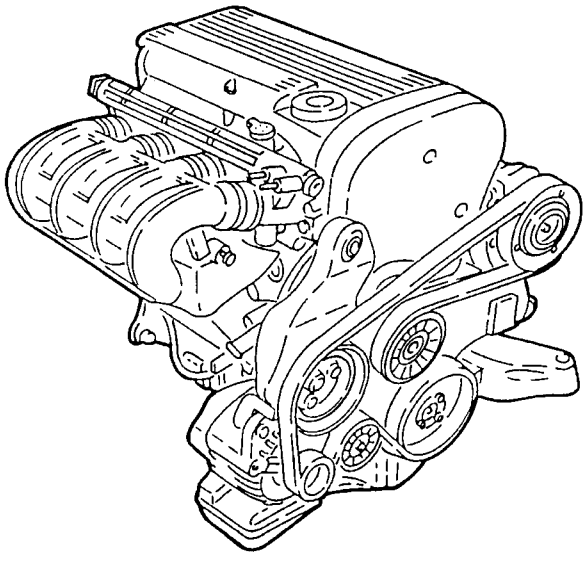
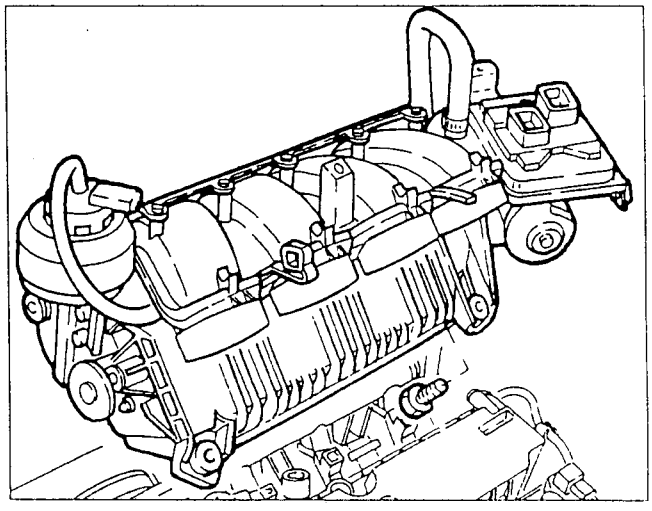
# INDEX

## DESCRIPTION

Four cylinder in line engine with double camshaft in head, four valves per cylinder, phase variator, static injection and twin ignition controlled by a single ECU.
The rear engine is connected to the clutch-gearbox-differential unit which constitutes a sole assembly. The engine is installed frontally and transverse at a 18°30 slant. The engine is "suspended" by means of two damper mounts to the underbody and one scissors mount to the suspension crossmember. To contain vibrations, the engine top is connected to the underbody by means of a shock-proof connecting rod.
All belts are fitted with automatic take-up devices to ensure long belt working life.
The fuel feed system (unleaded petrol) is fitted with suitable pollution prevention devices which ensure low exhaust emissions as per "EEC PHASE 2" standards.

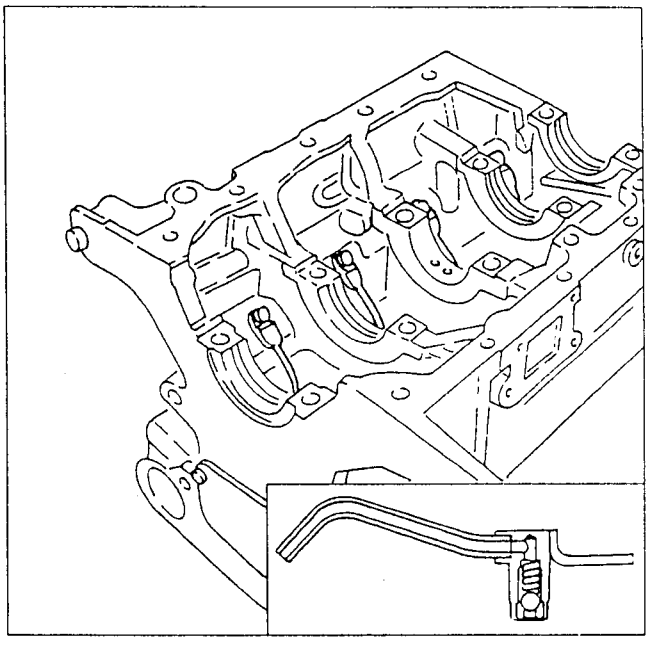


AR 32301 engines are fitted with a plastic intake manifold with variable geometry instead of an aluminium intake manifold.
The fuel feed system is returnless, i.e. with a single feed pipe.



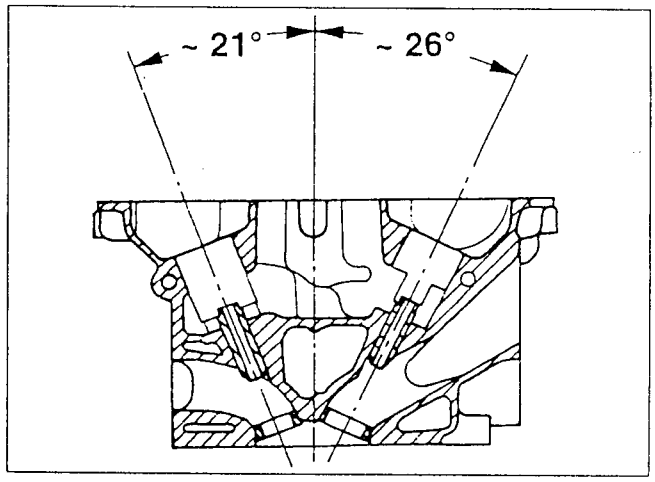
## CRANKCASE

The engine block is made of high mechanical resistance cast iron.
The crankshaft is supported by means of five main journals which house five thin casing half-bearings.
The cylinders are directly cut into the crankcase and are selected according to three size classes plus three oversized classes.
Two counter-rotating shafts, supported by means of a central bushing and ball bearings in the front and rear parts are housed in the crankcase.
Specific ducts in the crankcase walls ensure the passage of coolant and lubrication oil.
A nozzle, which sprays oils on the top of the piston thus ensuring partial cooling, is fitted in the lower part of each cylinder.

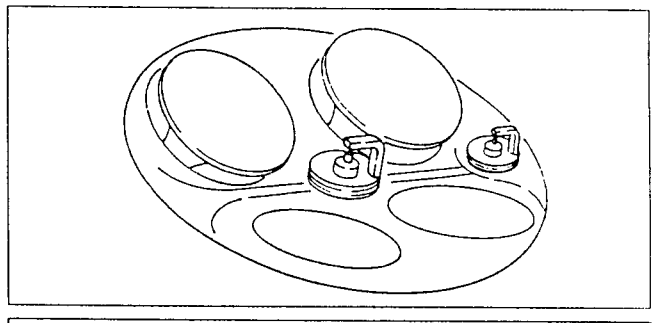


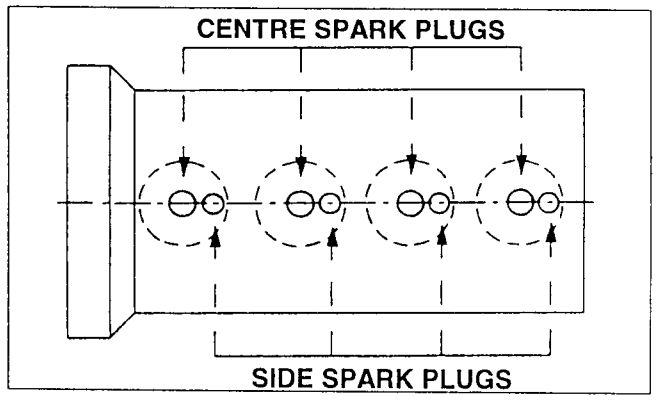
## CYLINDER HEAD

Monolith, compact, mould-cast aluminium and silicon alloy.
The four valves per cylinder are fitted in their respective V guides at approximately 47° and are controlled by two camshafts by means of hydraulic tappets.

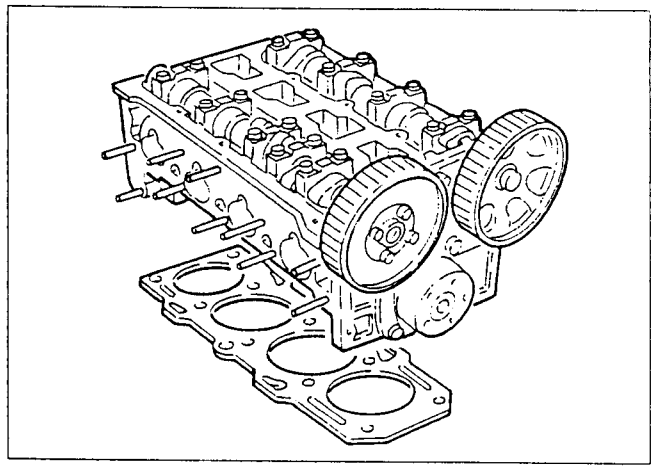



The space is organised so that the combustion chambers can house the four valve caps and the central and side spark plug holes without weakening the head structure.
The central spark plugs (larger) are tightened at a torque of 25 - 35 Nm, while the side (smaller) spark plugs are fastened at a torque of 10 - 12 Nm.
They should be replaced every 100,000 km.
The twin spark plugs positioned in this fashion, the two intake valves and the two exhaust valves ensure uniform distribution of the mixture and optimal combustion with improved engine thermal performance and reduced harmful emission in exhaust.






The camshaft on intake side turns on six journals. The camshaft on exhaust side turns on five journals. The shafts are controlled with a timing belt.
The valve seats are fitted in the cylinder head after it is heated to a temperature of 80°C. The seats are then cooled with liquid nitrogen. The valve guides are fitted in their seats in the cylinder head. Interference and internal diameter is perfected after assembly with a specific borer and controlled by means of a go-no-go set of gauges. The cylinder head and crankcase seal is made of aramide fibre. No head re-torque is required for the entire life of the engine.

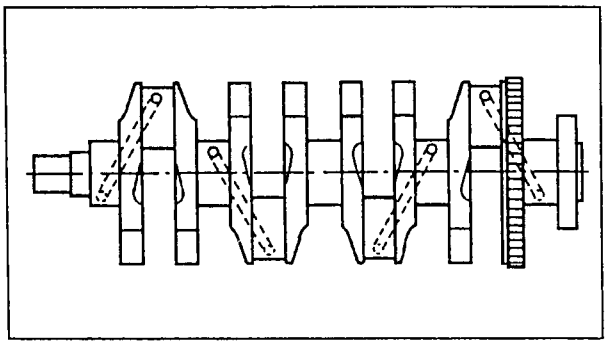


## OIL SUMP

The oil sump is a structural part of the engine with mechanical functions.
It contains the engine oil and is directly connected to the gearbox and to the rear engine mount. It is made of die-cast aluminium alloy and features internal shock-proof partitions.
It is fastened to the crankcase with a specific sealant.

## CRANKSHAFT

This is forged in high strength alloy steel, induction tempered on the journals and rolled on the grooves.
It rests on five main bearings and its end float is adjusted by two half rings housed in the centre main bearings.
Eight counterweights accurately balance the rotating masses.
A groove runs inside the shaft to lubricate the main and connecting rod journals.
At the rear of the crankshaft there is the phonic wheel for detecting the rpm and timing sensor.



## MAIN AND ROD BEARING HALVES

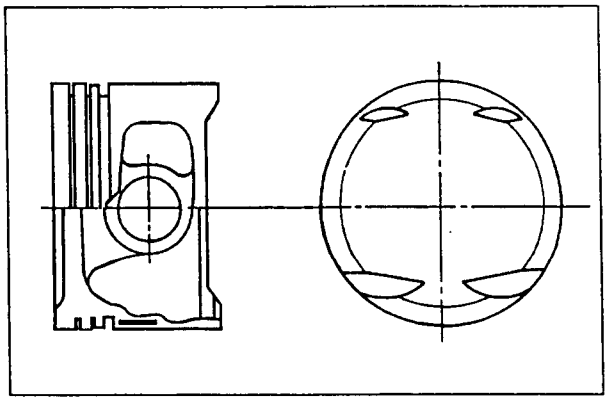
These are of the three-metal, thin shell type and they are divided into three dimensional classes.

## FLYWHEEL

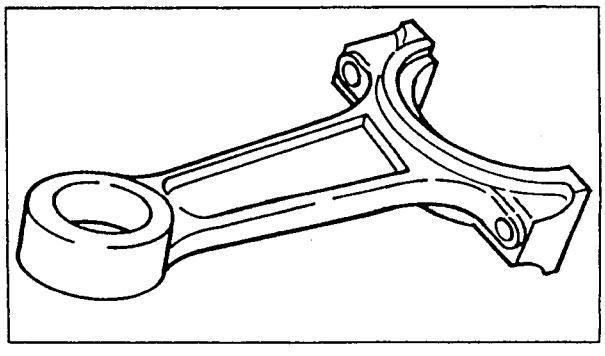
This is in cast iron with a hardened ring gear and suitably balanced.

## PISTONS AND CONNECTING RODS

The pistons are in aluminium-silicium alloy with self-heating inserts and are divided into three dimensional classes. To ensure correct assembly an arrow is stamped on the piston crown to indicate the direction of rotation of the engine.
The piston crown is concave and has four notches to prevent interference with the valve mushrooms.



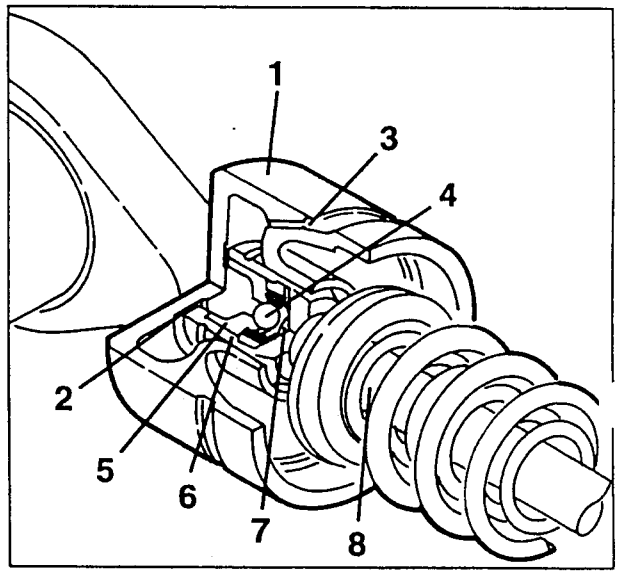
The connecting rods are in hardened and tempered alloy steel, with a bushing in copper alloy force-fitted for coupling with the piston gudgeon pin.
As the gudgeon pins are floating on the piston hubs and on the bushing force-fitted in the connecting rod small end, their side movement is stopped by two expanding circlips housed in the special hollows machined on the actual hubs.



## VALVE GEAR TIMING

Direct drive by toothed belts with automatic tensioner and with overhead camshaft in cast iron with induction tempered cams and bearings. The hydraulic tappets, in contact with the cams, control the valves directly. This device automatically eliminates "valve play" when the engine is running thereby dramatically reducing the need for periodical maintenance.

1. *Cup*
2. *Oil passage between chambers*
3. *Oil inlet groove*
4. *Check valve*
5. *Piston*
6. *Cylinder*
7. *Pressure chamber*
8. *Valve stem*

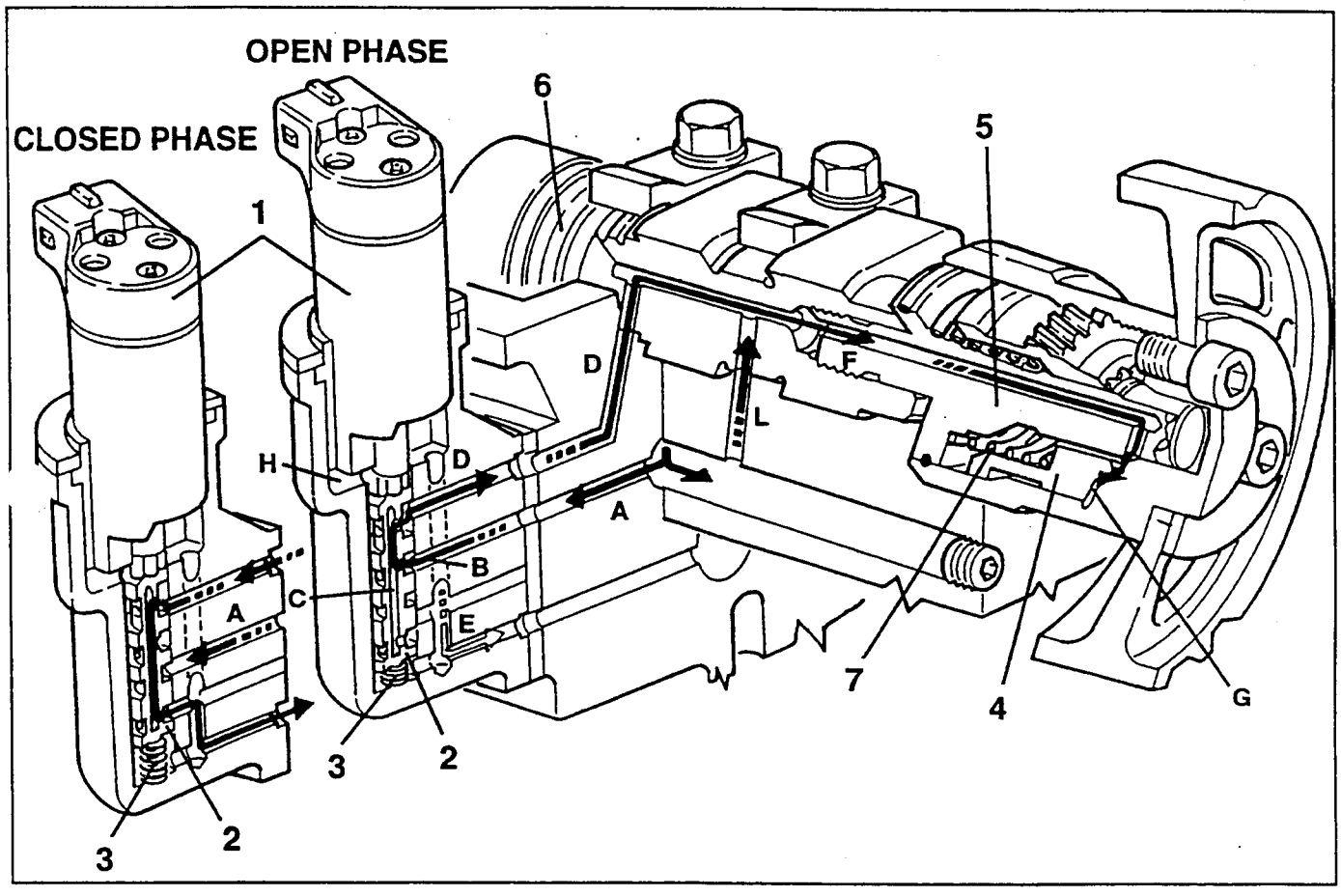



The stem of the exhaust valves is chromium plated and has a cavity inside filled 50 ÷ 60% with sodium to improve dispersion of the heat to which they are subjected.
The valve seats are sintered and made from material suitable for the use of unleaded petrol.

## TIMING VARIATOR

This is of the simplified type which ensures considerable timing precision, rapid intervention and high mechanical reliability. It is coupled to the intake pulley and fitted with two half bearings which support it. The inner parts ar nitrided and an O-Ring keeps the oil inside when the engine is not running. In order to reduce the size of the engine, the actuation valve seat has been machined on the intake manifold with suitable grooves which also involve the cylinder head, to regulate the flow of oil to the variator.
- The purpose of this device is to change the intake valve timing according to the engine load and speed required; this parameter is received and processed by the control unit in the form of an electric signal sent by the air flow meter and rpm sensor and transmitted as a command to the electromagnet via a relay.
- When the closed phase is required (idling and full power area), the electromagnet (1) is de-energized, thus the valve distributor (2) pushed by the counter spring (3), stays up preventing the passage of the oil leading from groove (A) from reaching the variator.
In this case the timing of the intake valves remains unchanged (closed).
- If the open phase is required (average speeds at high torque), the electromagnet (1) is energized, thus pushing the valve distributor (2) downwards. In this position the oil, leading from groove (A), enters chamber (B) of the piston, from where it passes through a special hole into groove (C) machined inside the latter.
The oil can only leave this groove through the upper hole (in communication with the oil delivery duct (D) to the variator) as the lower hole no longer leads to the exhaust duct (E) because the valve distributor (2) is lowered. The oil passes through duct (D) and (F) and reaches the chamber (G) moving piston (4) axially towards the engine. The outside of piston (4) is fitted with helical teeth and as a result of the above-mentioned axial movement it is forced to move clockwise (as seen from the timing side). The rotation is transmitted through a straight-toothed grooved profile to the pinion (5) which is screwed onto the threaded lug of the camshaft (6) and transmits the rotation to the shaft. This way the timing of the intake valves is changed by 25°.
When the electromagnet is de-energized, the valve distributor (2) returns to its initial position, shutting off the flow of pressurised oil to the piston (4), but allowing the oil to return to the exhaust due to the thrust of the counter spring (7).

- Duct (L) enables the camshaft journal to be lubricated under the various operating conditions.
- The oil which leaks into the electromagnet chamber (H) is discharged through the drainage hole (E).




## Vibration damper device with counter-rotating shafts

Combustion engines, in addition to the forces acting on the piston crowns caused by the expanding gases, there is the action of the following:
- centrifugal forces of inertia, caused by the rotating masses;
- alternated forces of inertia of the 1st and 2nd order generated by the masses with reciprocating motion.

The purpose of the balancing of the engine is to eliminate the vibrations that these imbalances caused during operation.
The imbalances produced by the centrifugal forces and by the alternated forces of inertia of the 1st order are eliminated by suitably counter-weighting the crankshaft.
The imbalance caused by the alternated forces of inertia of the 2nd order is generally not eliminated in 4-cylinder in line engines, in which the task of partially absorbing it is left to the engine bearings.
In this engine though, a device has been adopted which is capable of nullifying the vibrations caused by the above-mentioned forces: it comprises 2 shafts, located in the crankcase, with eccentric masses, which counter rotate with respect to one another.

The counter-rotating shafts are pulled by a special double-toothed belt, a set of gears and an automatic tensioner which make it possible to obtain twice the speed of the crankshaft and perfect synchronism with it.

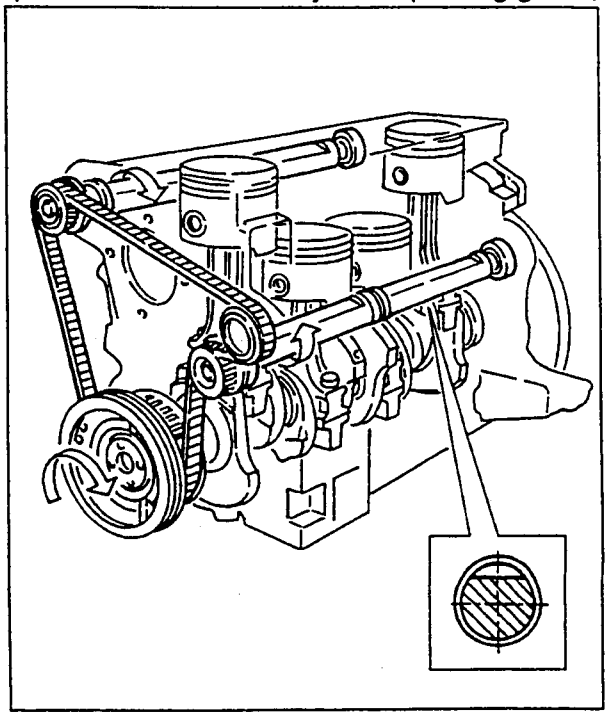
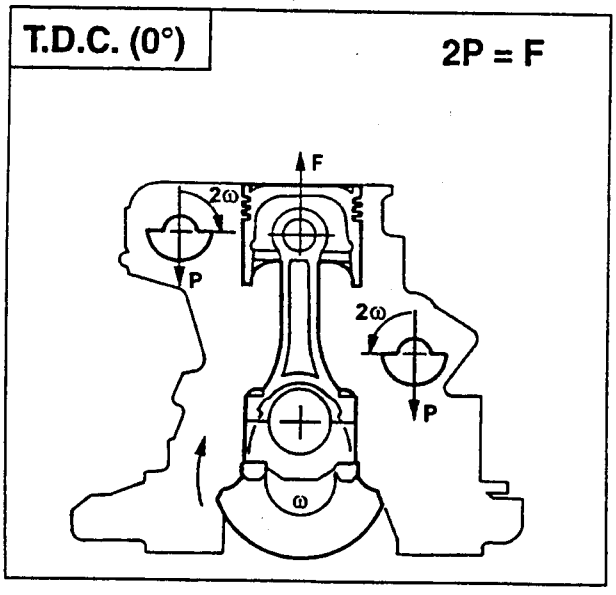
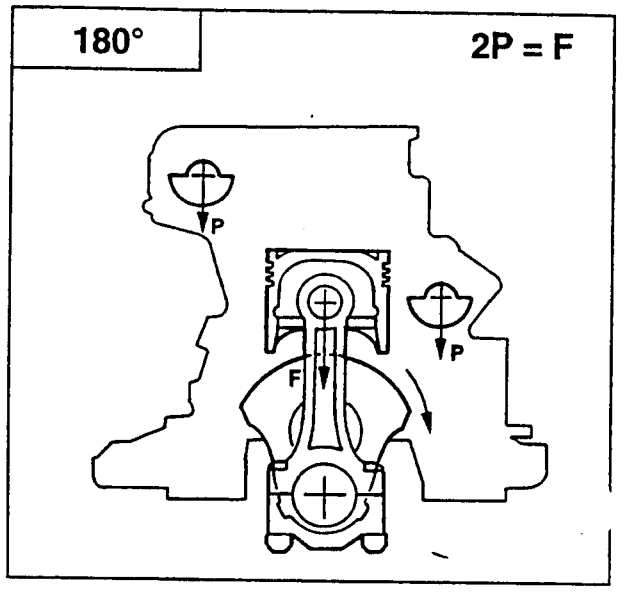
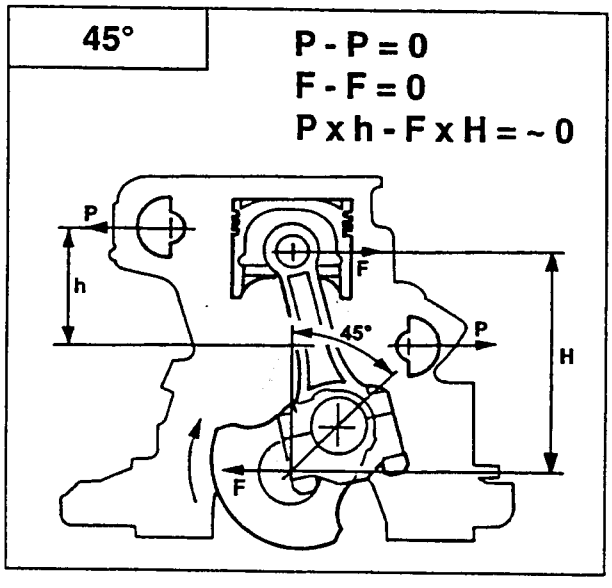
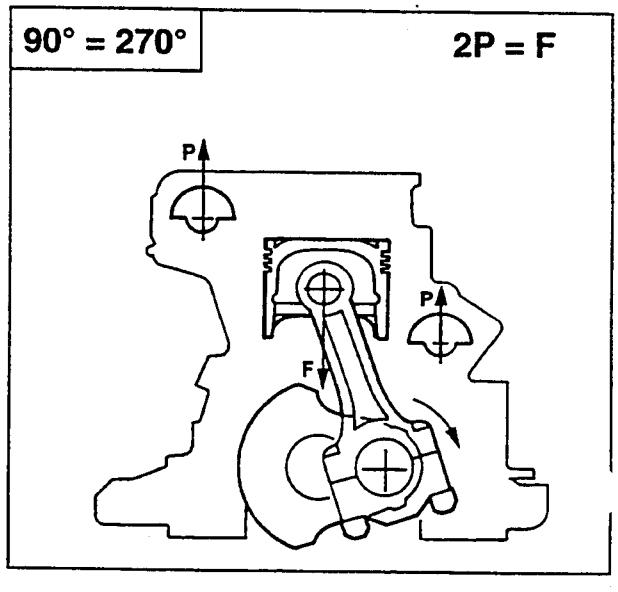


Illustration of the alternated forces of inertia of the 2nd order and of the balancing masses in the main operating positions.



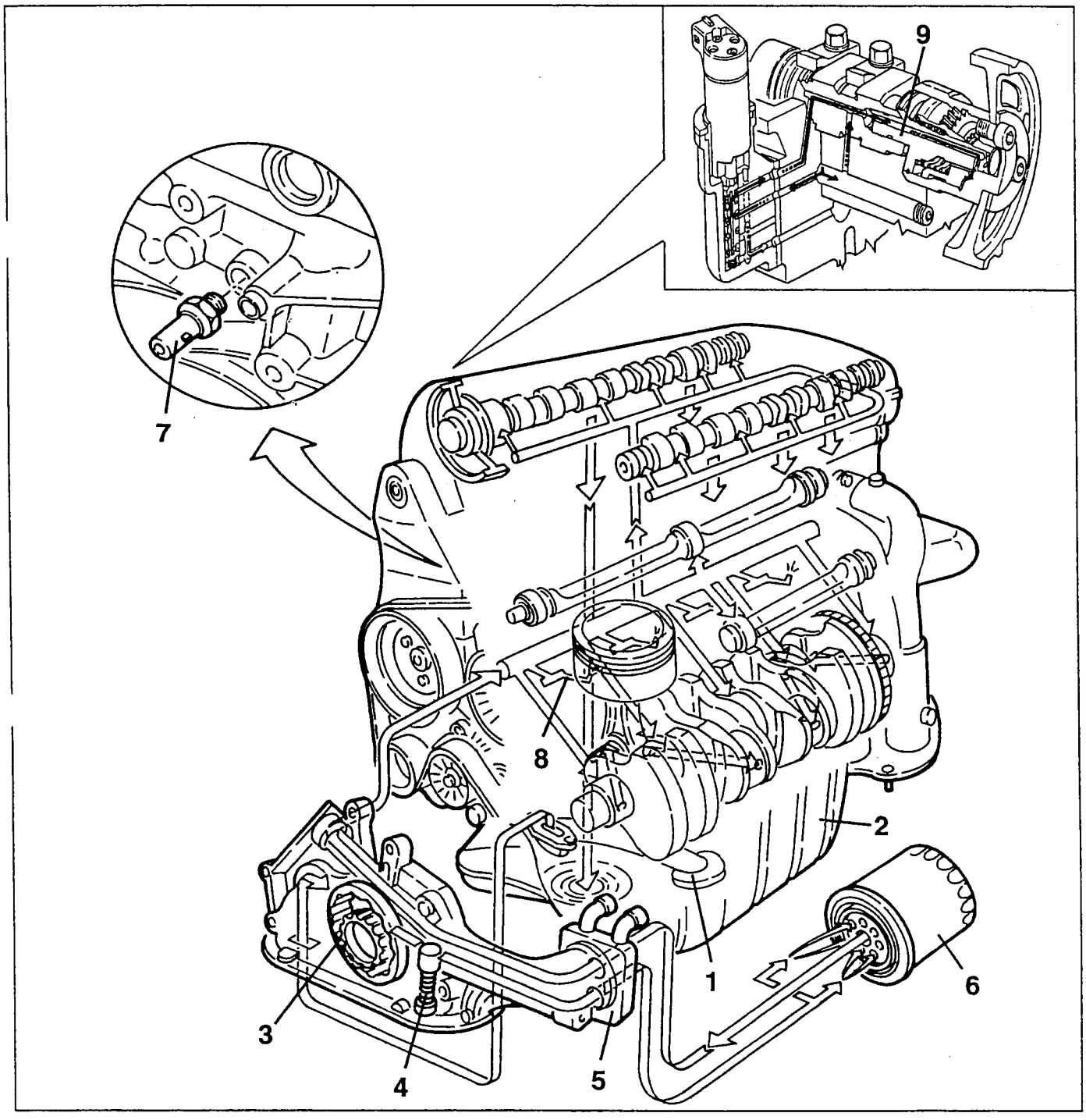




## LUBRICATION

The rotary lobe pump (3) fitted on the front of the crankcase is activated directly by the crankcase through keying.
The oil withdrawn from the sump by a suction device (1) is filtered by the gauze filter on the suction device and then sent under pressure by the pump through a duct to the full-flow cartridge oil filter (6) fitted with a by-pass safety valve, which ensures that the oil passes even if the cartridge is clogged.
A water-oil heat exchanger (5) is installed on the filter support to keep the oil temperature within the optimum limits.
The maximum lubricating pressure is regulated by a special limiting valve (4) fitted on the pump.
After being filtered, the oil passes through a duct machined on the front engine cover and reaches the main longitudinal delivery duct in the crankcase.
From here, it is then sent along five ducts to the grooves of the main bearings and from these to those of the connecting rod journals via special ducts machined in the crankshaft.
Another two vertical ducts machined in the crankcase lubricate the centre bearing of the counter-rotating shafts.
To improve the cooling of the piston skirts the crankcase is fitted with spray jets (8) with built-in ball valve which opens at a pressure of **2.25 ÷ 2.75 bar.**

From the main longitudinal duct in the crankcase, a vertical duct branches off which lubricates the camshaft bearings. On the intake side of the camshaft lubricating duct there are two special channels through which the oil for operating the timing variator passes. The recovery circuit is formed of a few ducts located in the cylinder head which collect the oil leading from the outlets and then drain it from the head from which it falls back into the sump.
The lubricating system is fitted with an oil vapour recirculation system which recovers the vapours leading from the sump and from the cylinder head.
The system is fitted with a minimum engine oil pressure sensor (7) which indicates insufficient lubricating pressure by turning on the warning light on the instrument cluster.




*1. Suction device with gauze filter*
*2. Oil sump*
*3. Oil pump*
*4. Pressure limiting valve*
*5. Heat exchanger*
*6. Filter with safety by-pass valve*
*7. Engine oil minimum pressure warning light sensor*
*8. Spray jets*
*9. Timing variator*

## INTRODUCTION

The instructions given in the following paragraphs refer to the complete overhauling of the engine on the bench, after having removed the power unit from the car. The instructions are subdivided as follows:

**- Engine dis-assembly:**
removal of the engine accessories and components and dis- assembly into the main units forming part of it.

**- Dis-assembly and overhauling of the cylinder head:**
complete overhauling of all the components of the head.

**- Crankcase overhauling:**
complete overhauling of the crank mechanism.

**- Instructions for re-assembly:**
these include the specific re-assembly operations which differ substantially from the dis-assembly instructions.

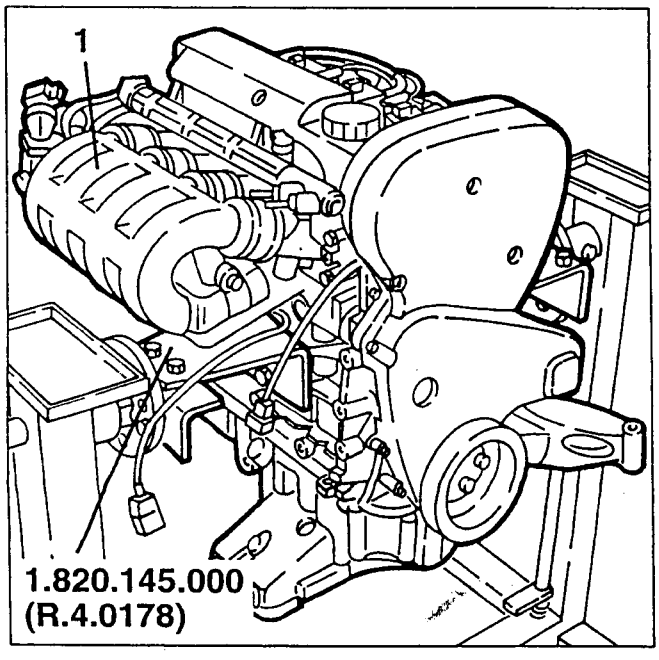
**- Checking and inspecting electric components of the lubrication circuit.**

**All the dis-assembly procedures described hereafter are also valid for re-assembly reversing the sequence described, unless otherwise specified.**
**The following procedures refer to the complete overhauling of the whole engine; it is however possible to use only certain parts of them separately, when necessary for dealing with specific components.**

## ENGINE DIS-ASSEMBLY

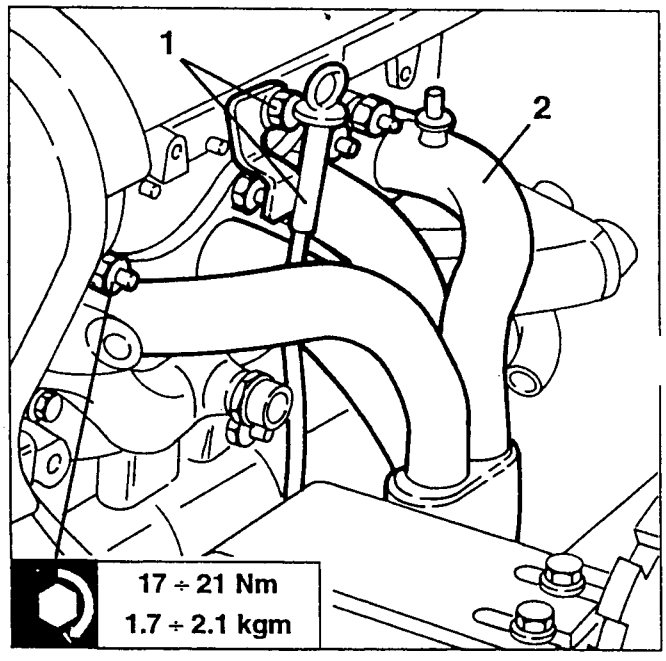
### PRELIMINARY OPERATIONS

1. Set the engine on a special overhauling stand using supports no. 1.820.145.000 (R.4.0178).



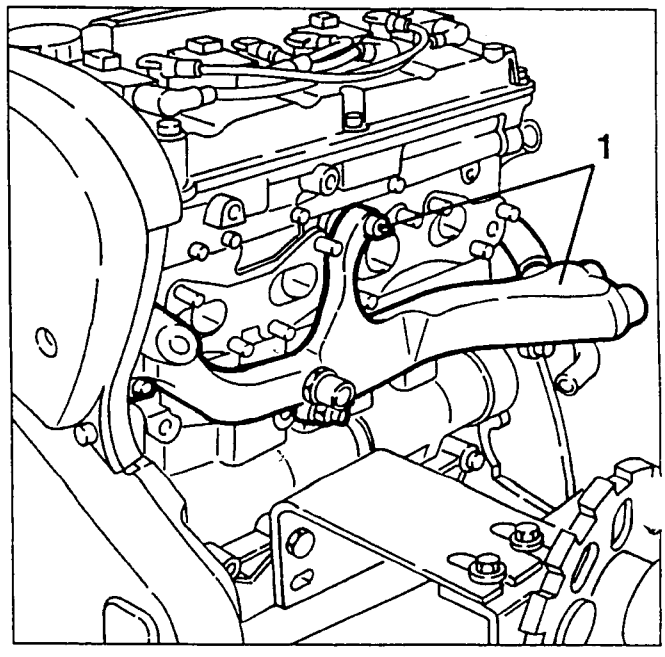

### REMOVING THE EXHAUST MANIFOLD

1. Slacken the fastening screw and remove the complete engine oil dipstick.
2. Slacken the fastening nuts and remove the exhaust manifold.



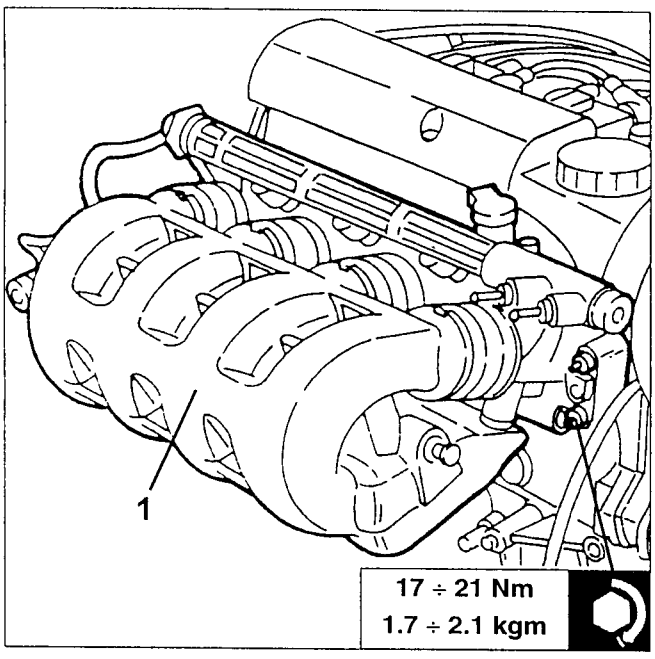

### REMOVING THE ENGINE COOLANT FLUID MANIFOLD

1. Remove the coolant return manifold, after disconnecting the pipe connecting to the thermostatic cu, and slackening the associated fastenings.
- Remove the exhaust manifold seal.



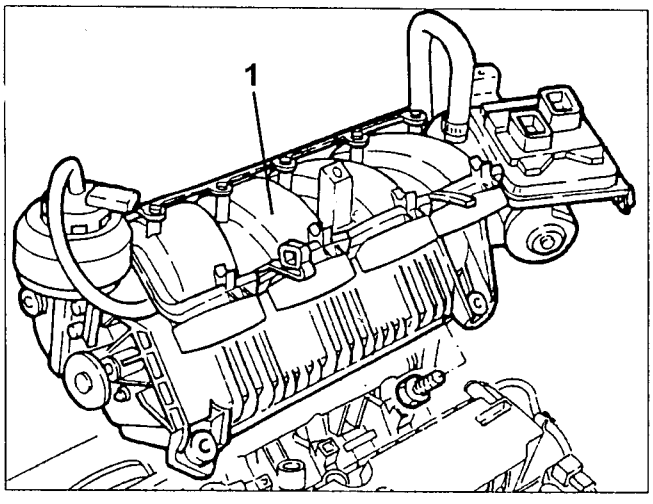
## INTAKE MANIFOLD REMOVAL (pre-change versions)

1. Loosen the fastening nuts and remove the intake manifold.
- Remove the respective seal.



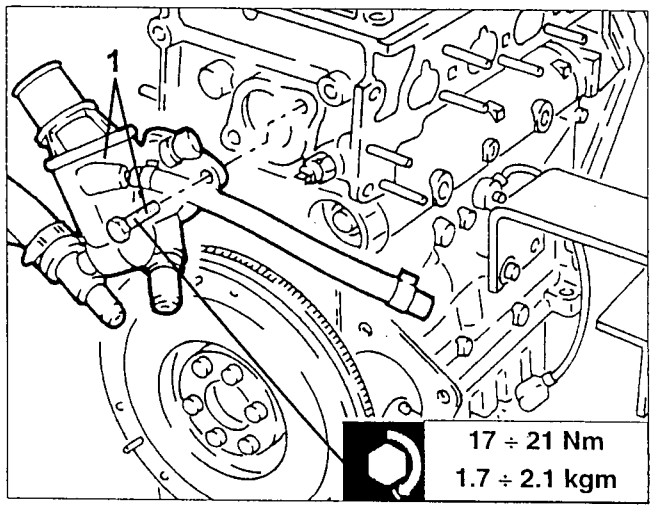

## INTAKE MANIFOLD REMOVAL (post-change versions)

1. Loosen the fastening nuts and remove the intake manifold.
- Remove the respective seal.



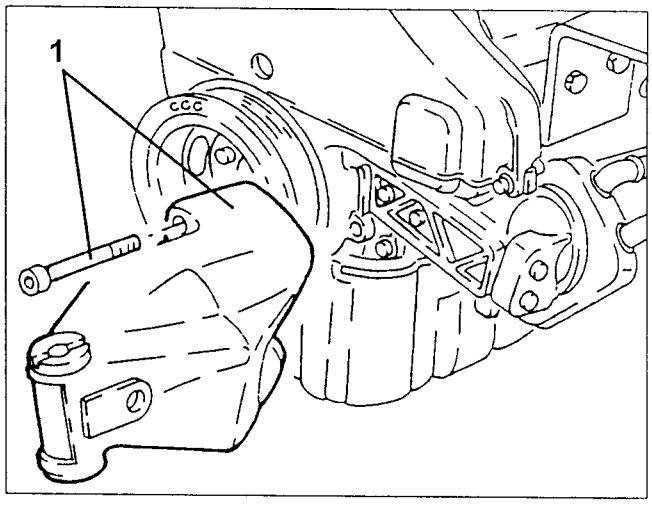

## THERMOSTAT UNIT REMOVAL

1. Remove the two fastening screws and remove the thermostat unit with coolant temperature sensor (NTC) and pipes
- Remove the respective seal.



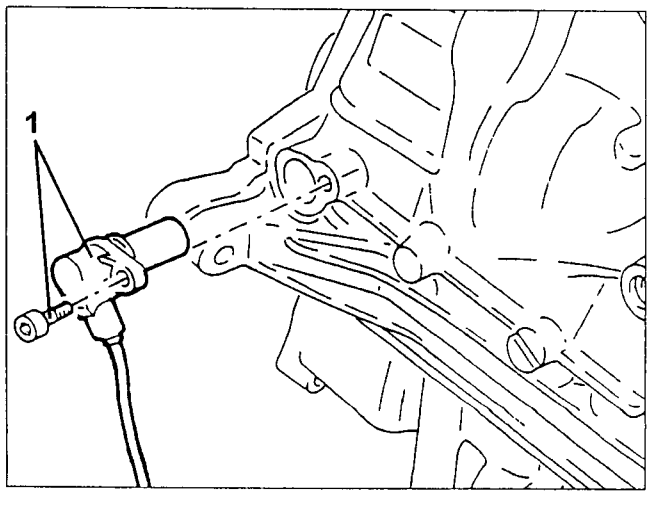

## FRONT ENGINE REMOVAL JOURNAL

1. Loosen the three fastening screws and remove the front engine journal.



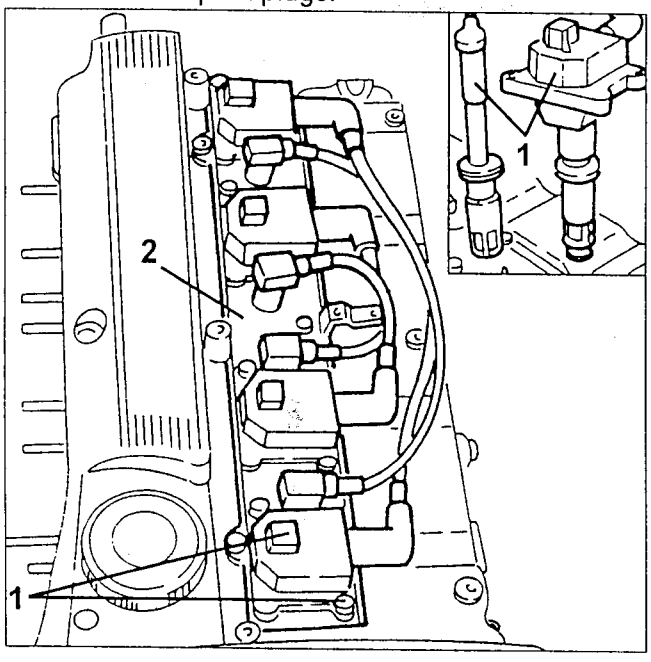

## RPM AND STROKE SENSOR REMOVAL

1. Loosen the fastening screw and remove the rpm and stroke sensor.



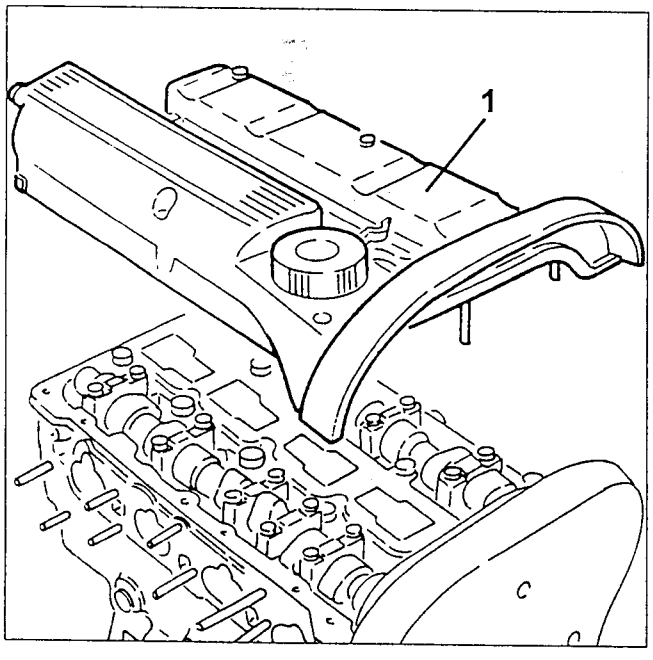
## IGNITION COIL REMOVAL

1. Loosen the fastening screws and remove the ignition coils and spark plug wires.
2. Loosen the fastening screws and remove the ignition coil bracket.
- Remove the spark plugs.

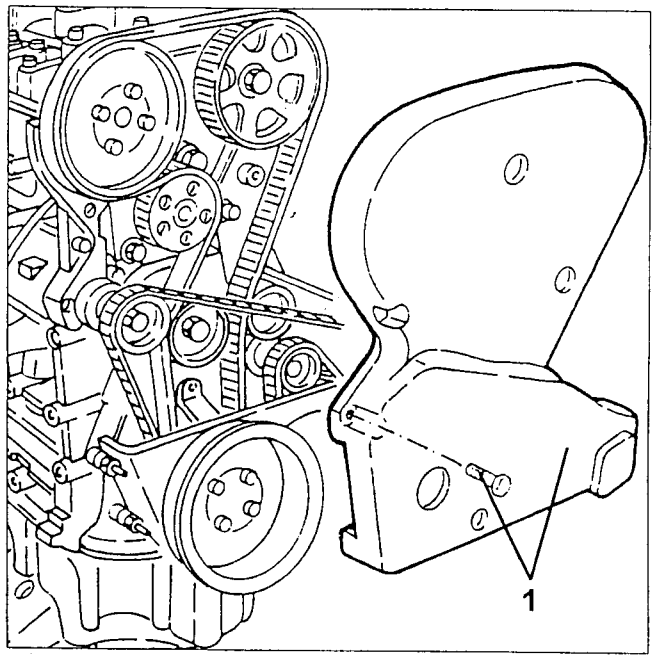



## COUNTER-ROTATING SHAFT BELT AND TIMING BELT REMOVAL

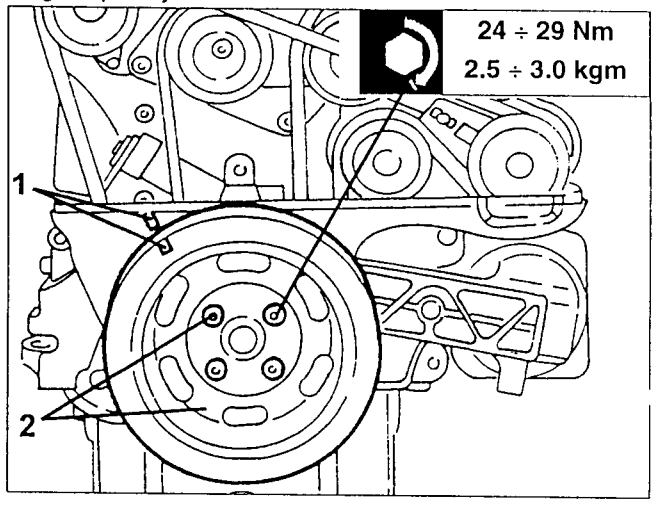
1. Loosen the fastening screws and remove the hydraulic tappet cover and seal.



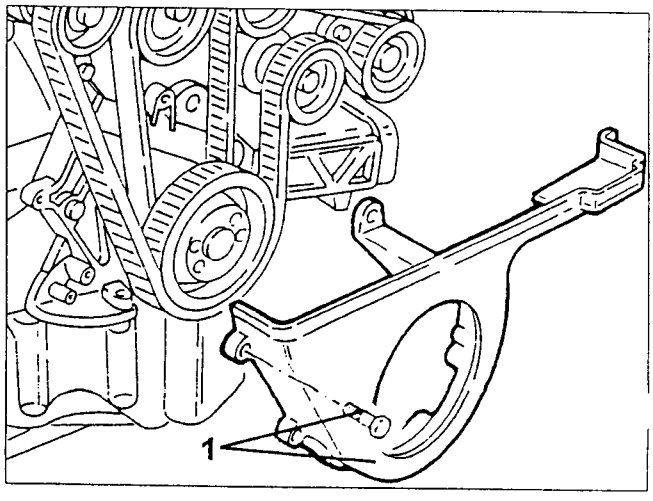

1. Loosen the fastening screws and remove the upper timing belt and counter-rotating shaft belt cover.



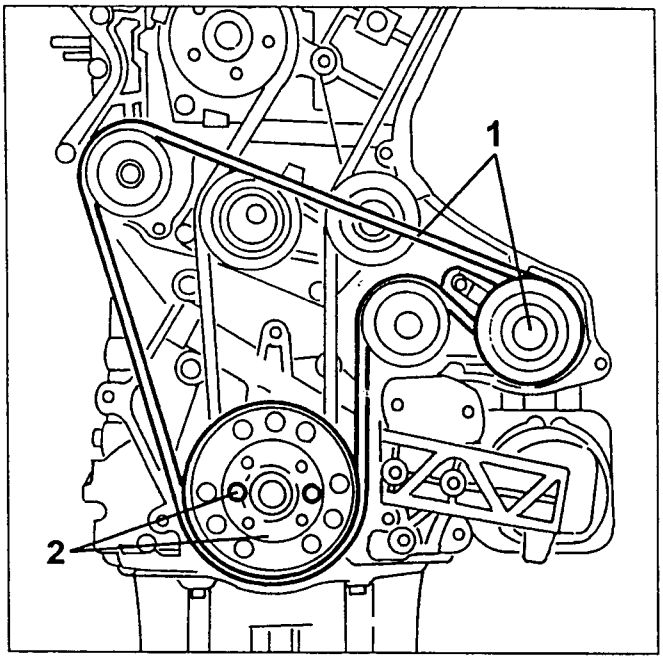

1. Turn the crankshaft until the notch on the engine pulley corresponds to that on the lower belt cover (cylinder 1 at DTC, firing stroke).
2. Loosen the fastening screws and remove the engine pulley.



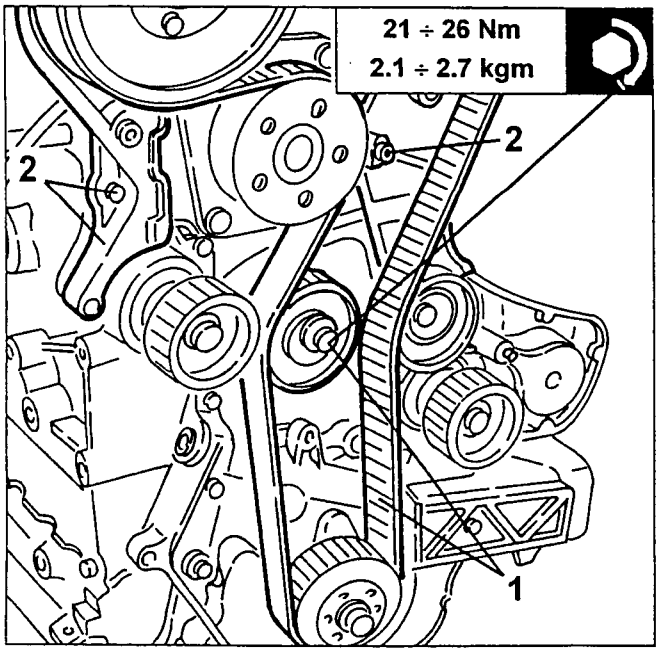

1. Loosen the three fastening screws and remove the lower belt cover.



1. Slacken the counter-rotating shaft belt tensioner then prise and remove the belt.
- Completely unscrew the fastening nut and remove the counter-rotating shaft belt tensioner.
2. Slacken the two fastening screws and remove the counter-rotating shaft belt drive pulley.

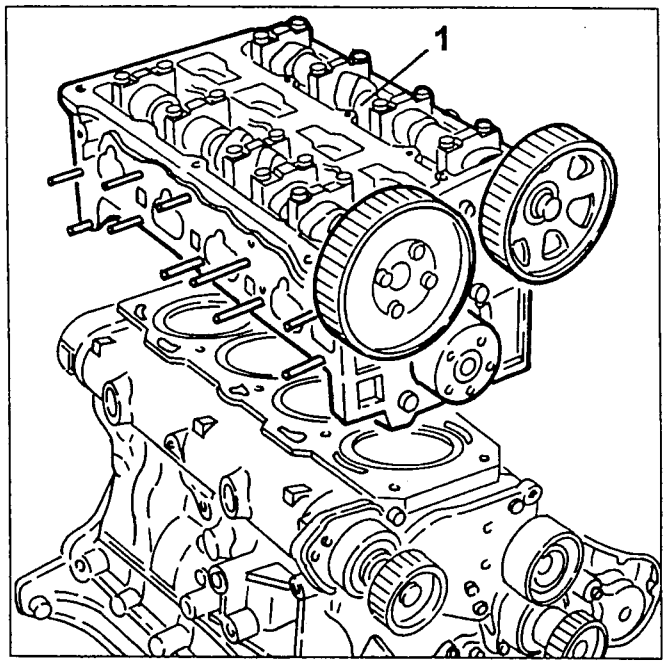



1. Slacken the camshaft belt tensioner, then prise and remove the belt.
- Completely unscrew the fastening nut and remove the camshaft belt tensioner.
2. Slacken the fastening screws and remove the side guards of the camshaft belt and counter-rotating shaft belt.



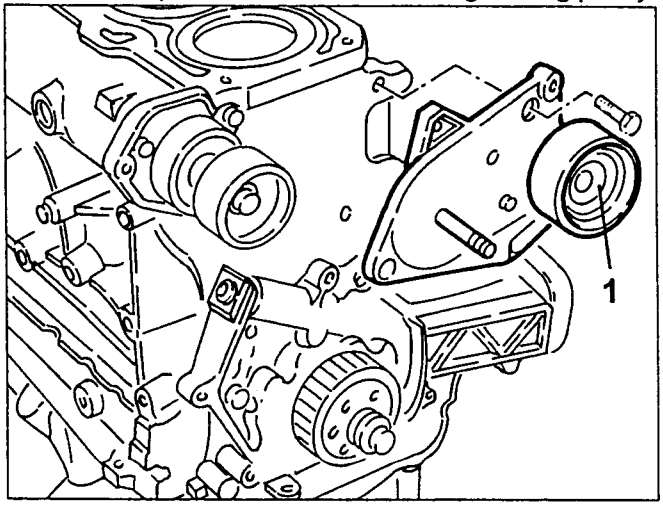

## REMOVING THE CYLINDER HEAD

1. Slacken the fastening screws and remove the cylinder head.
- Remove the seal.

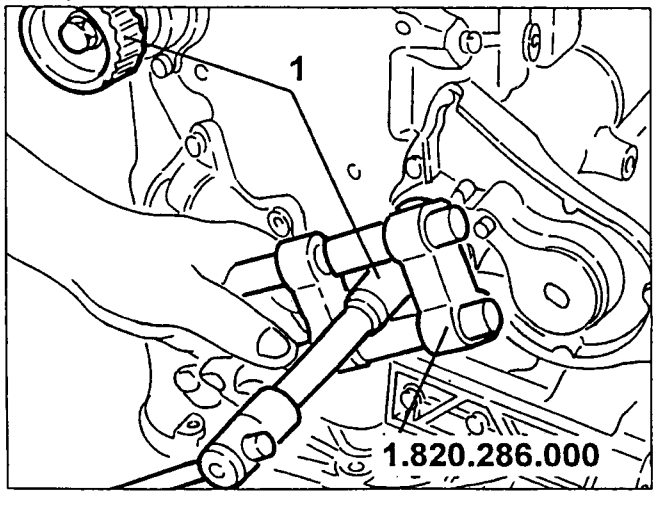



## REMOVING THE COUNTER-ROTATING SHAFTS

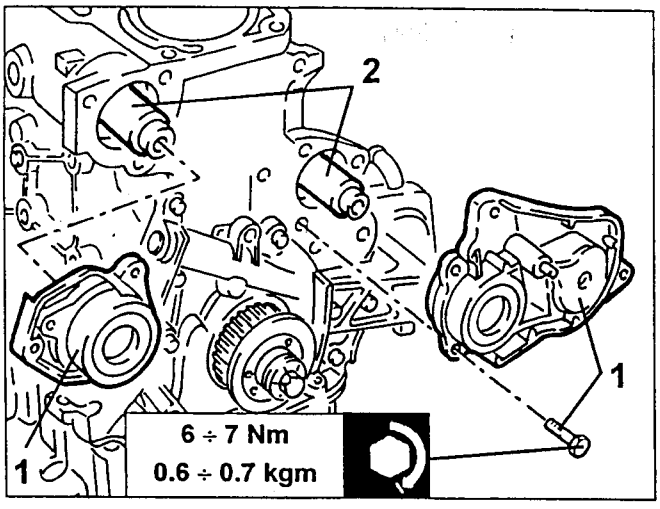
1. Slacken the three fastening screws and remove the bracket complete with the camshaft tightening pulley.



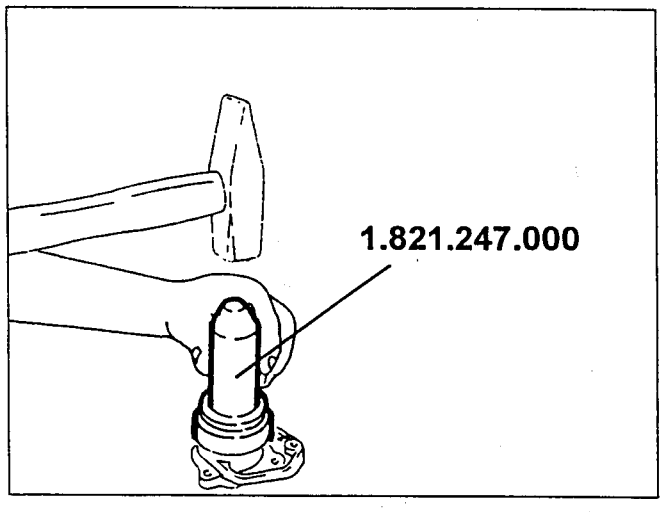

1. Using tool no. 1.820.286.000, slacken the fastening screws and remove the counter-rotating shaft drive pulleys.



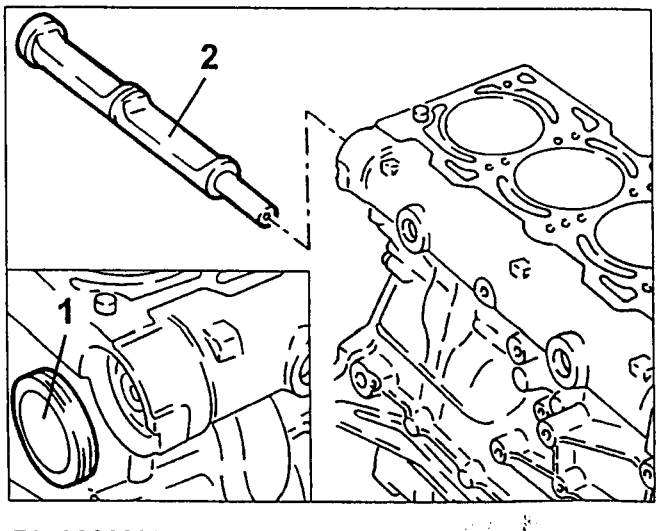
1. Slacken the fastening screws and remove the counter-rotating shaft front contcovers complete with oil seal rings.
2. Withdraw the two spacers from the counter-rotating shafts.



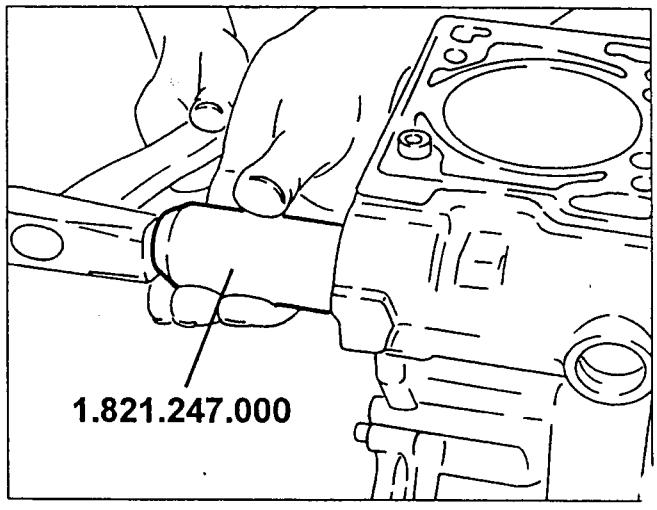

**When refitting the oil seal rings, use tool no. 1.821.247.000.**



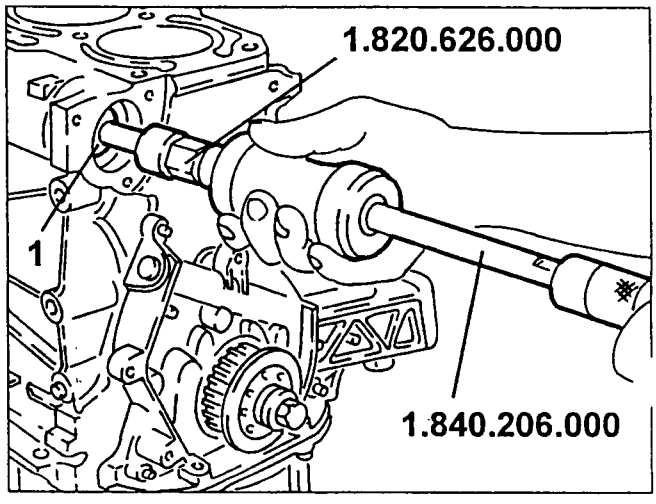

1. Prise and remove the counter-rotating shaft rear plugs.
2. Using a plastic mallet remove the counter-rotating shafts from the rear of the engine.



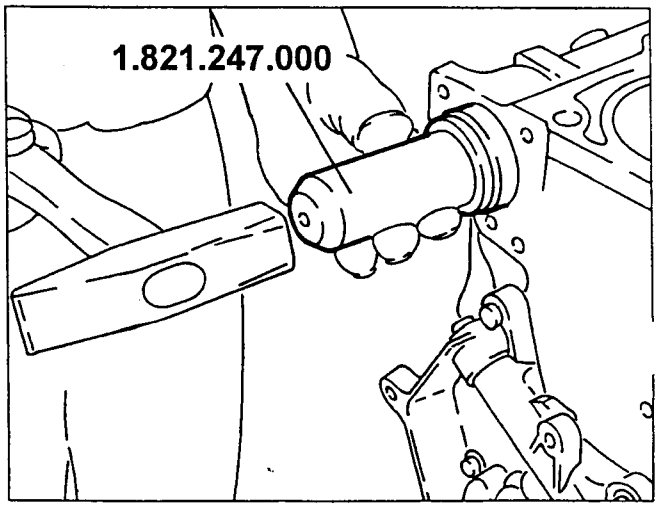

**When refitting, insert the counter-rotating shafts complete with rear bearings using tool no. 1.821.247.000.**




- Using a suitable puller tool remove the rear bearings from the counter-rotating shafts.
1. Using tools no. 1.820.626.000 and no. 1.840.206.000 remove the two front bearings from the counter-rotating shafts.

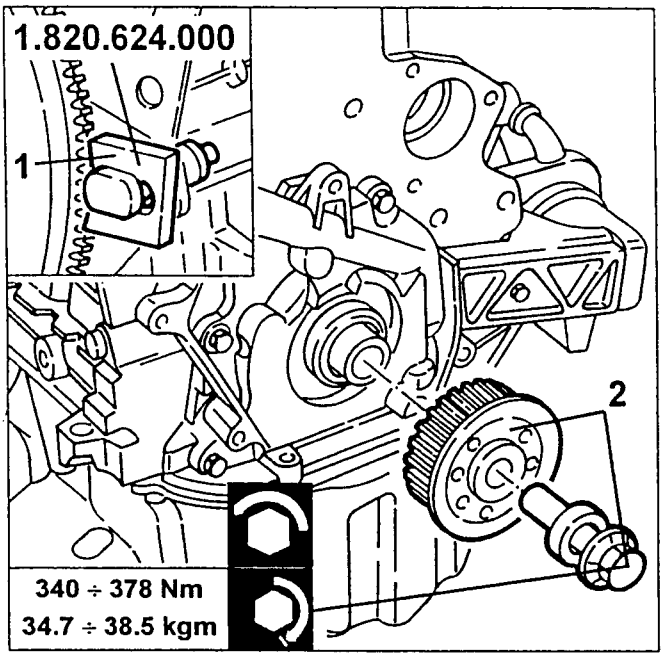



**When refitting insert the counter-rotating shaft front bearings using tool no. 1.821.247.000.**



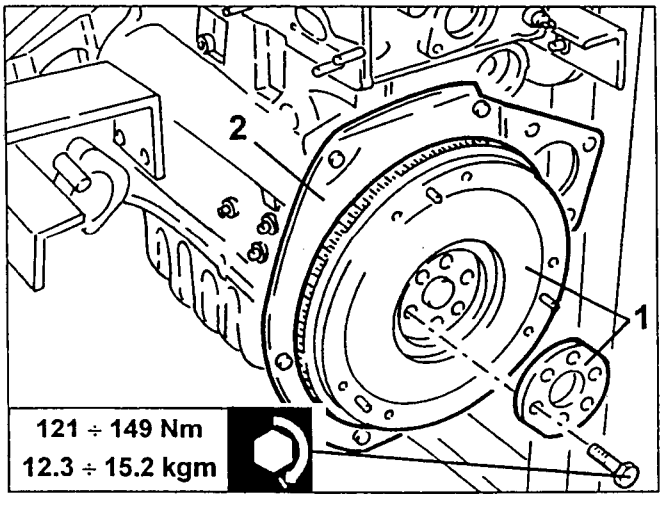
## REMOVING THE CAMSHAFT DRIVE BELT PULLEY

1. Install flywheel stopper tool no. 1.820.624.000.
2. Slacken the left-handed screw and remove the camshaft drive belt pulley.




## REMOVING THE FLYWHEEL

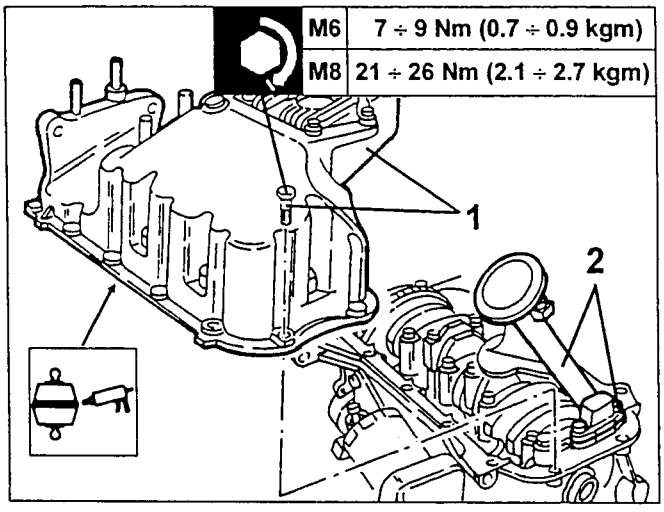
1. Slacken the fastening screws and remove the flywheel.
2. Retrieve the flywheel cover.




- Remove the flywheel stopper tool installed previously.

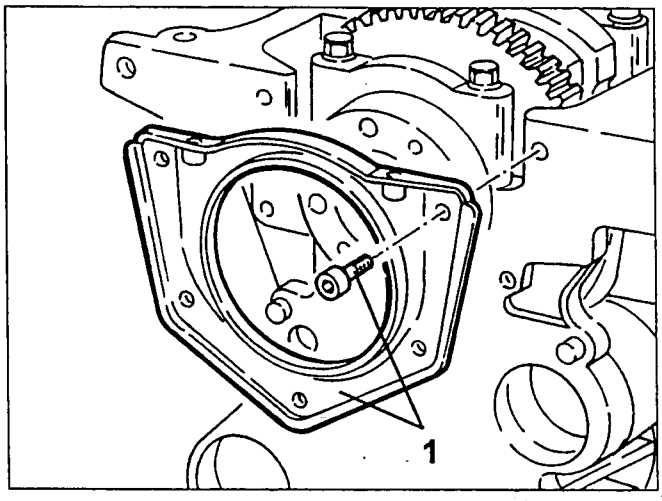
## REMOVING THE OIL SUMP

1. Turn the engine on the overhauling stand, then slacken the fastening screws and remove the oil sump.
2. Slacken the two fastening screws and remove the oil suction device with its seal.



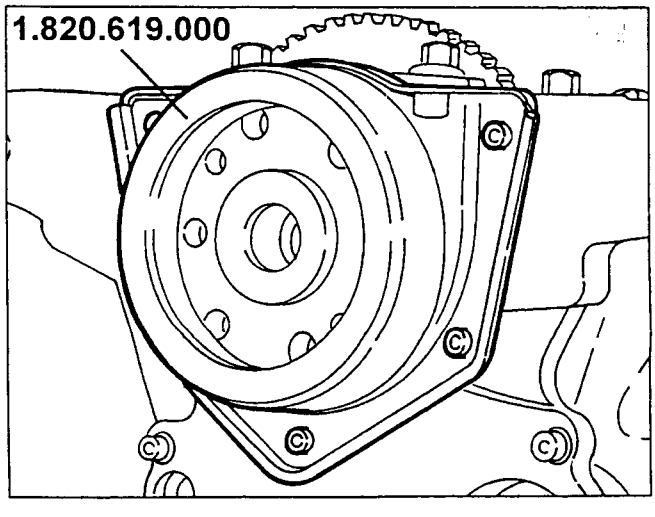

## REMOVING THE CRANKCASE REAR COVER

1. Slacken the fastening screws and remove the crankcase rear cover with incorporated oil seal ring.



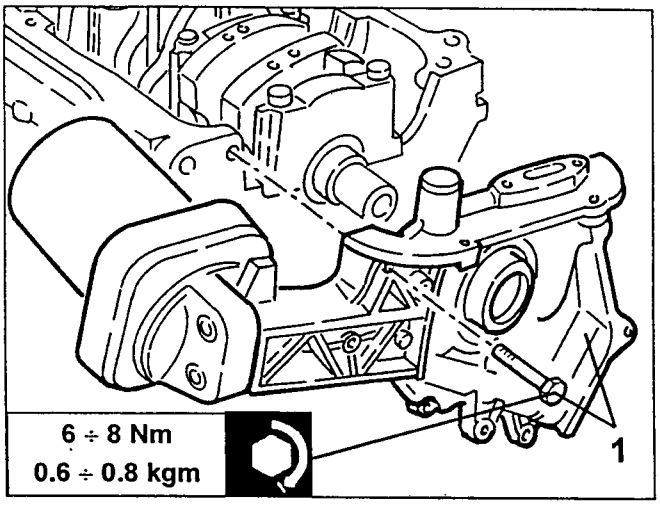

**Refit the rear cover as follows:**

- **Fit tool no. 1.820.619.000 on the oil seal of the rear crankcase cover;**
- **fit the tool - rear cover together and tighten the screws fastening to the crankcase; the tool should be removed only after also tightening the screws fastening the rear cover to the oil sump.**



## REMOVING THE ENGINE OIL PUMP ASSEMBLY

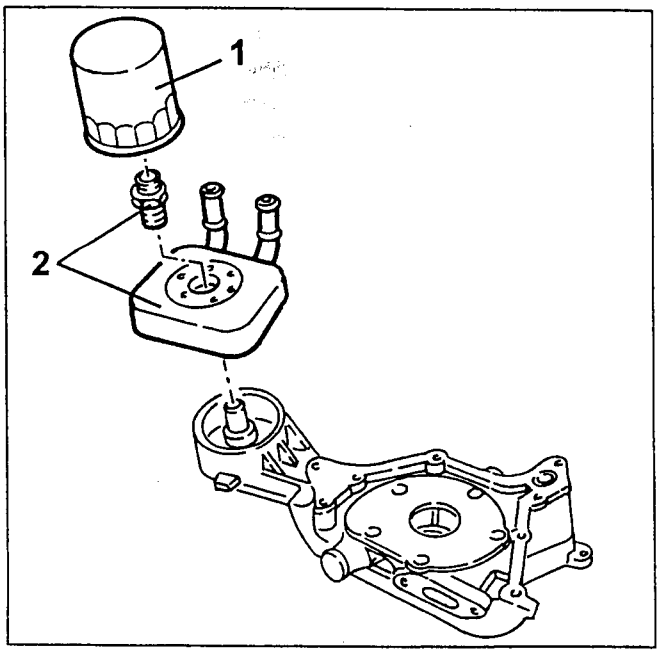
1. Slacken the fastening screws and remove the engine front cover with incorporated oil pump, filter and heat exchanger.



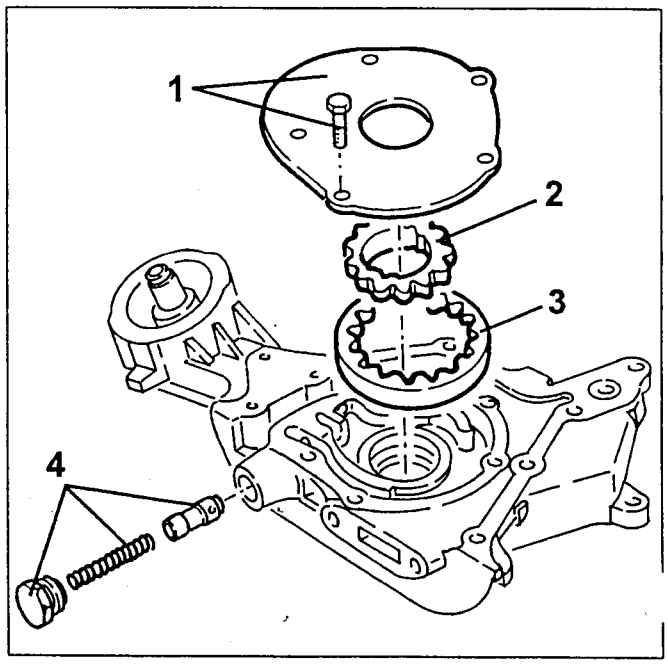

- Prise and remove the crankshaft front oil seal.

**When refitting the crankshaft front oil seal, after fitting it on the oil pump assembly and assembling this on the crankcase, use tool no. 1.821.247.000.**

1. On the bench, slacken and remove the oil filter.
2. Remove the fastening pin and remove the engine oil-coolant fluid heat exchangr complete with O-Ring.

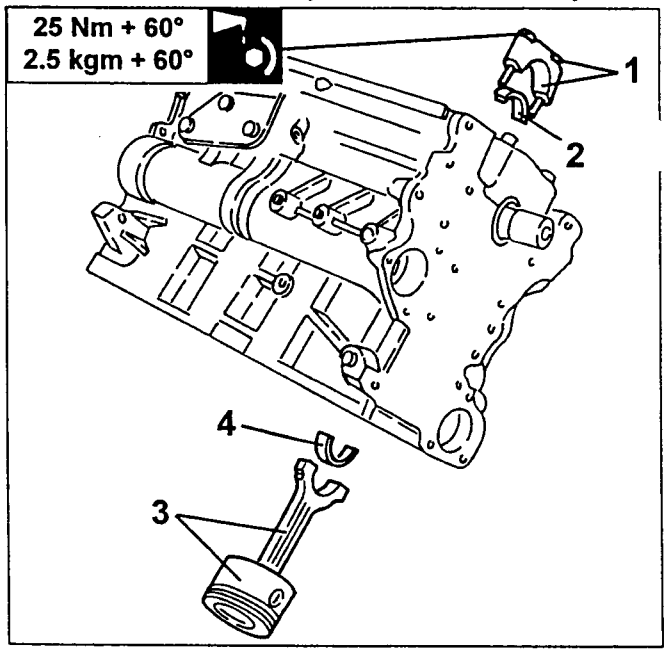



1. Slacken the fastening screws and remove the engine oil pump cover.
2. Remove the driving gear.
3. Remove the driven gear.
4. Slacken the fastening pin and remove the spring and the engine oil pump overpressure sliding valve.




## REMOVING PISTONS AND CONNECTING RODS

- Turn the crankshaft so that the pistons of the 1st and 4th cylinder reach the T.D.C.
1. Slacken the fastening screws and remove the connecting rod caps of the 1st and 4th cylinder.
2. Remove the corresponding connecting rod half bearings.
3. Withdraw the pistons and connecting rods of the 1st and 4th cylinder.
4. Remove the corresponding connecting rod half bearings.
- Proceed in the same way for the 2nd and 3rd cylinder.



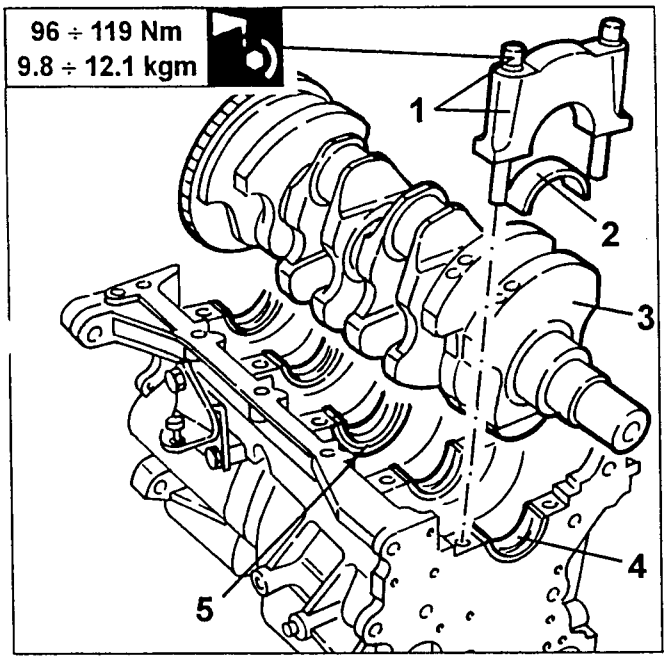

- Using a suitable tool, remove the seal rings and scraper ring from the piston.

**WARNING: Proceed with care to avoid accidentally breaking any re-usable rings.**

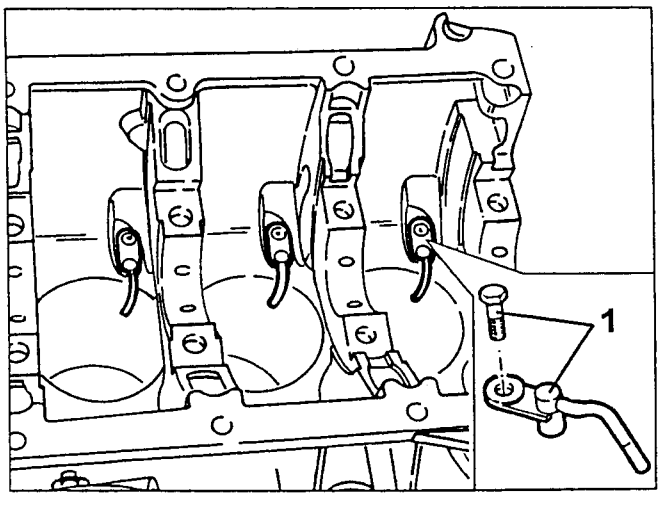
- Remove the two gudgeon pin circlips.
- Remove the gudgeon pin and separate the piston from the connecting rod.

## REMOVING THE CRANKSHAFT

1. Slacken the fastening screws and remove the main bearing caps.
2. Remove the corresponding main half bearings.
3. Remove the crankshaft.
4. Remove the main half bearings from the supports.
5. Remove the two half thrust rings.



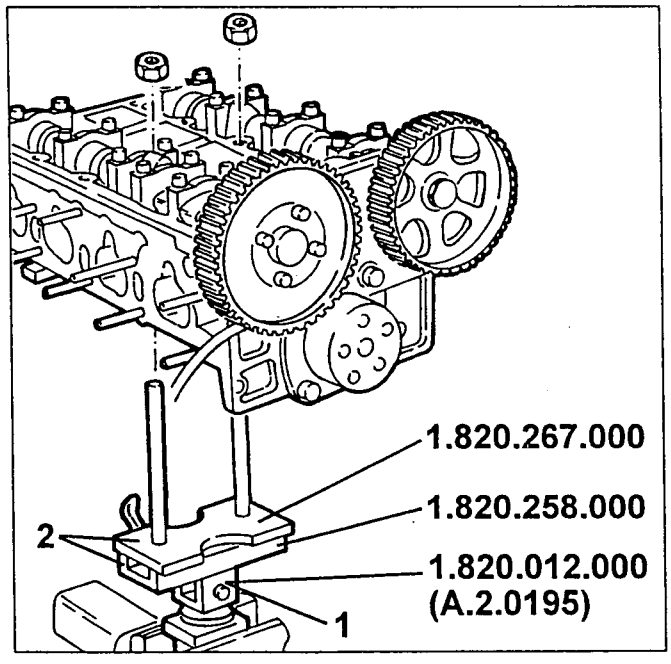

1. If necessary, slacken the fastening screw and remove the oil spray jets for lubricating and cooling the pistons from the crankcase.



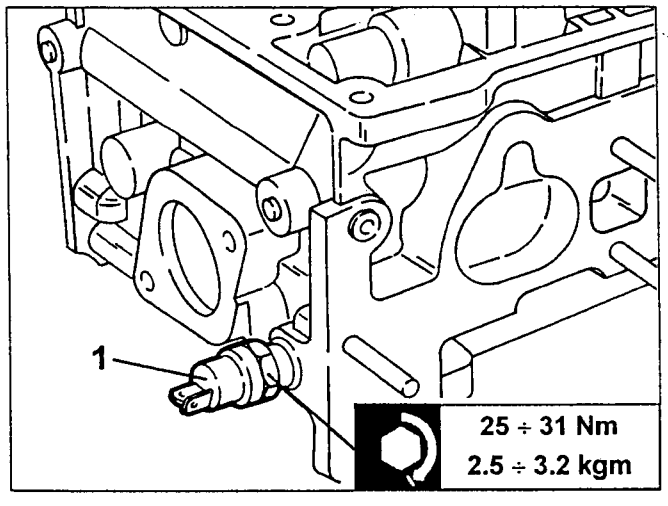

## CYLINDER HEAD DISASSEMBLY

### PRELIMINARY OPERATIONS

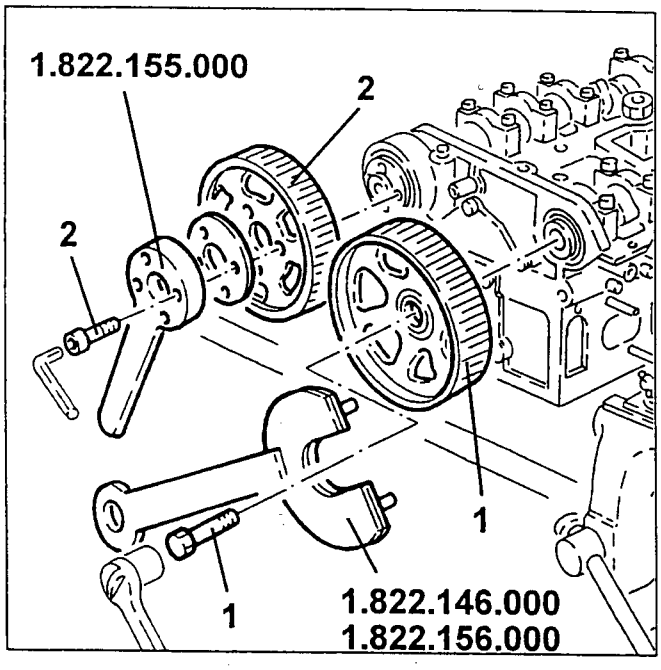
1. Fasten swivel support no. 1.820.012.000 (A.2.0195) in a vice.
2. Fasten tools no. 1.820.258.000 and no. 1.820.267.000 on the swivel support, then fasten the cylinder head on them.



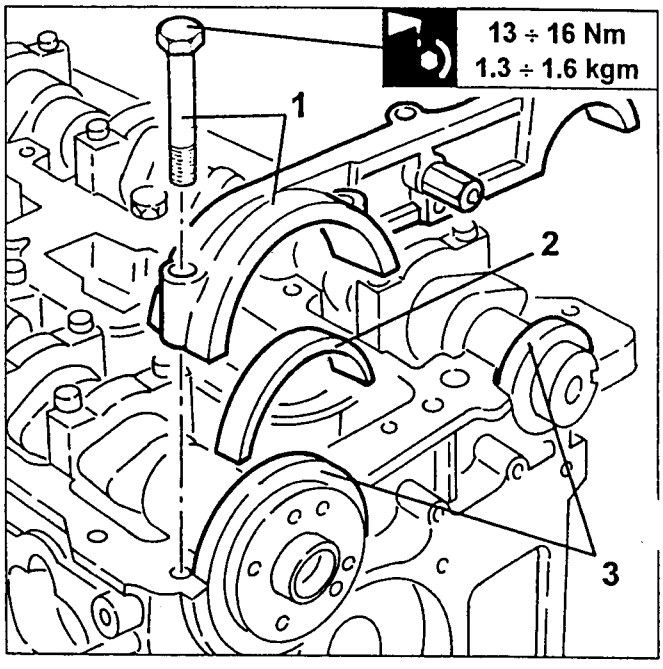

1. Remove the engine coolant temperature gauge transmitter and maximum temperature warning light contact from the cylinder head.



1. Slacken the fastening screw using tools no. 1.822.146.000 and no. 1.822.156.000 and remove the exhaust side camshaft drive pulley.
2. Slacken the fastening screws using tool no. 1.822.155.000 and remove the intake side camshaft drive pulley.

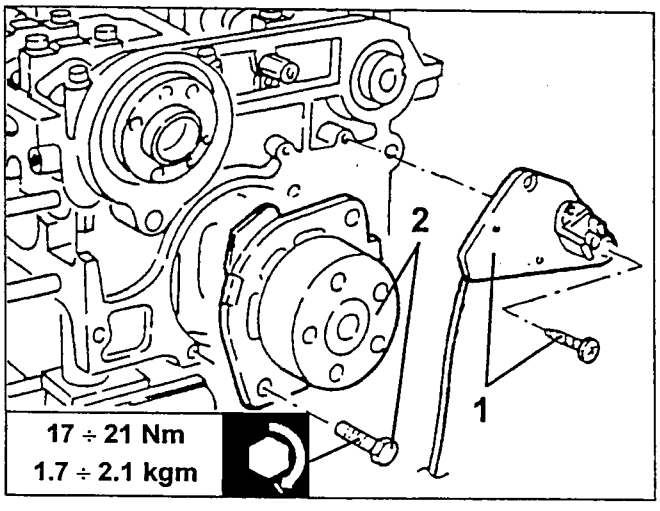



2. Remove the intake side half bearing.
3. Remove the oil seal rings from the camshafts.

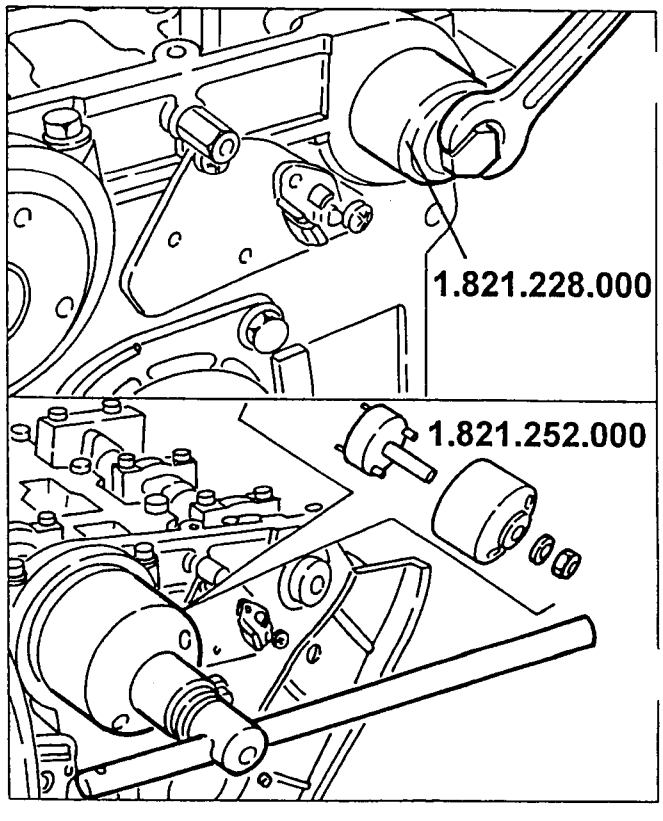



## REMOVING THE WATER PUMP

1. Slacken the two fastening screws and remove the timing sensor complete with support.
2. Slacken the two fastening screws and remove the water pump complete with O-ring.



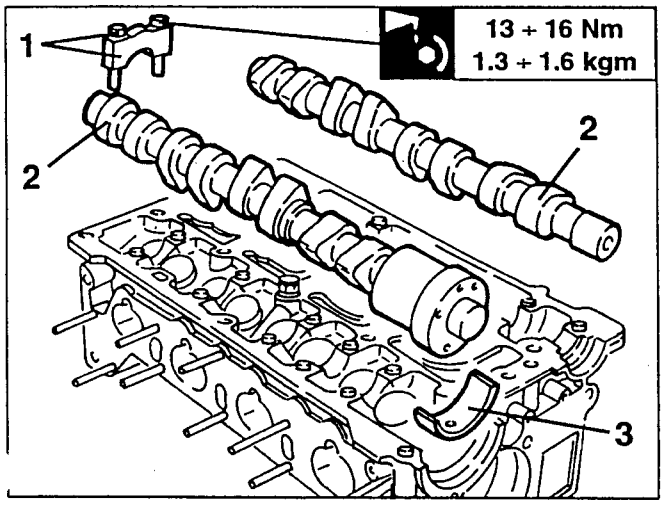

**When refitting using tool no. 1.821.228.000 insert the exhaust side oil seal.**
**Using tool no. 1.821.252.000 insert the intake side oil seal.**




## REMOVING THE CAMSHAFTS

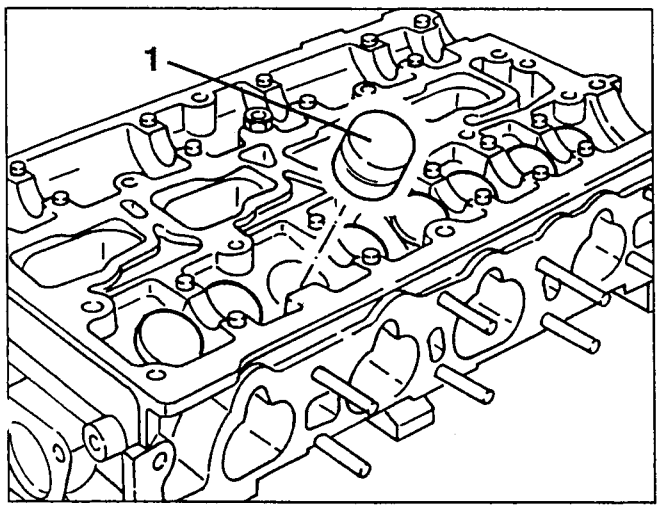
1. Slacken the four fastening screws and remove the camshaft front cap.

1. Slacken the fastening screws and remove the camshaft caps.
2. Remove the camshafts.
3. Remove the intake side half bearing.

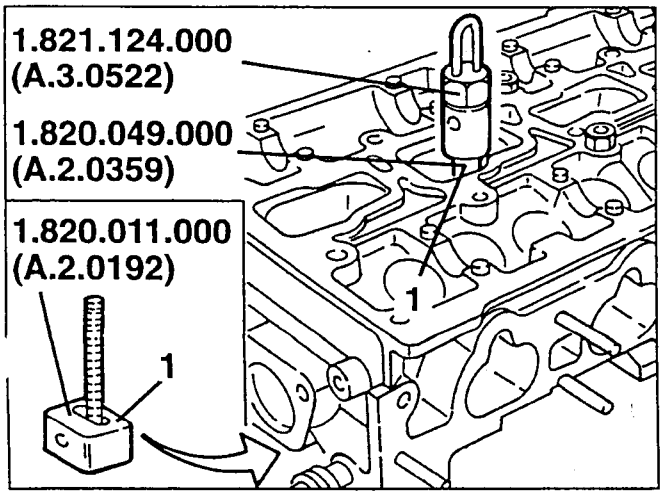



## VALVES DIS-ASSEMBLY

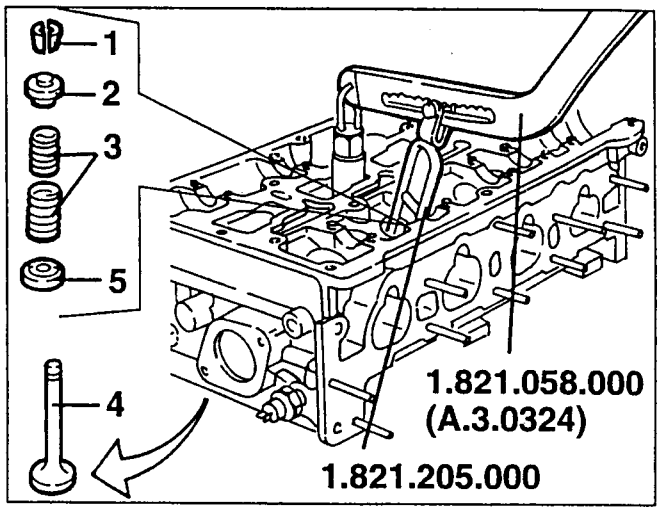
1. Withdraw the hydraulic tappets from their housings.



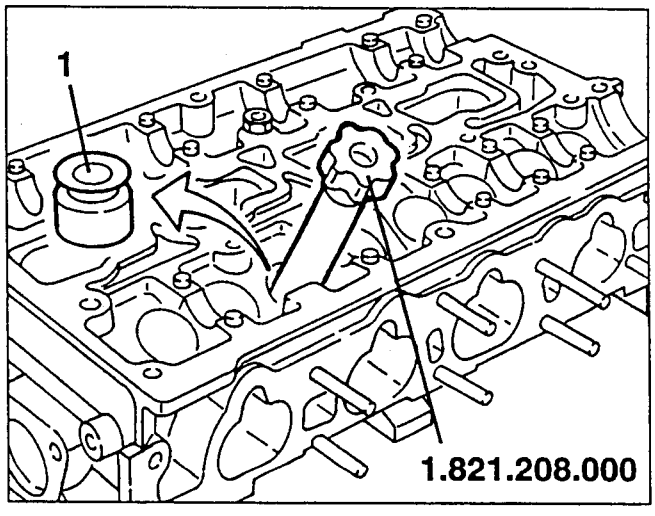

1. On the cylinder head assemble tools no. 1.820.011.000 (A.2.0192), no.1.820.049.000 (A.2.0359) and no. 1.821.124.000 (A.3.0522).



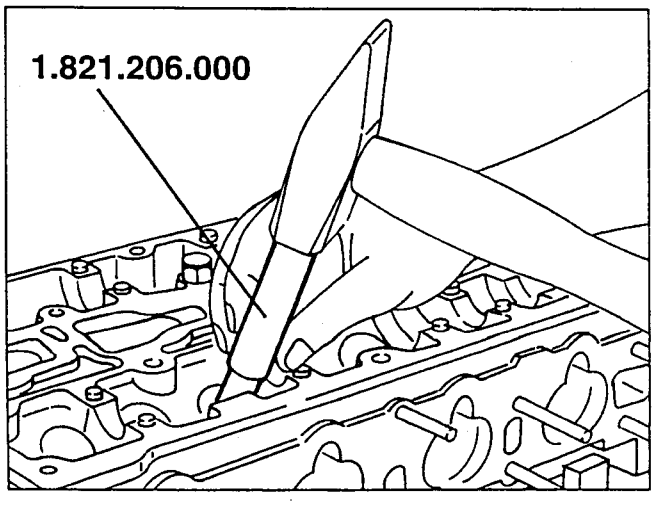

1. Using lever no. 1.821.058.000 (A.3.0324) and cage no. 1.821.205.000, remove the half cones from the valve stem.
2. Remove the upper plate.
3. Remove the outer and inner springs.
4. Remove the tools and retrieve the valve.
5. Remove the valve lower plate.




1. Using tool no. 1.821.208.000, remove the oil seal cap.




**When refitting the oil seal cap use tool no. 1.821.206.000.**

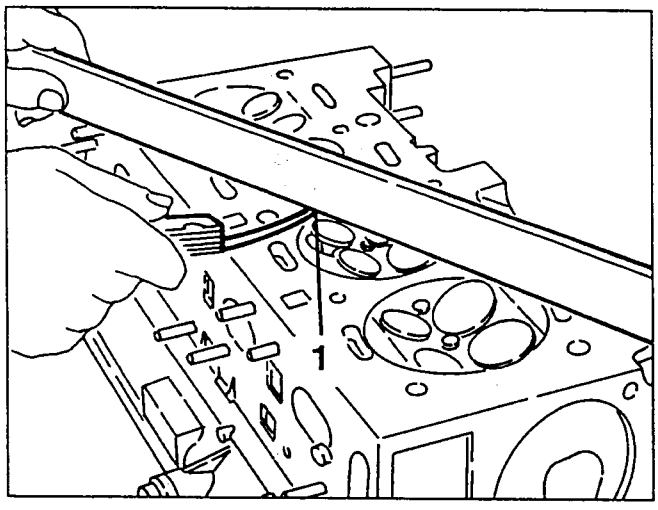


# CHECKS AND INSPECTION CYLINDER HEAD

## Checking the lower surface of the cylinder head

1. Check the flatness of the lower cylinder head surface; reface if it is excessively worn.

| Maximum flatness error of cylinder head lower surface |
|---|
| 0.1 mm |

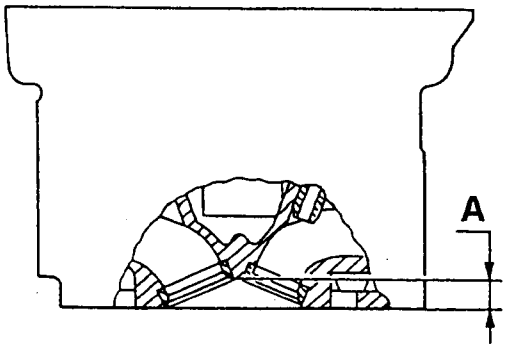



- After refacing, check that the depth of the combustion chamber, on the head, exceeds the minimum allowed limit.

**WARNING:**
**Exceeding the minimum allowed limit involves serious engine operating failures.**

| Minimum depth "A" of the combustion chamber in the head |
|---|
| 13 ± 0.2 mm |

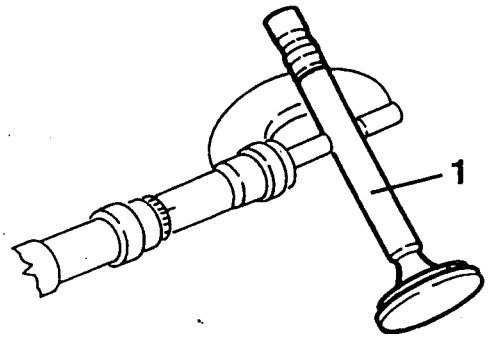
- Check that the finishing of the lower cylinder head surface is satisfactory.




## Checking the clearance between valve guides and valve stems

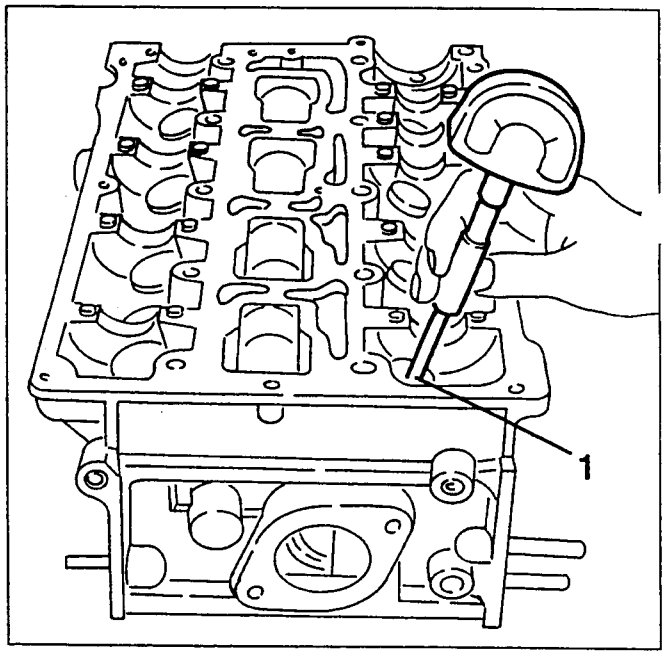
1. Measure the diameter of the valve stems and check that it is within the specified limits.

| Diameter of valve stems | |
|---|---|
| Intake | 6.975 ÷ 6.990 mm |
| Exhaust | 6.960 ÷ 6.975 mm |




1. Measure the inside diameter of the valve guides and check that it is within the specified limits.

| Inside diameter of valve guides |
|---|
| 7.022 ÷ 7.040 mm |

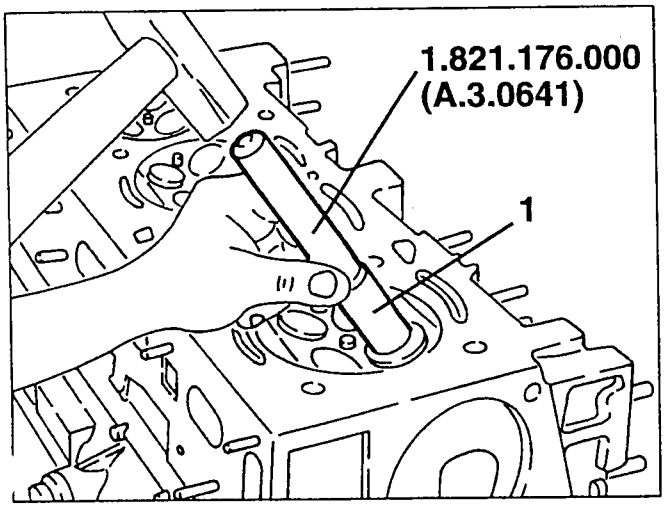



- Calculate the clearance between valve guides and stems and check that it is within the specified limits, if not, change any worn parts.

| Radial clearance between valve guides and stems | |
|---|---|
| Intake | 0.032 ÷ 0.065 mm |
| Exhaust | 0.047 ÷ 0.080 mm |

## Changing the valve guides

1. Using puller tool no. 1.821.176.000 (A.3.0641), remove the worn valve guides.



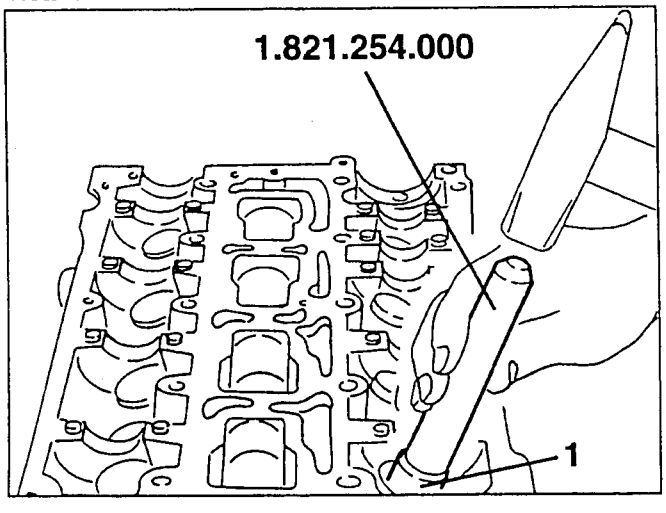

- Check that the outside diameter of the valve guides and their seats on the head are within the specified limits and that their assembly interference is correct.

| Outside diameter of valve guides |
|---|
| 13.010 ÷ 13.030 mm |

| Diameter of valve guide seats |
|---|
| 12.950 ÷ 12.977 mm |

| Interference between valve guides and seats |
|---|
| 0.033 ÷ 0.080 mm |

1. Insert the new valve guides using tool no. 1.821.254.000.




- Bore the valve guide inside diameter to calibrate the holes to the specified diameter.

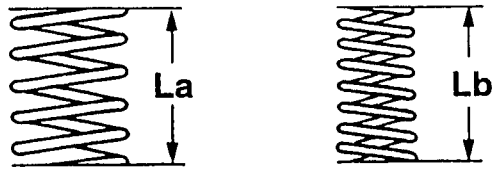
| Inside diameter of valve guides |
|---|
| 7.022 ÷ 7.040 mm |

## Checking the valve springs

- Check that the "free" length of the valve springs is within the specified limits.

**NOTE: The rest surfaces must be parallel with each other and perpendicular to the axis of the spring with a maximum error of 2°.**

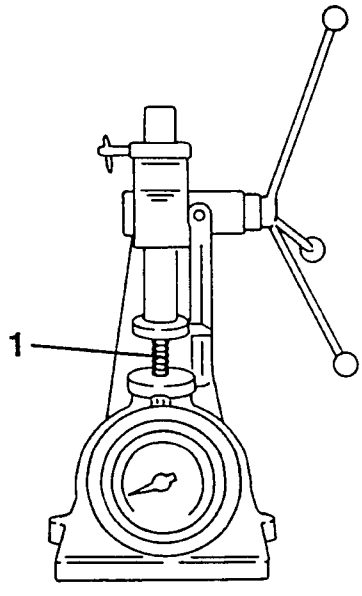
| Free length of valve springs | |
|---|---|
| outer spring "La" | 46 mm |
| inner spring "Lb" | 39 mm |




1. Using a torque meter, check that the characteristic data of the springs are within the specified limits.

| Outer spring | | |
|---|---|---|
| Length of spring mm | | Control load N (Kg) |
| With valve closed | 34 | 271 ÷ 294 (27.6 ÷ 30) |
| With valve open | 24.5 | 485 ÷ 524 (49.4 ÷ 53.4) |

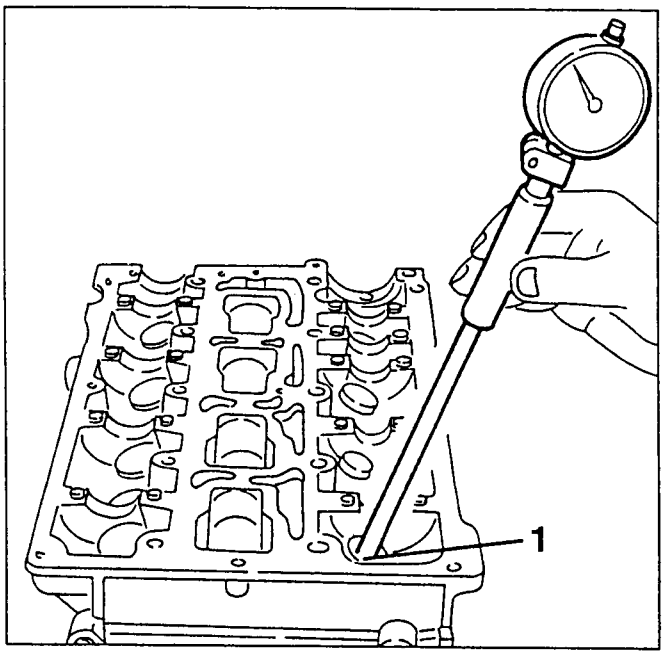
| Inner spring | | |
|---|---|---|
| Length of spring mm | | Control load N (Kg) |
| With valve closed | 29.5 | 96 ÷ 106 (9.8 ÷ 10.8) |
| With valve open | 20 | 201 ÷ 221 (20.5 ÷ 22.5) |



## Checking the clearance between the cups and their seats

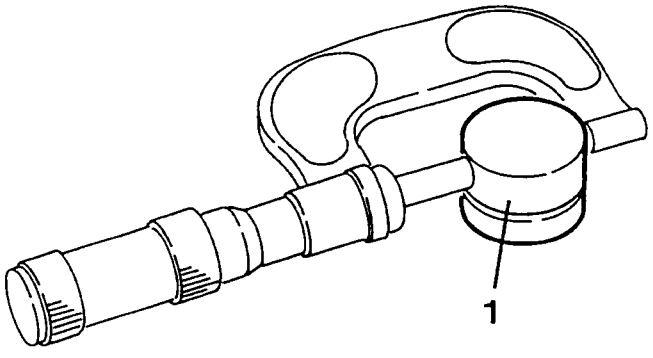
1. Check that the diameter of the cup seats is within the specified limits.

| Diameter of valve cup seats |
|---|
| 33.000 ÷ 33.025 mm |




1. Check that the outside diameter of the cups is within the specified limits.

| Diameter of valve cups |
|---|
| 32.959 ÷ 32.975 mm |




- Calculate the clearance between the cups and their seats checking that it is within the specified limits.

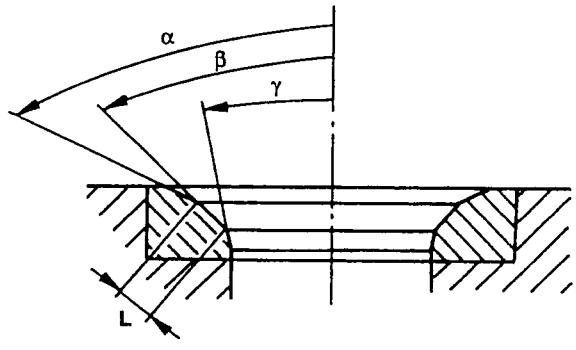
| Clearance between cups and seats |
|---|
| 0.025 ÷ 0.066 mm |

## Turning the valve seats

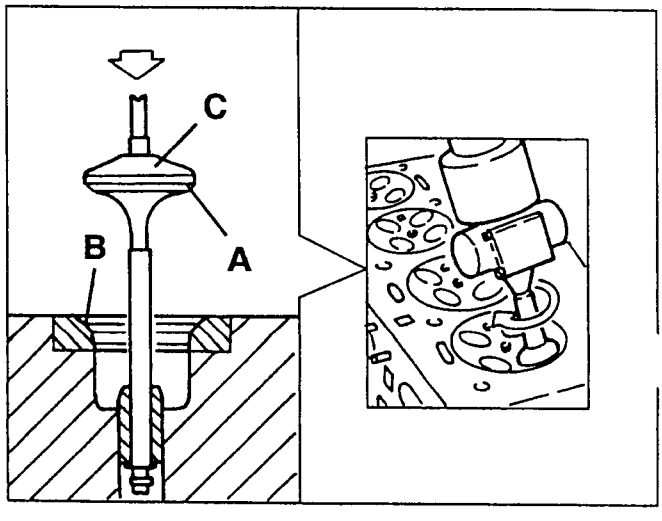
- If necessary, turn the valve seats using suitable equipment within the following limits.

| | |
|---|---|
| Taper of contact area with valve "β" | 90° ± 10' |
| Taper of upper valve seat area "α" | 150° |
| Taper of lower valve seat area "γ" | 30° |

| Dimension "L" contact area with valve | |
|---|---|
| Intake | 6.5 mm |
| Exhaust | 5.5 mm |




- After machining, grind each valve in its seat as follows:
- coat the contact surfaces "A" and "B" of the valves and their seats with abrasive paste (SIPAL AREXON Carbosilicium for valves);
- lubrificate the valve stem with engine oil;
- fit the lower surface of the valve mushroom to the suction cup "C" of a pneumatic grinder;
- insert the valve in its guide and grind;
- after grinding, thoroughly clean the valve and the seat.



When turning and grinding the valve seats it is advisable to check the valve tightness with the spark plugs in place, proceeding as follows:
- fill the hollow of the combustion chamber with petrol;
- admit low pressure air into the intake manifolds and check that no bubbles form in the petrol;
- check the tightness of the exhaust valves in the same way, admitting air to the exhaust manifolds;
- if any leaks are noted, make sure that the valves are perfectly settled in their seats and repeat the check; if the result is negative, grinding must be repeated.

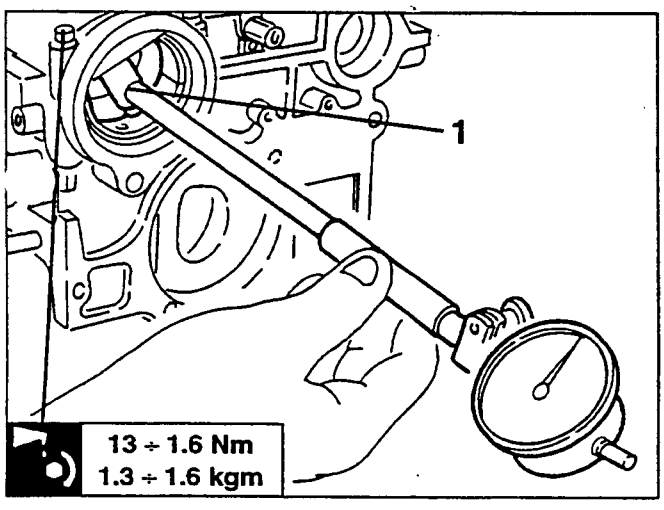
## Camshafts and timing system bearings

Assemble the camshaft caps and tighten the fastening screws to the specified torque, then check that the diameter of the supports is within the specified limits.

**NOTA: The half bearings should be assembled on the intake side front support.**

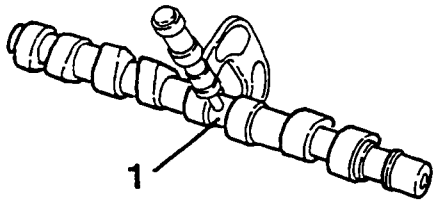
| Diameter of camshaft supports |
|---|
| 26.045 ÷ 26.070 mm<br>50.034 ÷ 50.071 mm (*) |

(*) Front intake side support with half bearings assembled (for timing variator)




1. Check that the diameter of the camshaft journals is within the specified limits.

| Diameter of camshaft journals |
|---|
| 26.000 ÷ 26.015 mm |



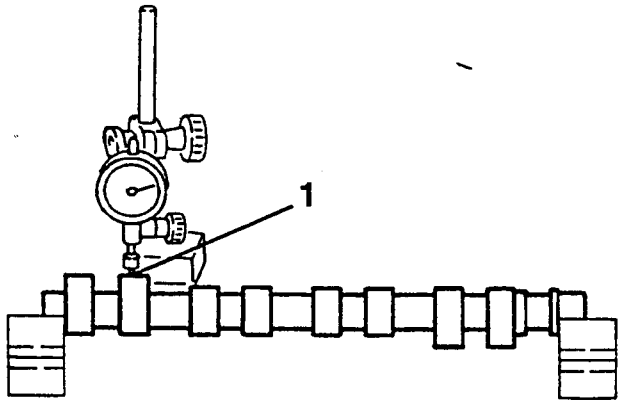

- Calculate the clearance between the camshaft journals and their bearings and check that it is within the specified limits.

| Clearance between camshafts and bearings | |
|---|---|
| 0.03 ÷ 0.07 mm | 0.034 ÷ 0.086 mm (*) |

(*) Specific for timing variator

1. Check that the cam lifts are within the specified limits.

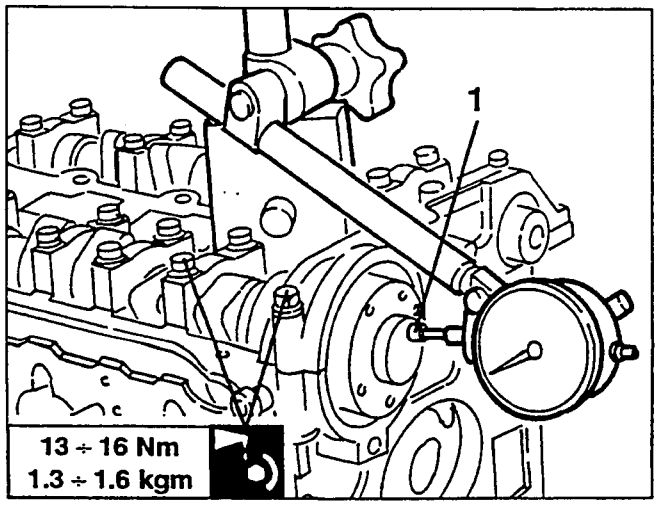
| Cam nominal lift | |
|---|---|
| Intake | 9.50 mm |
| Exhaust | 9.50 mm |




## Checking the camshaft end float

- Place the camshafts on the cylinder head, assemble the corresponding caps and tighten the fastening screws to the specified torque.
1. Install a centesimal dial gauge and measure the end float of the camshafts checking that it is within the specified limits.

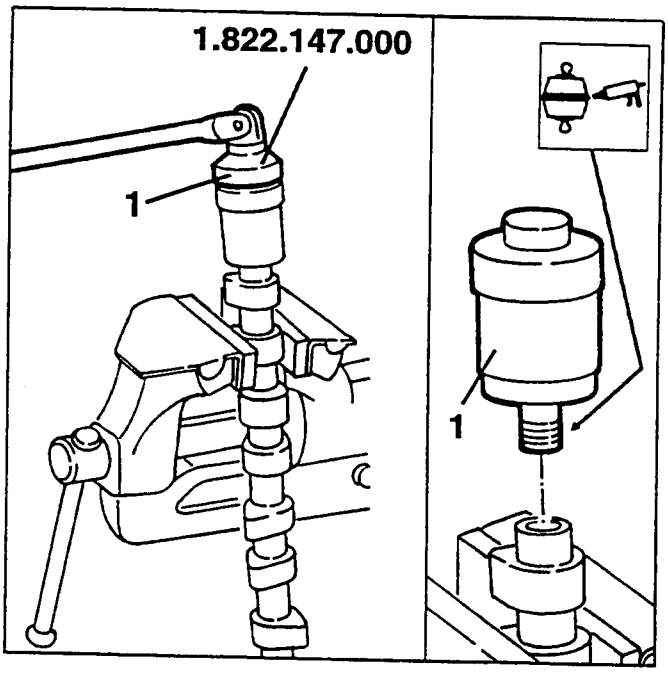
| Camshafts end float |
|---|
| 0.10 ÷ 0.23 mm |



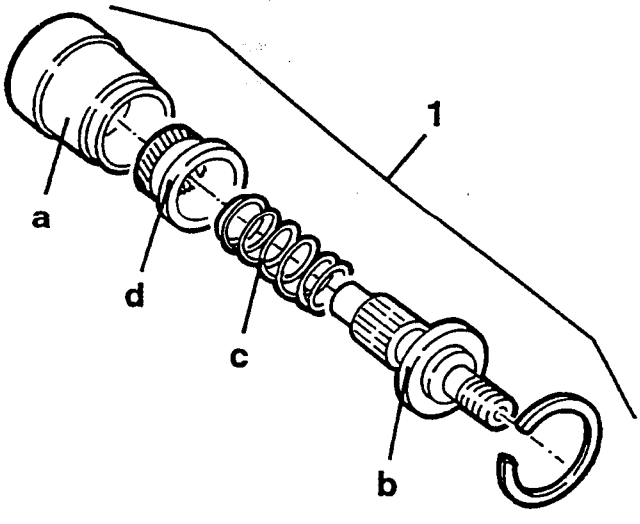
## Removing the timing variator from the camshaft

- Position the camshaft intake side in a vice fitted with protective jaws.

1. Using tool no. 1.822.147.000, slacken and remove the timing variator from the camshaft.




1. Remove the stop ring and remove the outer body (a) of the variator pinion (b), spring (c) and the piston (d).




**WARNING:**
**When refitting the timing variator, follow the instructions given below:**
**- Make sure that the mastic on the thread coupling the timing variator to the camshaft does not obstruct the oil ducts.**
**- Wait for about two hours before assembling the shaft on the cylinder head.**

# CHECKS AND INSPECTION CRANKCASE

- Visibly check the crankcase for cracks and signs of excessive wear of the sliding surfaces; check that all the threads are intact.
- Remove the lubrication and cooling groove caps and clean the ducts with a suitable detergent, then dry with a jet of air and fit new caps.
- Accurately remove any traces of seals or sealants from the crankcase surfaces.

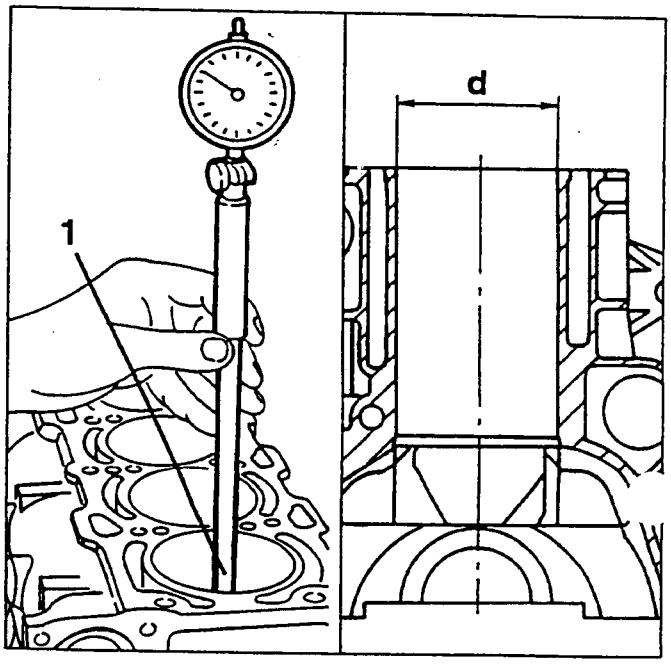
## Checking the cylinders

1. Using a bore gauge fitted on a dial gauge, measure the inside diameter of the cylinders and check that it is within the specified limits.

| Inside diameter "d" | |
|---|---|
| Class A | 83.000 ÷ 83.010 mm |
| Class B | 83.010 ÷ 83.020 mm |
| Class C | 83.020 ÷ 83.030 mm |
| Oversize of 0.1 mm | |

| Maximum cylinder taper |
|---|
| 0.010 mm |

| Maximum cylinder ovalization |
|---|
| 0.005 mm |

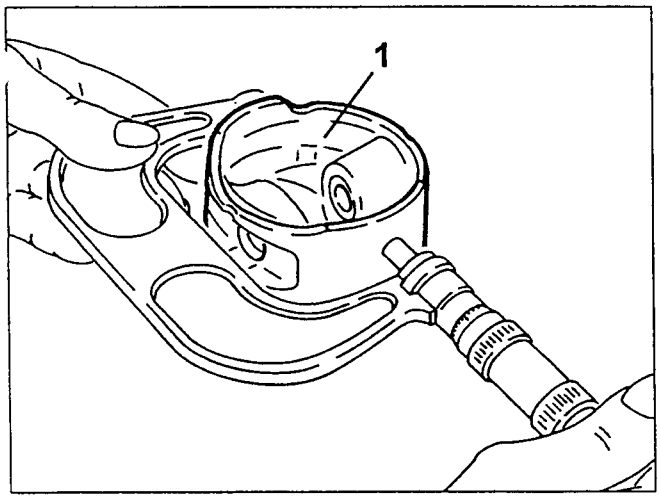


## Checking the pistons

1. Measure the outside diameter of the pistons and check that it is within the specified limits.

| Outside diameter of pistons (1) | |
|---|---|
| Class A (Blue) | 82.952 ÷ 82.962 mm |
| Class B (Pink) | 82.959 ÷ 82.971 mm |
| Class C (Green) | 82.968 ÷ 82.978 mm |
| Oversize of 0.1 mm | |

(1) To be measured at right angles to the gudgeon pin hole at a distance of 12.5 mm from the lower edge of the piston skirt.

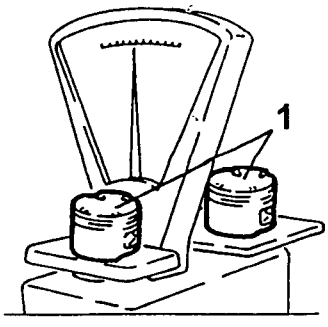



- Calculate the clearance between the cylinder and the piston and check that it is within the specified limits.

| Clearance between piston and cylinder |
|---|
| 0.038 ÷ 0.062 mm |

1. Check that the difference in weight between the pistons complete with gudgeon pins and seal rings is within the specified limits.

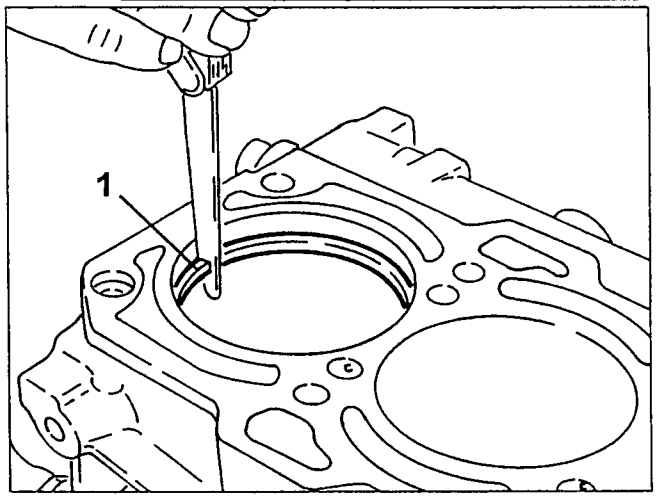
| Difference in weight between pistons |
|---|
| ± 5 g |




## Checking the seal ring gap

1. Insert the seal rings in the cylinder, check that they adhere to the whole circumference and that the gap is within the specified limits.

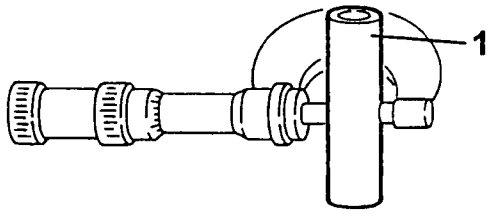
| Ring gap | |
|---|---|
| First ring | 0.25 ÷ 0.50 mm |
| Second ring | 0.30 ÷ 0.50 mm |
| Oil scraper ring | 0.25 ÷ 0.45 mm |




## Checking the play between gudgeon pins and seats on pistons

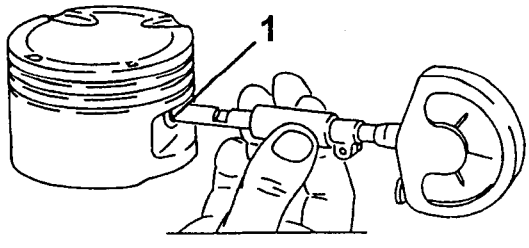
1. Measure the outside diameter of the gudgeon pins and check that it is within the specified limits.

| Outside diameter of gudgeon pins |
|---|
| 19.996 ÷ 20.000 mm |




1. Measure the diameter of the pin mating hole in the piston and check that it is within the specified limits.

| Diameter of pin seat in pistons |
|---|
| 20.002 ÷ 20.007 mm |



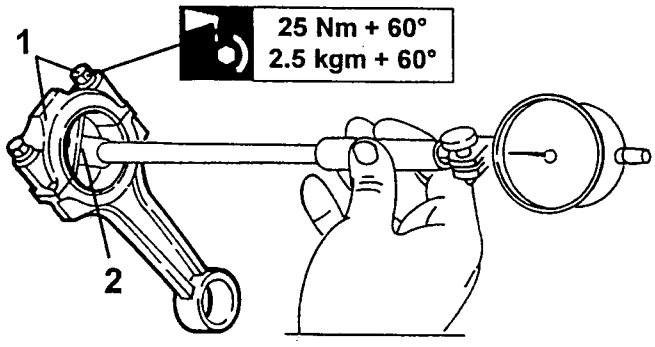
- Calculate the clearance between the pins and their seats on the pistons and check that it is within the specified limits.

| Clearance between pins and seats on pistons |
|---|
| 0.002 ÷ 0.011 mm |

## Checking the clearance between connecting rod journals and the corresponding half bearings

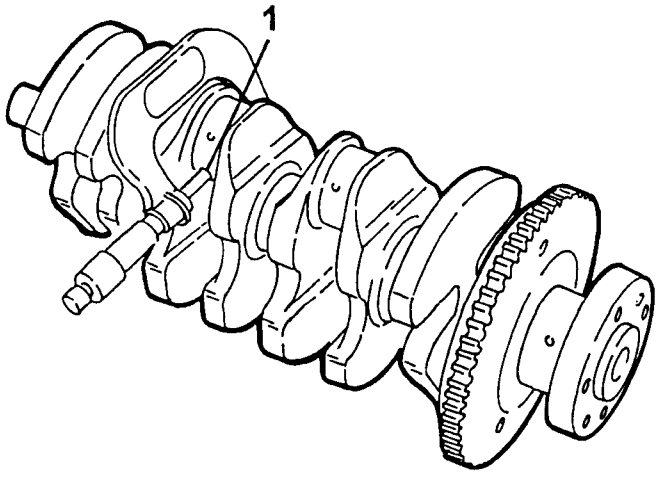
1. House the rod half bearings in the connecting rod big end and on the corresponding cap, then join them tightening the fastening screws to the specified torque.
2. Measure the diameter of the connecting rod big end and check that it is within the specified limits.

| Inside diameter of connecting rod half bearings | |
|---|---|
| Class A | 50.835 ÷ 50.855 mm |
| Class B | 50.829 ÷ 50.849 mm |
| Class C | 50.823 ÷ 50.843 mm |




1. Measure the diameter of the connecting rod journals and check that it is within the specified limits.

| Diameter of connecting rod journals | |
|---|---|
| Class A | 50.799 ÷ 50.805 mm |
| Class B | 50.793 ÷ 50.799 mm |
| Class C | 50.787 ÷ 50.793 mm |



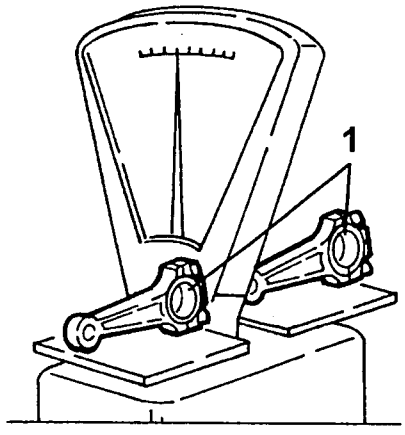

- Calculate the clearance between the rod journals and the corresponding half bearings and check that it is within the specified limits.

| Clearance between rod journals and half bearings |
|---|
| 0.03 ÷ 0.056 mm |

## Checking the connecting rods

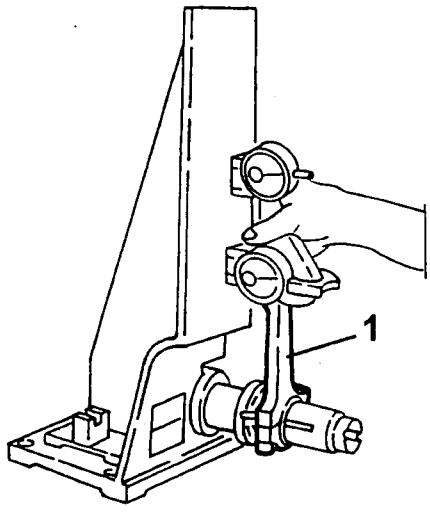
1. Check that the difference in weight between the connecting rods complete with half bearings, caps and screws is within the specified limits.

| Difference in weight between connecting rods |
|---|
| ≤ 5 g |



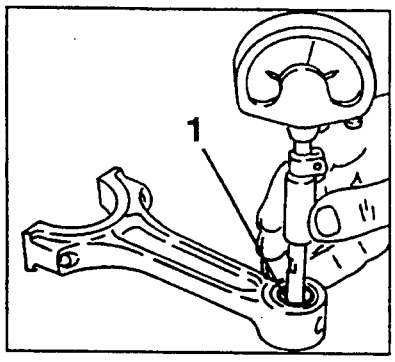

1. Check that the connecting rods are perpendicular using a reference plane as illustrated.

**NOTE: If perpendicularity is not perfect, the connecting rod must be changed to avoid abnormal stresses when the engine is running, resulting in uneven wear of the piston and of the rod itself.**



## Checking the clearance between pins and small end bushings

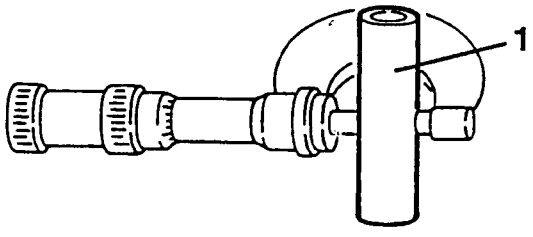
1. Measure the inside diameter of the small end bushing and check that it is within the specified limits, if not, change the bushing.




| Inside diameter of small end bushing |
|---|
| 20.006 ÷ 20.012 mm |

1. Measure the outside diameter of the pins and check that it is within the specified limits.

| Outside diameter of pins |
|---|
| 19.996 ÷ 20.000 mm |




- Calculate the clearance between the pins and small end bushings and check that it is within the specified limits.

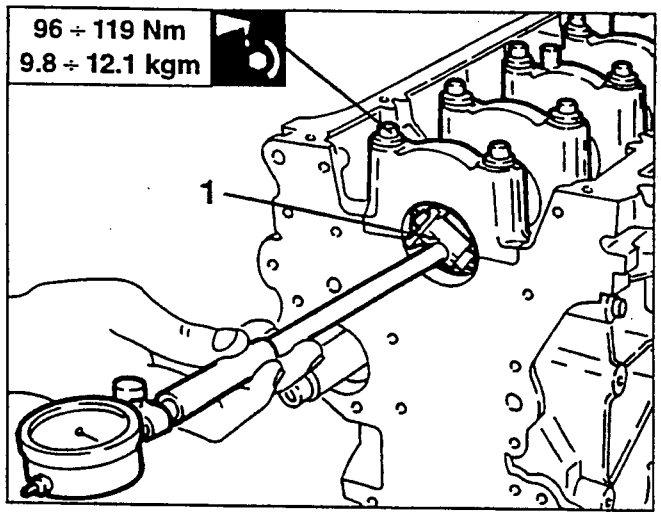
| Clearance between pins and small end bushing |
|---|
| 0.006 ÷ 0.016 mm |

## Checking the clearance between main bearing journals and half bearings

1. House the half bearings and fit the main bearings caps on the crankcase tightening the fastening screws to the specified torque.
2. Measure the diameter of the main bearings and check that it is within the specified limits.

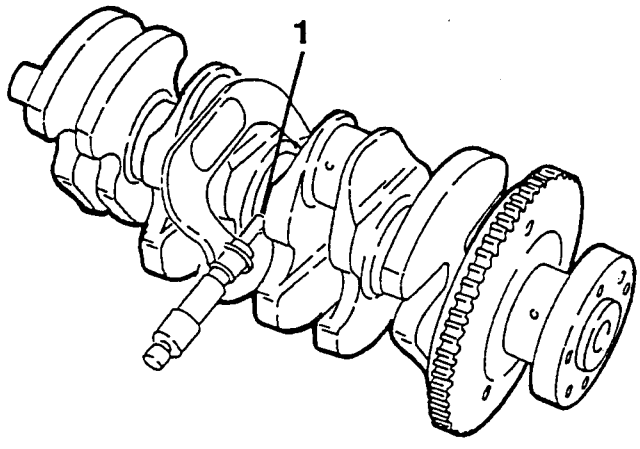
| Diameter of main bearings | |
|---|---|
| Class A (Red) | 53.025 ÷ 53.046 mm |
| Class B (Blue) | 53.019 ÷ 53.040 mm |
| Class C (Yellow) | 53.013 ÷ 53.034 mm |

96 ÷ 119 Nm
9.8 ÷ 12.1 kgm




1. Measure the diameter of the main bearing journals and check that it is within the specified limits.

| Diameter of main bearing journals | |
|---|---|
| Class A | 52.994 ÷ 53.000 mm |
| Class B | 52.988 ÷ 52.994 mm |
| Class C | 52.982 ÷ 52.988 mm |




- Calculate the clearance between the main bearing journals and half bearings and check that it is within the specified limits.

| Clearance between main bearing journals and half bearings |
|---|
| 0.025 ÷ 0.052 mm |

## Checking the engine flywheel

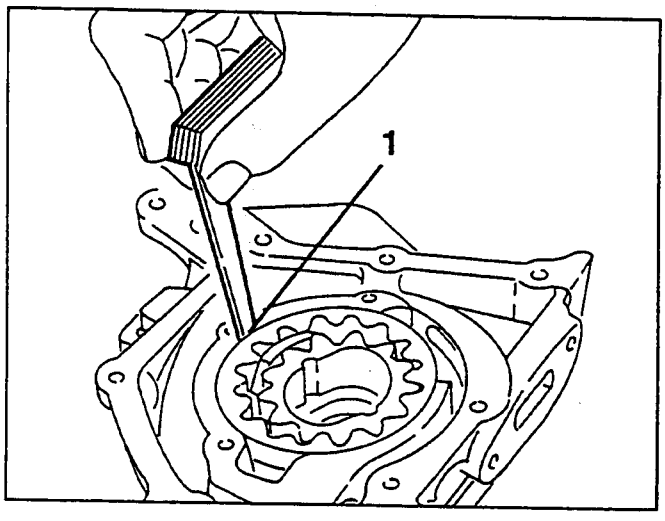
- Check that the ring gear teeth are not cracked or show signs of seizure; if they do, change the ring gear as described below:
- working under the press remove the old ring gear;
- accurately clean the contact surfaces of the new ring gear and of the flywheel;

• evenly heat the new ring gear to 80° ÷ 100° C and fit it on the flywheel: leave to cool naturally, do not force cool.

## Checking the oil pump

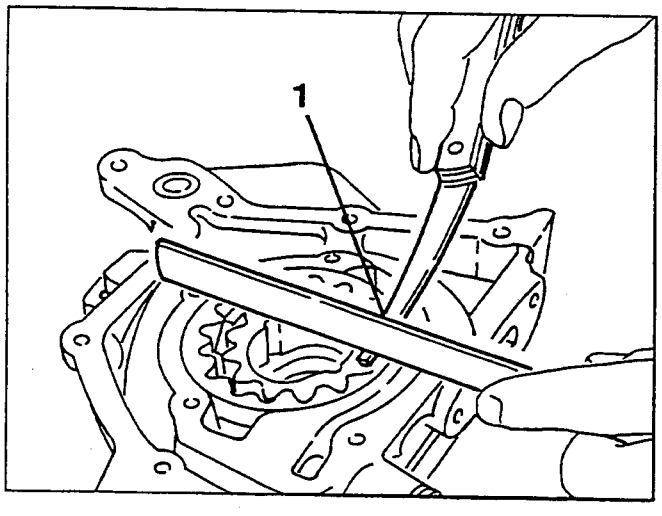
1. Check that the clearance between the pump casing and the driven gear is within the specified limit.

| Clearance between pump casing and driven gear |
|---|
| 0.080 ÷ 0.186 mm |




1. Check that the clearance between the pump cover rest surface and the upper side of the gears is within the specified limit.

| Clearance between pump cover rest surface and upper side of gears |
|---|
| 0.025 ÷ 0.070 mm |




**WARNING: If the clearances measured are not within the specified limits, change the front crankcase cover with oil pump incorporated.**

- Using a torque meter check the characteristic values of the engine oil pressure limiting valve control spring.

| Control load Kg | Spring length mm |
|---|---|
| 6.8 | 36 |

# INSTRUCTIONS FOR RE-ASSEMBLY

**For re-assembly operations reverse the sequence described for dis-assembly, unless otherwise indicated below.**

- Check valve tightness when the cylinder head assembled (see "Turning the valve seats").

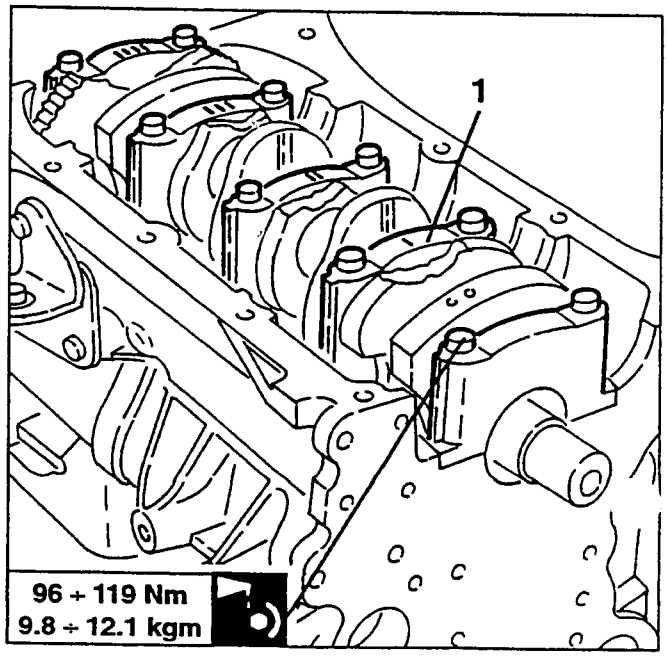
## Reassembling the crankshaft

- Assemble the crankshaft on the crankcase complete with half bearings and half thrust rings.

**Reassemble the half thrust rings with the grooved surfaces facing the crankshaft.**

1. Assemble the main bearing caps complete with half bearings on the supports and tighten the fastening screws two or three times starting from the centre main bearing cap.

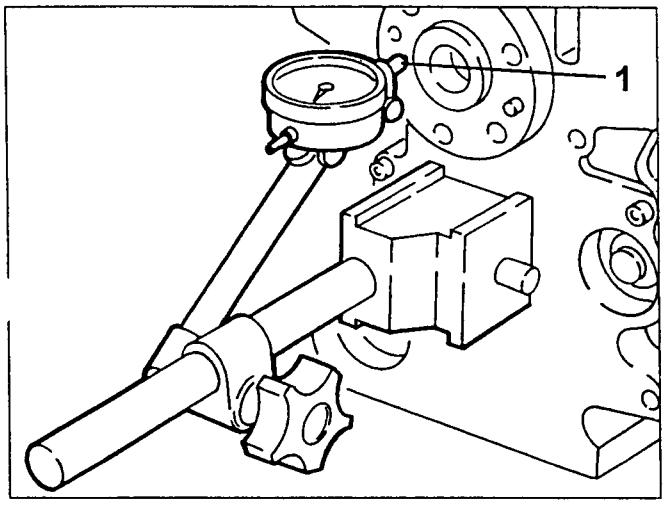
**The position of each cap is given by a serie consecutive notches (from zero to four start...g from the front of the engine) etched on the caps themselves.**



## Checking the crankshaft end float

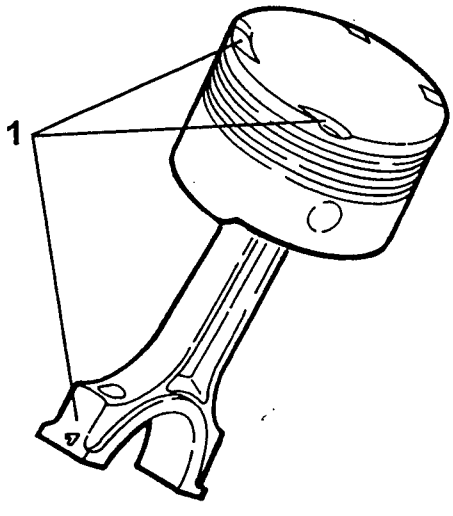
1. Using a dial gauge on a magnetic base, measure the crankshaft end float and check that it is within the specified limits.

| Crankshaft end float |
| --- |
| 0.059 ÷ 0.221 mm |



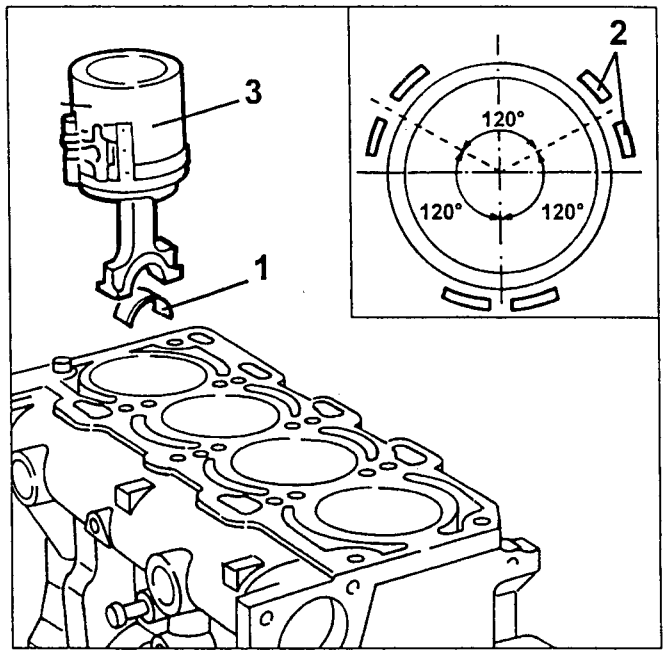

## Refitting the pistons and connecting rods

1. Assemble the piston and connecting rod so that the number stamped on the connecting rod big end is on the same side as the large notches (for intake valves) on the piston crown.




- Turn the crankshaft until the connecting rod journals of the 1st and 4th cylinder are in the position corresponding to the B.D.C.
1. House the half bearings on the connecting rod big ends.
2. Insert the rings in the pistons with the cuts offset by 120° and the word TOP printed on them facing upwards.
3. Using a suitable tool, insert the pistons and connecting rods in the 1st and 4th cylinder.

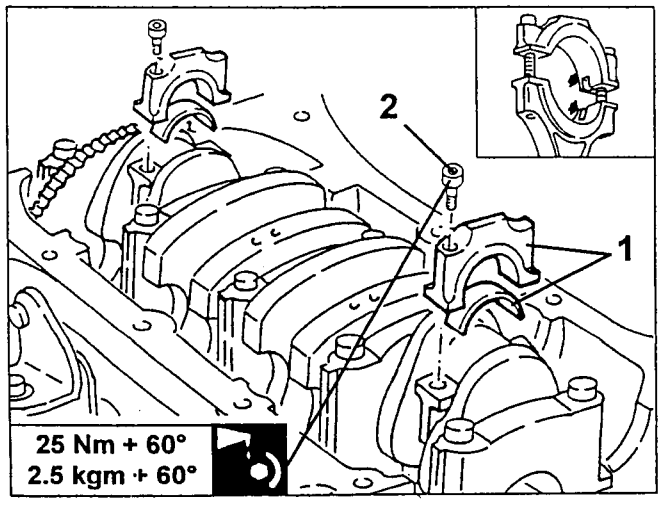
**Assemble the connecting rod - piston unit in the crankcase directing the arrow stamped on the piston crown in the direction of rotation of the engine.**




- Turn the crankcase 180°.
1. House the half bearings on the connecting rod caps, then assemble those of the 1st and 4th cylinder directing the safety notch towards the same side as the corresponding notch on the connecting rod big end.

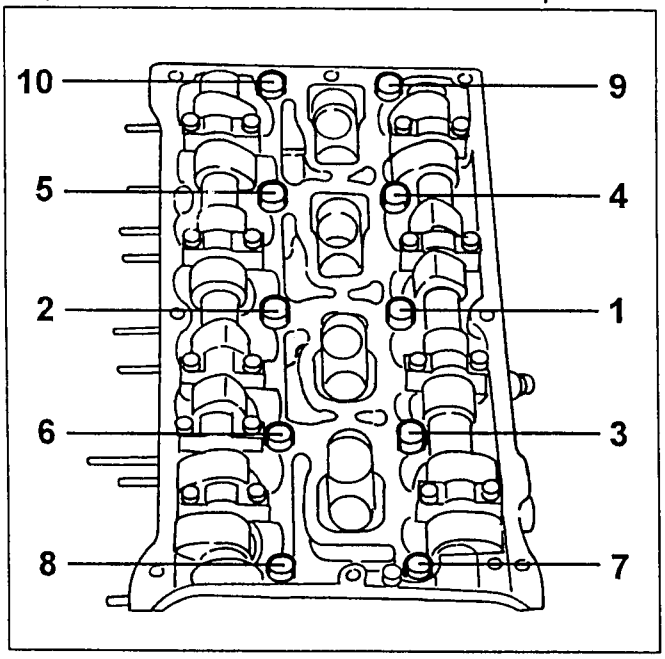
**On one side, the connecting rod caps have the number of the cylinder to which they belong; when refitting, this number must always be on the same side as the one stamped on the connecting rod big end.**

2. Tighten the connecting rod cap fastening screws in oil to the specified torque.
- In the same way, reassemble the pistons and connecting rods of the 2nd and 3rd cylinder.



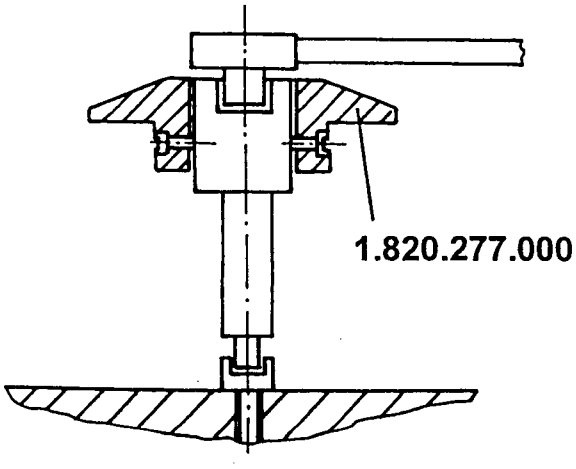
## Reassembling the cylinder head

- Turn the crankshaft to take the pistons of the 1st and 4th cylinder to the T.D.C.
- Position the gasket on the crankcase, then the cylinder head.
- Tighten the cylinder head fastening screws as described below and bearing in mind that the tightening sequence is the one shown below for each phase.




| Tightening procedure | |
|---|---|
| Set in all the screws to a torque of: | 20 Nm (2.0 kgm) |
| Tighten the screws to the preliminary torque of: | 40 Nm (4.1 kgm) |
| Turn all the screws with an angle of: | 90° + 90° + 90° |

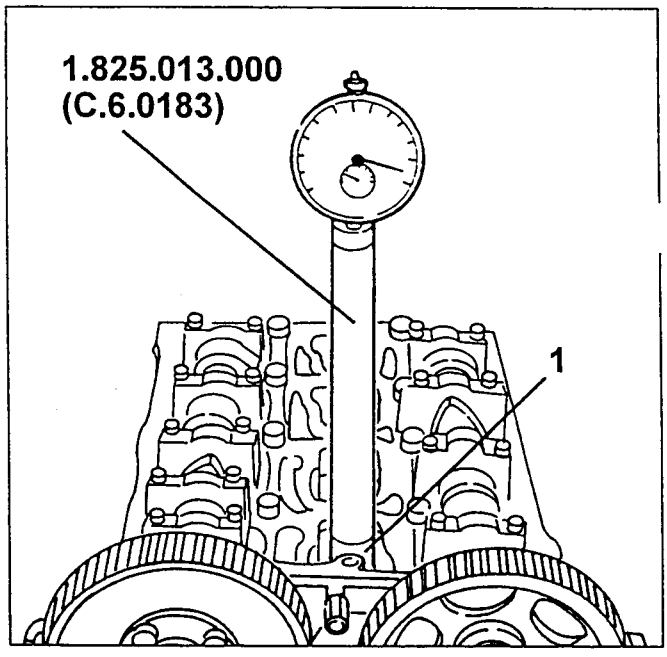
- For angle tightening use the graduated disk no. 1.820.277.000 as illustrated.



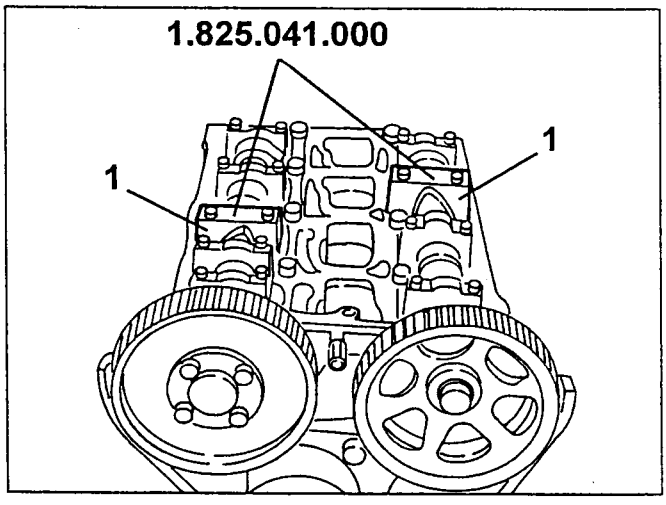

**The gasket between the cylinder head and the crankcase is in aramidic fibre and cylinder head retightening is unnecessary throughout the life of the engine.**

## Assembling the timing gear drive belt and checking timing

- Assemble the camshaft toothed pulleys without tightening the fastening screws, the timing drive belt pulleys and the corresponding belt tensioners.
1. Install tool no. 1.825.013.000 (C.6.0183) fitted with a dial gauge in the seat of the centre spark plug of the 1st cylinder.
- Turn the crankshaft until the piston of the first cylinder reaches the T.D.C. in the bursting stroke.




1. Remove the camshaft caps illustrated and in their place insert templates no. 1.825.041.000 tightening the fastening screws to a maximum torque of **10 Nm (1 Kgm)** and checking for correct coupling with th cams.

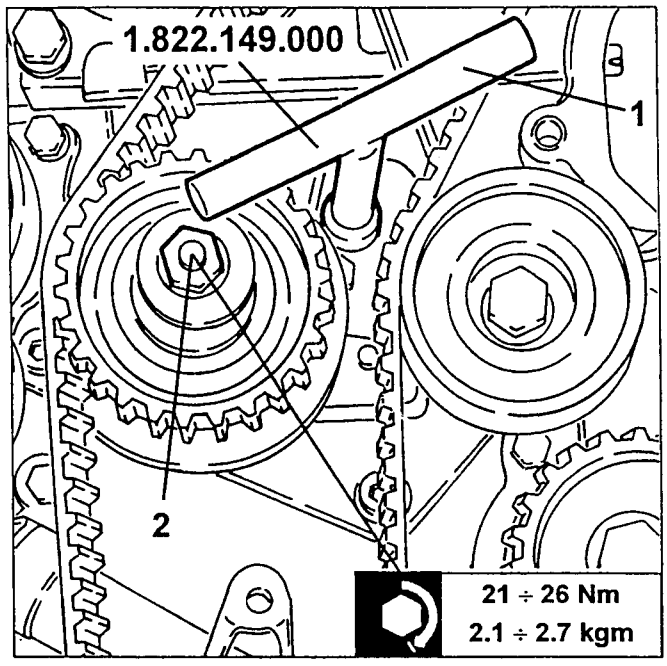


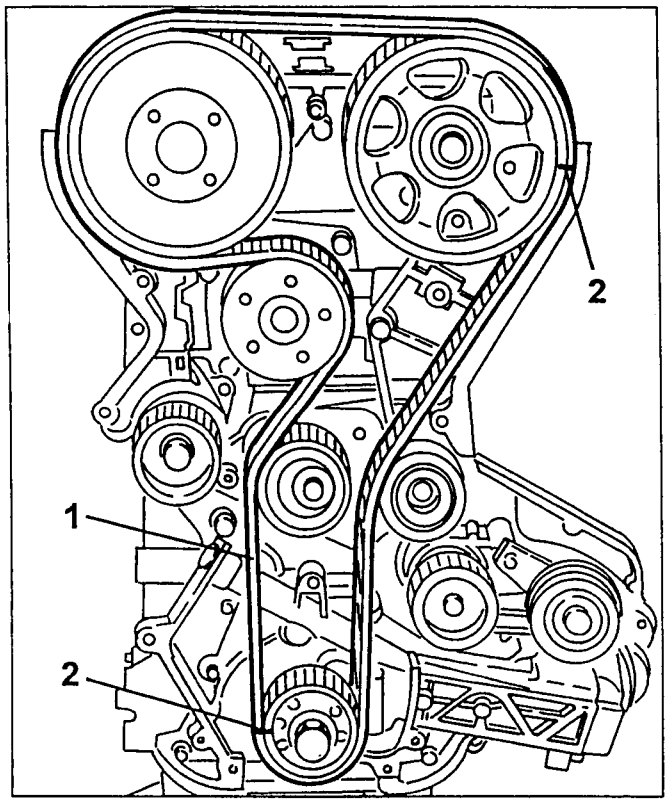

**NOTE: For turning the camshafts, use tool no. 1.822.155.000 for the intake side and tools no. 1.822.146.000 and no. 1.822.156.000 for the exhaust side, to be applied on the corresponding pulleys.**

1. Assemble the timing gear drive belt taking care to check correct coupling with the pulley teeth, installing it in the following sequence:
- crankshaft pulley
- fixed tightening pulley
- exhaust side camshaft pulley
- intake side camshaft pulley
- automatic tensioner pulley
- coolant fluid pump pulley

2. The notches painted on the belt must coincide with the indexes made on the crankshaft pulley and on the exhaust side camshaft pulley.

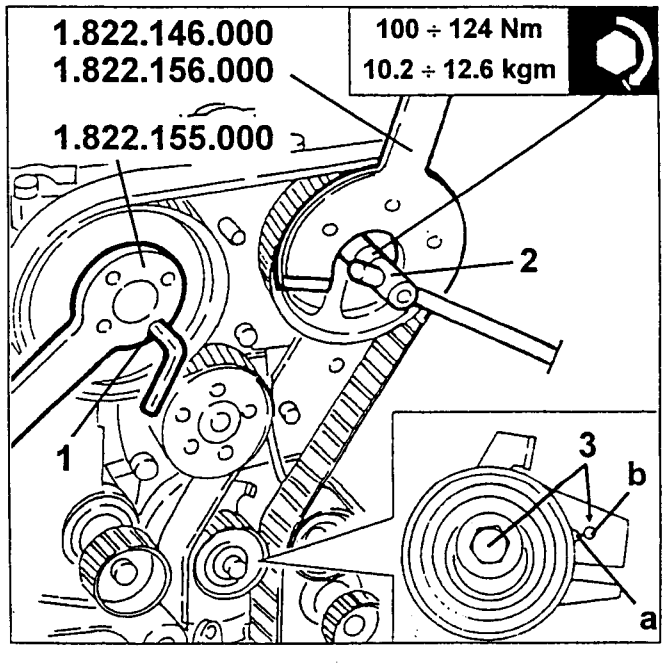
**WARNING:**
**When assembling the toothed belt, to avoid damaging the structure of the fibres that form it, never cause sharp bends.**
**For correct assembly the belt has an arrow on it which shows the direction of rotation of the engine.**




1. Using tool no. 1.822.149.000 as illustrated, tension the belt to the maximum.
2. Tighten the nut fastening the automatic camshaft belt tensioner.

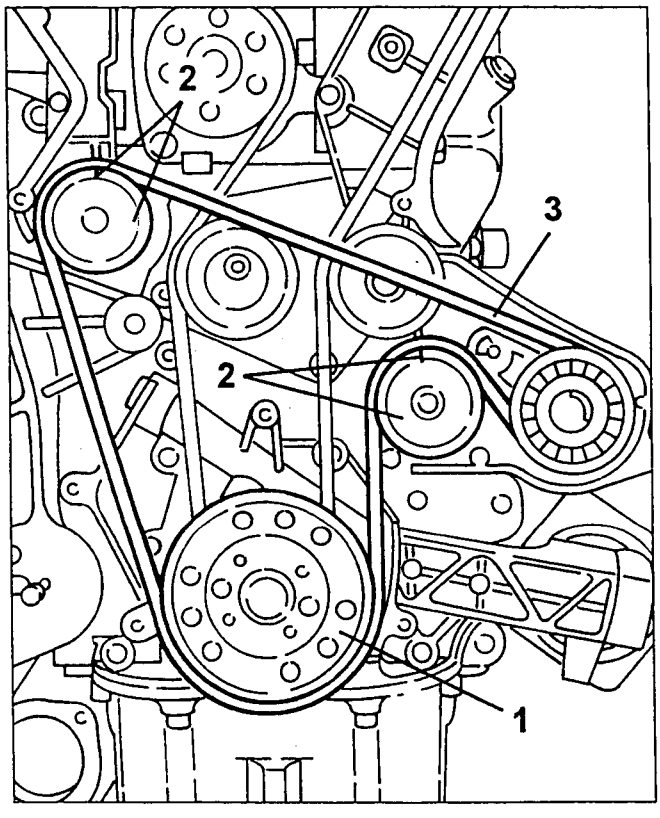
1. Using tool no. 1.822.155.000, tighten the screws fastening the intake side camshaft drive pulley.
2. Using tool no. 1.822.146.000 complete with tool no. 1.822.156.000, tighten the screw fastening the exhaust side camshaft drive pulley.
- Remove the two templates from the camshafts and turn the crankshaft twice in its direction of rotation until the piston of the 1st cylinder reaches the T.D.C. in the bursting stroke.
3. Release the nut fastening the automatic tensioner, then using tool no. 1.822.149.000, move the mobile index (a) to coincide with the reference hole (b).
- Tighten the automatic tensioner fastening nut to the specified torque.



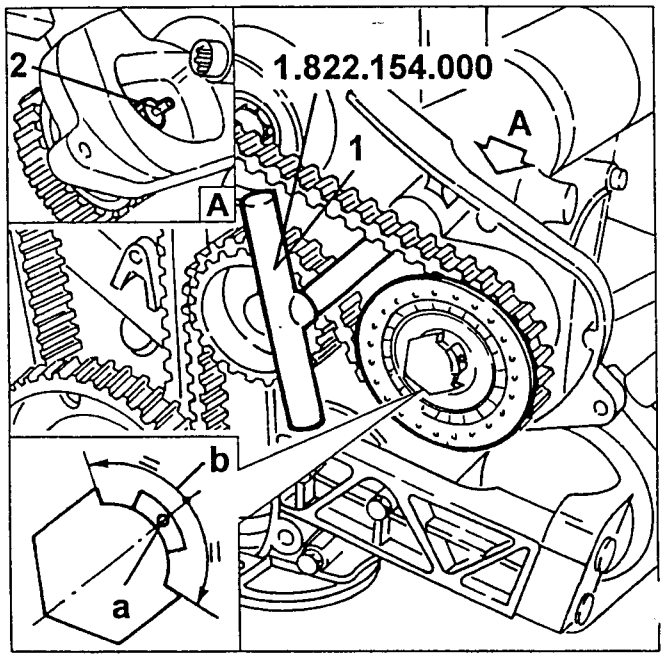
## Assembly of counter-rotating shaft drive belt and checking valve gear timing

1. Move the piston of cylinder no. 1 to the T.D.C. in the bursting stroke, then assemble the counter-rotating shaft drive pulley.
2. Position the counter-rotating shaft pulleys so that the notches on them correspond with the reliefs on the rear covers (tooth at the side of the reference notch on the vertical).
3. Assemble the counter-rotating shaft drive belt checking correct mating of the teeth on all the toothed pulleys.

**WARNING:**
**When assembling the toothed belt, to avoid damaging the structure of the fibres that form it, never cause sharp bends.**




1. Using tool no. 1.822.154.000, as illustrated, tension the counter-rotating shaft drive belt until the reference hole (a) on the tensioner reaches the centre of the rotation sector (b).
2. Tighten the nut fastening the counter-rotating shaft automatic tensioner.




- Turn the crankshaft twice in its direction of rotation until the piston of the 1st cylinder reaches the T.D.C. in the bursting stroke and check that all the timing references correspond.

## CHECKING LUBRICATION CIRCUIT ELECTRIC COMPONENTS

### ENGINE OIL MINIMUM PRESSURE WARNING LIGHT SENSOR

1. Check the setting of the engine oil minimum pressure warning light sensor. If the ratings are not as specified, replace the sensor.

| Contact opening/closing pressure |
|---|
| 0.2 ÷ 0.5 bar |