

Technical information

# Engine



Volvo 850 GLT

**VOLVO**

# Volvo 850 Engine

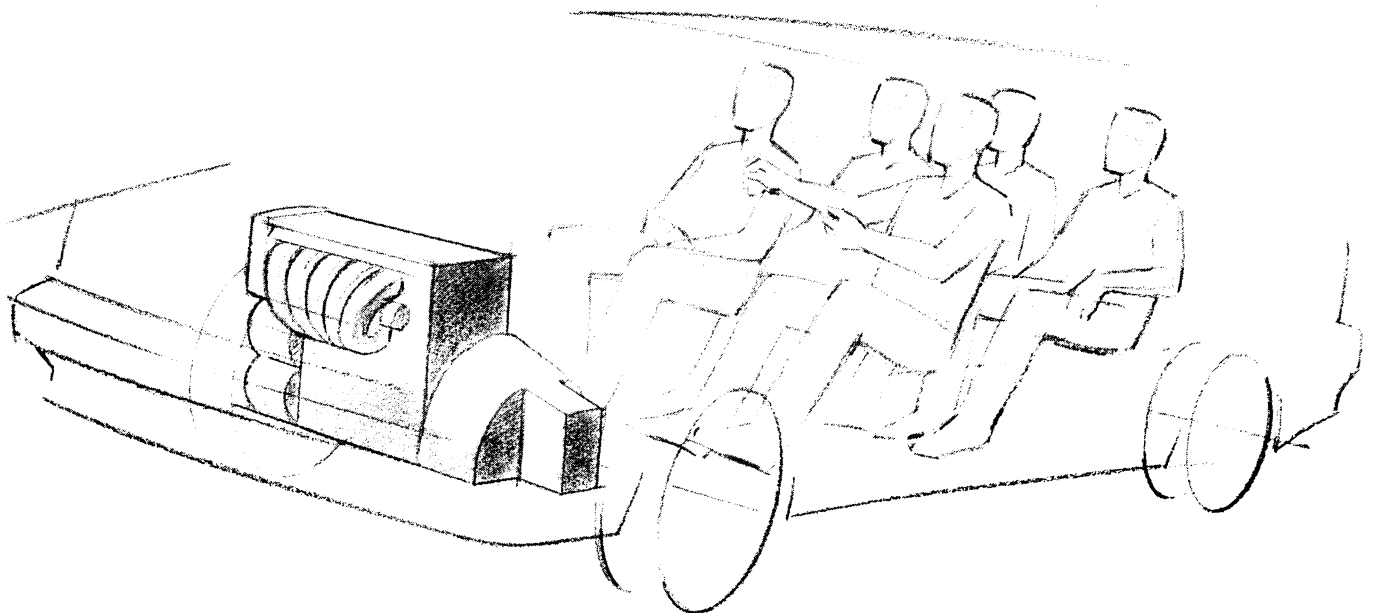
## Introduction

The demands on the car of the 90's are very high in every respect. As vehicle manufacturer one can no longer concentrate only on a subset of all properties. To gain success, excellence is required in all areas.

Furthermore, the customer of the 90's will not accept having to adapt himself or herself to the vehicle. The vehicle must instead be adapted to man. This

makes it necessary to study man-machine interactions when developing a new car.

These demands, coupled with the many properties affected by engine characteristics, create the need for a property oriented development process where the combination of all properties are taken into consideration from the very beginning.



# Development goals

Every customer expects good comfort, good performance and fuel economy from their car. This in turn, places a demand for effective and efficient technical solutions; to choose, as Volvo sees it, the best solution for each specific purpose.

The challenge for Volvo consequently meant to combine a roomy interior with a solid safety structure, compact exterior dimensions and effective energy absorption with a powertrain combining comfort, performance and energy efficiency.

A transverse installation of an in-line engine is today accepted as the best technical and most space efficient solution. This is a solution already chosen for the Volvo 400-series and was on space, packaging and handling grounds also chosen for the Volvo 850 GLT.

The development of the new engine is the second step of Volvo's new modular engine family, the N-series. The first step was the in-line six B6304F, which was introduced in the Volvo 960 in August 1990.

The modular engines have several identical components. The major components are machined in a common transfer line, in a highly rational and most cost-effective manufacturing process.

The normal order of priority for engine properties during design and development within Volvo Car Corporation is the following:

- Exhaust emissions
- Fuel economy
- Driving pleasure
- Performance

The interactions between these four main properties are very strong and it is very difficult to alter one without affecting the others.

Since a lot of emphasis during the development of the Volvo 850 was put on performance and driving pleasure, this had its effect on the internal relationships of the four properties given priority. In order to meet the performance requirements with maintained fuel economy, a variable induction system was introduced. This made it possible to combine high torque at low engine speeds with high power at high engine speeds, keeping fuel consumption optimized.

Big efforts have also been made to reduce noise and vibrations. Therefore the best ignition timing has not only been determined by emissions, fuel consumption, performance and driveability but also by its effect on noise and vibrations. Comfort is a property that also has been given high priority when developing the engine for the Volvo 850.

Another example of this is throbbing and sawing powertrain motions that goes with a transverse engine installation and front wheel drive. Such motions have been minimized by electronic dashpot functions and other features of the engine management systems.

# The Volvo 850 engine concept

The engine in the Volvo 850 GLT is an in-line 2.5 litre five-cylinder called the B5254F. Thanks to an extremely compact design of the engine and transmission (See Technical information Transmission) it has been possible to install it transversely (figure 1), still allowing for excellent handling properties and an extremely small turning circle (10.2 metres) for a front wheel drive car of this size. The Volvo 850 GLT is the first passenger car that has an in-line five-cylinder engine installed transversely driving the front wheels. Overall length of the complete powertrain, engine and transmission, is only 948 mm.

The main characteristics of the B5254F are:

- Five cylinders with four valves per cylinder and a high compression ratio
- High performance and good fuel economy without negative influence on driveability
- Minimized engine vibrations thanks

to inherent engine and transmission rigidity, damped engine and suspension system and a separate insulated sub-frame carrying the powertrain.

- A variable induction system, the V-VIS (Volvo Variable Induction System) and an extractor type exhaust manifold. Since this is located between the engine and the firewall, the position of the catalyst could be close to the engine which provides faster warming-up of the catalyst and thus low exhaust emissions.

Among the basic development goals for the engine concept were a high degree of reliability and long service life; high energy efficiency; easy maintenance; rational manufacture; compactness in size; low weight and low noise level.

As for reliability and service life, the engine has a life span of more than 20 years or a total driving distance of more than 200.000 without needing disassembly and with all vital parts in

good working condition.

Regarding high energy efficiency, the gas flow has been optimized with the aid of computer simulations and laser measurement technology in order to ensure efficient use of energy.

During the development of the engine, Volvo Car Corporation service personnel have contributed with their know-how in order to achieve high reliability with a minimum of maintenance. A number of automatic functions minimize the need for manual adjustments:

- Hydraulic tappets (no adjustment of valve clearance)
- Automatic belt tensioners for camshaft and auxiliary drives
- Adaptive functions of the control systems compensating for system tolerances and wear, temperature and fuel variations ensuring optimum fuel metering and ignition timing
- Automatic idling speed adjustment and air/fuel ratio

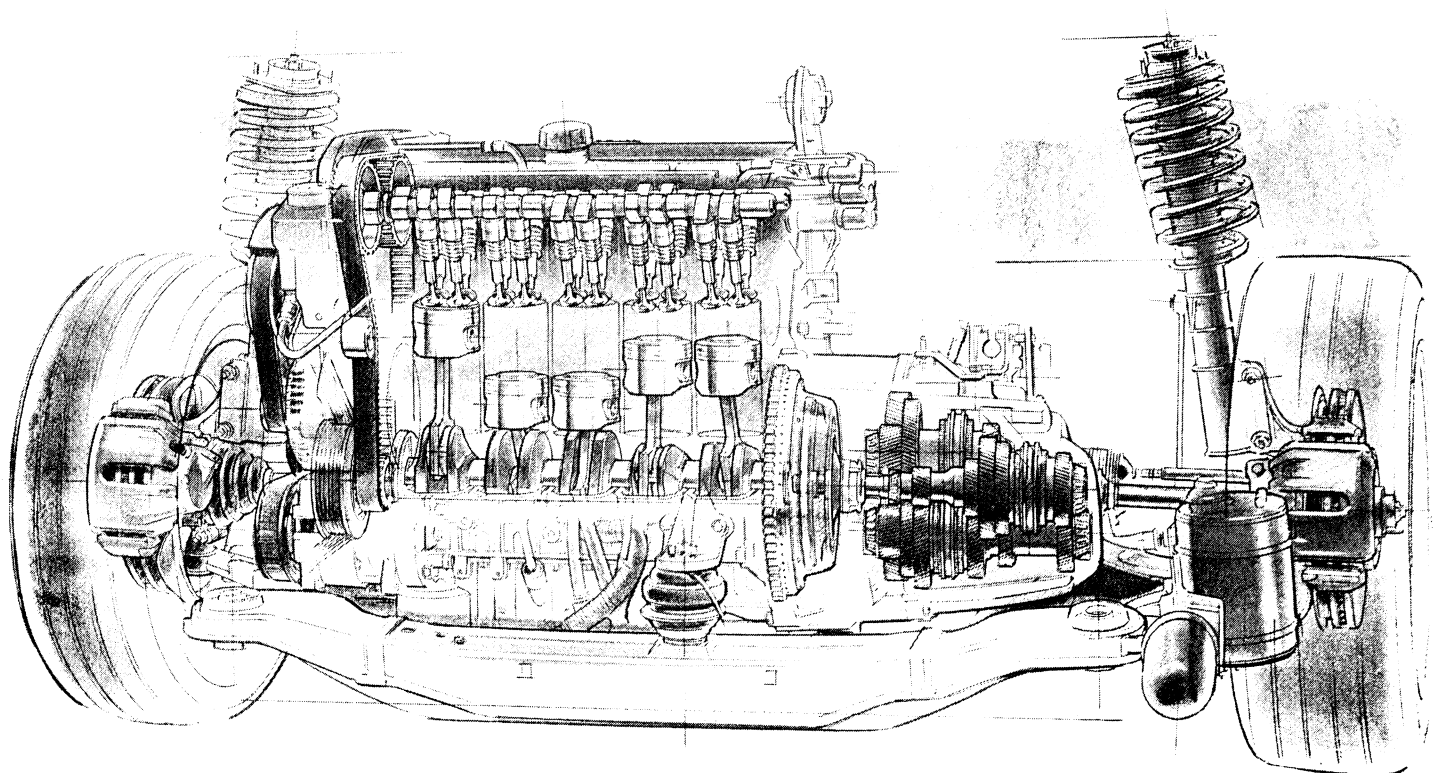
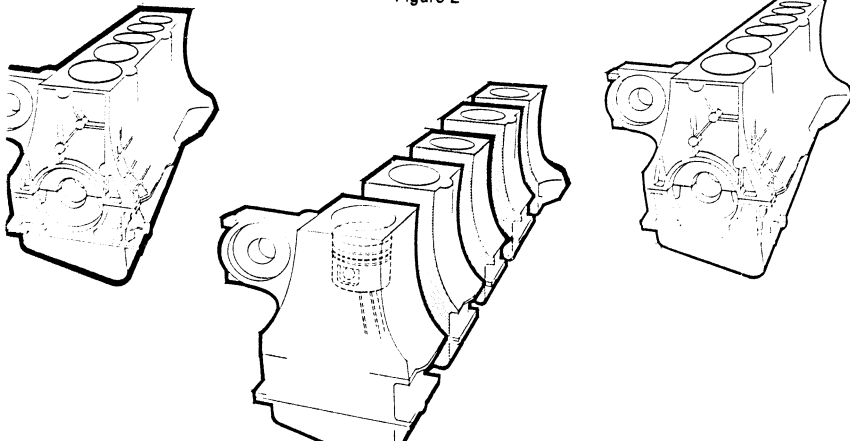


Figure 1

Figure 2



The modular engine concept (figure 2) grants advantages in product as well as in industrial structure. Thanks to using the same basic design, the achievements are:

- Flexibility in size, power output, installation possibilities and production. Different versions of the same basic design can consequently be used in many different cars, optimized for specific purposes and needs.
- Economy through reduced development costs, lower total product and production costs, lower cost for logistics and spares.
- Quality through fewer components and fewer suppliers

As mentioned before, the B5254F is the second step of the new engine family. The first one being the in-line

six which is installed longitudinally in the rear-wheel driven Volvo 960. Both versions clearly illustrates the rational and flexible manufacture of a modular engine system.

The major components for the five and six cylinder engines are machined in a common transfer line in the Volvo Skovde plant. This new plant is part of the investments carried out by Volvo for the 90's and which also include the complete Volvo 850 car.

A large number of the components are identical for both engine versions: pistons, rings, gudgeon pins, con rods, bearings, seals, valve guides, valve seats, valve springs, tappets, water pump, camshaft drives and covers, auxiliary drive and brackets.

Components machined in common

transfer lines are: cylinder heads and blocks, camshaft bearing housings, lower crankcases, crankshafts, camshafts and oil pumps.

Figure 3 shows a disassembled B5254F-engine.

The development goals for compactness were achieved by choosing a cylinder centre distance of only 91 mm, in combination with compact front and rear ends of the engine.

Long stroke was also chosen for this reason. Furthermore, hydrocarbon emissions are somewhat lower in a long stroke engine, which is important from an environmental point of view. Bore is 83 mm and stroke is 90 mm.

Low weight has primarily been achieved by using aluminium for major basic engine components, and also by the compact design. Low noise emissions are the result of comprehensive calculation and development, based on a very rigid cylinder block and lower crankcase design concept (figure 4), in combination with a very rigid crankshaft.

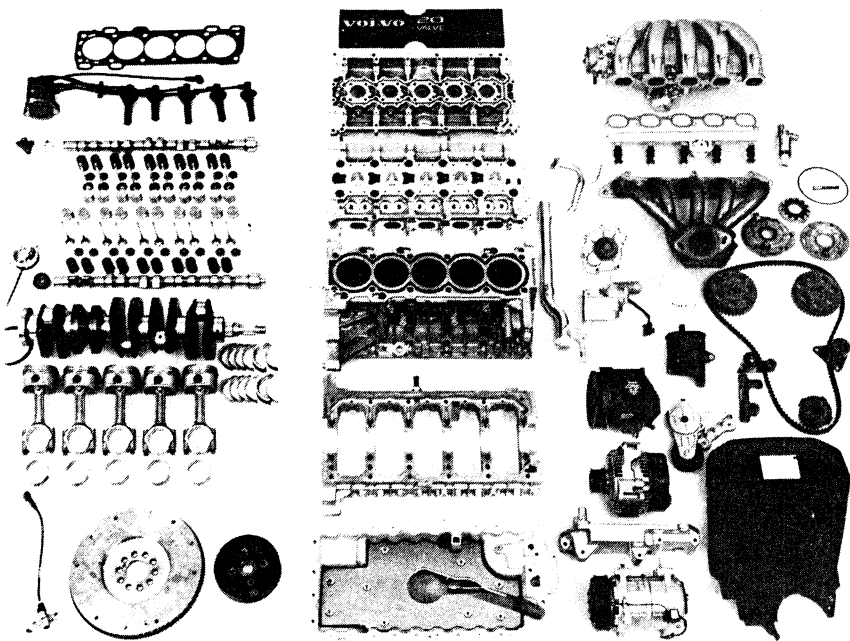


Figure 3



Figure 4

# Technical solutions

## Cylinder block and lower crankcase

### Figure 5

The cylinder block and lower crankcase are manufactured of high-pressure die-cast aluminium. Based on FEM (Finite Element Method) analysis and simulation, the block has been designed to produce a compact and rigid engine, featuring extremely low noise and vibration emissions. The lower crankcase, with its integrated cast-in reinforcements in the main bearing caps, and cylinder block together form a very compact and rigid unit. Furthermore, the walls of both sections have been given a reinforced ribbing structure in order to minimize panel vibrations and the transmission of noise.

The grey iron cylinder liners are cast-in during the high-pressure die-cast process of the cylinder block. The liners offer high wear resistance and reduce the risk for leaks. The production process is also cost-effective and environmentally friendly.

The slots between the cylinders at the upper edge of the block have been specially machined to minimize the

risk for ovality in the cylinders as a result of thermal expansion.

The lower crankcase has reinforcements of cast nodular iron in the main bearing caps. This minimizes the increase of clearance in the main bearing that can be caused by thermal expansion.

During the manufacturing process, the main bearing bores are machined with the block and the lower crankcase bolted together as one unit. In order to ensure that the unit is tight and stable, a liquid gasket is applied between the two parts. They are then joined to each other with yield-point tightened bolts during final assembly.

Oil channels and coolant ducts are cast in during the production of block and lower crankcase. This obviates the need for subsequent drilling and machining of the channels. This design principle is very cost-effective and well suited for series production.

## Cylinder head and camshaft bearing housing

### Figure 6

The cylinder head is made of chill-cast aluminium to ensure a homog-

enous material. The combustion chambers is of the pent-roof type with four valves per cylinder. The valves are set at a relative angle of 58 degrees and flank the centrally located spark plug (figure 7). By selecting this valve angle it has been possible to obtain an extremely compact combustion chamber, allowing for coolant ducts between the valves and the spark plug.

The camshaft bearing housing has integrated upper bearing halves and forms the top part of the cylinder head. The lower bearing halves are integrated in the cylinder head.

The camshaft bore is machined with the camshaft bearing housing and cylinder head assembled. In final assembly, a liquid gasket is applied between both parts in order to obtain a tight and stable joint. Oil and coolant ducts are produced in the same way as with block and lower crankcase.

The double overhead camshafts and cam profiles have been designed with the aid of computer calculations and simulations in order to minimize torsional vibrations in the camshaft while at the same time retaining excellent gas flow properties. The cams offer maximum 8.45 mm lift. At 0.1 mm lift the overlap is 24 crankshaft degrees between the exhaust valve closing and the inlet valve opening.

Valve diameters are 31 mm for inlet valves and 27 mm for exhaust valves. The valve stems are chromium-plated and has a 7 mm diameter.

The valve guides are cast iron. Hydraulic maintenance-free valve tappets are used.

The cylinder head is bolted to the cylinder block with yield-point tightened bolts and a head gasket which, like all other gaskets in the engine, is asbestos-free.

Figure 5

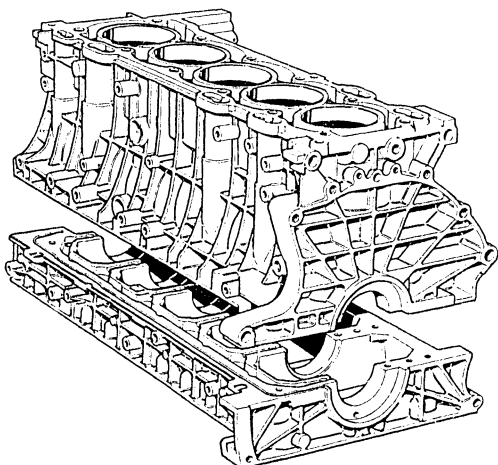
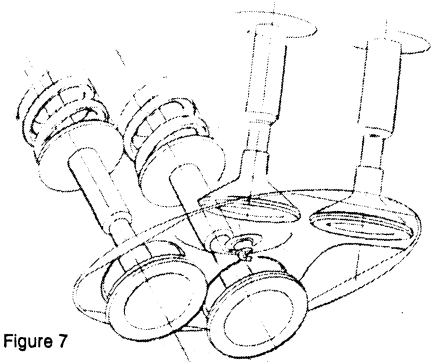


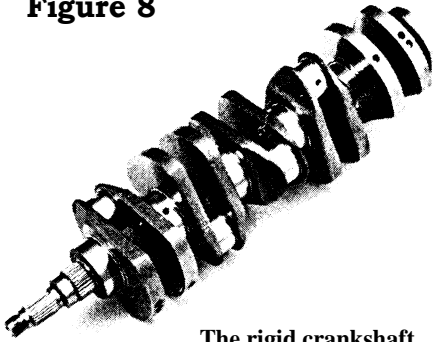
Figure 6



Figure 7



## Crankshaft Figure 8



The rigid crankshaft runs in six main bearings and has ten counterweights. It is made of forged vanadium-steel and is precipitation hardened. The thrust bearing is placed at the *fifth* main bearing from the front to minimize both engine overall length and crankshaft rear end movements. FEM analysis has been used to optimize the crankshaft and the vibration damper in combination with the engine block under simulated dynamic conditions, thus giving long service life and good comfort. The main and big end bearing surfaces are induction hardened, with press-rolled fillet radii for maximum fatigue strength. The crankshaft nose incorporates two sets of splines, to drive the oil pump and the vibration damper hub. These splines, and the end thread, are all rolled in a single operation, thus combining high strength with cost-effective production. The bearing surfaces are finally ground in a data controlled point measurement grinding machine, which stops machining automatically once the correct dimensions have been obtained. The main bearing shells are aluminium while big-end shells are lead-bronze.

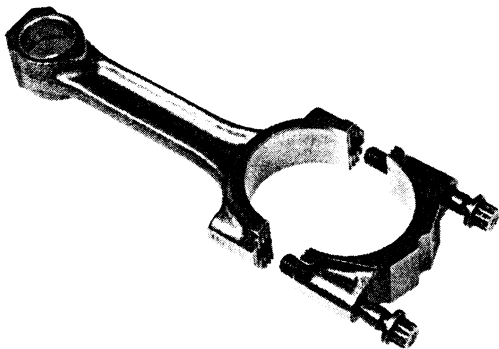
## Connecting rods and pistons Figure 9

The connecting rods are forged from vanadium alloy steel with an effective length of 139.5 mm. High strength is achieved through a precipitation hardening process. The rods have a 15° degree thrust face against the crankshaft by virtue of the fact that the bearing caps are 0.7 mm narrower than the big end of the rods.

To achieve exact radial control between con rods and con rod caps, these parts have ground serrated joints employing yield-point tightening bolts without nuts.

The connecting rod small and big end weight is controlled and kept within very narrow tolerances by means of a special machining operation in order to minimize engine vibration.

The pistons are made of aluminium with cast-in steel expansion control. The piston ring package consists of two compression rings and one oil scraper ring.



## Camshaft drive Figure 10

Camshafts and water pump are driven by the vibration damper hub on the crankshaft by a toothed belt. For optimal engine performance it is necessary to ensure extreme accuracy in camshaft timing during assembly. This is achieved by fixing the crankshaft and camshaft positions with special locking tools while the drive is fitted and adjusted. The belt is automatically tensioned by means of a spring-loaded piston assembly which is hydraulically damped, to maintain constant tension and compensate for wear and temperature variations.

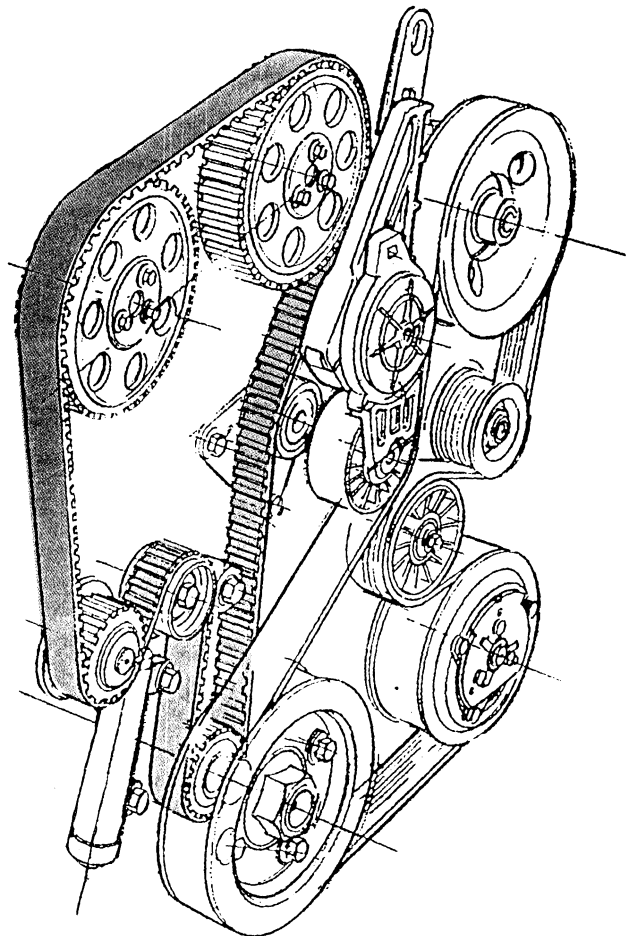


Figure 10

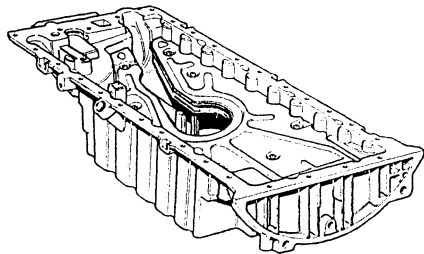
Figure 9

## Lubrication system

The oil is circulated by a rotor oil pump of the crescent-type and has a maximum capacity of 70 litres per minute at 6000 rpm and 80° C oil temperature. The inner rotor of the pump is driven directly by splines on the crankshaft. The pump design permits a compact installation, with the oil pump at the front end of the cylinder block.

The oil sump (figure 11) is manufactured in high-pressure die-cast aluminium and is equipped with cast baffle plates and a steel windage tray to ensure a constant oil supply and to minimize foaming when driving hard.

Figure 11



## Cooling system

The water pump is designed to meet high demands for reliability and compactness. The housing is integrated in the engine block and the pump is driven by the crankshaft via the camshaft belt. It has a capacity of approx 160 litres per minute at 6000 rpm. Shaft sealing is based on a ceramic ring and a sintered carbon ring to eliminate leakage.

The cooling fan is electrically powered with two speeds, regulated by the engine's control or climate system.

## Auxiliary drive and installation Figure 12

Auxiliary units such as alternator, power steering pump and air conditioning compressor, are grouped together on the left side of the engine in a very compact and rigid installation. The left side was chosen in order to protect the auxiliaries from the exhaust heat. The compactness makes it possible to use the same installation for both transverse and longitudinal engine installations. Thanks to the rigidity of the system, high strength and low noise is achieved.

Drive is by a six-groove Poly V-belt and tension is maintained at a constant level by a friction damped belt tensioner. The installation is very cost-effective with one one tensioner and one idler. The same components are used for version with or without AC-compressor. The only difference is additional belt length.

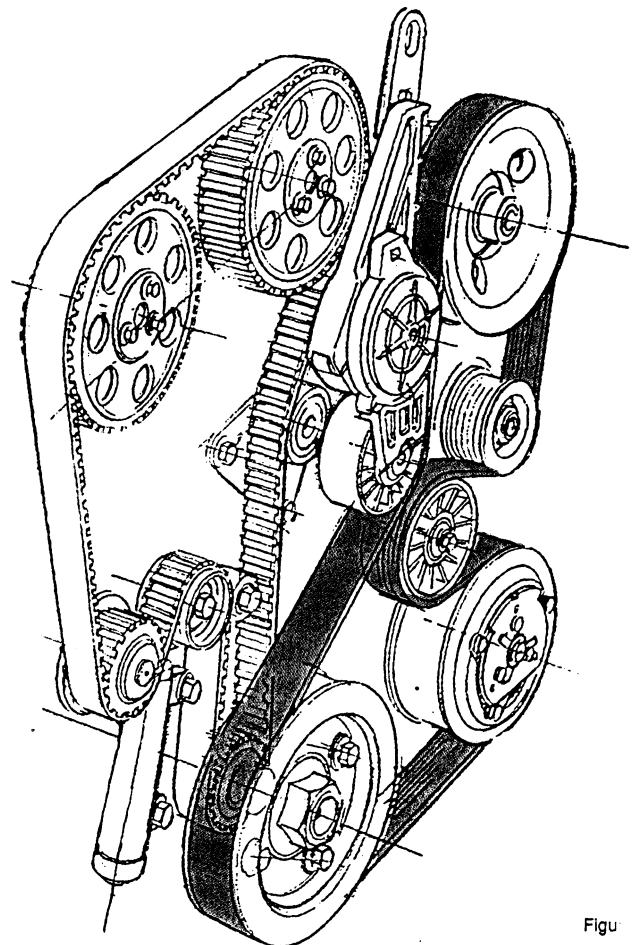


Figure 12



## Combustion

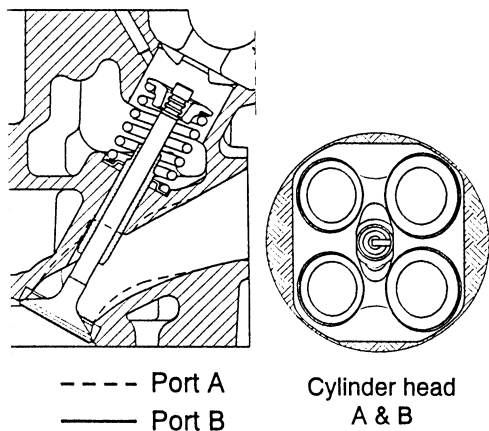
The combustion system must provide good fuel economy, low exhaust emissions, good part load stability and allow for high specific performance. It is a well-known fact that the in-cylinder turbulent flow field has a major influence on engine performance. Turbulence is initially generated during the intake process. The knowledge that the intake generated turbulence decays too fast to really influence the combustion process, has led to the use of swirl and tumble.

All pent-roof combustion chambers show more or less pronounced tumbling motion. A tumbling vortex is generated during the intake stroke and breaks down during compression. The dissipation of the tumbling motion results in turbulence generation especially at the end of the compression stroke. The strength of the tumbling motion can be varied by changes to the intake port. By making the intake port more tangential, the velocity of the tumbling vortex can be increased, that is less downward flow under the intake valves.

Particle Tracking Velocimetry (PTV) in a motored single-cylinder rig was used when developing the intake ports for the engine. A tumble ratio could be determined by calculations, and this tumble ratio is a direct measure of the kinetic energy of the flow.

The tumble ratios from PVT-analysis for the two intake ports (figure 13) are: Port A 0.66 and port B 1.0. Port B is the design used for the actual engine.

Figure 13



## Air inlet system

Inlet air is taken ahead of the radiator and passes through the air filter and air mass meter of hot-film type. The air temperature is thermostatically regulated to a minimum of  $+10^{\circ}\text{C}$  by mixing with warm air taken from the exhaust manifold. The inlet air then passes through the throttle housing.

## Air inlet manifold

### Figure 14

The geometry of the inlet manifold was designed with the aid of simulated unsteady compressible air flow. Dynamometer testing confirmed the computer models and the result is V-VIS

(Volvo Variable Induction System). V-VIS consists of a conventional plenum chamber with twin inlet ducts to each cylinder, parallel but of different length. The compact "roll" shape achieves good space and use of material at minimum weight.

The shorter ducts are closed by a set of electro-pneumatically controlled valves when the throttle is more than 80 per cent open and with engine speed lying between 1500 and 4100 rpm. At smaller throttle opening, or at other revs, the valves remain open and form part of the wall of the short ducts in order to minimize flow losses. Figure 15 shows the calculated volumetric efficiencies with open and closed control valves.

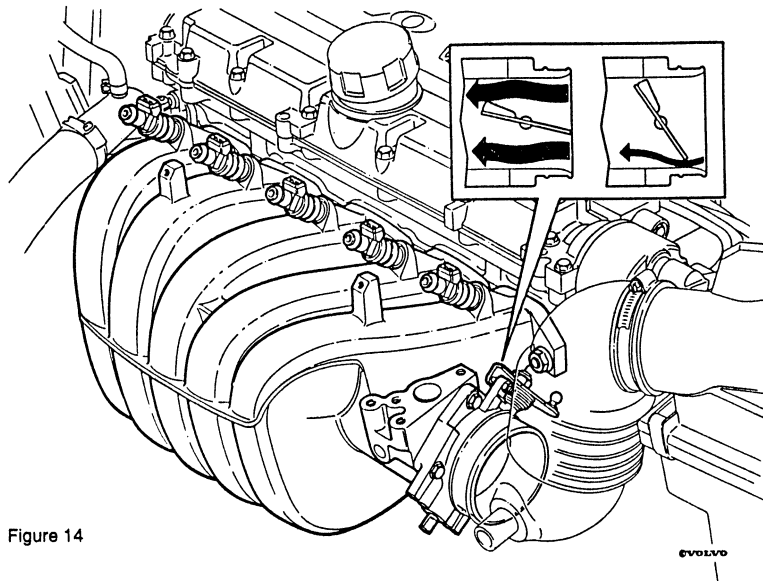


Figure 14

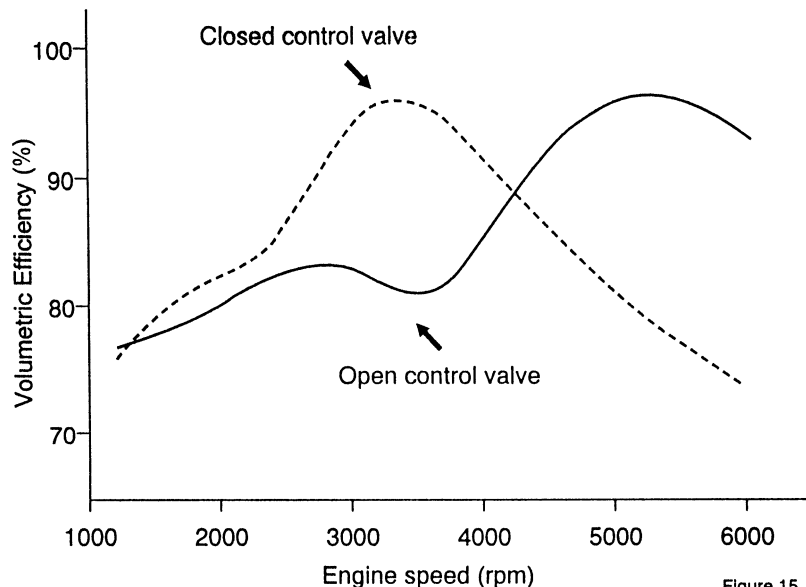


Figure 15

With closed control valves a negative wave, caused by the descending piston and the inertia of the gas in the longer duct, accelerates the air column in the duct. At resonance rpm the inertia causes the air to ram into the cylinder just before the inlet valve closes. This results in a considerable gain in volumetric efficiency and hence increased torque.

Figure 16 shows the calculated instantaneous pressure variation at the inlet valve antler full load and resonant rpm with open and closed control valve. The increase in pressure between BDC and inlet valve closing is clearly visible.

The V-VIS system thus provides a major increase in engine torque in the most used medium range of engine speed during normal driving. The system requires an absolutely tight closure of the valves to work effectively. This is achieved by using stainless steel valves with soft heat resistant rubber sealing lips. These form a tight seal against the cast wall of the ducts, thus avoiding expensive internal machining of the ducts.

Control information is fed from the throttle potentiometer and the ignition system to a solenoid valve which controls the vacuum driven servo unit to operate the split valve spindles via a torque balanced beam. This also to aid tight valve closure (figure 17).

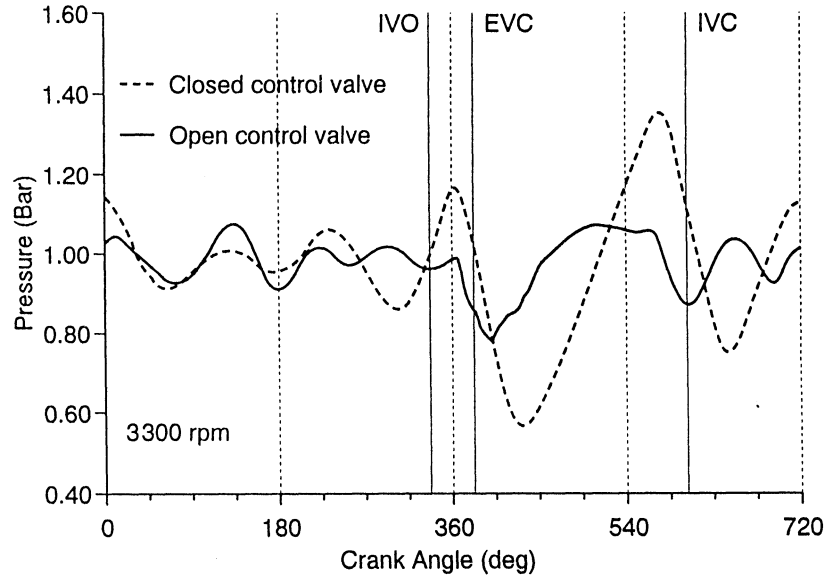


Figure 16

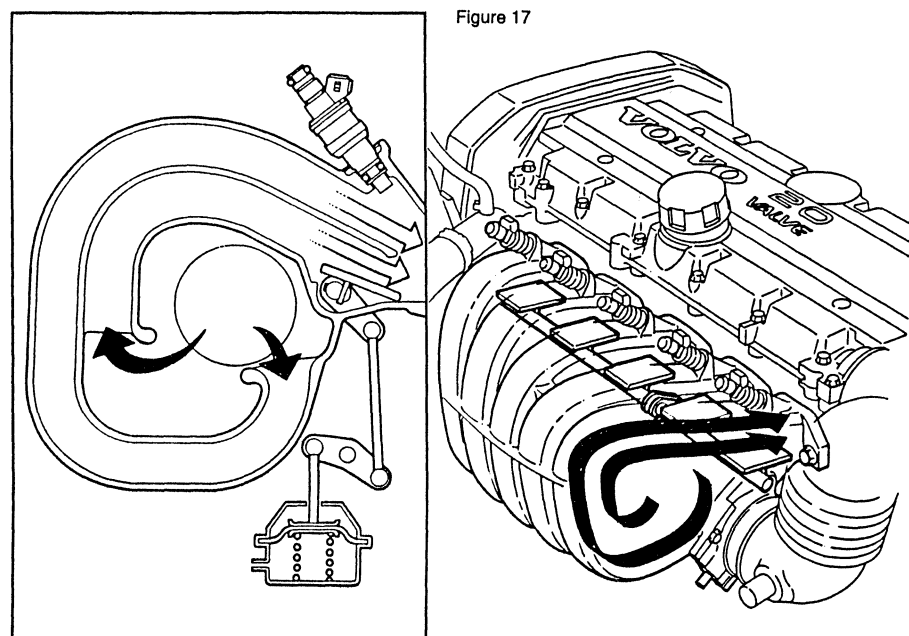
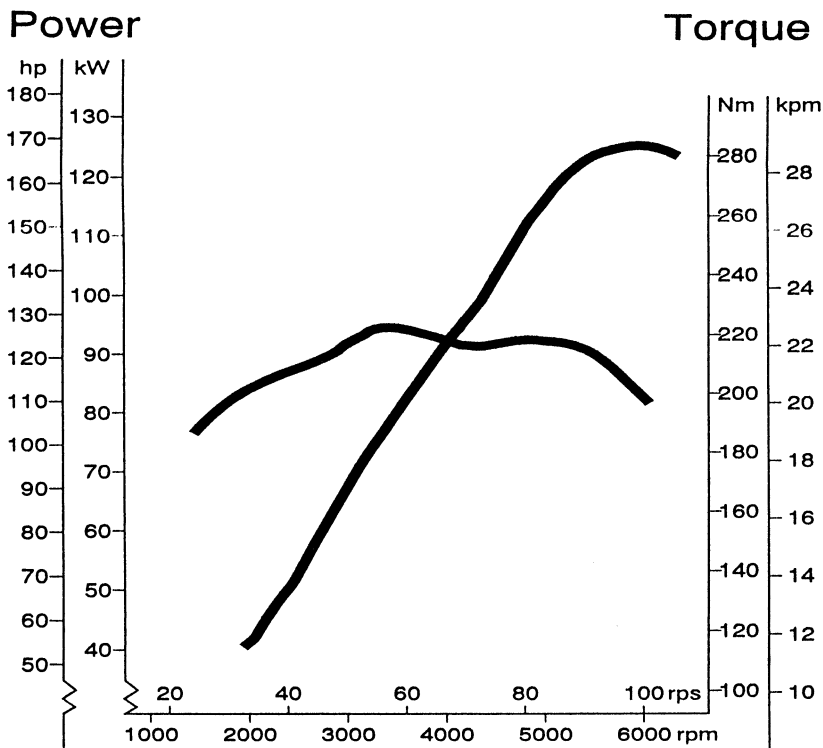


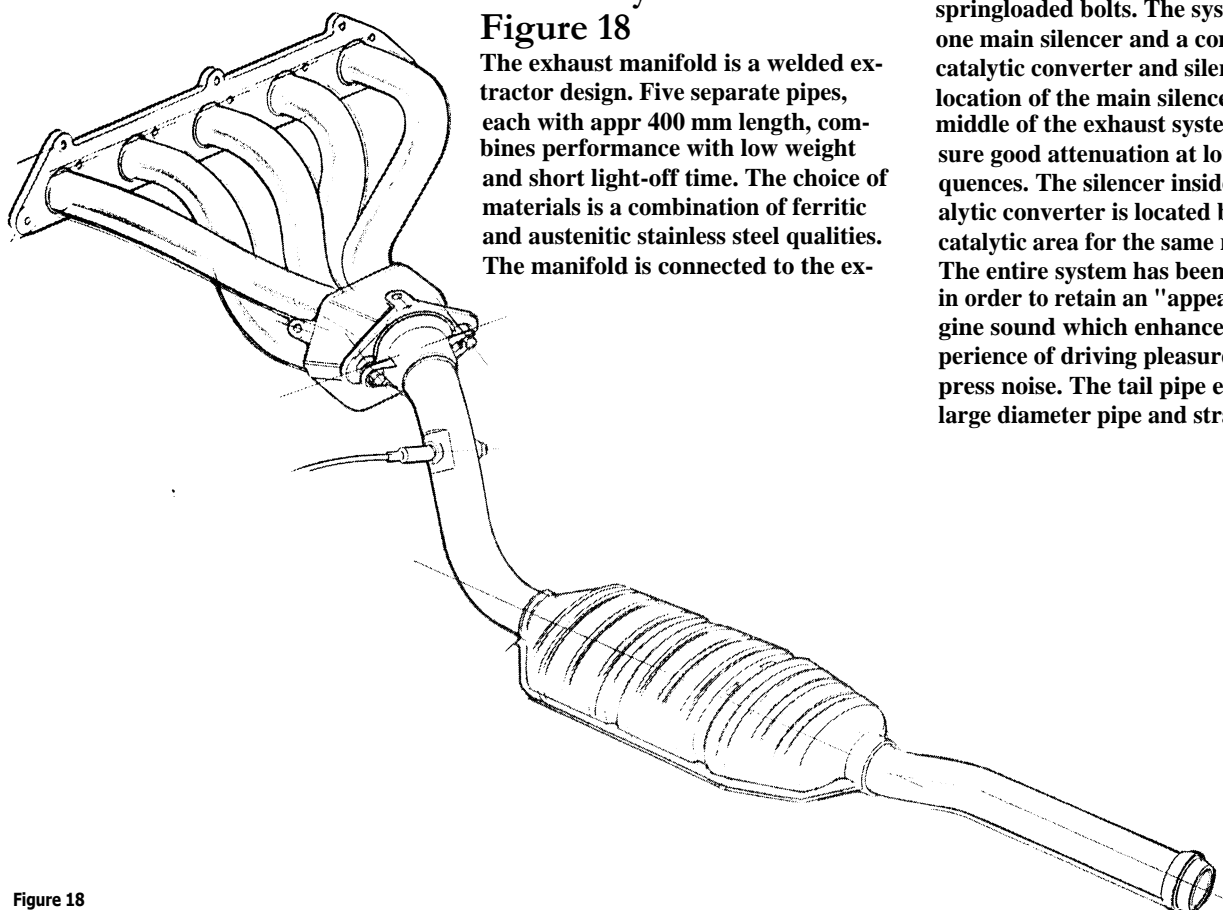
Figure 17



Max output for the B5254F is 170 hp (125 kW) at 6000 rpm. Max torque is 220 Nm at 3300 rpm. Thanks to the V-VIS system, 90 per cent of the maximum torque is available between 2000 and 6000 rpm.

### Exhaust system Figure 18

The exhaust manifold is a welded extractor design. Five separate pipes, each with appr 400 mm length, combines performance with low weight and short light-off time. The choice of materials is a combination of ferritic and austenitic stainless steel qualities. The manifold is connected to the ex-



haust system by a flexible joint and springloaded bolts. The system has one main silencer and a combined catalytic converter and silencer. The location of the main silencer is in the middle of the exhaust system to ensure good attenuation at low frequencies. The silencer inside the catalytic converter is located behind the catalytic area for the same reason. The entire system has been fine-tuned in order to retain an "appealing" engine sound which enhances the experience of driving pleasure but suppress noise. The tail pipe ending is of large diameter pipe and straight.

Figure 18

## Engine control systems

The B5254F-engine is controlled by two advanced electronic control systems, the LH 3.2 fuel injection system and the EZ 129K ignition system.

These systems are further developments of the well known systems used in the current four-cylinder Volvo cars.

The development goal has been to produce a completely integrated system, based on the current components, which is less expensive, more flexible, more reliable and more efficient. A new cable harness concept is used, and the engine control units include the functions of a number of electronic relays to reduce the number of components (figure 19).

## Fuel injection system L H3.2

The system has a new air mass meter of hot-film type. Together with an angular position throttle potentiometer, it gives an accurate air mass measure at low cost. It has a closed-loop lambda control and an idle speed control, both with adaptive functions.

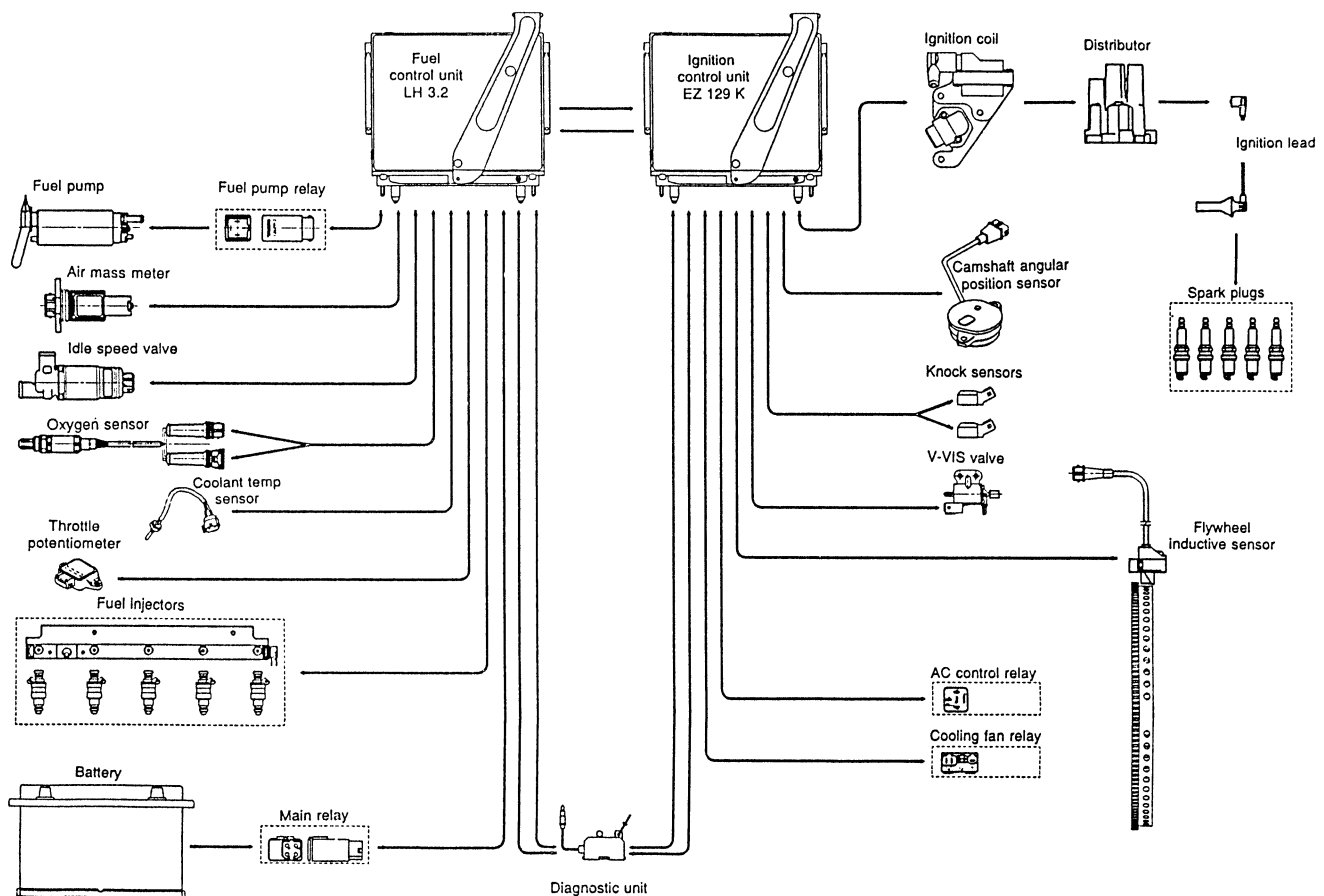
Previously each system in the vehicle has had its own temperature sensor for coolant temperature. On this engine, however, there is only one sensor of so-called NTC-type. This signal is used by the LH3.2 to form a period-time modulated signal to all other systems which need this information.

While the electronic control unit has been moved from the passenger compartment to the engine compartment, the fuel pump relay has for safety

reasons been replaced by an electronic type. It is kept triggered by the control unit with a constant pulse train, instead of just a "high" or "low" signal. This is also for safety reasons to avoid the possibility of petrol leakage in the engine compartment caused by a broken fuel pipe and a running fuel pump after a crash.

## Ignition system EZ129K

To measure the engine speed and angular position, a flywheel speed sensor of inductive type and a camshaft position sensor of Hall-effect type are used. The system has two knock sensors for best performance of the ignition timing regulation of each cylinder, with adaptive functions. The electronic control unit also controls the V-VIS system plus the air conditioning compressor and the electric cooling fans.



## Engine vibration levels

The firing order of the B5254F is 1-2-4-5-3, with even firing interval of 144 crank degrees.

Both theory and practical experience show that there are primarily two vibration characteristics which must be considered when installing the engine in a car. The engine is excited by a first order of rotating inertia couple with magnitude

$$0.449 \cdot m \cdot r \cdot \omega^2 \cdot a$$

and a second order oscillating inertia couple with magnitude

$$4.980 \cdot m \cdot r^2 \cdot \omega^2 \cdot a/l$$

$m$  = oscillating mass

$r$  = crank radius

$\omega$  = angular speed

$a$  = cylinder centre distance

$l$  = length of con rod

From the principal vibration pattern due to these excitations, it is possible to minimize the disturbance input to

the vehicle by carefully selecting the engine mounting system. The mounting system for the Volvo 850 has been designed on the following grounds:

- The two main engine mounts (hydromounts) are located at the node for the vibrations. This means on a line through the centre of gravity for the powertrain.

- By using soft support at the front of the engine, the engine is kept in balance while the main mounts do not carry bending loads.

- By using two nonlinear reaction rods, extreme loads from the drive shafts are taken care of.

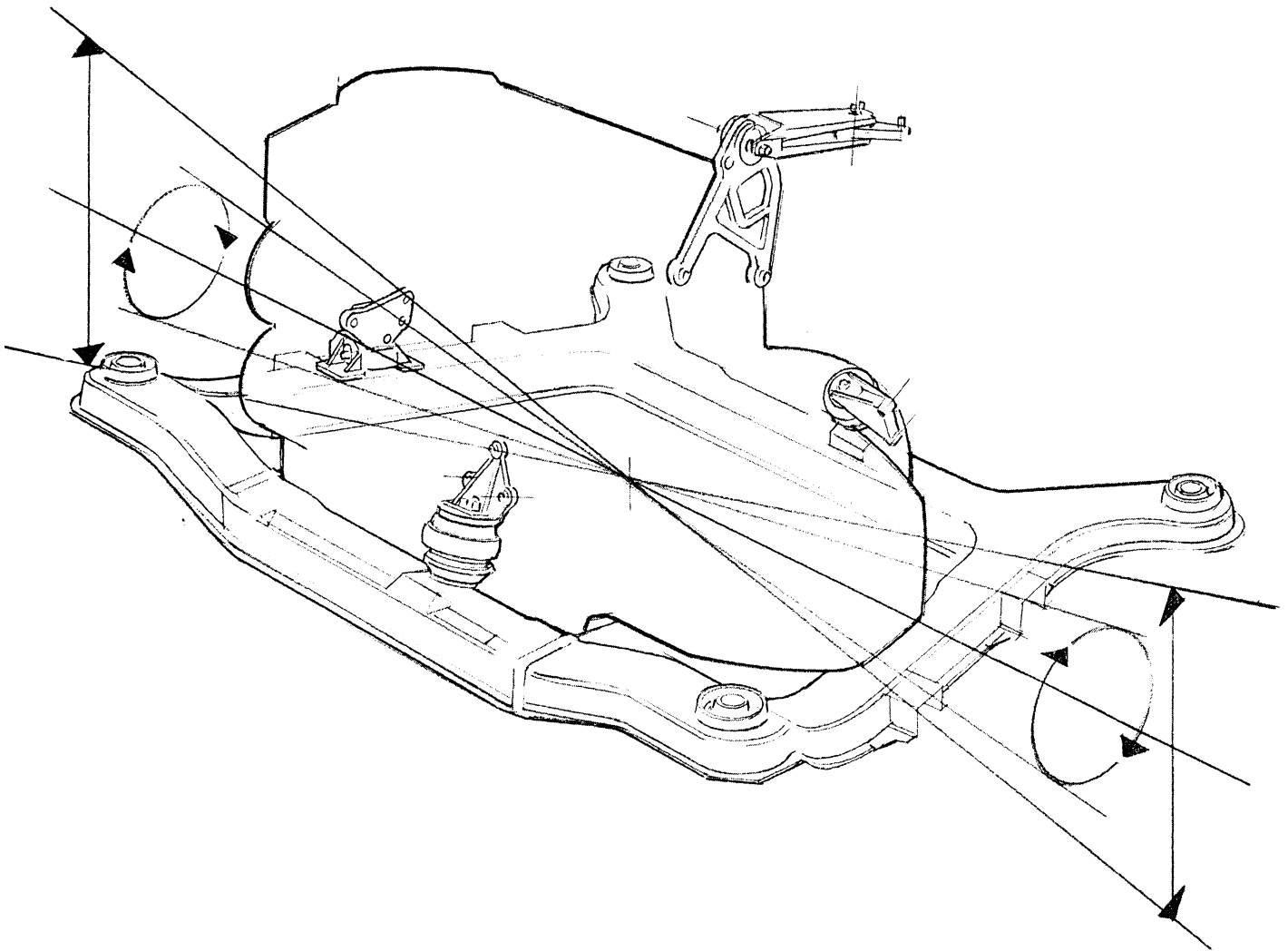
When designing the engine mounting system great attention was taken to the engine vibration characteristics. The engine mounting consists of a two-way insulation system, where two main hydromounts, one support mount and the lower torque reaction rod are mounted to a rubber insulated

subframe (figure 20). This gives an excellent insulation of engine vibrations.

The main mounts and the torque reaction rods are located in positions with low displacement amplitude of vibration. The dynamic stiffness of the mounts is low to give a good vibration isolation for small displacement amplitudes. Large displacement amplitudes from the chassis are damped by the hydraulic system of the hydromounts, which is essential for a good ride comfort.

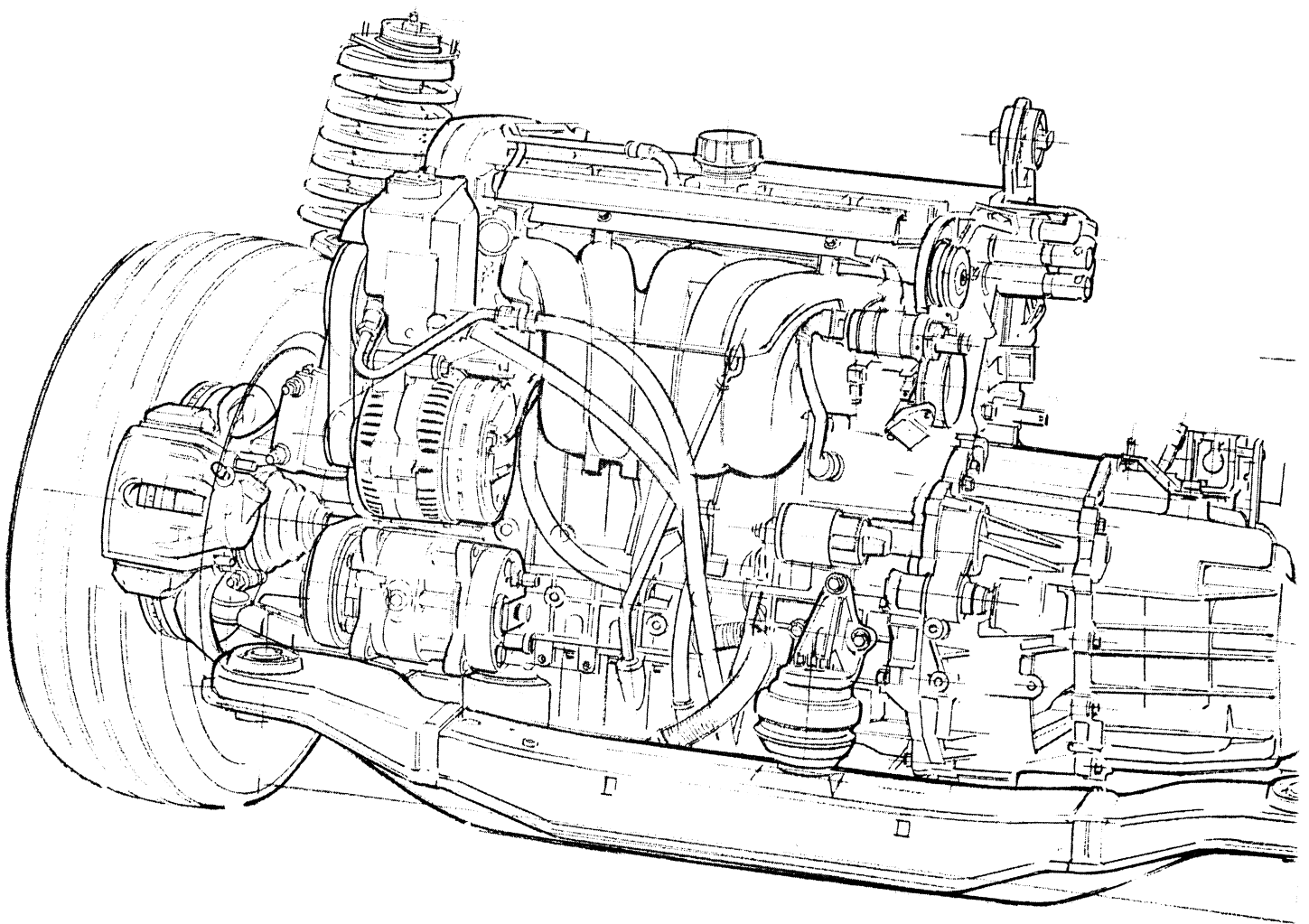
Due to the engine vibration characteristics, the displacement amplitude of vibration is larger in the position where the support mount is located. Therefore it has progressive characteristics with a low initial dynamic stiffness.

The main purpose of the torque reaction rods is to restrict the engine motions due to the torque of the engine. Their characteristics are softly progressive with a low initial stiffness.



The B5254F has been developed to meet the high demands on engines in a car, typified by the Volvo 850 GLT by using modern CAE technology. The result is a compact and light-weight in-line five-cylinder engine, characterized by excellent performance and torque, good fuel economy and a remarkable comfort level.

The manufacturing process, based on extremely high demands for accuracy and quality to guaranteed engine reliability, is particularly cost-effective since both the five and six cylinder engines were designed and developed as a modular engine family with a considerable degree of integration.



## Volvo 850 GLT Engine specifications

Type:	Transverse 5-cylinder in-line DOHC all-aluminium V-VIS Volvo Variable Induction System
Displacement:	2435 cc
Bore x stroke:	83 x 90 mm
CR:	10.5:1
Valves:	4 per cylinder, angled at 58 degrees
Max output;	170 hp (125 kW) at 6000 rpm
Max torque:	220 Nm at 3300 rpm
Fuel system:	LH Jetronic 3.2
Ignition system:	EZ 129K
Emission control:	Three-way catalytic converter, electrically heated lambda-sond, vacuum controlled evaporation system
Electrical system:	Alternator 100 amp. Battery 440/520 amp
Weight;	153 kgs
Fuel consumption:	Sweden average 0.89 litre per 10 km with manual gearbox, 0.91 litre per 10 km with automatic transmission Europe R15 12.4 litres per 100 km with manual gearbox 12.9 litres per 100 km with auto- matic transmission 90 km/h 6.6 litres per 100 km with manual gearbox
Top speed:	215 kph manual, 205 kph aut
Acceleration:	0-100 kph: 8.9 sec manual, 9.6 sec aut

