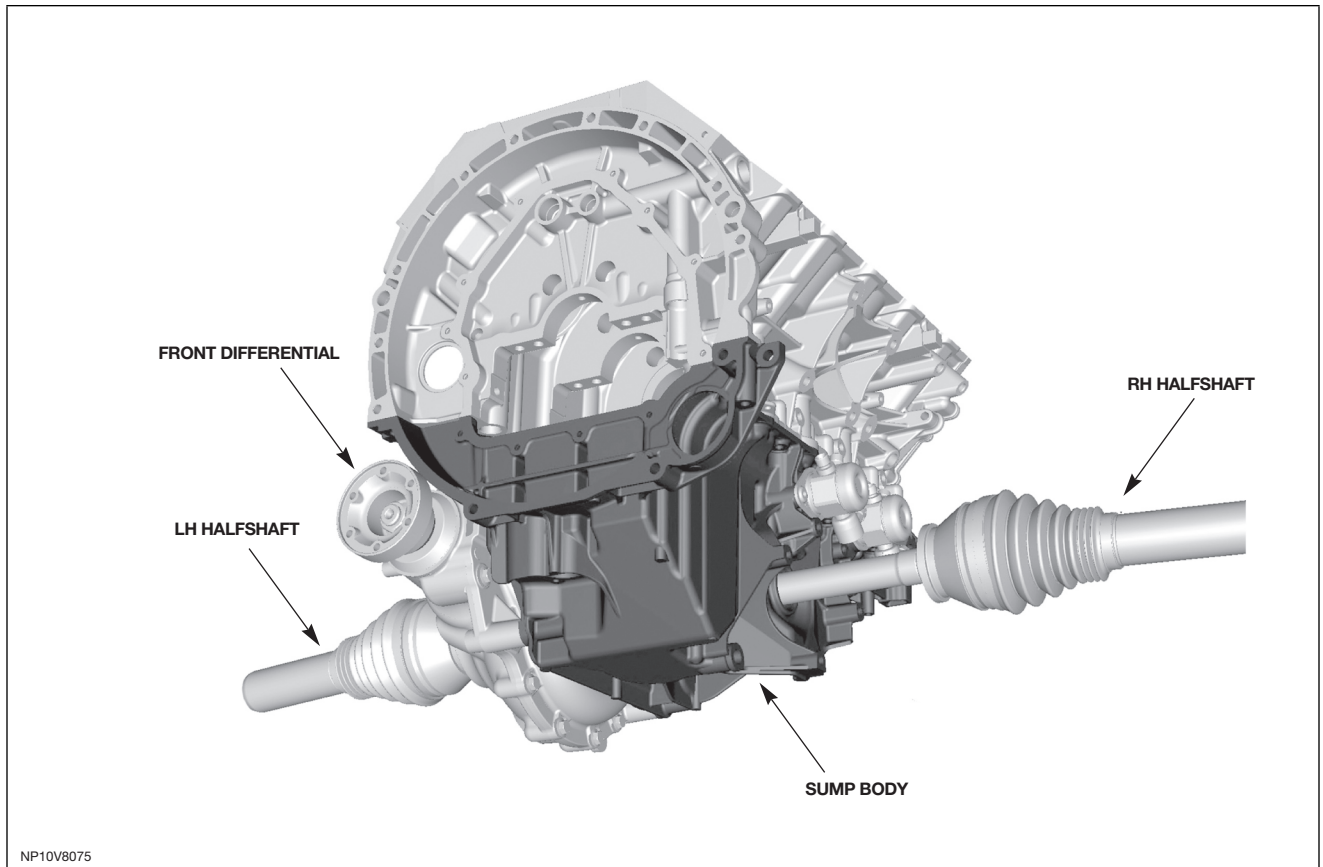
LA and LS Sump Assembly

LA and LS employ a deep single-piece sump with a larger oil capacity to cope with the extreme range of permitted vehicle operating angles.



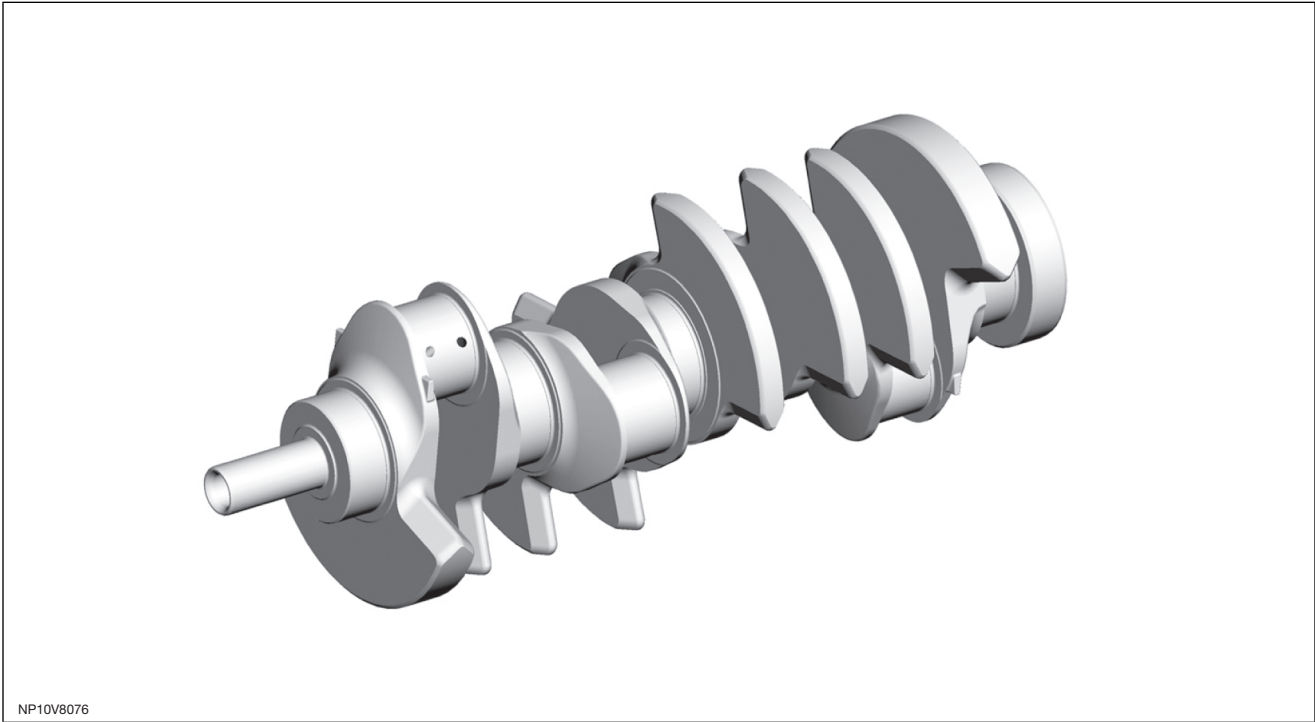
LM Sump Assembly

The LM's deep single-piece sump incorporates the mounting of the front differential, which is located on the left hand side. The right hand axle shaft passes through a cast tube in the sump.



Crankshaft

The heart of the new engine is a very strong, spheroidal graphite (SG) cast iron crankshaft, which has higher mechanical strength, ductility, and increased shock resistance when compared with grey cast iron. The undercut and rolled fillets also improve strength. Eight counter-balance weights ensure low vibration levels and the large cross-drilled main bearing journals are designed to help eliminate any risk of high mileage in-field failures.



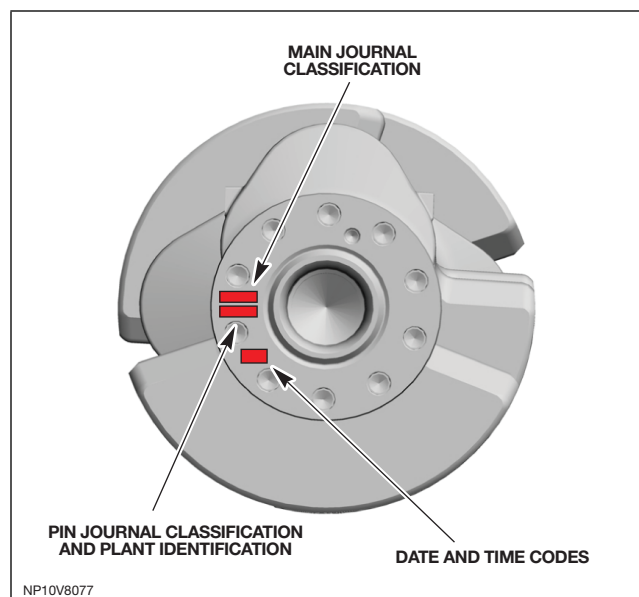
Forged steel connecting rods are manufactured from 36 Mn VS4 steel, chosen for its very high-yield strength. These are fracture-split to ensure precision re-assembly for bearing shell alignment.

At the front of the crankshaft, a tuned torsional vibration damper has been incorporated into the crankshaft front pulley. At the rear of the engine, a pressed-steel drive plate with a steel starter ring gear is installed supplying drive from the engine to the automatic transmission.

An oil groove in the upper half of each main bearing transfers the oil into the crankshaft for lubrication of the connecting rod bearings. A thrust washer is installed each side of the top half of the center main bearing.

Service

Crankshaft Identification

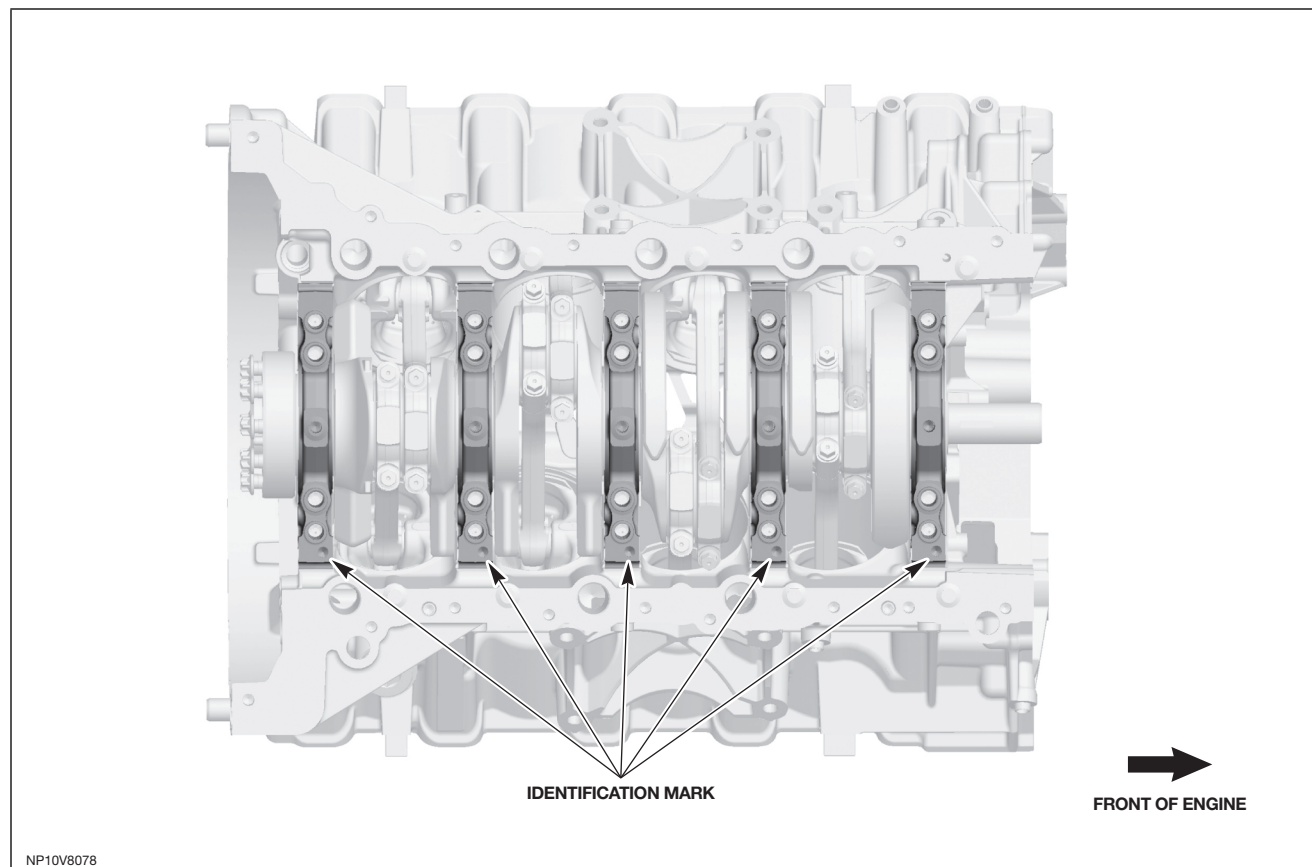


Main Bearing Identification

There are five grades of main bearing available, each color-coded for identification.

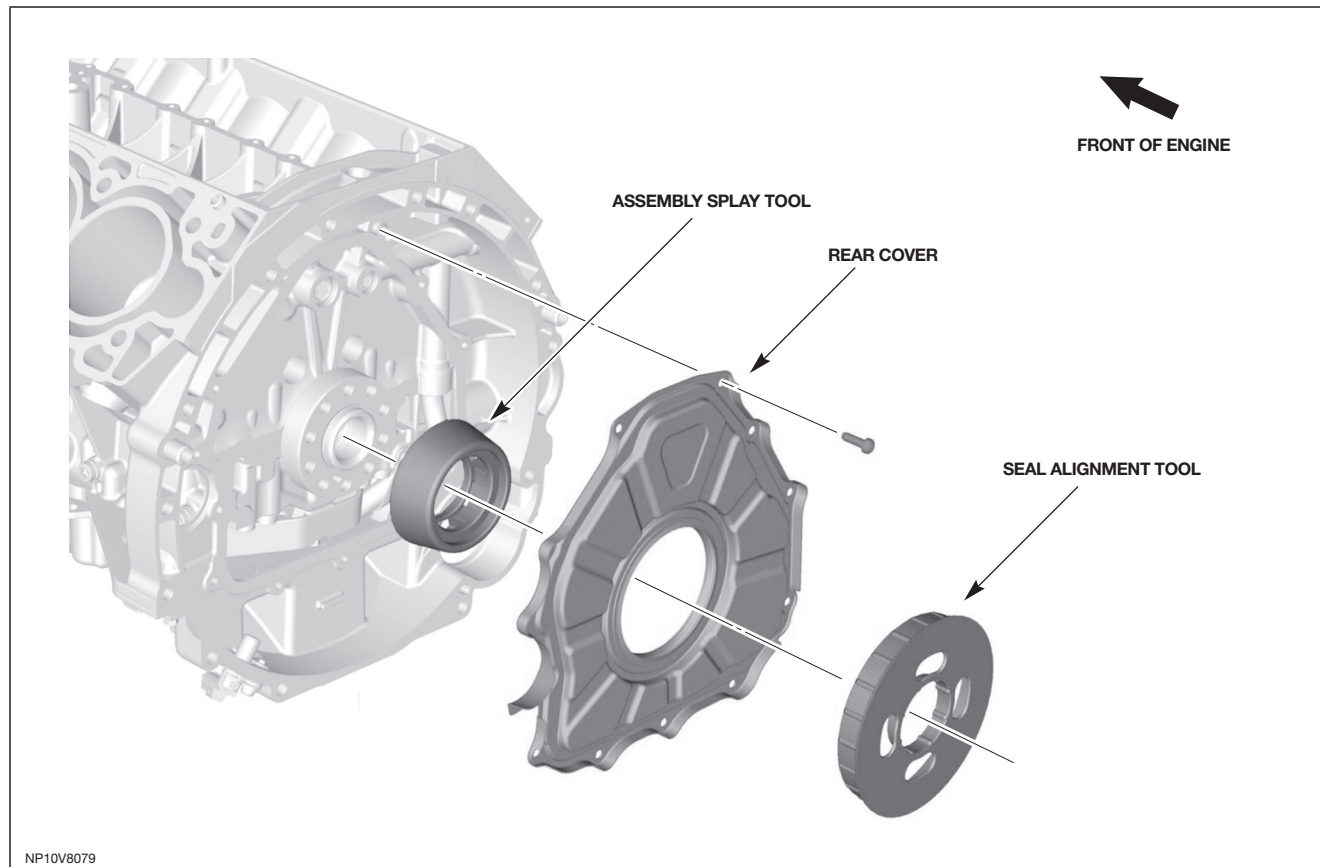
Grade	Number	Grade Color	WERS Number
A	1	Blue	8W93-6331/3-AAA
B	2	Green	8W93-6331/3-ABA
C	3	Yellow	8W93-6331/3-ACA
D	4	Brown	8W93-6331/3-ADA
E	5	Red	8W93-6331/3-AEA

The main bearing cap must always be installed with the identification mark to the front of the cap, facing the front of the engine. The bearing caps are also numbered 1 to 5, with 1 being located at the front of the engine. Used bearing cap bolts must be returned to their original location.



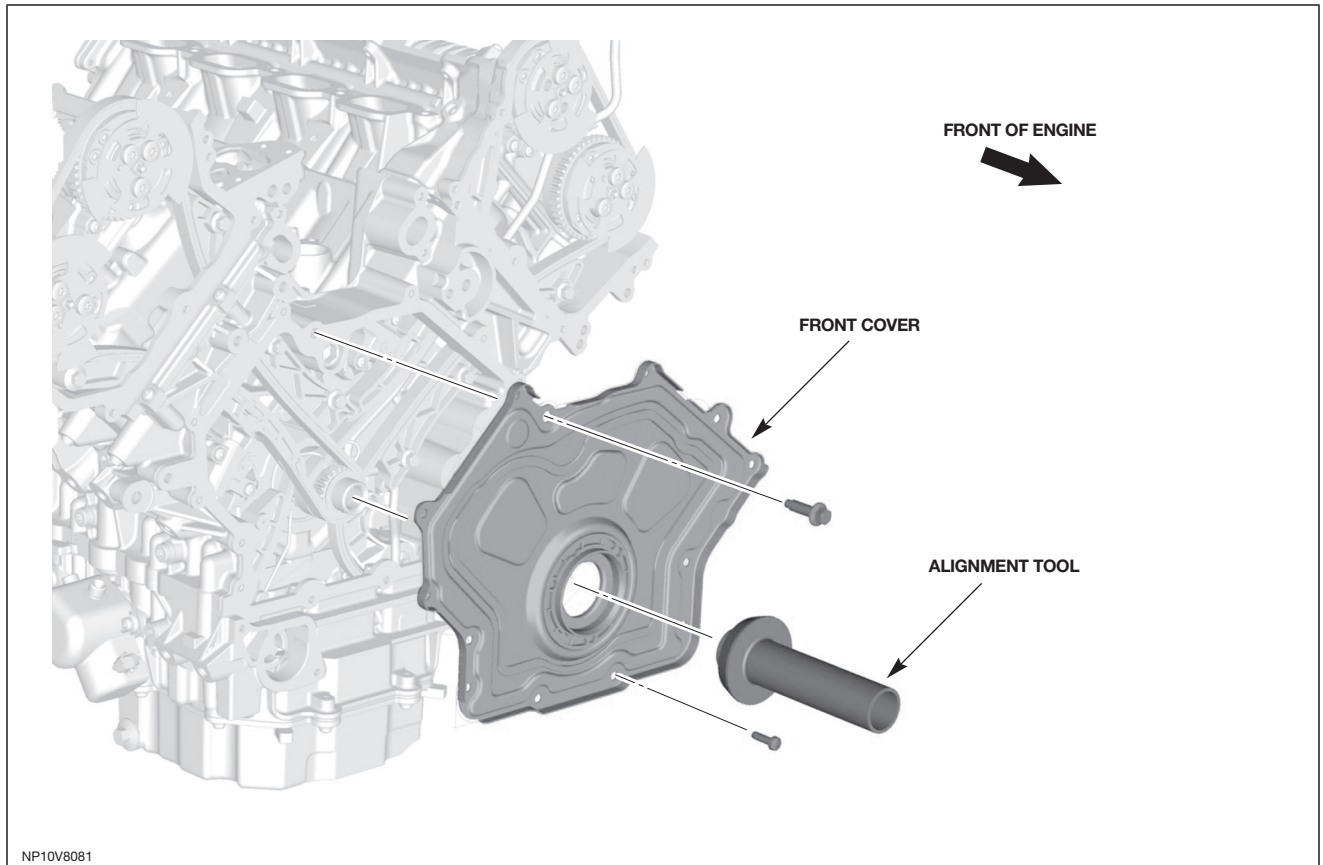
Rear Cover Installation

The rear seal is incorporated into the rear cover and is not serviced separately. An assembly splay tool and a seal alignment tool are required for cover installation.



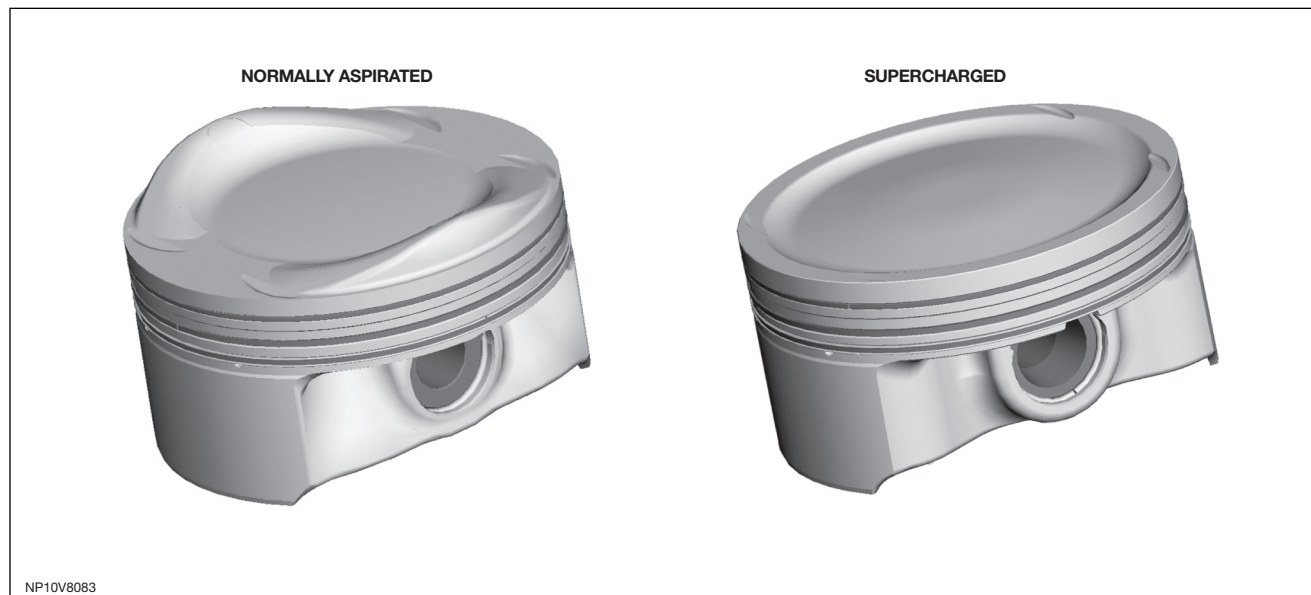
Front Cover Installation

The front crankshaft seal is serviced separately. A remover/installer tool is used to remove the seal from the cover. The crankshaft seal should be assembled without lubricant.



Pistons and Connecting Rods

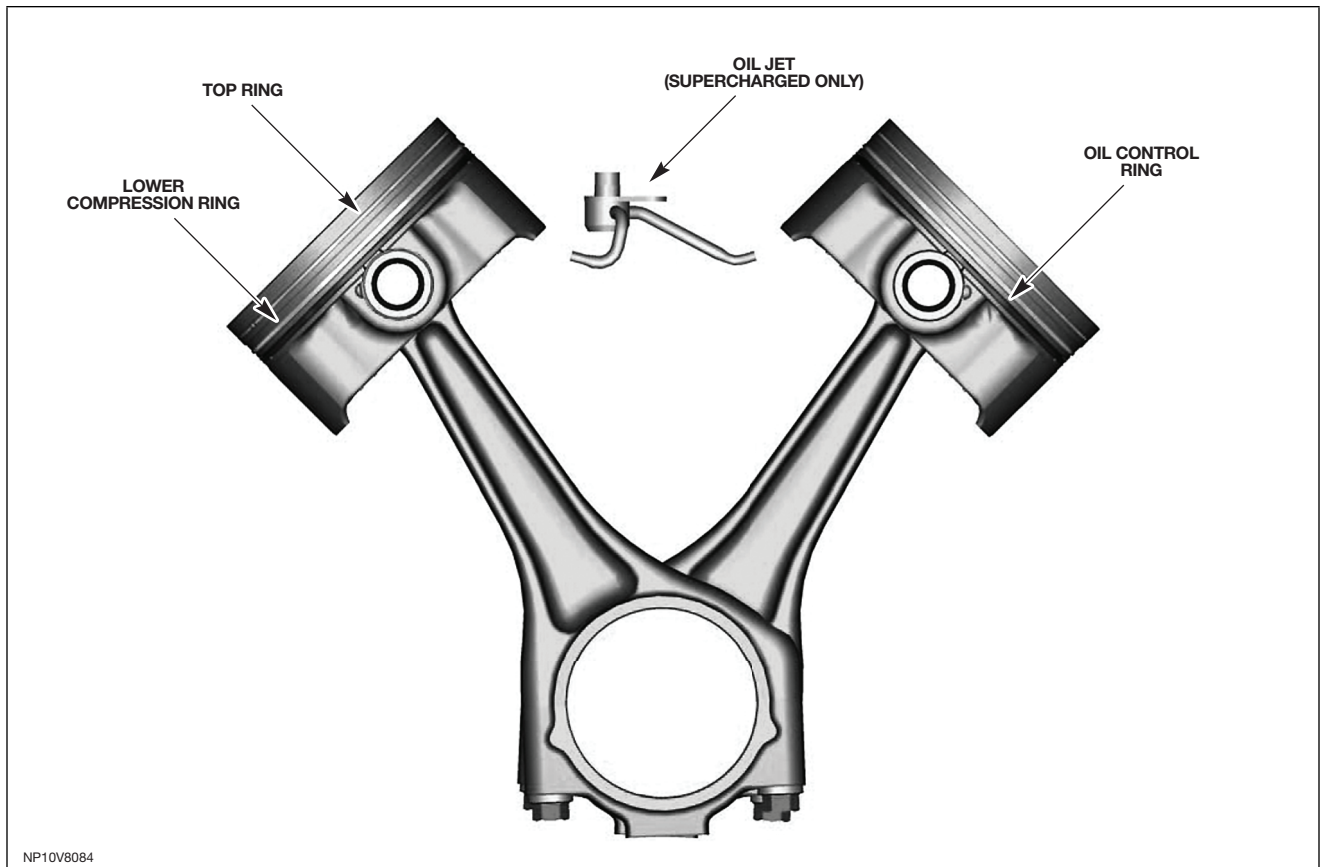
The cast pistons incorporate a number of features designed to enhance durability, minimize friction, and reduce wear.



Only one piston grade is available. In a vertical plane, the pistons have a slight barrel form; this is designed to help assure a reliable oil film between piston and block. A solid film lubricant coating is applied to both reaction faces of the piston to help reduce wear and improve fuel economy.

Piston and Connecting Rod Assembly

NOTE: SC shown

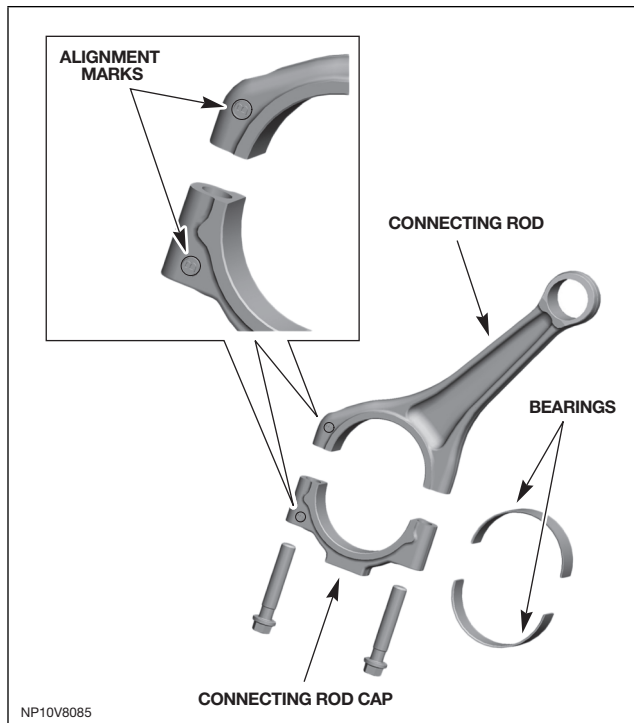


For the SC engine, oil jets at the base of the block supply cooled engine oil to control piston temperatures at high loads; oil is continually directed onto the underside of the piston.

A three-ring piston-sealing system is used. The steel top ring is treated with a physical vapor deposition (PVD) peripheral coating, a vaporization coating technique where materials can be deposited with improved properties to ensure good cylinder bore compatibility and wear resistance. A second Napier ring helps cylinder pressure and oil management, while the lower three-piece oil control ring is produced from nitrided steel.

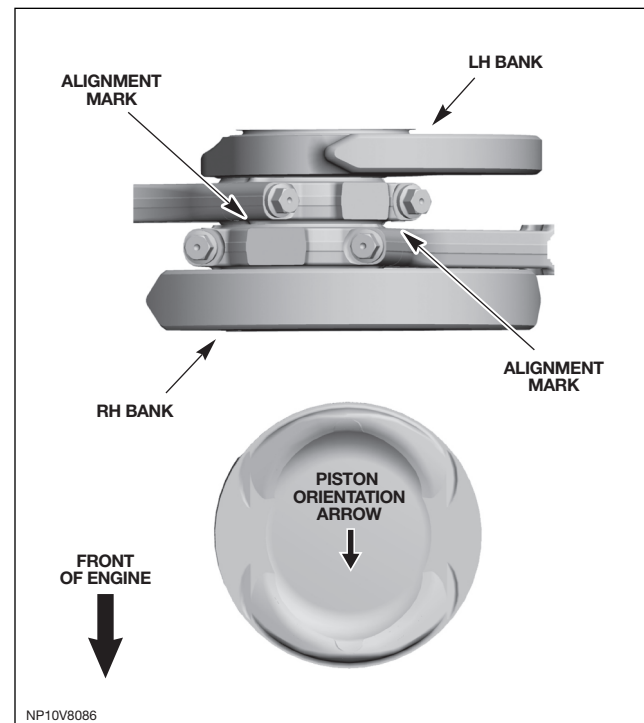
Connecting Rod Installation

Connecting Rod Alignment Marks



RH Bank: The arrow on the piston crown must face the front of the engine and the cap and connecting rod alignment marks must face the rear of the engine.

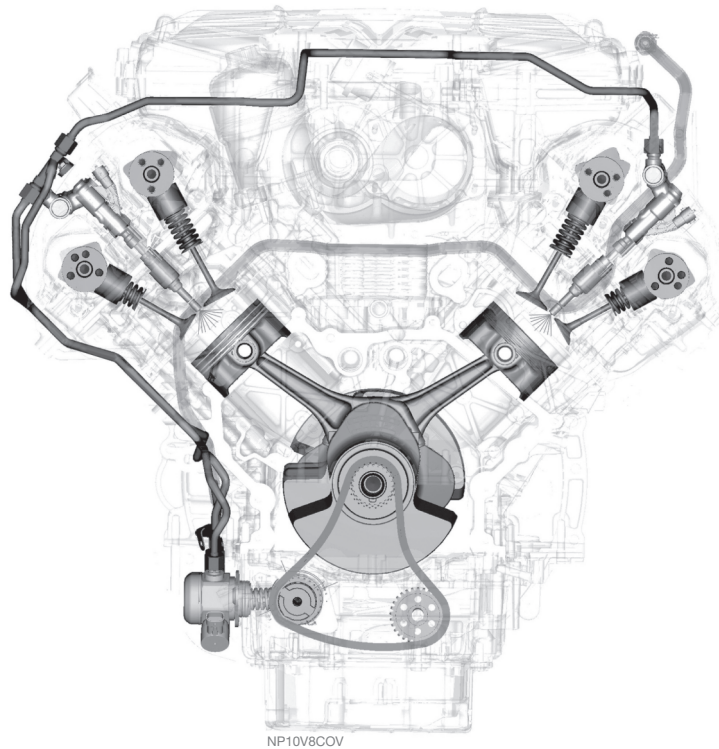
LH Bank: The arrow on the piston crown must face the front of the engine and the cap and connecting rod alignment marks must face the front of the engine.



There are three grades of connecting rod bearings available, each color-coded for identification.

Technical Training
Technical Introduction

NP10-V8JLR: AJ133 5.0-Liter DFI V8 Engine



Engine Management System



NP10-V8JLR 04/2009
Printed in USA

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OVERVIEW

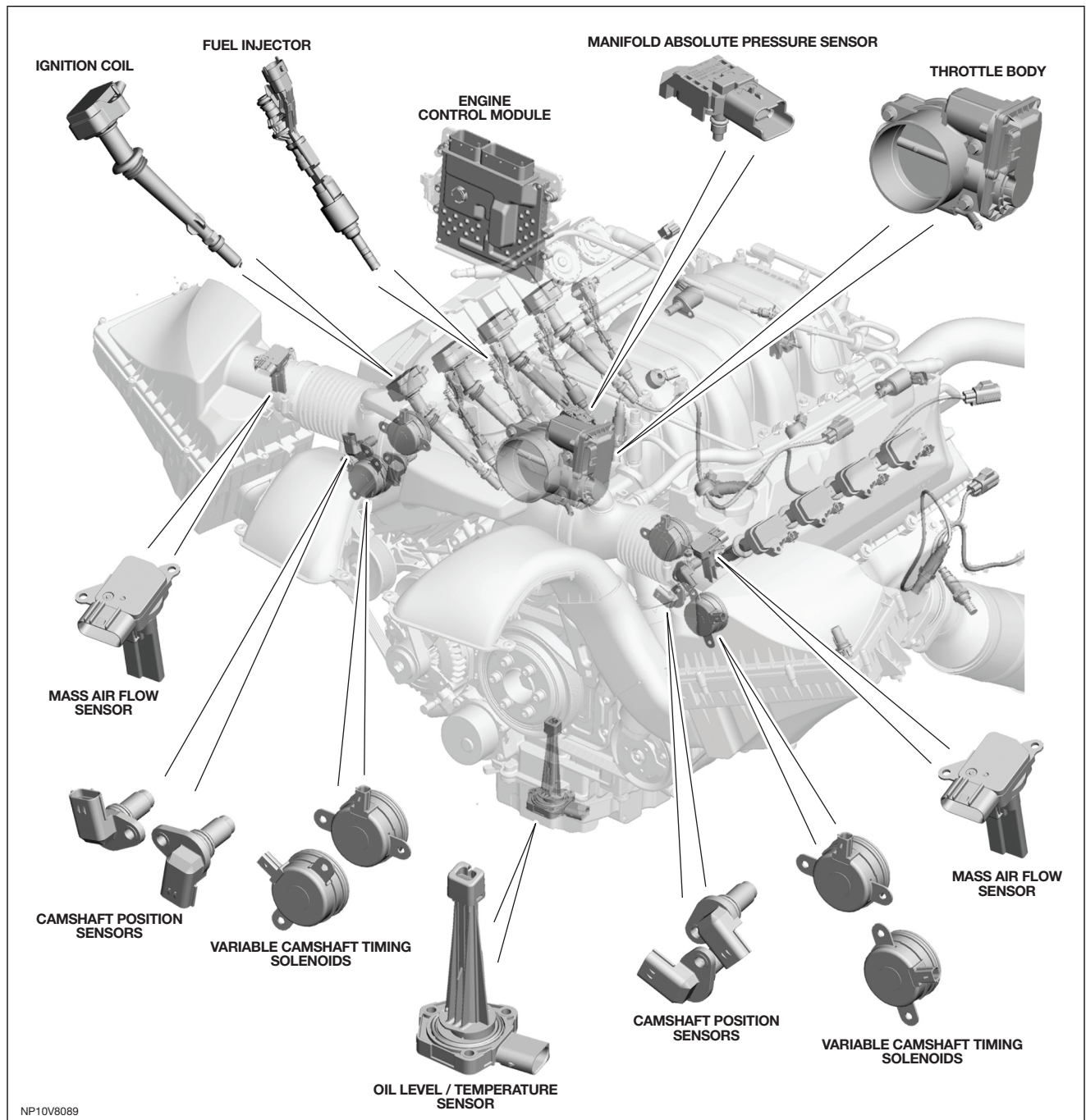
The 5.0-Liter V8 normally aspirated (NA) and super-charged (SC) engines are managed by the engine control module (ECM), which controls the following:

- Engine fuel metering
- Ignition timing
- Camshaft timing
- Camshaft Profile Switching (CPS)
- Closed loop fuel metering
- Knock control
- Idle speed control
- Emission control
- On-Board Diagnostics (OBD)
- Interface with the immobilization system
- Speed control

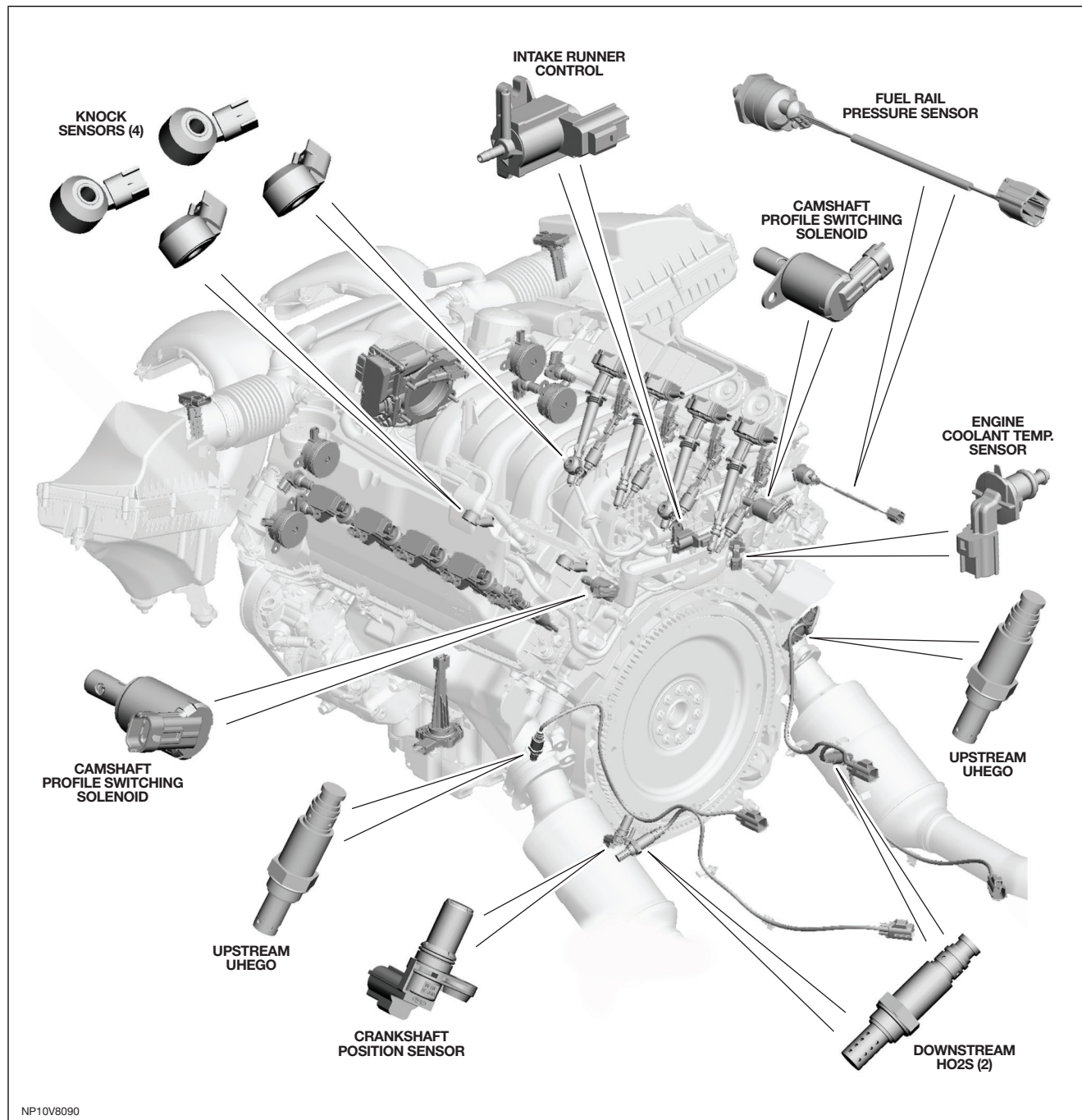
The ECM controls the engine fuel metering by providing sequential fuel injection to all cylinders. Ignition is controlled by a direct ignition system, provided by eight coil-on-plug (COP) units. The ECM is able to detect and correct for ignition knock on each cylinder and adjust the ignition timing for each cylinder to achieve optimum performance.

The ECM uses a torque-based strategy to generate the torque required by driver demand and the other vehicle control modules, using input from various sensors to calculate the required torque. The ECM also interfaces with other vehicle electronic control modules to obtain additional information (road speed from the ABS control module, for example). The ECM processes these signals and determines how much torque to generate, using various actuators to supply air, fuel, and spark to the engine (electronic throttle, injectors, coils, etc.).

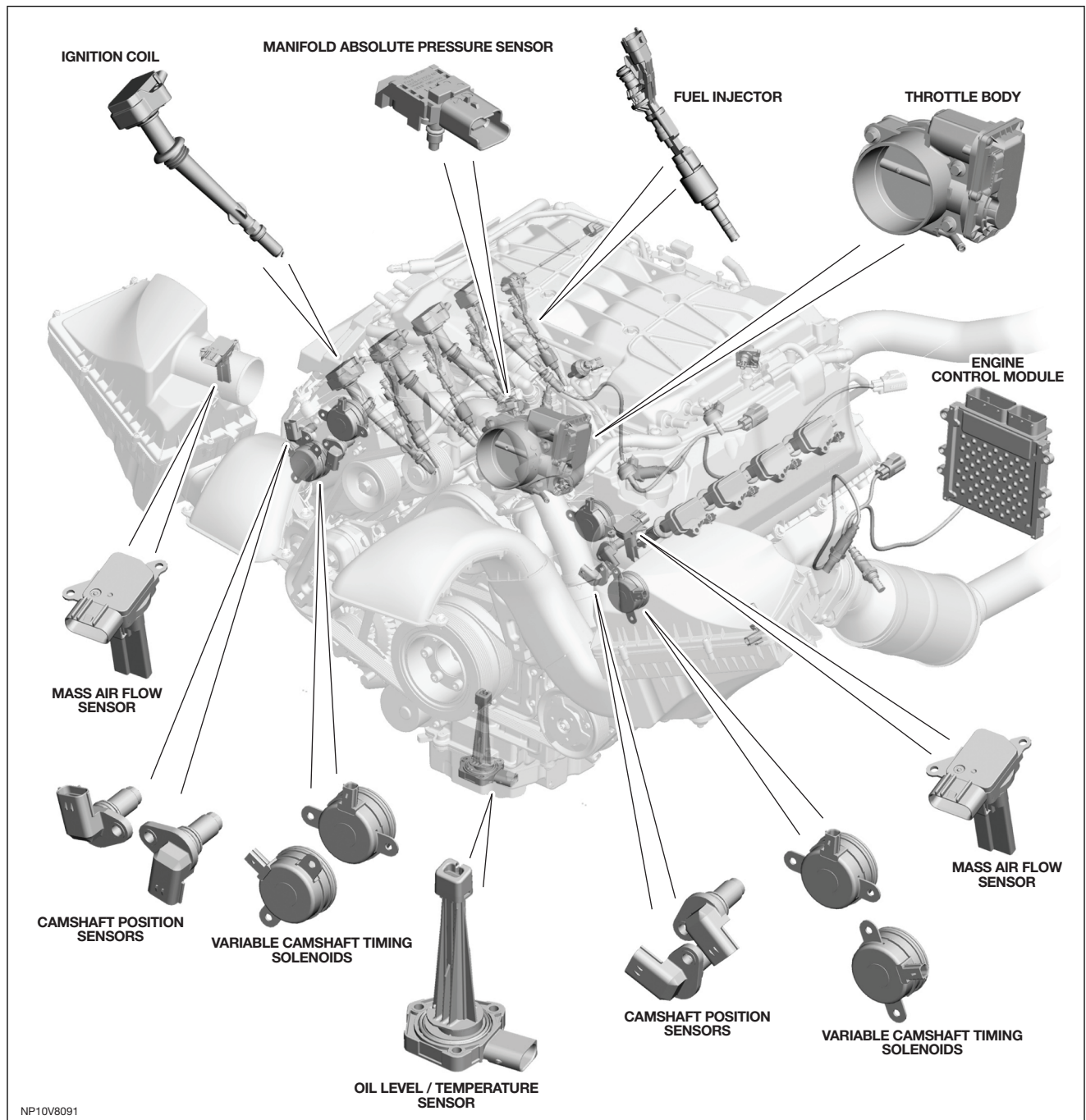
NA Component Location: Front of Engine



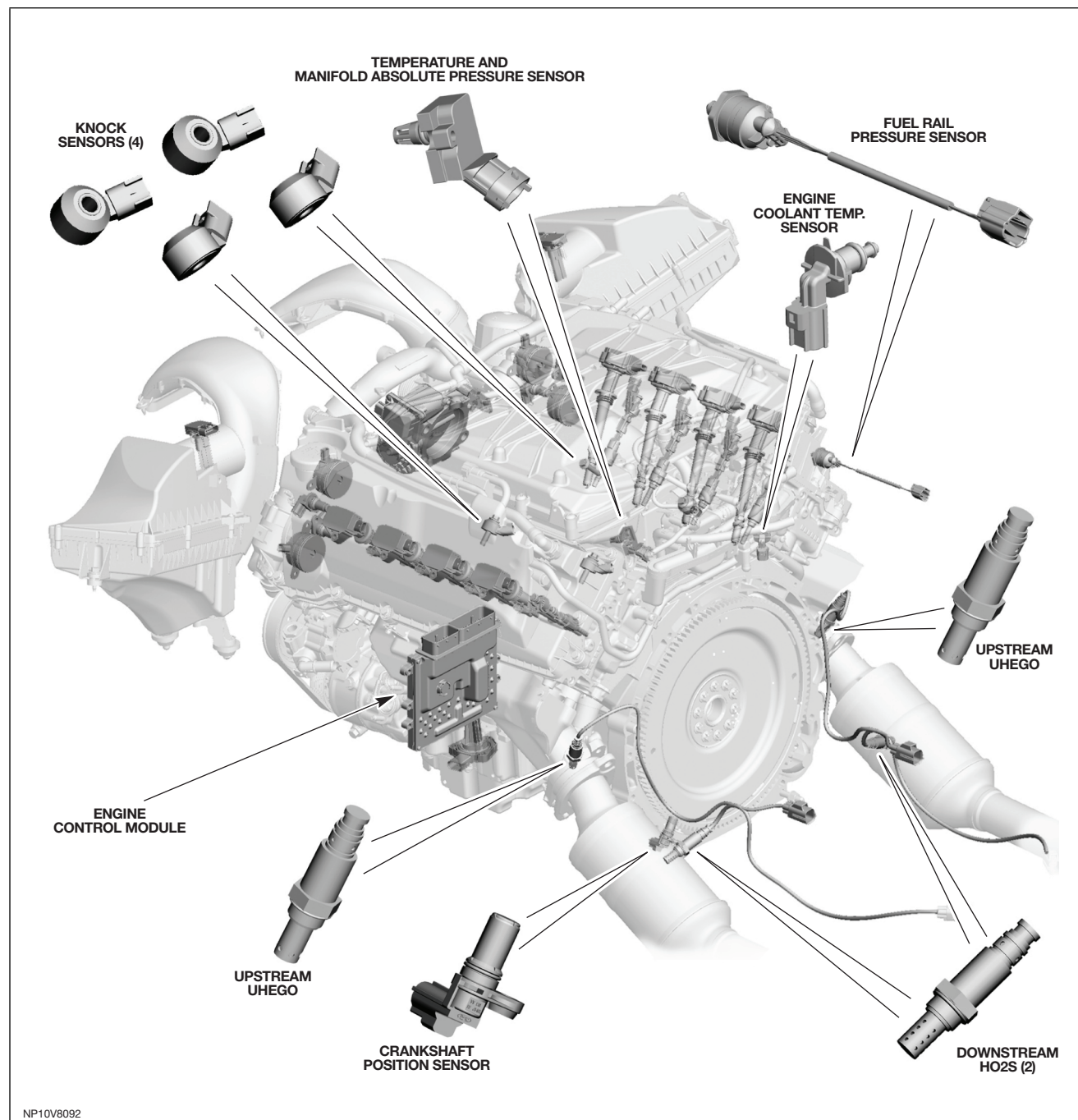
NA Component Location: Rear of Engine



SC Component Location: Front of Engine



SC Component Location: Rear of Engine



WARNINGS:

- **Direct injection injectors require high booster voltages (65V); special care must be taken to guarantee proper electrical isolation of the cable harness and all connectors. The ECM outputs for the injectors are protected in case of open and short circuit.**
- **Due to the high currents in the injectors, strong magnetic fields are created. An influence within a distance of up to 0.2m from the wiring harness or control unit is to be expected. Each vehicle type must therefore be checked to ensure that this distance is maintained. In particular, the interference-free function of pacemakers cannot be guaranteed.**

CAUTIONS:

- **DO NOT connect test probes connected to battery positive supply to any ground pins, as this will DESTROY the ECM.**
- **Use care when probing connectors for wiring checks. The gold plating used on low current signal connector terminals is easy to damage by inserting a probe.**
- **Do not use probes that pierce wiring insulation since they damage/sever wiring, leaving it vulnerable to corrosion.**

ENGINE CONTROL MODULE

The ECM is supplied with battery voltage from a 5A fuse and an ignition supply from the ECM relays through a 15A fuse, both located in the CJB. A regulator located within the ECM supplies a 5V current to internal components such as the microprocessor unit. Other components or functions requiring full battery voltage are controlled by external relays or internal switching modules.

The microprocessor within the ECM receives signals from different components and control modules and uses a program within the ECM software to interpret the signal information and issue signals which relate to how the engine components and functions should be controlled. The ECM communicates with other control modules via bidirectional Controller Area Network (CAN) communication interfaces.

The ECM uses the following inputs and outputs:

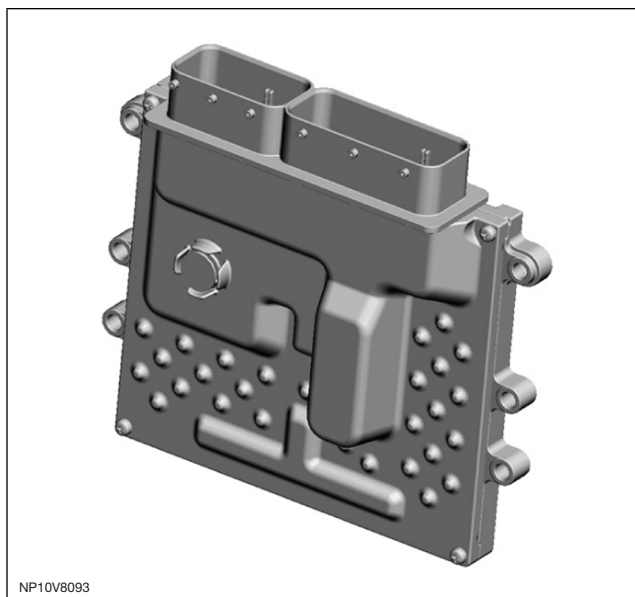
Inputs

- Camshaft position (CMP) sensor
- Crankshaft position (CKP) sensor
- Fuel rail high-pressure sensor
- Mass air flow (MAF) sensors (2)
- Knock sensors (4)
- Engine coolant temperature (ECT) sensor
- Manifold absolute pressure (MAP) sensor
- Electronic throttle position sensor
- Accelerator pedal position (APP) sensor
- Cooling fan speed
- Upstream Universal Heated Exhaust Gas Oxygen (UHEGO) sensors (2)
- Brake switch
- Speed control cancel/suspend switch
- Intake air temperature (IAT) sensor (integrated into the MAF) (2)
- Ambient air temperature (AAT) sensor
- Engine oil level and temperature sensor
- Temperature and manifold absolute pressure (TMAP) sensor (SC only)

Outputs

- Throttle Actuator
- Coil-on-plug (COP) ignition coils (8)
- Upstream Universal Heated Exhaust Gas Oxygen (UHEGO) sensors (2)
- Downstream Heated Oxygen Sensors (HO2S) (2)
- Direct injection fuel injectors (8)
- Variable camshaft timing (VCT) solenoids (4)
- Camshaft profile switching (CPS) solenoids (2)
- Intake manifold tuning solenoid
- Carbon canister purge valve
- Fuel pump relay
- Starter relay
- A/C condenser fan relay
- ECM main relay viscous fan control
- Generator control
- Air flap solenoid (SC only)
- Pump control diagnostics
- Diagnostic Monitoring of Tank Leakage (DMTL)

The aluminum ECM case has two large black electrical connectors with red lock-levers. The label indicates an engineering number with the format ***** – 12B864 – **.



The dimensions of the ECM are 155 x 170 x 40mm (6 x 6.7 x 1.6 in.).

Diagnostics

Diagnostic Trouble Codes (DTCs) are listed in the Diagnosis and Testing section of the GTR WSM. Codes are listed in numerical order and each entry has:

- A notes column to detail any care points relating to the failure
- An indication column. 2-trip MIL means that the failure must be detected on two subsequent drive cycles for the MIL to illuminate. Any other lamp indicator will be recorded in this column. There may also be a message displayed on the instrument cluster while the failure is being detected that is not detailed in this document.
- A description of any default action the module undertakes in response to the detection of the failure
- A list of possible causes of the failure
- Which pin (if any) on the control module is associated with the failure
- The DTC description
- Test conditions. Operating the vehicle as described in this column should result in the running of the monitor relating to the DTC.

NOTE: The operating conditions described have been specified to ensure successful monitor operation is possible in most cases; however, the monitor may operate outside of these conditions.

NOTE: Not all DTCs may be logged by all vehicle types.

RELAYS

Main Relay

The main Engine Management System (EMS) relay is not a main power input; it is used to initiate the power-up and power-down routines within the ECM.

This input comes from the engine junction box (EJB). When the ignition is turned on 12V is applied to the ignition sense input. The ECM then starts its power-up routines and turns on the ECM main relay, the main power to the ECM and its associated system components.

When the ignition is turned OFF, the ECM will maintain its powered-up state for several seconds (or up to 20 minutes in extreme cases when cooling fans are required) while it initiates its power-down routine and, on completion, will turn off the ECM main relay.

The main relay is located in the EJB. The operation of the main relay is controlled by the ECM, which provides a ground path for the main relay coil, energizing the relay and closing the relay contacts.

The main relay supplies battery voltage to the following engine sensors and actuators:

- Throttle position (TP) sensor (through ECM)
- Fuel injectors
- Ignition coils
- Coil capacitor
- CPS solenoids
- All heated oxygen sensors
- Evaporative emission (EVAP) canister purge valve
- Diagnostic Monitoring of Tank Leakage (DMTL)

Failure Modes

- Relay drive open circuit
- Short circuit to battery voltage or ground
- Component failure

Failure Symptoms

- Engine will not start

Starter Relay

The starter motor relay is located in the EJB. Operation of the starter motor relay is controlled by the ECM, which provides a ground path for the relay coil, energizing the relay and closing the relay contacts. When the relay contacts are closed, battery voltage is supplied, through the starter motor relay, to the starter module solenoid coil.

The starter solenoid is energized and connects the starter motor with a direct battery feed to operate the starter motor.

Once the engine has started, the ECM removes the starter motor relay ground, opening the relay contacts and terminating the battery feed to the starter solenoid, which in turn stops the operation of the starter motor.

NOTE: Diagnose using Jaguar Land Rover approved diagnostic equipment.

CRANKSHAFT POSITION SENSOR

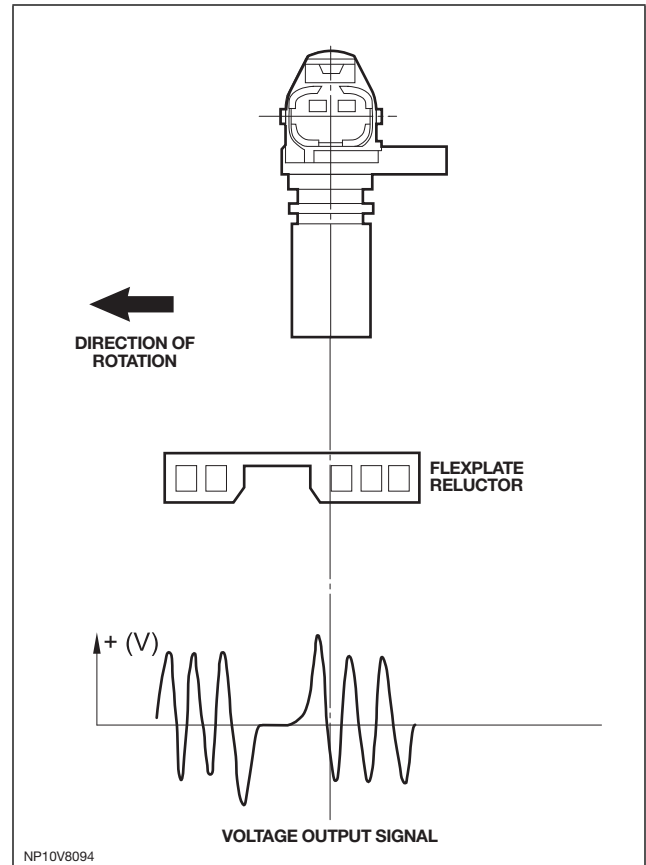
The crankshaft position (CKP) sensor is located on the forward side of the transmission torque converter housing, in line with the engine flexplate.

The sensor is secured with a single bolt into the flywheel housing. A reluctor ring is fitted to the outer diameter of the crankshaft flexplate; the sensor reacts to the gaps in the reluctor ring to determine engine speed and position information.

The CKP sensor is an inductive-type sensor which produces a sinusoidal output voltage signal. This voltage is induced by the proximity of the moving reluctor ring gaps, which excite the magnetic flux around the tip of the sensor when each gap passes.

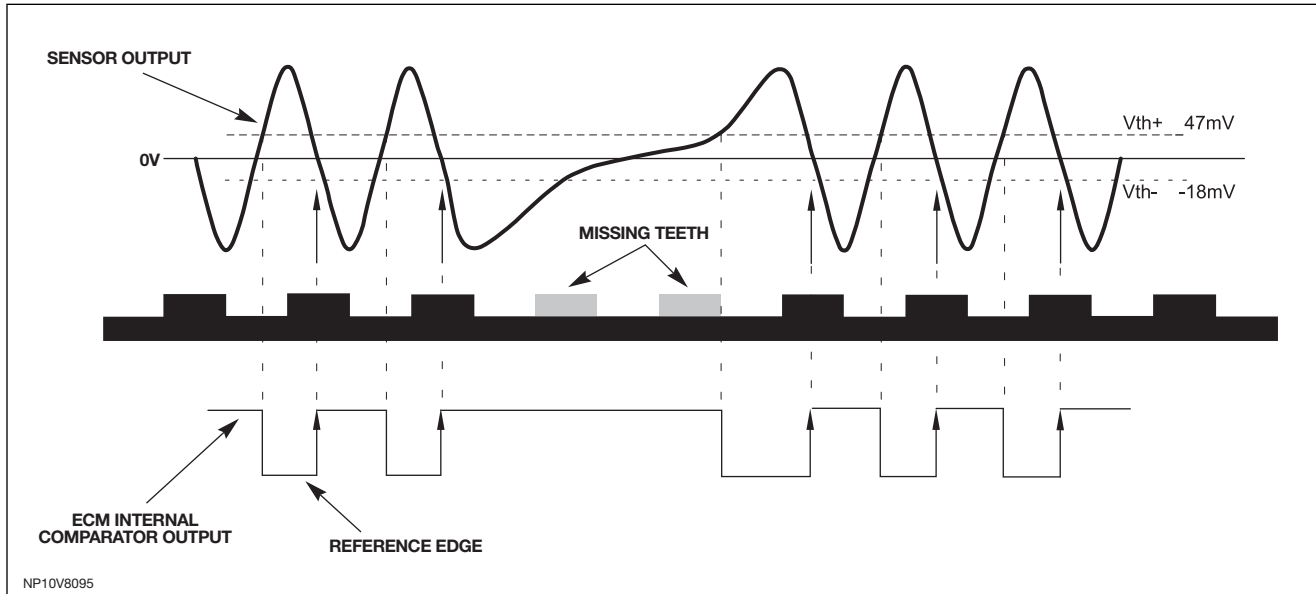
The output voltage increases in magnitude and frequency with the engine speed and, consequently, with the speed at which the reluctor ring gaps pass the sensor.

NOTE: The output is also dependent on the air gap between the sensor and the teeth (the larger the gap, the weaker the signal, the lower the output voltage).



The reluctor is manufactured to have a 'tooth' pattern based on 60 – 2 pattern, where there are 58 teeth in total at 6° intervals. The two teeth are removed to provide a hardware reference mark, with a centerline that is 21° BTDC on cylinder 1, RH bank.

The signal voltage can be as low as 0.1V at low engine speeds and up to 100V at high engine speeds. The ECM does not react to the output voltage (unless the voltage is extremely low or high); instead it measures the time intervals between each pulse (signal frequency).



Safety Precautions

⚠ CAUTIONS:

- Before installing the CKP sensor, check that no ferrous material has been attracted to the device by its internal magnet.
- Ensure that the air gap is correct.
- Due to the location and orientation of the sensor, ensure that it is not damaged during engine installation or by any debris that may be picked up from the road.

Failure Modes

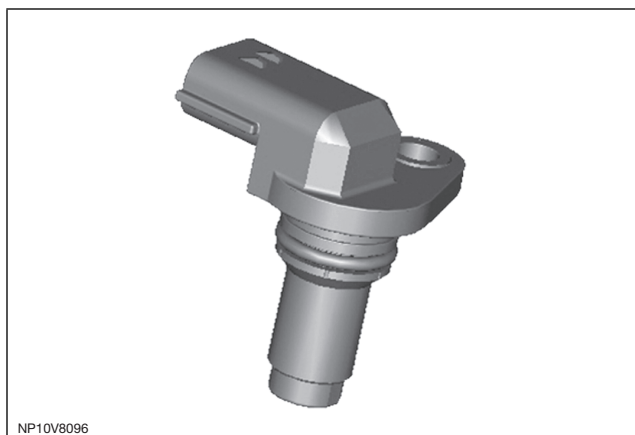
- Sensor assembly loose
- Incorrect air gap – Nominal air gap 1.5mm (This is normally pre-set unless there is damage to the mounting)
- Short/open circuit
- Mounting and integrity of the sensor
- Water/coolant ingress within connector
- Inability of the ECM to detect the software reference point
- Ferrous contamination of CKP sensor pin/reluctor

Failure Symptoms

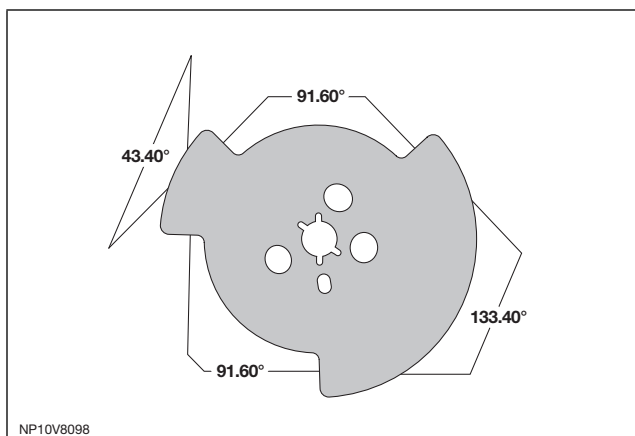
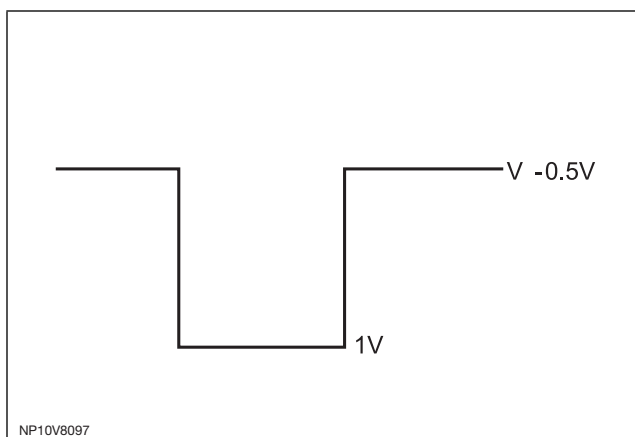
- Engine will start picking up a signal from the CMP sensors (long crank time)
- Default 3000rpm (limp home mode)

CAMSHAFT POSITION SENSOR

The camshaft position (CMP) sensors are magneto-resistive element (MRE) sensors, which have digital output with zero speed recognition. They show a high signal if the camshaft position target is directly in front of the sensor, and low if the camshaft position target is not in front of the sensor.



There are four common sensors, one per camshaft.



Failure Modes

- Sensor open circuit
- Short circuit to vehicle battery supply or ground
- Mechanical fitting and integrity of the sensor
- Camshaft wheel tolerances/camshaft end float excessive
- Camshaft and crankshaft misalignment/valve timing error
- Camshaft wheel magnetized/residual magnetism
- Speed signal correlation with crankshaft sensor input
- Incorrect air gap between camshaft and sensor

NOTE: If both the CKP sensor and the CMP sensor fail, the engine will stall or not start.

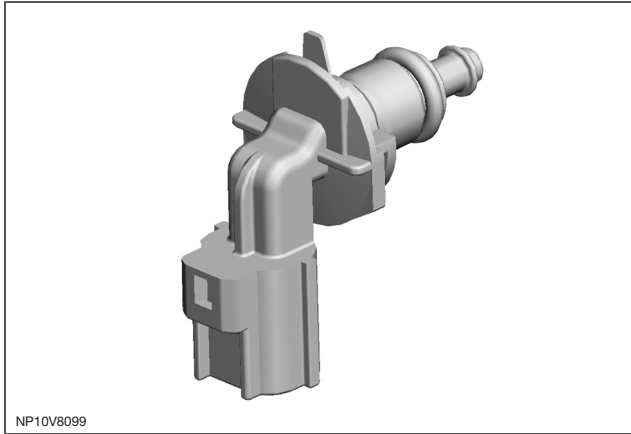
Failure Symptoms

- Ignition timing reverting to the base mapping, with no cylinder correction
- VCT is disabled

Specification	Function
Pin 1	Supply
Pin 2	Ground
Pin 3	Signal
Operating voltage	4.5 to 7 V
Maximum supply current	22 mA

ENGINE COOLANT TEMPERATURE SENSOR

The engine coolant temperature (ECT) sensor is a negative temperature coefficient (NTC) thermistor, used to monitor engine coolant temperature.



The ECT sensor is vital to the correct running of the engine, as a richer mixture is required at lower block temperatures for good quality starts and smooth running, leaning off as the temperature rises to maintain emissions and performance.

The sensor has a twist-lock design with a latch mechanism, and is located at the rear of the engine in the water crossover pipe, between the two heads.

Failure Modes

- Uses engine-off time and MAF for calculation

Failure Symptoms

- Poor cold and hot start
- Poor driveability
- Cooling fans on permanently

Specification	Function
Supply voltage	5V $\pm$ 0.1V
Operating temperature range	-30°C to 125°C (-22°F – 257°F)
Pin 1	Sensor output signal
Pin 2	Sensor ground

Sensor Resistance vs. Coolant Temperature

Coolant Temperature	Approx. Resistance
-20°C (-4°F)	15.04 +0.90/-0.83 kOhms
20°C (68°F)	2.45 +0.10/-0.09 kOhms
80°C (176°F)	0.318 $\pm$ 0.007 k Ohms
110°C (230°F)	0.1471 $\pm$ 0.0018 k Ohms

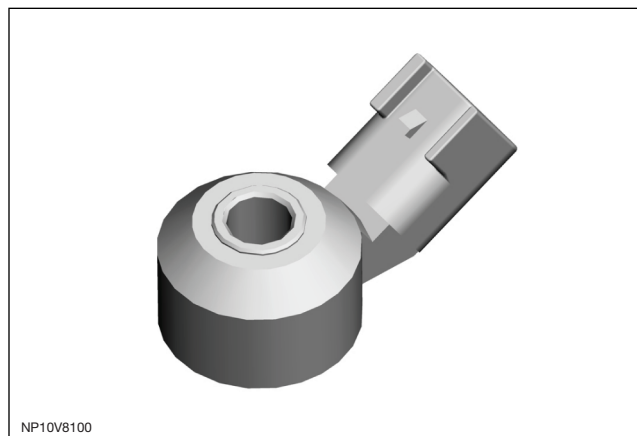
NOTE: If the ECT sensor fails, the ECM uses a default value. The electric fan control module is sent a default coolant temperature value and switches the cooling fan(s) on permanently.

The voltages shown represent the signal processed by the ECM. When a defective coolant sensor is detected, the coolant value defaults to 40°C (104°F) and remains fixed until the ECM is powered down.

KNOCK SENSORS

The ECM uses active knock control, which serves to prevent engine damaging pre-ignition or detonation under all operating conditions, enabling the engine to operate without additional safety margins.

The ECM uses 4 piezo-ceramic knock sensors to determine the point at which a cylinder is pre-detonating. Two sensors are mounted on the intake side of each cylinder head.



Each sensor monitors engine knock by converting the engine block noise into a suitable electrical signal, which is then transmitted back to the ECM via a twisted-pair cable. The signal is processed within the ECM to identify the data that characterizes knocking.

This information is compared to known signal profiles to determine whether pre-ignition is present. If so, the closed loop control system retards the ignition on that cylinder for a number of cycles, after which it gradually moves back towards its original setting.

Safety Precautions

⚠ CAUTION: Terminals in sensor and connector are gold plated for corrosion/temperature resistance. Do not probe connections.

NOTE: Accurate orientation of the knock sensors on the cylinder block is required to ensure correct connection to the vehicle wiring harness.

Failure Modes

- Sensor open circuit
- Short circuit to vehicle ground or battery voltage
- Faulty component or incorrectly torqued / coming loose
- Noise on vehicle 12V supply could look like knock signal causing knock fault
- Min fault usually due to open circuit
- Max fault short circuit to battery voltage or extreme mechanical engine noise/piston slap
- ECM calculates the default value if one sensor fails on each bank of cylinders

Failure Symptoms

- Knock control is disabled and a default 'safe ignition map' is used
- Possible rough running and reduced engine performance

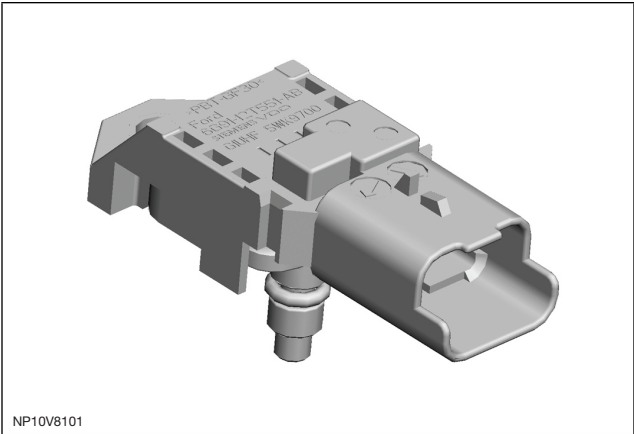
Failure Mode Behaviors

- The vehicle control system constantly checks open circuit of knock sensor. Therefore, the knock sensor is connected to the power source via pull-up line of the ECM.
- When short/open circuit occurs to the knock sensor signal circuit, the system detects it, sets failure flag, and commences maximum retard control on spark advance.
- As far as the behavior of knock sensor is concerned, however, the above-mentioned failure modes cannot cause serious outcomes such as heat generation, smoke emission and/or fire hazard.

Specification	Function
Power Source	N/A
Wiring Type	Twisted Pair
Shunt Resistance	4.8M Ohms
Operating Range	3kHz – 22kHz
Mounting Torque	20Nm +/- 3.8Nm

MANIFOLD ABSOLUTE PRESSURE SENSOR

The manifold absolute pressure (MAP) sensor provides a voltage proportional to the absolute pressure in the intake manifold. This signal allows the load on the engine to be calculated and used within the internal calculations of the ECM.



The MAP sensor is mounted on the top of the engine, at the front behind the throttle body. The purpose of the sensor is to measure the absolute pressure in the intake manifold and provide information to the ECM, which will determine the injection time.

The sensor is a semi-conductor type, which responds to pressure acting on a membrane within the sensor, altering the output voltage.

The sensor receives a 5V reference voltage and a ground from the ECM and returns a signal of between 0.5 – 4.5V to the ECM. A low pressure returns a low voltage signal to the ECM and a high pressure returns a high voltage.

The MAP sensor detects quick pressure changes in the intake manifold after the electronic throttle. The signal is used in conjunction with the MAF sensor signal to calculate the injection period. The ECM monitors the engine MAP sensor for faults and can store fault related codes.

Failure Modes

- Sensor open circuit
- Short circuit to battery voltage or ground
- Intake air restricted
- Default value of 1 bar (14.5 psi)

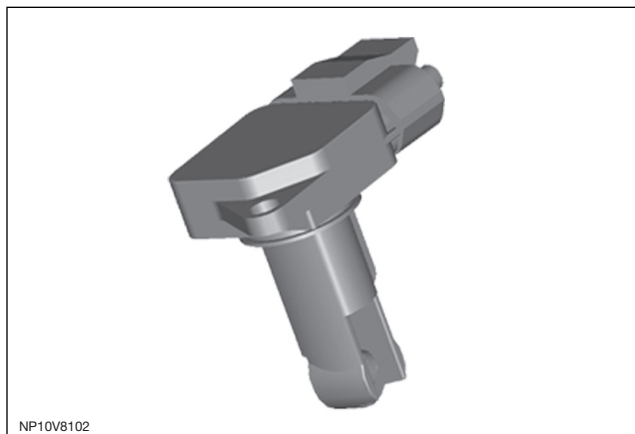
Failure Symptoms

- Rough running
- Difficult starting
- Poor driveability

Specification	Function
Power Source	5V $\pm$ 0.25V
Pin 1	Power
Pin 2	Ground
Pin 3	Output Signal
Operating Range	13.3 kPa – 250 kPa

MASS AIR FLOW SENSOR

Mass air flow is determined by the cooling effect of intake air passing over a 'hot film' element contained within the device. The higher the air flow the greater the cooling effect and the lower the electrical resistance of the 'hot film' element. The ECM then uses this analog signal from the mass air flow (MAF) sensor to calculate the air mass flowing into the engine.



The measured air mass flow is used in determining the fuel quantity to be injected in order to maintain the stoichiometric air/fuel mixture required for correct operation of the engine and exhaust catalysts. Should the device fail, there is a software backup strategy that will be activated once a fault has been logged.

The intake air temperature (IAT) sensor is integrated into the MAF sensor. The IAT sensor is an NTC thermistor, meaning that the sensor resistance decreases as the sensor temperature increases.

The sensor forms part of a voltage divider chain with an additional resistor in the ECM. The voltage from this device changes as the sensor resistance changes, thus relating the air temperature to the voltage measured by the ECM.

Because the engine requires a twin air intake induction system, there are two MAF sensors per vehicle.

Safety Precautions

⚠ CAUTIONS:

- **Component should not be dropped or handled roughly.**
- **Ensure that no contamination enters the device.**
- **Some terminals in MAF and connector are gold-plated for corrosion resistance – DO NOT probe.**

Failure Modes

- Sensor open circuit
- Short circuit to battery voltage or ground
- Contaminated/damaged sensor element
- Air leak after MAF sensor
- Intake air restricted
- Resistance in the harness, causing signal offset
- Damaged sensor element

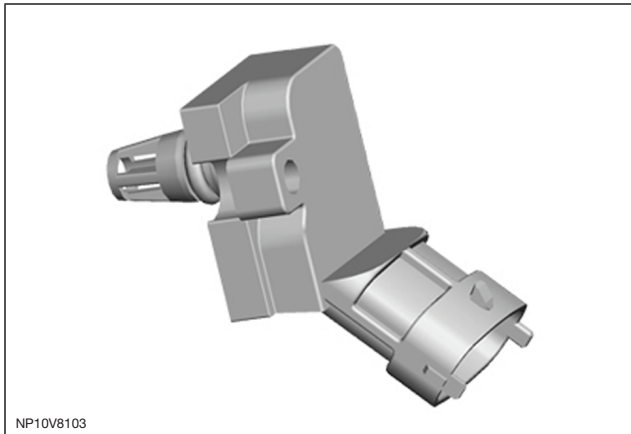
Failure Symptoms

- During driving the engine rpm might dip (before recovering)
- Difficulty in starting or start/stall
- Poor throttle response/engine performance
- Emissions incorrect
- Lambda control and idle speed control halted
- MAF signal offset

Specification	Function
Supply Voltage	8 – 14V (rated supply voltage: 14V)
Pin A	Output (Vg)
Pin B	Ground for Output (Vg)
Pin C	Power Source
Pin D	IAT Sensor Ground
Pin E	IAT Sensor Output

TEMPERATURE AND MANIFOLD ABSOLUTE PRESSURE SENSOR

The temperature and manifold absolute pressure (TMAP) sensor is used only on SC variants. The TMAP sensor provides a voltage proportional to the absolute pressure between the supercharger intercooler and the intake valve and the air charge temperature. These signals allow the ECM to calculate the air charge density.



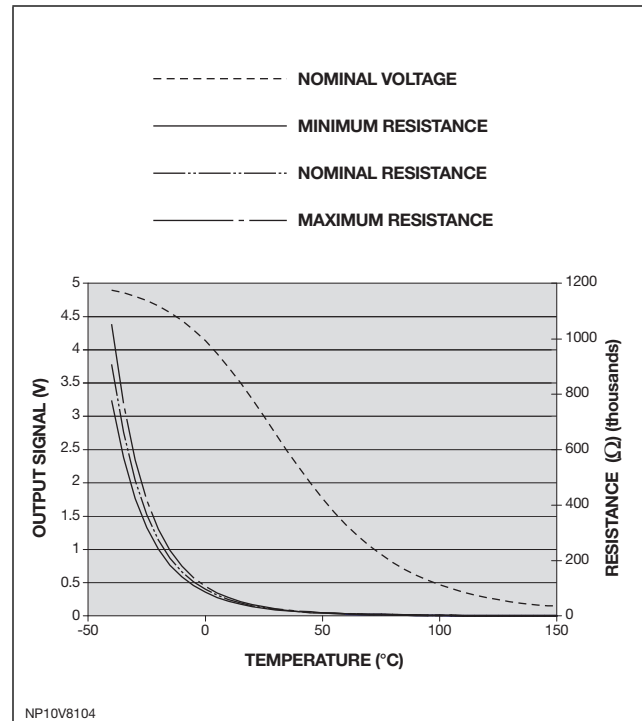
The TMAP sensor is mounted at the rear of the engine, below the charge air cooler of the LH bank.

Failure Modes

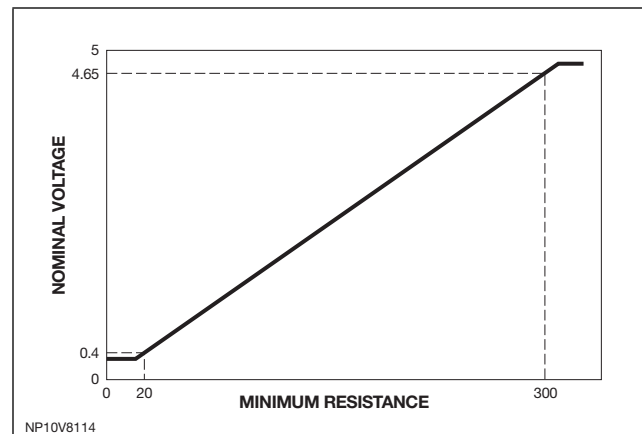
- Sensor open circuit
- Short circuit to battery voltage or ground
- Intake air restricted
- Boosted air leak

Specification	Function
Pin 1	Pressure Output Signal
Pin 2	Supply Voltage
Pin 3	Temperature Signal
Pin 4	Ground

Temperature Signal



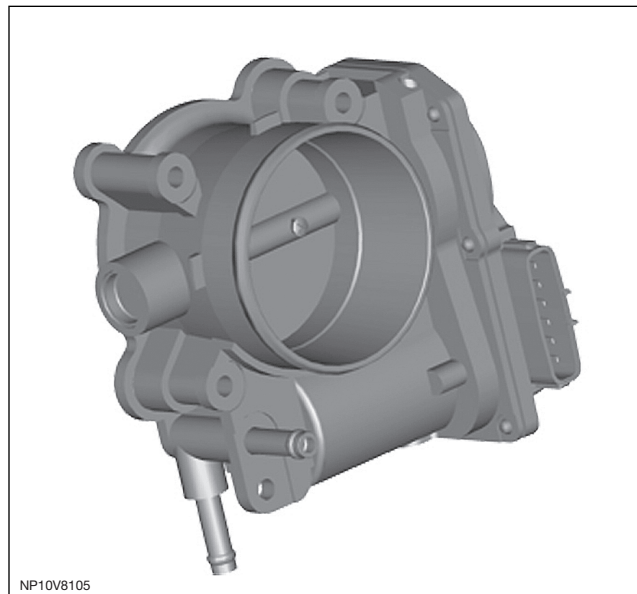
Pressure Signal



THROTTLE POSITION SENSOR

The engine torque is regulated via an electronic throttle body ('drive-by-wire' system), where an electronic pedal assembly determines throttle opening.

The throttle position (TP) sensor is mounted in the integrated cover plate on the throttle body assembly. The throttle body assembly is mounted at the top front of the engine, in a similar position for both NA and SC variants.



This value is input into the ECM and the throttle is opened to the correct angle by means of an electric direct current (DC) motor integrated into the throttle body. Movement of the motor is achieved by changing the PWM signal to the DC motor, allowing it to be operated in both directions.

The dual-output TP sensor in the throttle body is used to determine the position of the throttle blade and the rate of change in its angle.

A software strategy within the ECM enables the throttle position to be calibrated each ignition cycle. When the ignition is turned ON, the ECM commands the throttle to open and close fully, thus performing a self-test and calibration, learning the position of the full closed hard stop position.

Safety Precautions

⚠ CAUTION: Terminals in sensor and connector are gold-plated for corrosion/temperature resistance – DO NOT probe.

Failure Modes

- Sensor open circuit
- Short circuit to battery voltage or ground
- If signal failure occurs the ECM will enter a limp home mode where the maximum engine speed is 2000 rpm
- Signal offset
- Vacuum leak

Failure Symptoms

- Poor engine running and throttle response
- Limp home mode – maximum 2000 rpm
- Emission control failure
- No closed loop idle speed control

Specification	Function
Supply voltage	5V $\pm$ 0.2 V
Supply current	Max. 10 mA/1 output
Tolerance – closed position	$\pm$ 150 mV
Tolerance – WOT position	$\pm$ 150 mV
Operating temperature range	-40°C – 160°C (-40°F – 320°F)
Pin 1	Throttle motor valve open: direction +
Pin 2	Throttle motor valve open: direction –
Pin 3	Position sensor output 2 (Gold)
Pin 4	Ground (Gold)
Pin 5	Position sensor output 1 (Gold)
Pin 6	Position sensor 5V supply (Gold)

Throttle Body Motor

The air mass flow through the throttle body is a function of throttle angle, air temperature, air pressure before throttle plate, and differential air pressure over the throttle plate.

Specification	Function
Control signal	500Hz PWM
Resistance	1.2 Ohms
Normal operating voltage range	13.5 V to 14.2 V
Tolerance – WOT position	±150 mV
Operating temperature range	-40°C – 160°C (-40°F – 320°F)

ACCELERATOR PEDAL POSITION SENSOR

The accelerator pedal position (APP) sensor provides a pedal position signal to the ECM. The ECM uses this information to actuate the damper motor in the electronic throttle assembly to move the throttle disc to the correct angle in relation to the pedal position.

The APP sensor signals are checked for range and plausibility. Two separate reference voltages are supplied to the pedal. Should one sensor fail, the other is used as a limp home input.

The accelerator pedal position (APP) sensor provides two outputs. If the ECM detects a difference between the two signals, a fault code is stored. The ECM will use the signal with the lowest value for electronic throttle control.

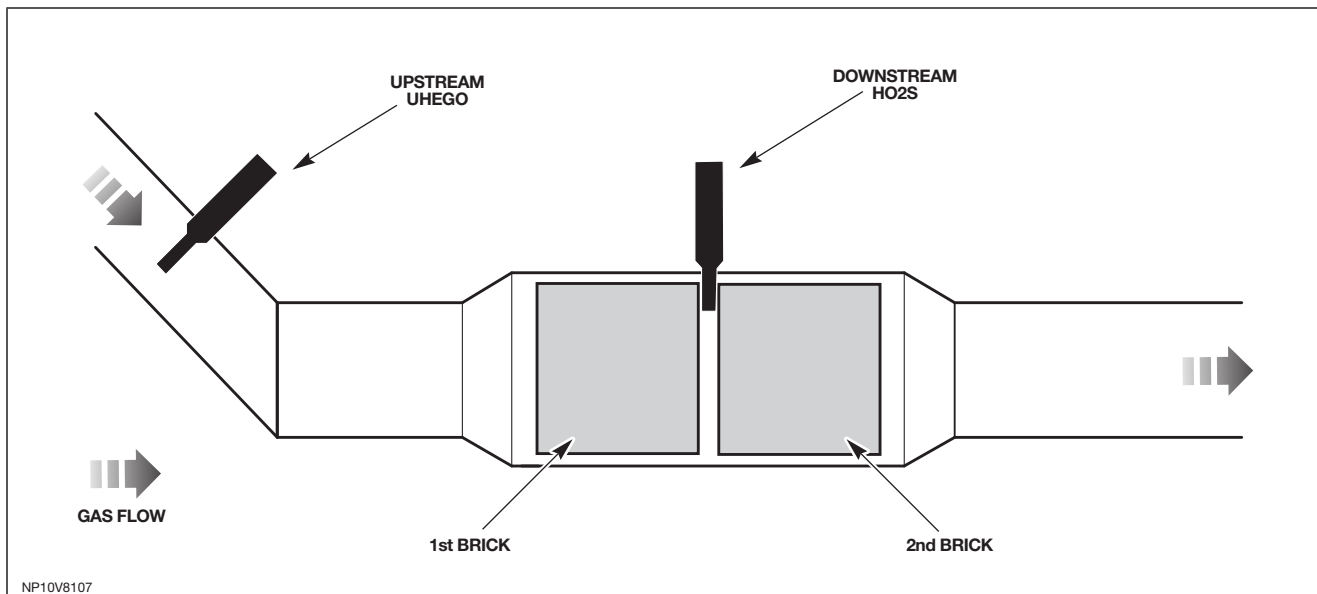
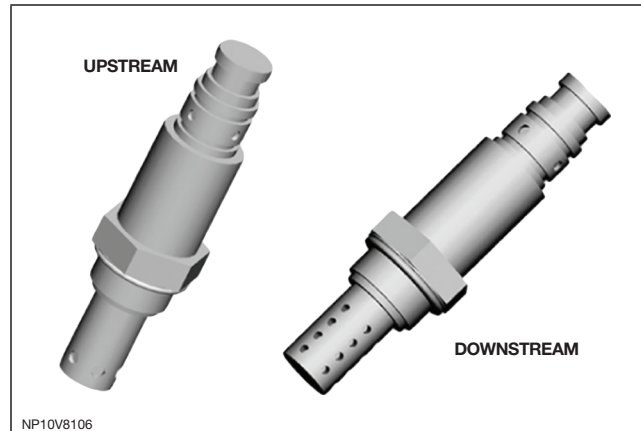
Pin	Function
Pin 1	5V 1
Pin 2	Demand 1
Pin 3	Ground 1
Pin 6	5V 2
Pin 5	Demand 2
Pin 4	Ground 2

HEATED OXYGEN SENSORS

The heated oxygen sensors monitor the level of oxygen in the exhaust gases and are used to control the fuel/air mixture. Positioning the sensors in the stream of exhaust gasses from each bank enables the ECM to control the fuel metering on each bank independently of the other, allowing much closer control of the air/fuel ratio and catalyst conversion efficiency.

There are four heated oxygen sensors per engine:

- One upstream Universal Heated Exhaust Gas Oxygen (UHEGO) sensor per bank
- One downstream Heated Oxygen Sensor (HO2S) per bank.



Upstream Universal Heated Exhaust Gas Oxygen Sensors

In order to improve the control of the air : fuel ratio (AFR) under varying engine conditions, a linear or 'universal' heated exhaust gas oxygen (UHEGO) sensor is used in the upstream location. The UHEGO has a varying current response to changes in the exhaust gas oxygen content.

The AFR can be maintained more precisely within a range from approximately 12:1 to 18:1, not just stoichiometric. Voltage is maintained at approximately 450 mV by applying a current.

The current required to maintain the constant voltage is directly proportional to the AFR. A higher current indicates a leaner condition; a lower current indicates a richer condition. The current varies with the temperature of the sensor and is therefore difficult to measure for technician diagnostic purposes.

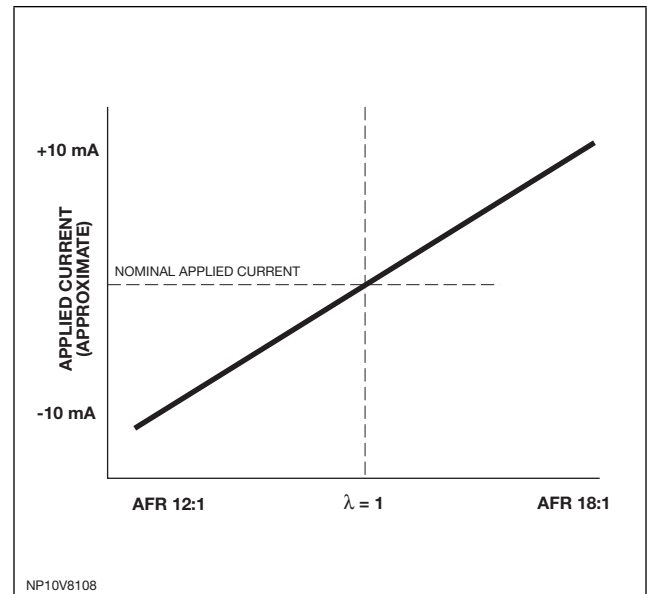
The upstream UHEGO sensors need to operate at high temperatures – 750°C (1,382°F) – in order to function correctly. To achieve this, the sensors are fitted with heater elements that are controlled by a PWM signal from the ECM.

The heater elements are operated immediately following engine start and also during low load conditions when the temperature of the exhaust gases is insufficient to maintain the required sensor temperatures.

A non-functioning heater delays the sensor's readiness for closed loop control and influences emissions. The PWM duty cycle is carefully controlled to reduce thermal shock risk to cold sensors.

The upstream UHEGO sensors are mounted to the engine on the exhaust manifolds, in the mating flange to the exhaust pipes. There is one sensor per bank. The sensors are fitted during engine assembly.

Upstream UHEGO Output



Downstream Heated Oxygen Sensors

The latest switching downstream exhaust sensors are precise-control heated oxygen sensors (HO2S). These sensors have a tighter lean/rich tolerance compared to previous HO2S. The only visible distinction between the current and previous HO2S is the part number.

The downstream HO2S uses smaller elements in its construction to enable quicker heat-up times to control fuel metering at lower temperatures (emissions).

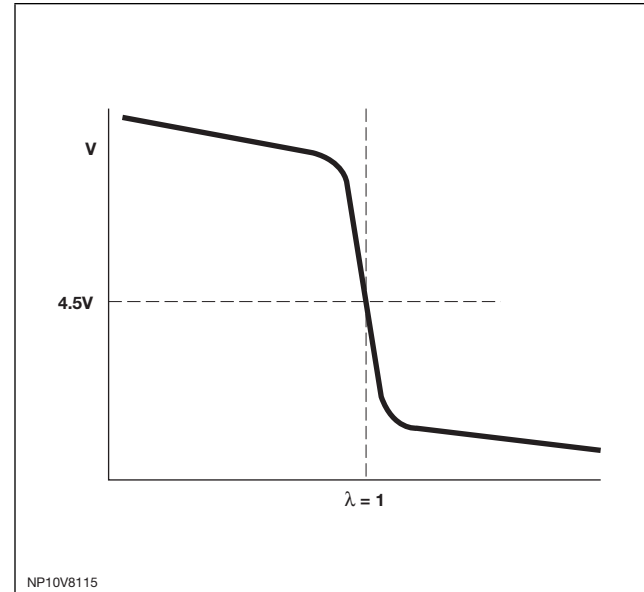
The primary function of the downstream HO2S is to ensure correct operation of the three way catalyst.

The downstream HO2S uses Zirconium technology that produces an output voltage dependant upon the ratio of exhaust gas oxygen to the ambient oxygen. The device contains a Galvanic cell surrounded by gas-permeable ceramic, the voltage of which depends upon the level of O₂ diffusing through.

Nominal output voltage of the device for $\lambda = 1$ is 300 – 500mV. As the fuel mixture becomes richer (<1) the voltage tends towards 900mV and as it becomes leaner ($\lambda > 1$) the voltage tends towards 0 volts.

The downstream HO2S are mounted in the exhaust system part way in the rear of the catalyst.

Downstream HO2S Output



Safety Precautions **WARNINGS:**

- Anti-seize compound used on service sensor threads may be a health hazard. Avoid skin contact.
- Exhaust system components, catalysts in particular, operate at high temperatures and remain hot for a long time after operation.

 CAUTIONS:

- Oxygen sensors must be treated with the utmost care before and during the fitting process. The sensors have ceramic material within them that can easily crack if dropped or over-torqued. They must be tightened to the specified torque figure with a calibrated torque wrench. Care should be taken not to contaminate the sensor tip when the anti-seize compound is used on the thread.
- To prevent damage to the sensors, a special tool (box spanner) should be used when removing.
- If the sensor sticks in the exhaust, apply de-seize product and use a repeating tighten and loosen strategy.
- Ensure that the sensor harness is robustly secured away from moving or hot parts.

Failure Modes

- Mechanical fitting and integrity of the sensor (i.e. cracked)
- Sensor open circuit/disconnected
- Short circuit to battery voltage or ground.
- Lambda ratio outside operating band
- Crossed sensors (RH bank fitted to LH bank and vice-versa)
- Contamination from leaded fuel or other sources
- Harness damage
- Air leak into exhaust system (cracked pipe/weld or loose fixings)

Failure Symptoms

- Default to open loop fuel metering
- High CO reading
- Strong smell of sulfur (rotten eggs) until default condition
- Excess emissions
- Unstable operation
- Reduced performance

AMBIENT AIR TEMPERATURE SENSOR

The ambient air temperature (AAT) sensor is located in the underside of the LH exterior door mirror. The sensor is an NTC thermistor – the element resistance decreases as the sensor temperature increases, which produces a low signal voltage.

The ECM supplies the sensor with a 5V reference voltage and ground, and measures the returned signal voltage as an outside temperature.

The AAT signal is used by the ECM for a number of functions including engine cooling fan control and A/C compressor displacement control.

The ECM also transmits an ambient temperature message on the high speed CAN bus for use by other control modules.

Pin	Function
Pin 1	5V supply
Pin 2	Ground

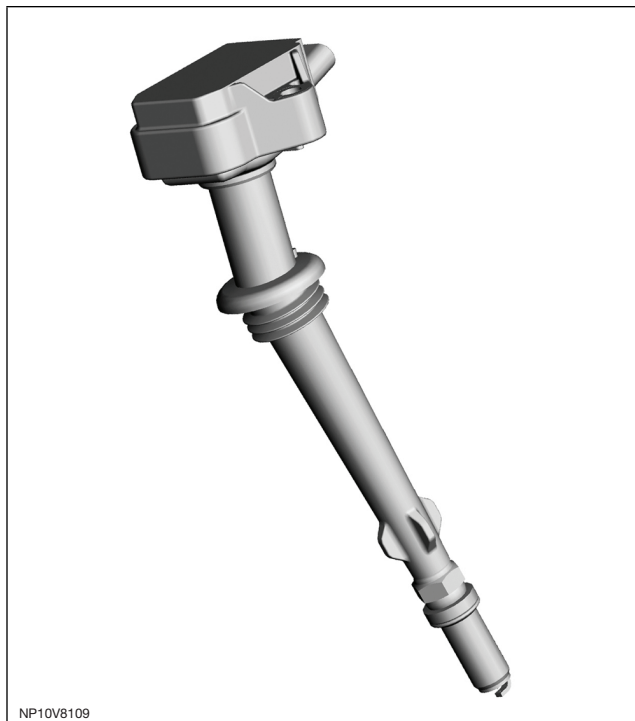
NOTE: If there is a fault with the AAT sensor, the ECM calculates the AAT from the temperature inputs of the IAT sensors. If the AAT sensor and the temperature inputs of the IAT sensors are all faulty, the ECM adopts a default ambient temperature value of 20°C (68°F).

Failure Mode

- Default value of 20°C (68°F)

IGNITION COILS

The ignition coil operates according to the laws of induction. The unit consists of two magnetically-coupled copper coils (primary and secondary windings). The coil has a 3-pin connector and incorporates an internal switching module.



Energy is stored in the primary winding's magnetic field by allowing a current to flow through the primary circuit switched by the switching module.

At the firing point the current flow is interrupted by the ECM, which induces secondary voltage in the coil's secondary winding.

The secondary circuit has a diode on the ground side in order to reduce any undesired switch-on voltage, which could lead to misfiring into the intake manifold to an uncritical value.

The switching module will limit the primary current to a maximum value. It also limits the maximum primary voltage by voltage clamping. This protects the switching module and (along with other parameters) determines the maximum possible secondary voltage.

Safety Precautions

⚠ WARNING:

- Ignition coils generate high voltages that can cause personal injury. Appropriate safety instructions on handling high voltages must be observed.

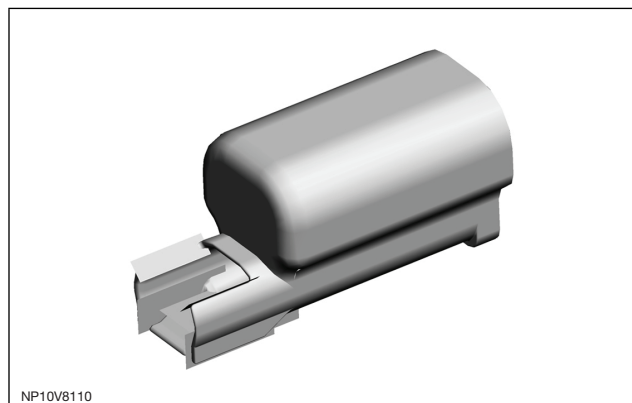
⚠ CAUTIONS:

- The spark plugs fitted are critical to the performance of the ignition and misfire detection systems. No attempt should be made to 'clean' or 'gap' these spark plugs. They are very reliable and unlikely to cause problems. If a faulty spark plug is suspected, try substituting it before condemning it. It is essential that only factory-approved spark plugs be used in service. **DO NOT** attempt to use 'equivalent' spark plugs, even if they are of a similar design. Use of unapproved spark plugs will cause the misfire detection system to malfunction and erroneously store misfire faults.
- To avoid damage to the insulator, always use the correct specified spark plugs and correct plug removal/refit plug socket.

NOTE: A single capacitor is used in the engine harness to suppress interference from the ignition coil power supply.

Radio Frequency Interference Suppressor

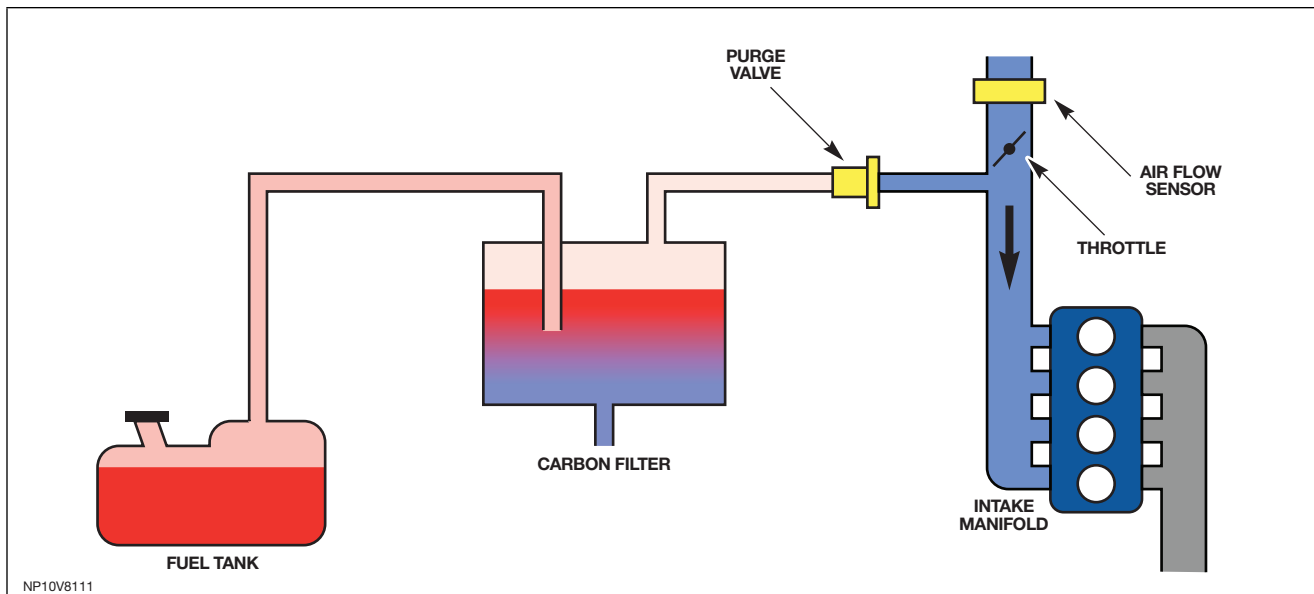
The radio frequency interference (RFI) suppressor is mounted on the harness carrier bracket on at the upper rear of the engine.



FUEL TANK CANISTER PURGE VALVE

To comply with legislation in fuel evaporative loss, the evaporative emissions loss control system is used on all vehicles. Its purpose is to minimize the evaporative loss of fuel vapor from the fuel system to the atmosphere. This is achieved by venting the fuel system through a vapor trap – a canister filled with vapor-absorbing charcoal. The charcoal acts like a sponge and stores the vapor until the canister is purged under the control of the ECM into the engine for combustion. The carry-over system uses the DMTL system to check for fuel tank integrity.

The canister is connected with the intake manifold, after the throttle body, via a purge valve. This valve is opened and closed according to a PWM signal from the ECM. The system does not work properly in the case of leakage or clogging within the system or if the purge valve cannot be controlled.



The canister is purged by drawing clean air through the charcoal, which carries the hydrocarbons into the engine where they are combusted. To maintain driveability and emission control, purging must be closely controlled as a 1% concentration of fuel vapor from the canister in the air intake may shift the air/fuel ratio by as much as 20%. Purging must be carried out at regular intervals to regenerate the charcoal, since the storage capacity is limited. The purge function is alternated with the fuel metering adaptation, as both cannot be active at the same time.

The ECM alters the PWM signal to the purge valve to control the rate of purging of the canister. The purging of the canister is done in a controlled manner in order to maintain the correct stoichiometric air/fuel mixture for the engine.

The ECM also ensures that the canister itself is purged frequently enough to prevent fuel saturation of the charcoal, which could lead to an excessive buildup of fuel vapor (and vapor pressure) in the system, increasing the likelihood of vapor leaks.

Failure Modes

- Valve drive open circuit
- Short circuit to battery voltage or ground
- Valve/pipe work blocked
- Valve stuck open
- Pipe work leaking/disconnected
- Noisy valve

Failure Symptoms

- Engine may possibly stall on return to idle (if valve stuck open)
- Poor idling quality (if valve stuck open)
- Fuel metering adaptations forced excessively rich if canister is clear with valve stuck open
- Fuel metering adaptations forced excessively lean if canister is saturated with valve stuck open
- Saturation of canister (if valve stuck closed)

VISCOUS FAN CONTROL (LAND ROVER ONLY)

On Land Rover vehicles, the ECM uses an electronically-controlled viscous-coupled fan to provide engine cooling. The ECM supplies the fan with a PWM signal that controls the amount of slippage of the fan, thus providing the correct amount of cooling fan speed and air-flow. The EMS uses a Hall-effect sensor to determine the fan speed.

Failure Modes

- Solenoid drive open circuit
- Short circuit to battery voltage or ground
- Fan speed monitor open circuit
- Physically damaged fan or viscous coupling

CONTROLLER AREA NETWORK

The Controller Area Network (CAN) is a high-speed serial interface for sharing dynamic signals between electronic control modules. CAN communications are 'self-checked' for errors, and if an error is detected the message is ignored by the receiving electronic control module.

Due to the high rate of information exchange, the system has a high degree of latency. This allows for a high number of errors to be present without reducing the data transfer rate. In practice, this is a very reliable system.

Each CAN message is transmitted by one electronic control module and received by all other electronic control modules on the CAN bus. Each message contains a fixed structure of signals. The data exchanged is used so that each electronic control module does not need to have a hardwired sensor for each input. The CAN message identifiers are arranged by a network tool, which can guarantee that all messages meet their specified timing needs.

Signal Overview

The CAN communication system is a differential bus using a twisted pair that is normally very reliable. If either or both of the wires of the twisted pair CAN bus is open- or short-circuited, a CAN time-out fault will occur.

Below is a list of additional electronic control modules that the ECM will communicate with on the CAN network:

- Instrument cluster
- Steering angle sensor
- TCM
- Active rear locking differential, if equipped
- Adaptive cruise control
- Electronic parking brake

Failure Modes

- CAN bus wiring short circuit or open circuit
- Incompatible software and message versions

ON-BOARD DIAGNOSTIC MONITORING

Some OBD monitors are continuous, that is they operate all the time the ignition is on.

Some OBD monitors have conditions that must be met before the monitor is allowed to operate, such as engine speed 1000 – 4000 rpm and engine airflow 10 – 100 g/sec and intake air temperature -10 – +50°C, in order to ensure the vehicle is operating in such a manner that the failure may be correctly diagnosed. For this reason it may be possible for a failure to be present on the vehicle but remain undetected by the module.

Most OBD monitors use 2-trip detection: if on the first occasion the failure is detected, a pending DTC is recorded. If the failure is again detected on the next drive cycle, then a confirmed DTC is logged and the MIL may be illuminated.

A few OBD monitors operate on a single-trip basis where the MIL is illuminated as soon as the failure is diagnosed.

Detection of a failure may prevent the operation of other OBD monitors. This is to prevent the logging of multiple DTCs for a single. However, the system is not infallible, and a single fault may result in two or more failures being detected, with two or more DTCs being recorded.

CRANKCASE VENTILATION SYSTEM

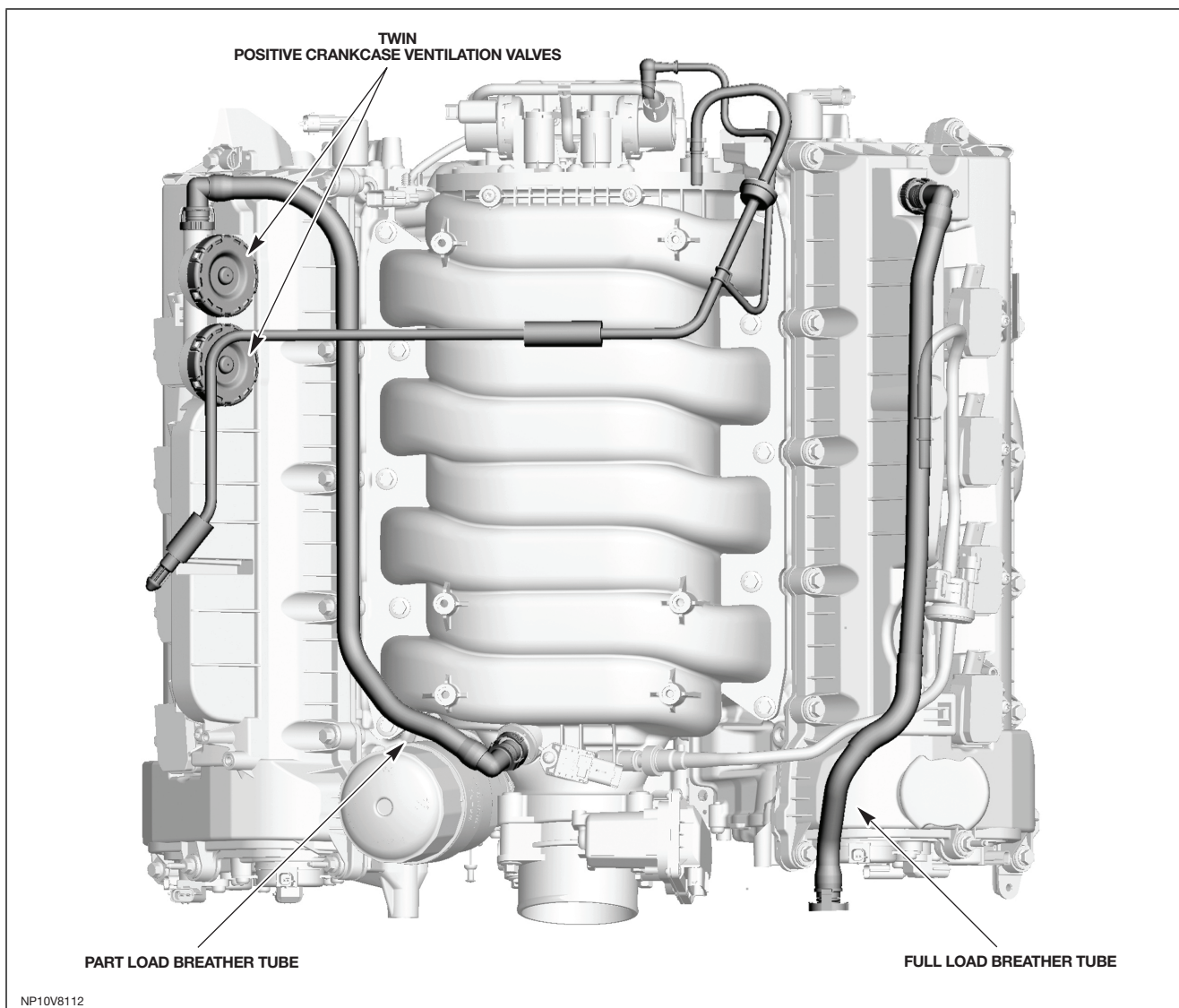
During a normal compression stroke, small amounts of gases in the combustion chamber escape past the piston. Approximately 70% of these gases are unburned fuel (Hydrocarbons).

The purpose of a Positive Crankcase Ventilation (PCV) system is to prevent crankcase pressure build-up, protect engine seals, and remove harmful gases from the crankcase and combine them with the engine's normal incoming air/fuel charge.

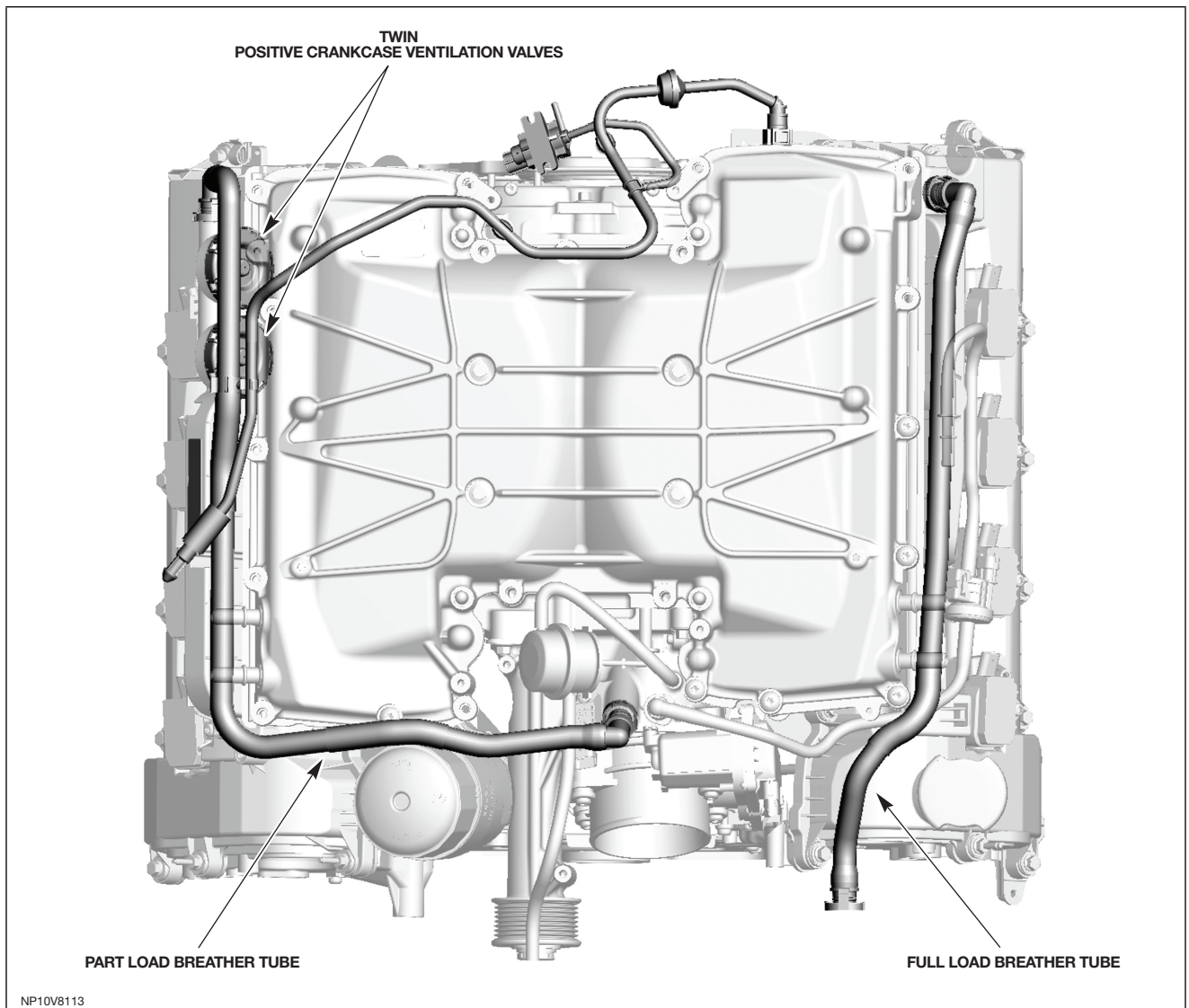
The crankcase is ventilated through part-load and full-load breathers and oil separators, which consist of a variable geometry oil separator, pressure control valves, and oil drain valve. This sophisticated system reduces oil pullover by over half.

The integrated twin PCV valves prevent the hose from icing and improve driveability in cold climates. The full load breather hose purges the crankcase and reduces condensation when the engine is cold.

NA Crankcase Ventilation System



SC Crankcase Ventilation System



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