

10 - ENGINE

CONTENTS

DESCRIPTION	P. 3	COOLING CIRCUIT	P. 33
Cylinder numbering and direction of crankshaft rotation		Description	
		Radiators and electric fans	
SPECIFICATIONS AND DATA	P. 5	Thermostatic valve	
Crankshaft		Radiator removal	
Connecting radius R		Filling up the system	
Crankcase		LUBRICATION CIRCUIT	P. 36
Piston liners		Description	
Pistons		Thermostatic valve	
Piston pin		Oil pump check	
Piston rings		Level check and oil replacement	
Tappets		PNEUMATIC UTILITY CONNECTIONS	P. 40
Valve guides (intake and exhaust)			
Fitting between valve stem and relevant guide			
Valve springs (intake and exhaust)			
Engine cooling			
REMOVAL AND REFIT	P. 22		
ASSEMBLY	P. 23		
CHECKS AND ADJUSTMENTS	P. 25		
Valve clearance			
Locking the phase variator			
Position check			
Positioning			
Timing regulation			
Adjustment			
Checking			
Locking check on phonic wheel for engine timing sensor			

DESCRIPTION

Otto cycle - 4 intake stroke engine, 12 V cylinders at 60°; timing system with 4 valves for each cylinder, double overhead camshaft controlled by double chain, phase variator on intake, indirect MPI injection (one injector for each cylinder), static electronic ignition (one coil per cylinder), liquid cooling with double radiator, forced lubrication with oil radiator, exhaust six in two in one with catalyst. Aluminium alloy and H+T silicon "open deck" type crankcase with wet inserted liners. Steel alloy liners with Nikasil treated internal surfaces. This treatment ensures a very high surface hardness.



This type of liner cannot be lapped.

Cr Mo hardened and tempered steel crankshaft, the working surfaces are hardened by gaseous nitriding. The crankshaft bearings are smooth. The main bearing caps are integrated in a block structure to give maximum stiffness.



Each time the crankshaft is undersized, it is most important to restore the surface hardness by the special heat treatment.

Titanium alloy connecting rods with modular head, smooth bearings at big and small ends.

The pistons are in pressed light alloy with three rings, two seals and one oil scraper.

The cylinder heads are aluminium alloy and H+T silicon, with bronze valve guides and cast iron valve seats.

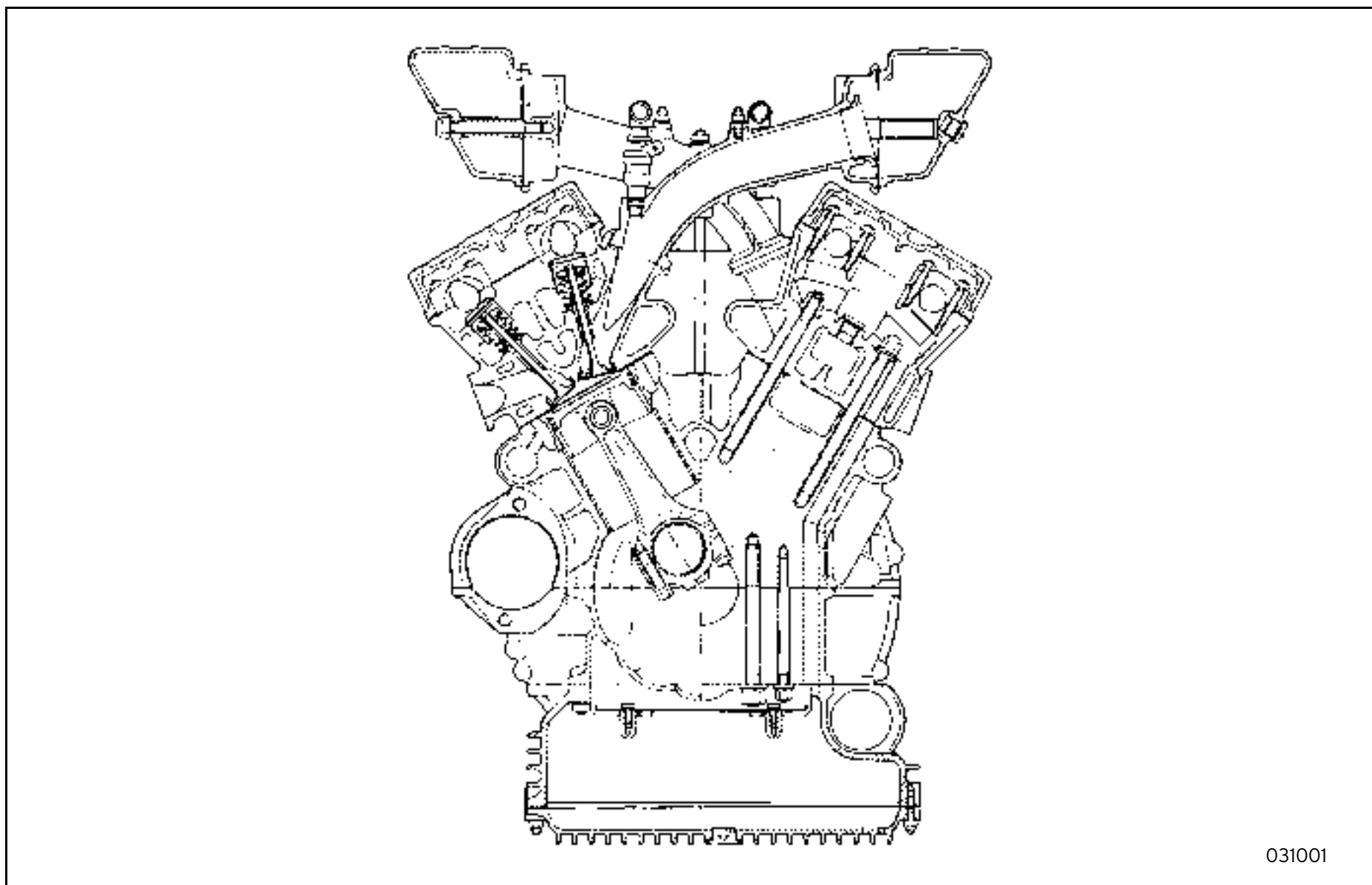
The timing system consists of two overhead camshafts for each cylinder bank, controlled by double chains with phase variator on the intake shafts.

Motion is transmitted directly from the crankshaft to two gear wheels by means of a double chain. Each of these gear wheels in its turn controls the two camshafts of each head by means of double chains.

The chain tension is ensured by hydraulic chain tighteners that operate with the lubrication circuit oil.

The cooling system with two cooling radiators is a closed loop system with forced circulation by a centrifugal pump belt driven by the crankshaft.

The lubrication is forced by a gear pump with a vented gas recycling system and radiator to cool the oil.



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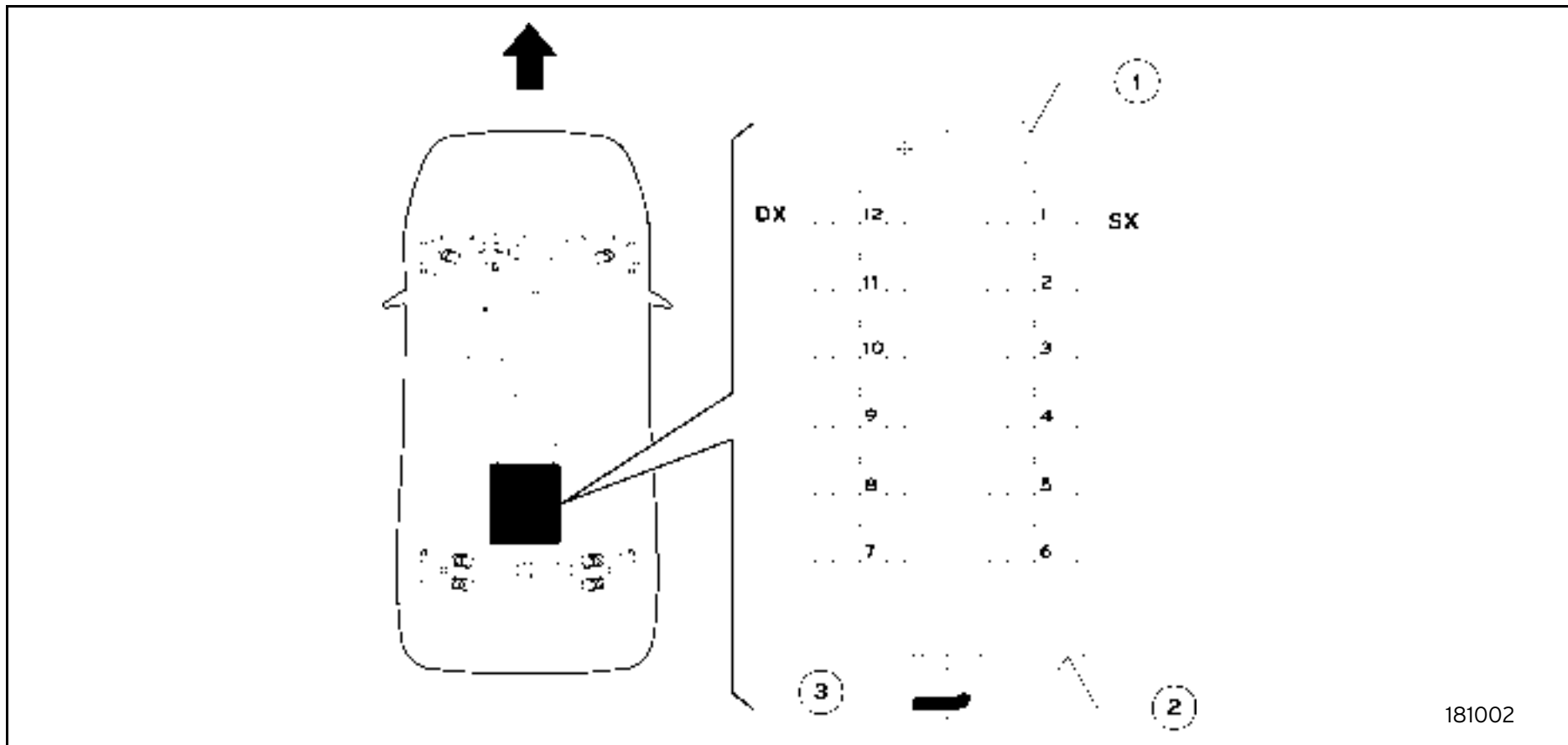
Fig.1 - Engine cross section

Cylinder numbering and direction of crankshaft rotation

The engine rotation is anticlockwise (as seen from the timing side).

The engine cylinder banks are defined as right and left hand as seen from the flywheel.

The No. 1 cylinder is the first of the left hand cylinder bank near the flywheel, the numbering continues following a U towards the right hand cylinder bank.



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Fig. 2 - Numbering of cylinders

- 1 Engine flywheel side
- 2 Timing side
- 3 Direction of rotation
(counterclockwise from timing side)

- 4 Travel direction
- SX = Left hand cylinder bank (cylinder bank 1-6)
- DX = Right hand cylinder bank (cylinder bank 7-12)

SPECIFICATIONS AND DATA

Crankshaft

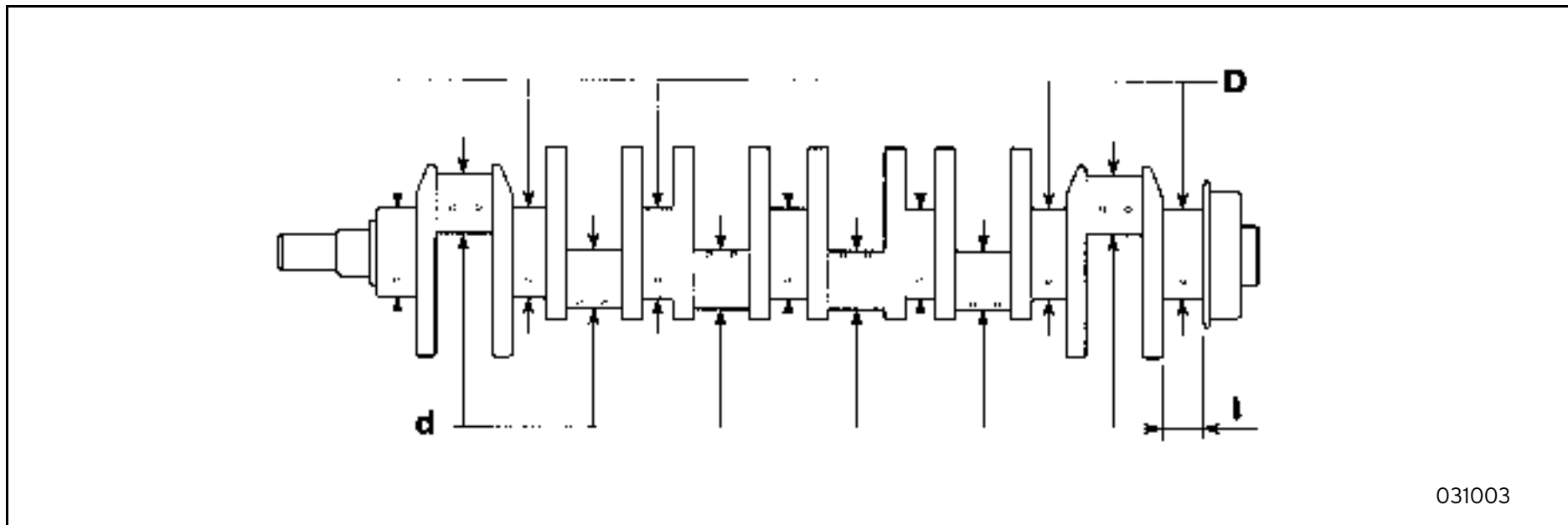
Crankshaft end float	0.155 to 0.315
Crankpin and conrod journals surface hardness	HV1 630
Crankpin and conrod journals surface finish	0.2 mm
Crankpins: Rated diameter D 2nd undersizing	62.966 to 62.979 62.712 to 62.722
Conrod journals: Rated diameter d 2nd undersizing	45.482 to 45.500 45.236 to 45.246
Shoulders: Rated width Oversized thickness	40.070 to 40.100 40.578 to 40.608

The 1st undersizing is no longer available.



Whenever crankshaft undersizing is performed, it is most important to restore the surface hardness with special treatment of the NITREG type, attaining to these specifications:

temperature:	530 °C
times:	rising 4 hours holding 40 hours descent 4 hours
depth of nitriding :	0.35 to 0.40 mm
hardness:	HV1: 600 to 680 HV10: 550 to 630
white sheet thickness:	< 10 microns



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Fig. 3 - Crankshaft

Connecting radius R

Crankpins	2.0 to 2.2
Conrod journals	2.0 to 2.2
Protrusion from crankcase edge (bushing) s	0.125 to 0.150 (*)
Bushing/shaft clearance	0.010 to 0.050

(*) apply a force $P=5200$ N as indicated in the figure.

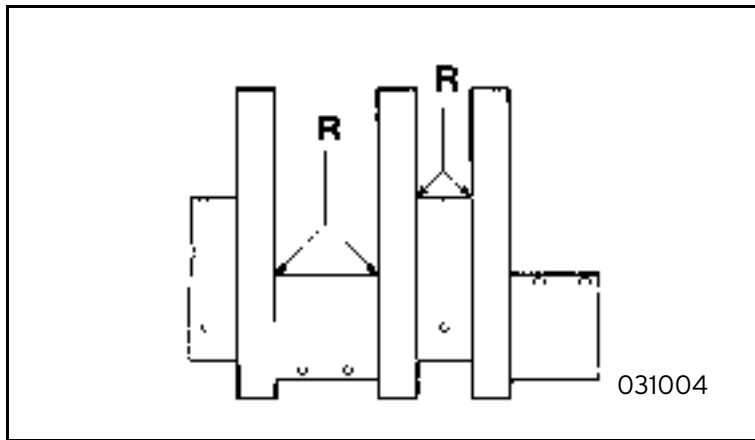


Fig. 4 - Crankshaft

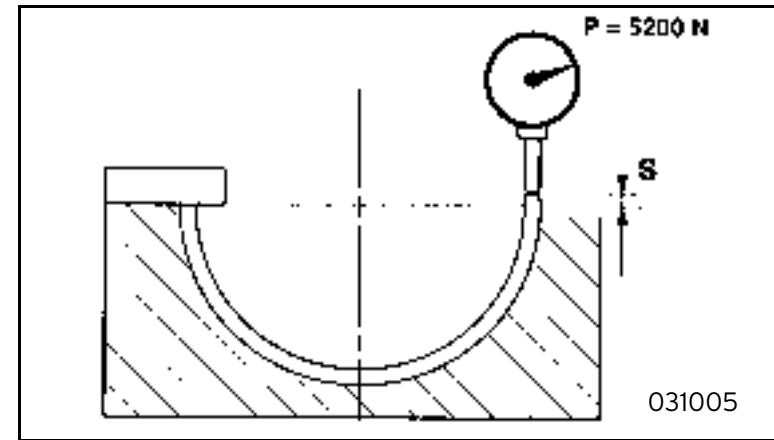


Fig. 5 - Crankshaft bearings

Crankcase

Crankpin seat diameter d	66.675 to 66.688
Liner seat diameter D	92.000 to 92.035

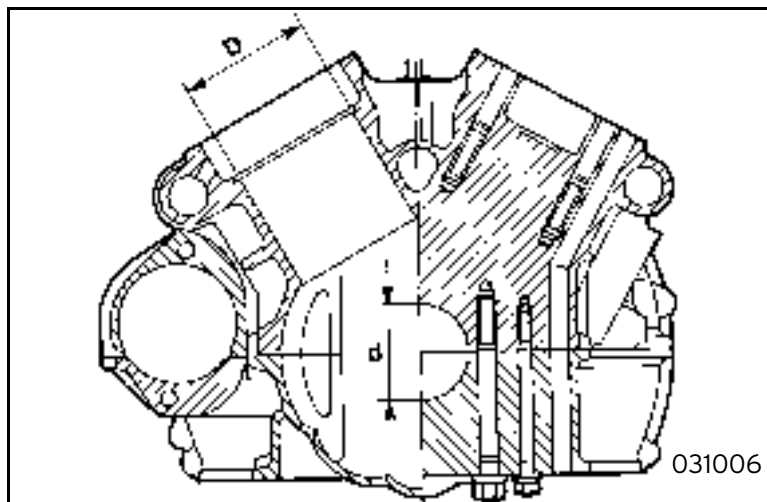


Fig. 6 - Crankcase

Conrods

Piston pin seat \varnothing (small end) d	20.020 to 20.030
Conrod bushing seat diameter (big end) D	48.626 to 48.642
Axis parallelism tolerance (piston pin-shaft)	C - C1= ± 0.03
Conrod big end width	19.900 to 19.905
Conrod small end width	20.750 to 20.755
Distance between centres i	135.97 to 136.03
Piston pin and conrod small end bushing assembly clearance	0.020 to 0.080
Interference between piston pin bushing and conrod hole	0.050 to 0.096
Conrod journal bearings on crankshaft assembly clearance	0.024 to 0.067

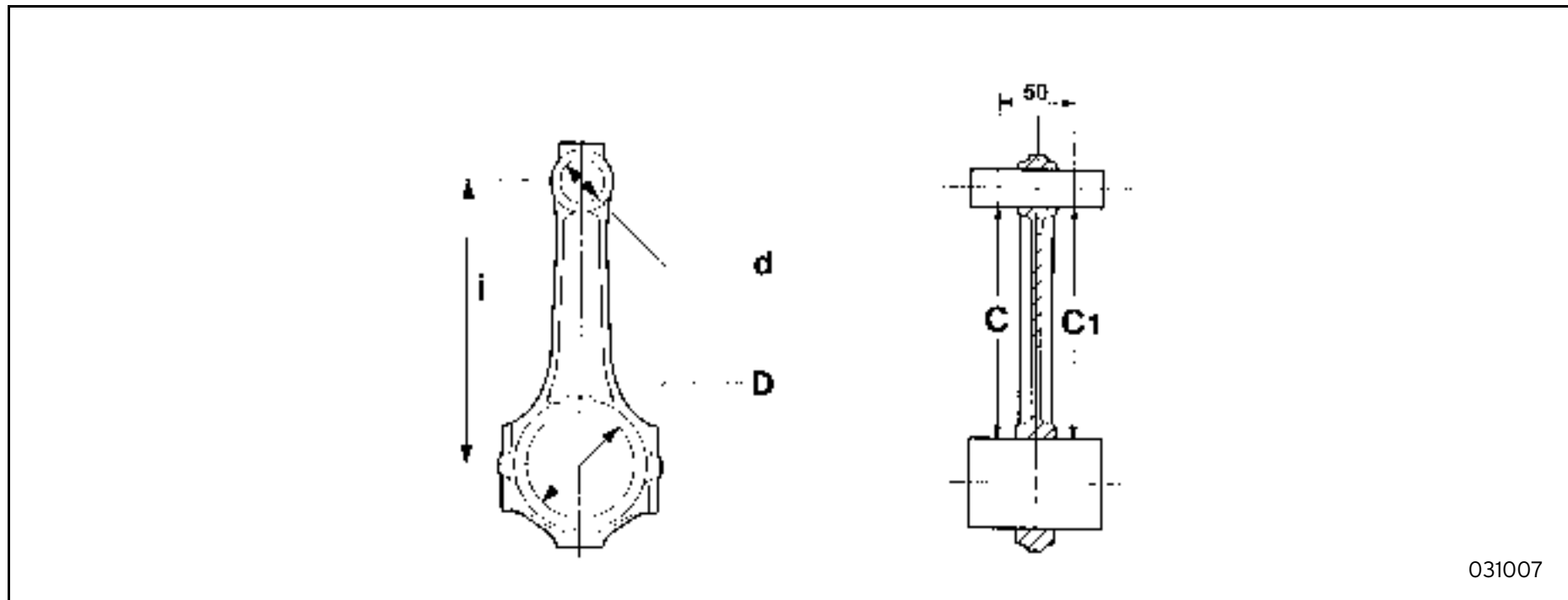


Fig. 7 - Conrods



The big end grooves are to face the crank arms when fitting the conrod-piston group.



If one or more conrods are replaced, it is essential that the spare parts are identical to the originals. (PANKL or LAM-BORGHINI).

Piston liners

Rated diameter	
Group A	86.995 to 86.985
B	87.005 to 86.995
C	87.015 to 87.005
Height ha	5
Diameter a	
Group A	86.995 to 86.975
B	87.005 to 86.985
C	87.015 to 86.995
Height hb	60
Diameter b	
Group A	89.995 to 86.985
B	87.005 to 86.995
C	87.015 to 87.005
Height hc	110
Diameter c	
Group A	87.005 to 86.985
B	87.015 to 86.995
C	87.025 to 87.005
Liner protrusion from crankcase edge s	0.4 to 0.7 (*)
Maximum taper	0.02
Maximum ovalisation	0.03
Surface roughness	0.3 micron

(*) measure with a liner-stop pre-load P=30 [N]



The liners cannot be shimmed.

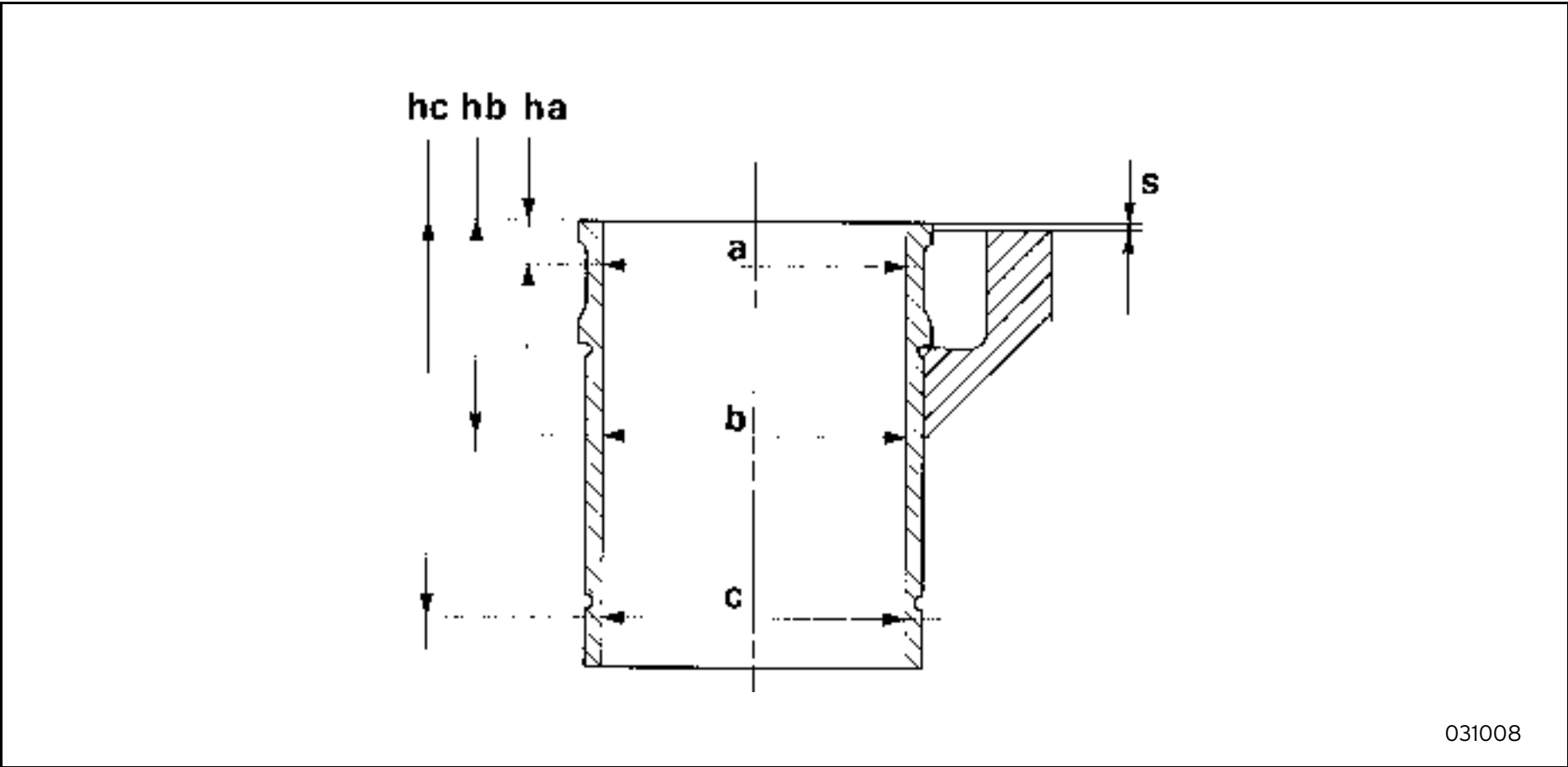


Fig. 8 - Liners

Pistons

Rated diameter	
	Group A 86.900 ± 0.009
	B 86.910 ± 0.009
	C 86.920 ± 0.009
Total height H	47.1
Piston crown-piston pin axis height H1	29.050 to 29.150
Piston pin axis-lower edge height H2	17.8 to 18.0
Step I - slot h height	6.1 to 6.3
Height I slot a	1.230 to 1.250
Height II slot b	1.770 to 1.790
Height III slot c	3.010 to 3.030



Pistons must always be coupled with liners belonging to the same group. Pistons and liners belonging to the same engine must all be of the same group.

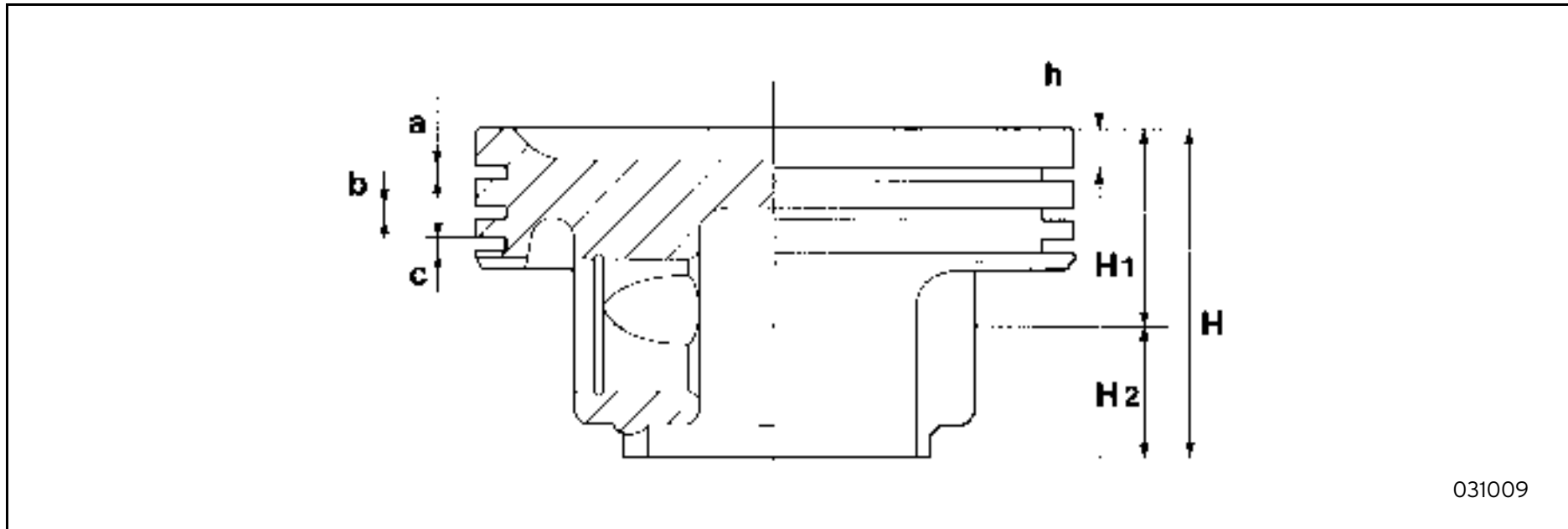


Fig. 9 - Pistons

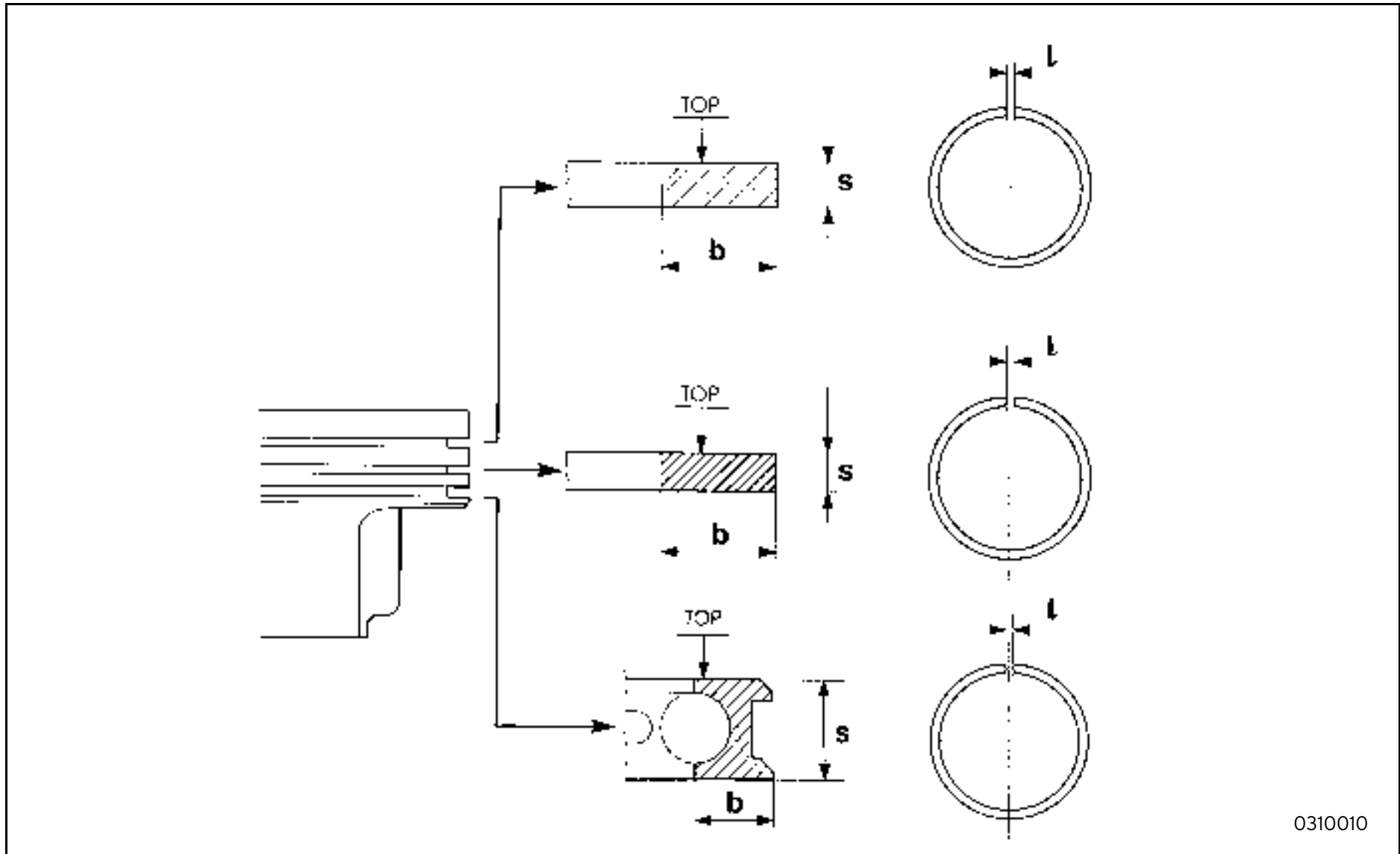
Piston pin

Diameter	19.995 to 20.000
Seat diameter	20.010 to 20.016
Piston pin-piston clearance	0.010 to 0.020

Piston rings

SLOT I	
Height s	190 to 1.175
Thickness b	3.70 to 3.45
Gap between ends l	0.20 to 0.40 (*)
Slot-piston ring clearance	0.040 to 0.075
SLOT II	
Height s	1.740 to 1.728
Thickness b	3.70 to 3.45
Gap between ends l	0.30 to 0.50 (*)
Slot-piston ring clearance	0.020 to 0.062
Diameter b	
SLOT III	
Height s	2.990 to 2.975
Thickness b	3.00 to 2.75
Gap between ends l	0.25 to 0.50 (*)
Slot-piston ring clearance	0.020 to 0.055

(*) measured with piston ring fitted in the liner.

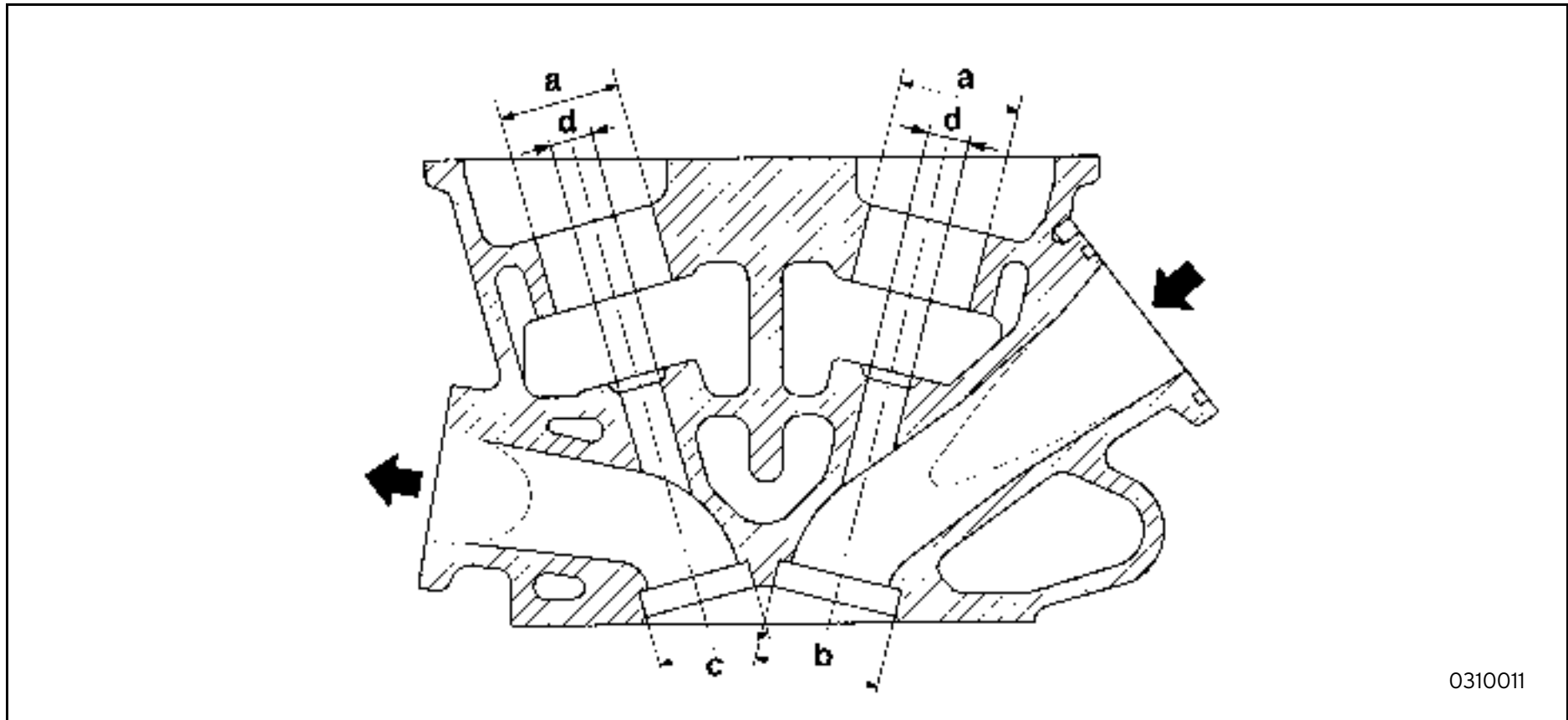


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Fig. 10 - Piston rings

Cylinder heads

Tappet housing diameter (a)	33.015 to 33.030
Intake valve seat housing diameter (b)	30.560 to 30.580
Exhaust valve seat housing diameter (c)	30.560 to 30.580
Valve guide housing diameter (intake and exhaust) (d)	12.00 to 12.018



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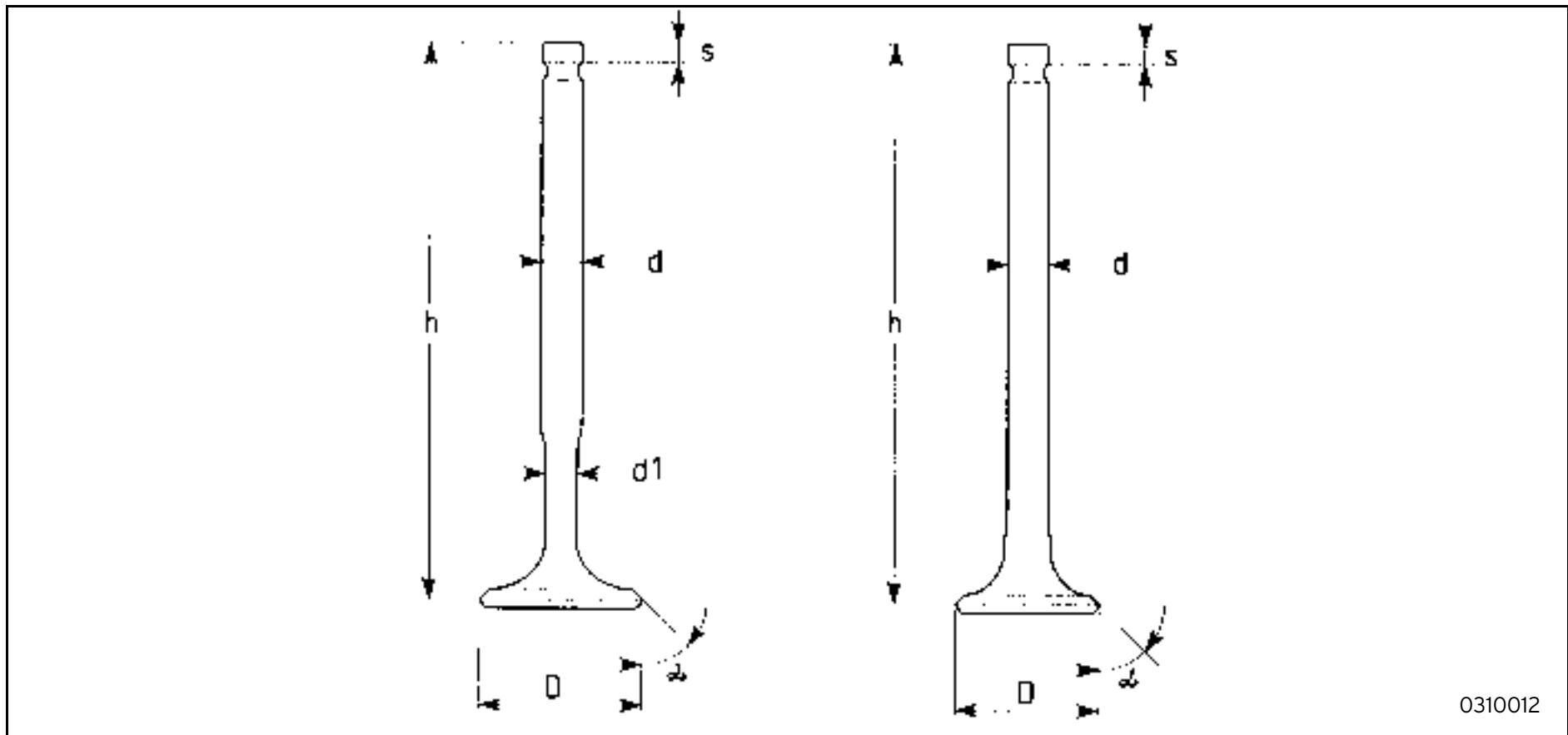
Fig. 11 - Cylinder head

Valves

Intake	
Stem diameter d	6.950 to 6.970
Reduced stem diameter d1	6.50 to 6.60
Valve head diameter D	33.3 to 33.5
Valve seat angle °	$45^{\circ} \pm 5'$
Height h	103.69 to 103.84
Tappets support thickness s	3.45
Exhaust	
Stem diameter d	6.950 to 6.970
Valve head diameter D	29.3 to 29.5
Valve seat angle °	$45^{\circ} \pm 5'$
Height h	103.59 to 103.74
Tappets support thickness s	3.35

Valve seats

Intake	
Rated inner diameter	30 ± 0.10
Rated outer diameter	34.7 ± 0.01
Contact fascia angle	45°
Exhaust	
Rated inner diameter	27 ± 0.10
Rated outer diameter	32.7 ± 0.01
Contact fascia angle	45°



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Fig. 12 - Valves

Tappets

Diameter	32.974 to 32.990
Washer thickness range	3.25 to 0.70
with intervals of	0.05

Valve guides (intake and exhaust)

Rated outer diameter	12.040 to 12.050
Inner diameter with pressed and bored guide	7.0 to 7.015
Stem-guide clearance Intake Exhaust	0.025 to 0.055 0.035 to 0.065

Fitting between valve stem and relevant guide

Intake assembly clearance	0.025 to 0.055
Exhaust assembly clearance	0.035 to 0.065
Maximum shift between valve shank and head (head-stem concentricity) Intake Exhaust	0.03 0.03
Assembly clearance between tappet and its seat (intake-exhaust)	0.025 to 0.071

Valve springs (intake and exhaust)

Inner spring	
Free length (a)	32.5
With valve closed (b)	28
With valve open (c)	19
Compressed (d)	16.36
Load (with closed valve) P1	58.86 ± 3.92 N
Load (with open valve) P2	176.58 ± 9.81 N
Number of active coils	4.82

External spring	
Free length (a)	38.9
With valve closed (b)	31
With valve open (c)	22
Compressed (d)	20.9
Load (with closed valve) P1	245.25 ± 3.92 N
Load (with open valve) P2	549.36 ± 9.81 N
Number of active coils	3.81

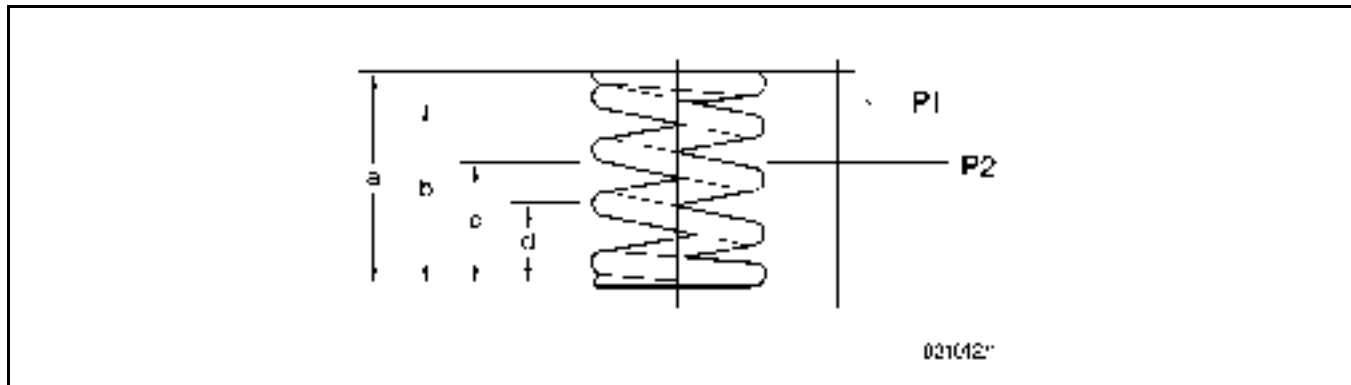


Fig. 12/1 - Valve springs

Engine lubrication

Circuit	Forced lubrication with radiator and thermostatic valve
Radiator oil	Single, separated
Pressure in circuit with hot engine (90°C) - at 1000 RPM - at 6000 RPM	1.5 - 2.5 [bar] 5 - 7 [bar]
Thermostatic valve - start - 9 mm - max. stroke	80 °C 95 °C 11

Engine cooling

Circuit	Forced circulation with thermostatic control
Radiators	Two with fan
Fans	80 °C
- on	74 °C
- off	
Circuit pressure with hot engine (max.)	1.2 [bar]
Thermostatic valve	
- start	80 °C
- 7 mm	86 °C
- Max. stroke (at 95 °C)	11

REMOVAL AND REFIT

This operation requires a car lift and a hoist with a rocking lever and 4 chains to sling the engine, to be fixed on the exhaust manifold hooks.

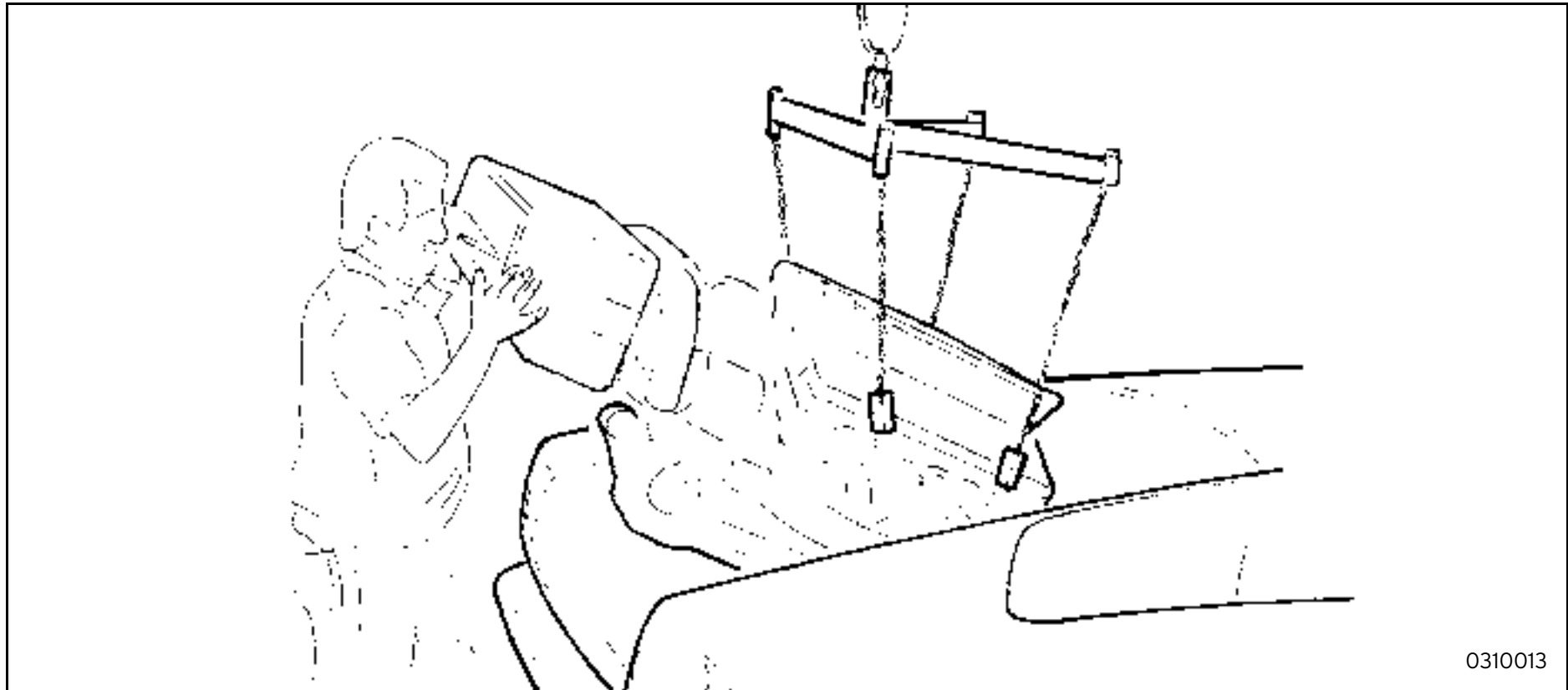


Fig. 13 - Engine-gearbox removal

List of operations to be carried out before the removal of the engine:

- disconnect the positive and negative wires from the battery
- disconnect the engine cooling hoses, oil system hoses, fuel system hoses and air conditioning hoses from their relevant radiators and accessories

- disconnect the engine injection wiring from the general wiring and all the secondary electric connectors, the earth cables and the starter motor wires
- disconnect the oil delivery hose from the clutch cylinder located on the clutch bell
- remove the gear knob and switch on the tunnel in the passenger compartment
- lift the car and working from underneath, remove the gearbox support; loosen the two engine supports on the sides of the crankcase
- remove the catalyts and harness the engine as described above
- remove the engine supports and, after checking all the hoses and wirings are disconnected, remove the engine-gearbox group.

ASSEMBLY

Every time the engine is disassembled clean the crankcase, especially the lubrication ducts.

Replace all oil seals and gaskets.

After the crankcase has been carefully cleaned, assemble the liners as follows:

- fit the rings to the liners;
- insert the liners one after the other in the crankcase;
- check that liners protrusion from the crankcase is in accordance with the values prescribed. Make this check using the liner holder tools (No. 961195027) tightened to the specified torque on the cylinder head bolts. Do not remove the tools before the heads are assembled;
- assemble the main bearings on the engine block;
- fix the crankshaft to the engine block using special supports No. 961495014;



Special supports No. 961495014 must be installed with the main bearings between support and shaft.

- before fitting the piston rings on the pistons, check that the end clearance is within the prescribed value;



To make this check, fit the piston rings on the liner. When fitting the piston rings make sure that the caption "TOP" is facing upwards.

- before assembling the piston-conrod group in the cylinder liner, lubricate the piston rings and the liner with engine oil. Position the piston ring notches so that they are displaced by about 120° and ensure that no notch coincides with the direction of the piston pin axis;

- assemble the conrod-piston group to each cylinder;



When performing this operation turn the crankshaft in the direction of its rotation.
The grooves on the conrod big end must face the crank arms when assembling the conrod-piston group.

- tighten the connecting rod big ends following this procedure:
 - clean the threads very carefully;
 - lubricate the bolt under the big end and the thread;
 - tighten the bolts following the specified procedure (see Section 02 - DRIVING TORQUES);
- before assembling the lower crankshaft support smear LOCTITE 518 paste on the contact surface;
- fit the main bearings on the lower support;
- tighten the lower support to the prescribed torque following the specified procedure (see Section 02 - DRIVING TORQUES);
- assemble the timing components on the front part of the crankcase; assemble the oil pump on the timing cover;
- place cylinder No.1 at T.D.C. using a dial gauge;
- fit the pre-assembled cylinder heads taking care that the camshaft positions coincide with the reference marks on the supports;



Cool the guides and valve seats (about -190°) before assembling onto the head. Pre heat the head to about 190°.

- before tightening the heads lubricate the upper surface of the washers, nuts and bolt threads with Molycote 1000 paste;
- tighten the head bolts following the prescribed procedure (see Section 02 - DRIVING TORQUES) using wrench No. 9008019;
- proceed with engine timing;
- before assembling the oil sump smear the contact surface with LOCTITE 518.

CHECKS AND ADJUSTMENTS

Valve clearance

Intake	0.35 [mm]
Exhaust	0.50 [mm]

Replace the spacer rings until the clearance required is found. Use tool No. 961195014 to remove and replace the spacer rings. When the cylinder heads are removed it is advisable to use tool No. 961195004 for the intake valve and No. 961195003 for the exhaust valve.

Position the spacer rings (pads) with the side indicating the thickness facing the tappet.



Check the valve clearance when the engine is cold.

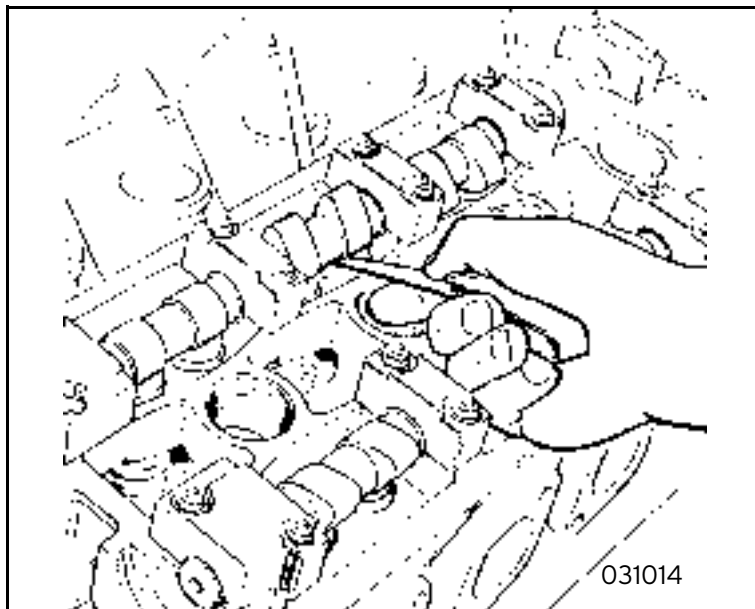


Fig. 14 - Valve clearance check

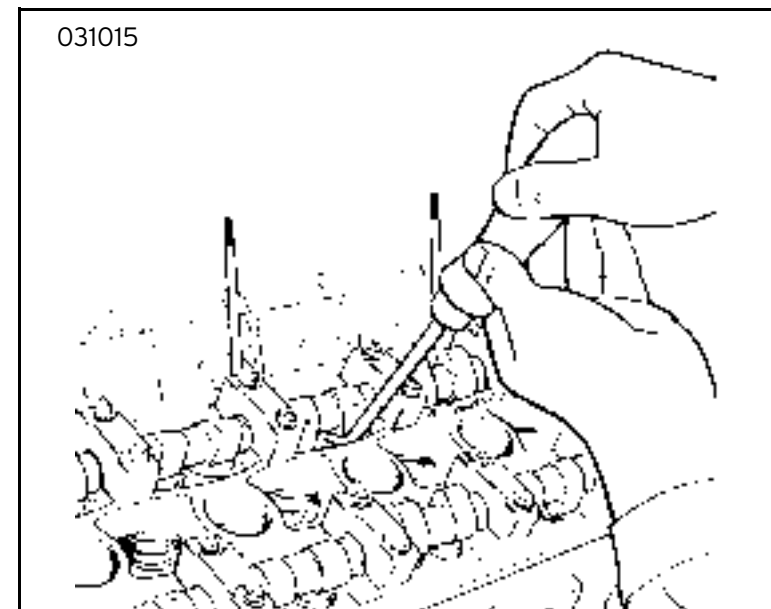


Fig. 15 - Spacer ring replacement

Locking the phase variator

A phase variator is installed in the engine on the intake timing shafts.

If this is removed, or when setting up the timing system, make sure that the slots on the moving part are correctly positioned in relation to the fixed part securing holes.

Position check

- visually check that the slot is centred to the hole (part A)
- if it is not (position B), proceed with the positioning.

Positioning

- take out the moving part (2) from the fixed part (1); find a new angle position of the moving part, making attempts by re-inserting it fully with a rotating movement and checking the position of the slots in relation to the holes (position A);
- when the correct position is found secure the moving part by inserting ring (4) and tightening the screws to the prescribed torque.

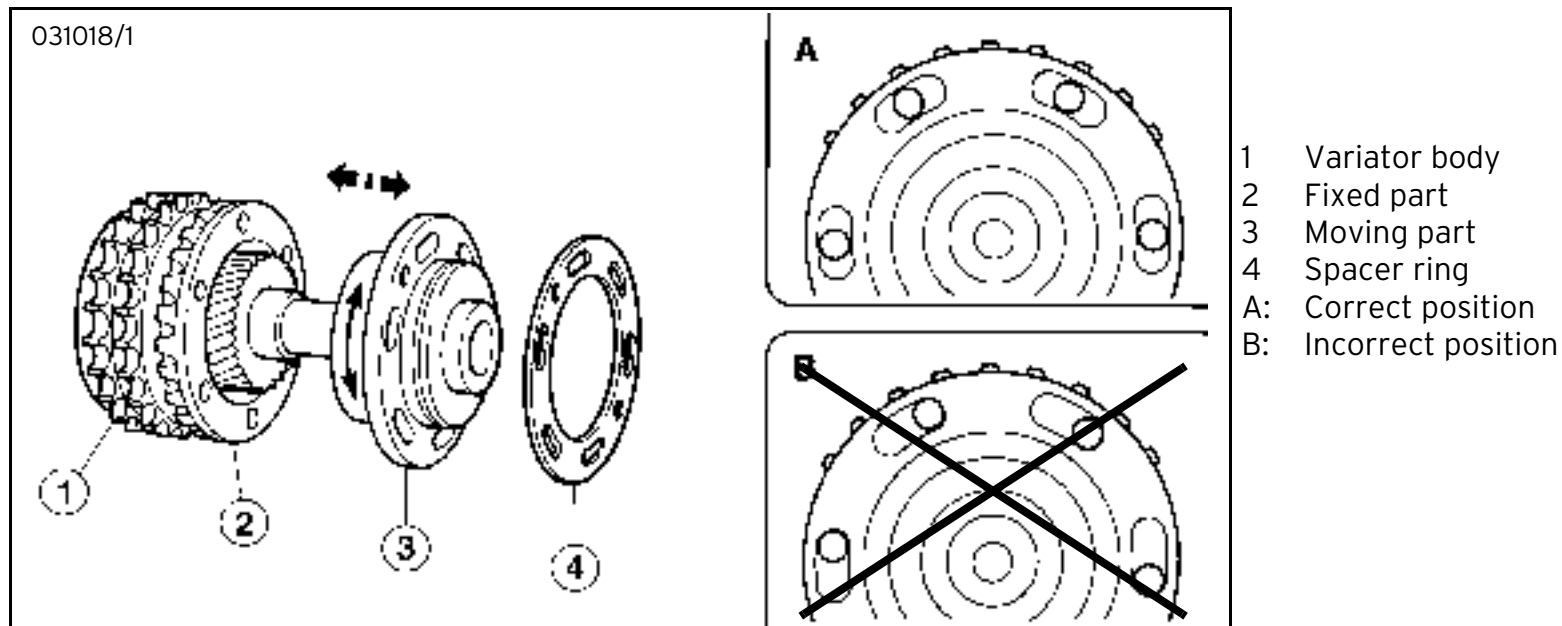


Fig. 16 - Locking the phase variator

Timing regulation

	Intake	Exhaust
Start before TDC [°]	40	---
End after BDC [°]	68	---
Start before BDC [°]	---	68
End after TDC [°]	---	22
Lift during overlap stage [mm]		
• New timing chain (less than 6 hours)	1.15 ± 0.05	0.20 ± 0.05
• Adjusted timing chain (more than 6 hours)	1.00 ± 0.05	0.35 ± 0.05

Adjustment

To adjust proceed as follows:

- rotate the crankshaft until the dial gauge shows that piston No. 1 coincides with the ignition TDC (use dial gauge holder No. 961195025);
- fit the setting dial and lever No. 961495012 to rotate the crankshaft;
- fix the reference point on the crankcase and goniometer for the TDC;

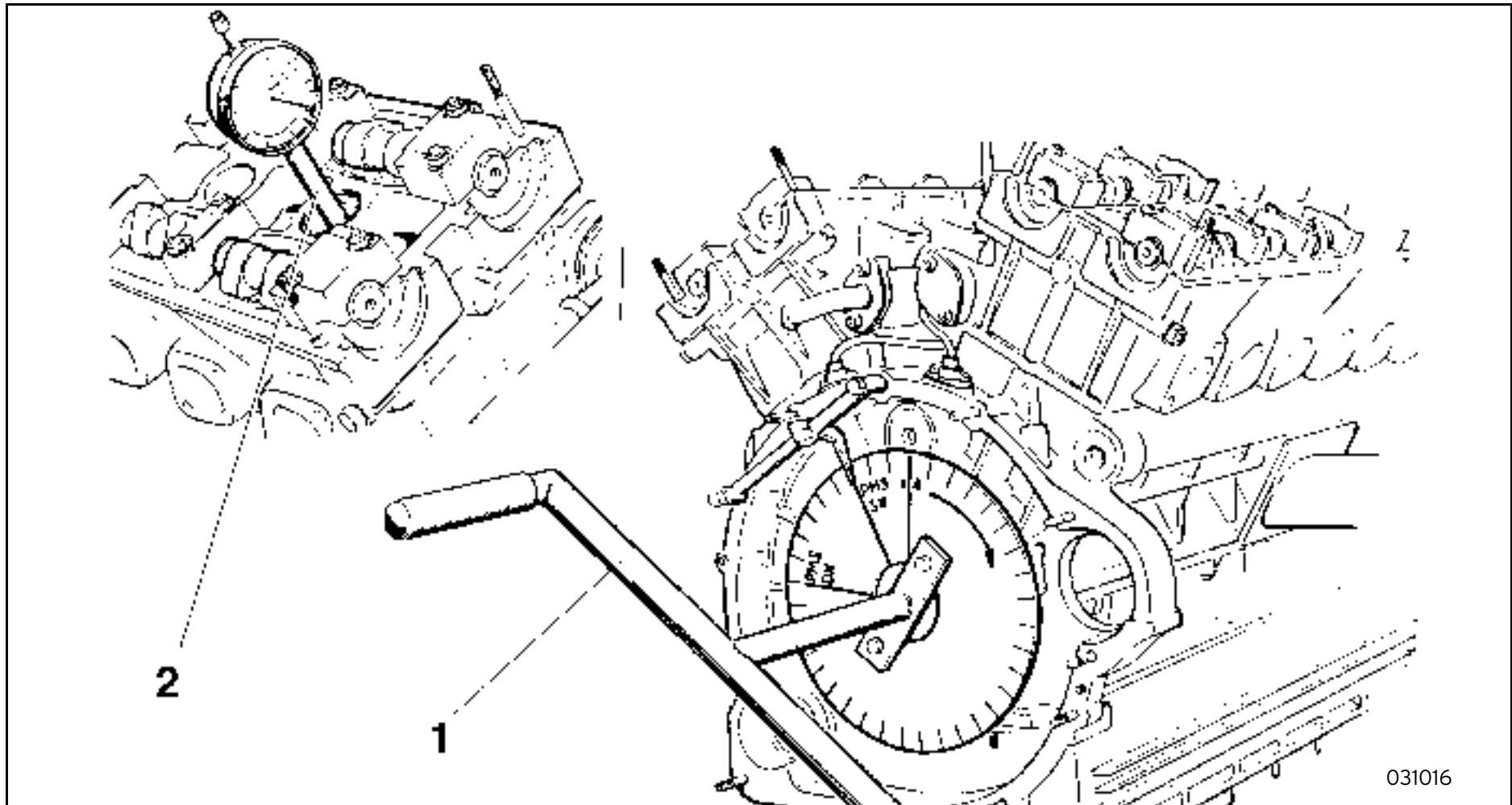


Fig. 17 - Checking TDC in cylinder No. 1

- 1 Tool No. 961495012
- 2 Tool No. 961195025

Exhaust:

- fit sprocket holder tool No. 961195042 to fix the gears on the camshafts;
- check that the reference marks (A) on the supports and the camshafts coincide;
- fix the centring dowel on the cams using the tool;

Intake:

- loosen the six variator screws;
- check that the reference marks (A) on the supports and the camshafts coincide;
- tighten the six variator screws without locking;
- make one turn (in the engine rotation direction) to recover the chain slack;
- check the reference marks (A) again on the supports and the camshafts and if necessary reposition the shafts;
- position holder No. 961195026 with the dial gauge to measure the valve lift on cylinder No. 6;

Exhaust:

- place the dial gauge on the exhaust valve tappet and check that the lift is that specified;
- if it is not, remove the centring dowel using tool No. 961195024 and turn the exhaust side camshaft with a 26 mm wrench until the correct exhaust valve lift of cylinder No. 6 is found (the position is at TDC overlap);

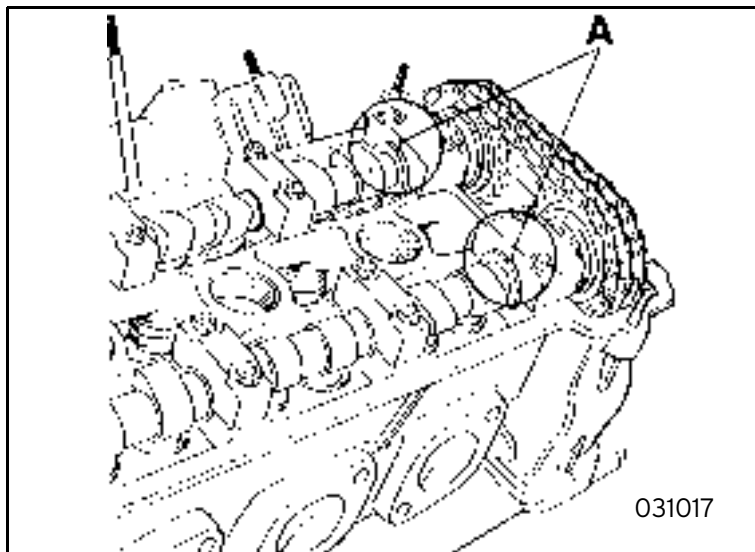


Fig. 18 - Reference marks

1 Tool No.
961495026

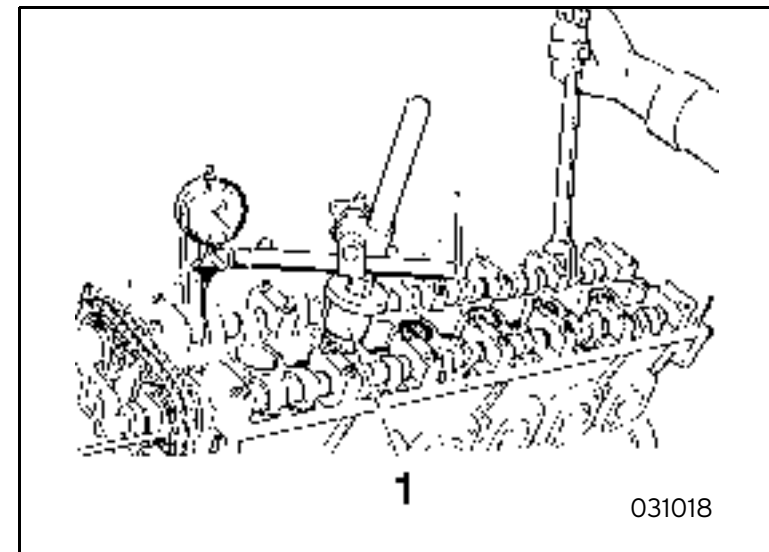


Fig. 19 - Checking and adjustment of lifts

- fit the centring dowel on the cams using the tool;

Intake:

- loosen the six variator screws;
- turn the intake side camshaft with a 26 mm wrench until the correct intake valve lift of cylinder No. 6 is found (the position is at TDC overlap);



To obtain the prescribed values at the end of the operations it is necessary to double the adjusting values of the lifts to be applied.

- tighten the six variator screws to the prescribed torque;
- repeat the whole procedure for the right-hand cylinder bank, bringing cylinder 7 to ignition TDC (60° after ignition TDC of cylinder 1) and measure the lifts on cylinder 12.

Checking

To check, proceed as follows:

- rotate the crankshaft until the dial gauge shows that piston No. 1 coincides with the ignition TDC (use dial gauge holder No. 961195025);
- fit the setting dial and lever No. 961495012 to rotate the crankshaft;
- fix the reference point on the crankcase and goniometer for the TDC;
- position holder No. 961195026 with the dial gauge to measure the valve lift on cylinder No. 6;
- place the dial gauge on the intake tappet and check the lift is that specified;
- place the dial gauge on the exhaust valve tappet and repeat the procedure;
- repeat the whole procedure for the right-hand cylinder bank, bringing cylinder 7 to ignition TDC (60° after ignition TDC of cylinder 1) and measure the lifts on cylinder 12.
- make the necessary adjustment if these conditions are not found.

Locking check on phonic wheel for engine timing sensor

Proceed as follows:

- remove the cover of the phonic wheel on the camshaft, then rotate it in the direction of engine rotation to bring the tooth near to cylinder bank 1-6 sensor using the starter motor;
- move the sensor tooth along the last section engaging the 5th gear and moving the vehicle in the travel direction;

- lift the vehicle and with a large screwdriver turn the camshaft to bring the reference notch 30° in advance of the flywheel to correspond with the reference on the engine block (two holes not in line);

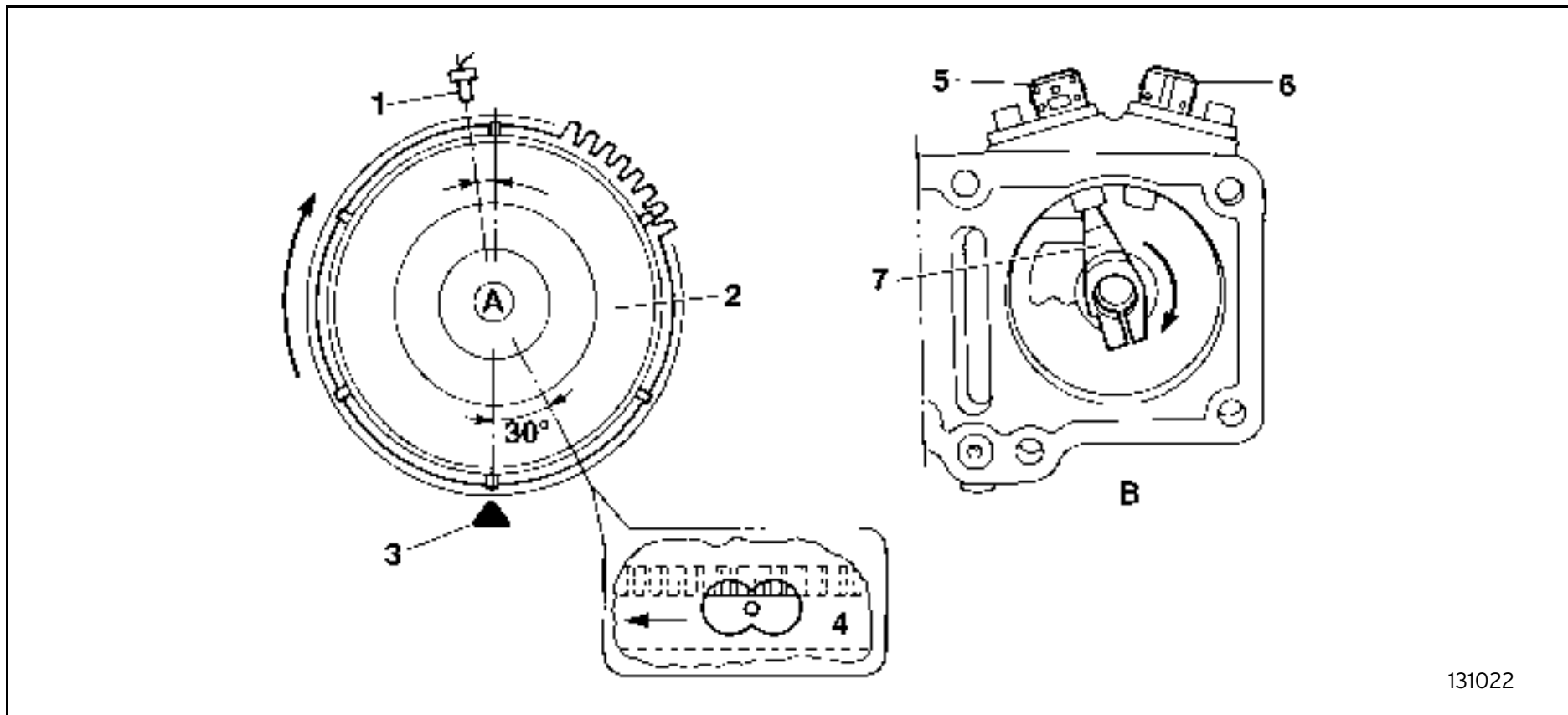


Do not reverse the direction of engine rotation to avoid errors caused by backlash: if you go beyond the point, make two complete engine rotations then repeat the procedure.



The 30° do not represent the ignition advance, but only an assembly reference.

- check that the tooth is perfectly centred to the sensor;
- if it is not, loosen the screw and direct the phonic wheel until centring is obtained;
- check that the distance between the tooth and the sensor (gap) is between 0.7 and 1 mm. If necessary shim the sensor.

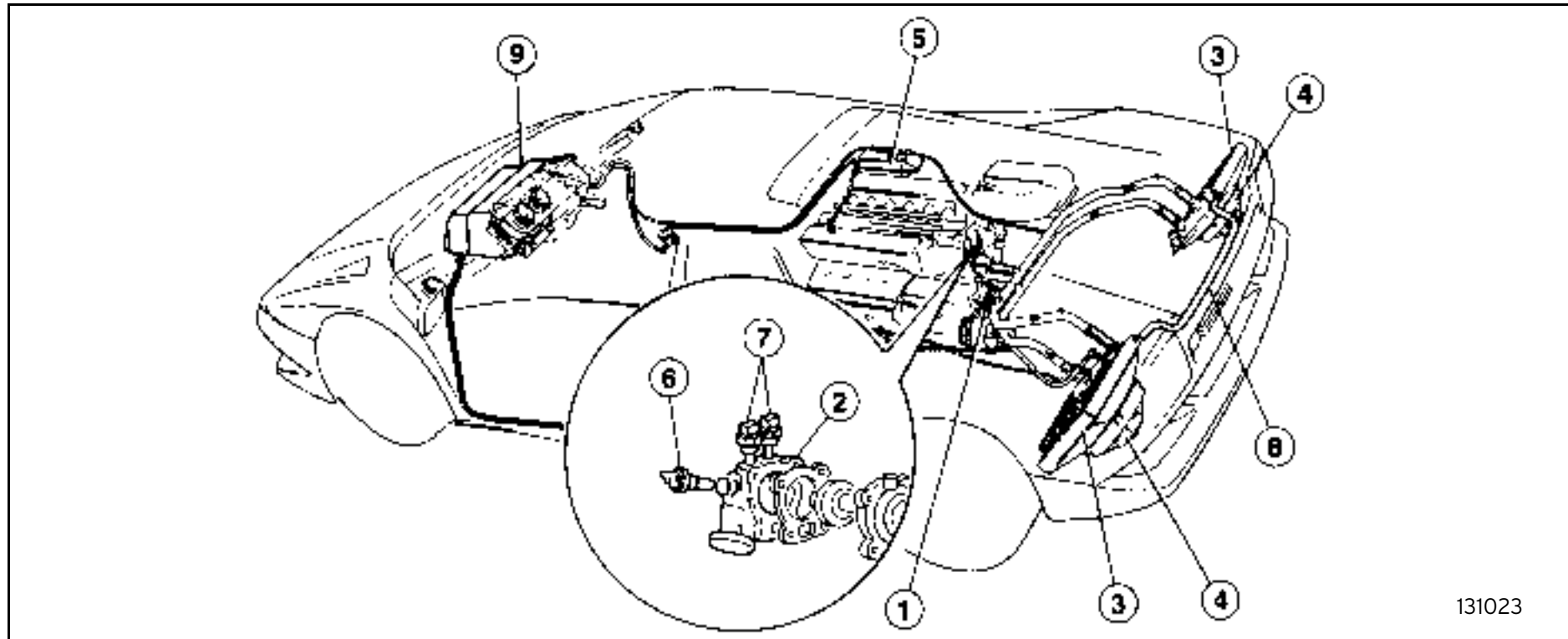


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Fig. 20 - Timing sensor-phonic wheel locking references

- 1 Speed sensor and TDC
- 2 Engine flywheel
- 3 Mechanical TDC reference
- 4 30° advance reference
- 5 Timing sensor cylinder bank 1-6
- 6 Timing sensor cylinder bank 7-12
- 7 Phonic wheel
- A Crankshaft
- B Camshaft

COOLING CIRCUIT



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Fig. 21 - Cooling circuit

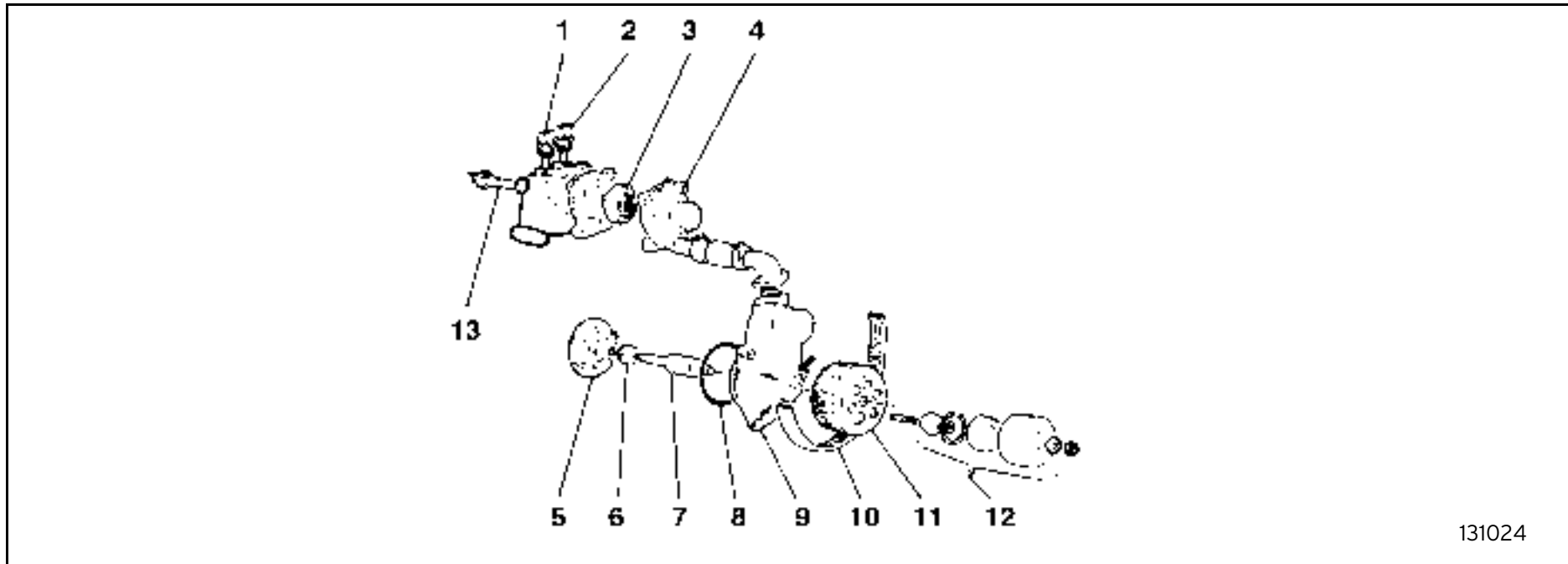
- 1 Water pump
- 2 Thermostatic body
- 3 Radiator
- 4 Electric fan
- 5 Expansion reservoir
- 6 Gauge temperature sensor
- 7 Engine control system temperature sensors
- 8 Self-drain pipe
- 9 Climate control unit

Description

Closed loop cooling system with forced circulation by centrifugal pump belt-driven by the crankshaft.

Main components:

- two radiators
- two electric fans
- thermostatic valve in thermostat body
- centrifugal pump
- sensor for temperature gauge
- pipes for self-drain system



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Fig. 22 - Water pump and thermostat

- | | | | |
|---|----------------------------|----|----------------------------|
| 1 | Coolant temperature sensor | 8 | O-ring |
| 2 | Coolant temperature sensor | 9 | Pump casing |
| 3 | Thermostat | 10 | Belt |
| 4 | Thermostat cover | 11 | Pulley |
| 5 | Pump impeller | 12 | Belt tensioner assembly |
| 6 | Front seal | 13 | Coolant temperature sensor |
| 7 | Shaft | | |

Radiators and electric fans

The radiators are fitted with a tap in the lower part to drain off the water, and two caps in the upper part to bleed off the air. The engine control unit governs the switching on of the electric fans according to the coolant temperature and when the air conditioning system is activated.



Since the coolant temperature is read by the relevant sensor the thermal contact is no longer installed on the radiator.

Thermostatic valve

The thermostatic valve is located in the thermostat body.

Expansion reservoir

The expansion reservoir compensates the coolant volume variations caused by engine heating.

The reservoir cap is fitted with a gauged valve that controls the system maximum pressure.

Always fill and top up the cooling system through the expansion reservoir filler.

Radiator removal

To remove the radiators proceed as follows:

- take off the exhaust system and the catalytic converters;
- remove the left and right wheel housings;
- remove the water sleeves;
- unscrew the radiator fixing bolts;
- take off the radiators from the side towards the car centre.

Filling up the system

- fill up the system through the expansion reservoir;
- remove the expansion reservoir cap;
- check the level in the expansion reservoir during heating;
- heat the engine to operating temperature to allow the thermostat valve to open;
- select HI C/F on the digital display of the air conditioner so that the heating radiator liquid starts to circulate;
- top up the expansion reservoir;
- as soon as the fans start, fit on the expansion reservoir cap;
- check the level again when the engine is cold.

LUBRICATION CIRCUIT

Description

Force feed lubrication system with gear pump with oil vapours re-cycling. Oil cooling system with thermostatic valve.

Main components

- oil pump with internal gears and pressure regulator valve;
- thermostatic valve in thermostat body-filter seat
- radiator;
- cartridge filter;
- pressure sender;
- temperature sender;

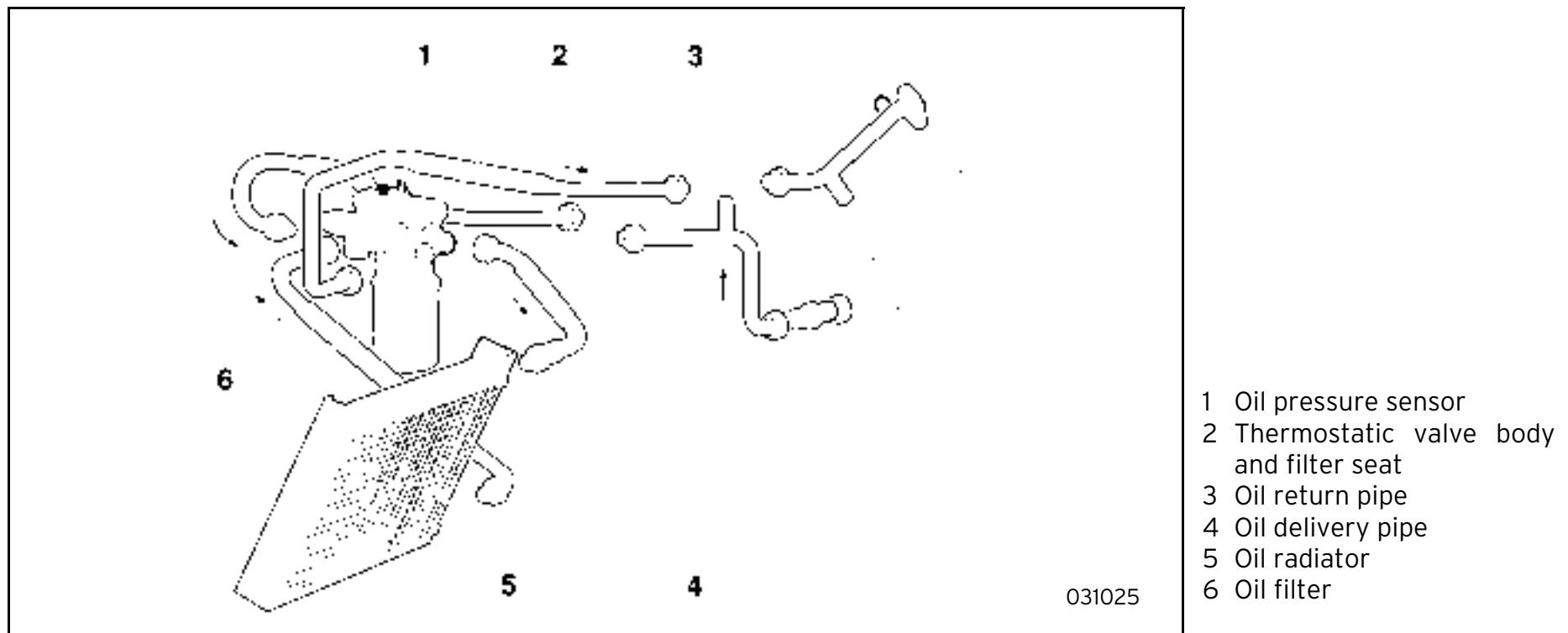


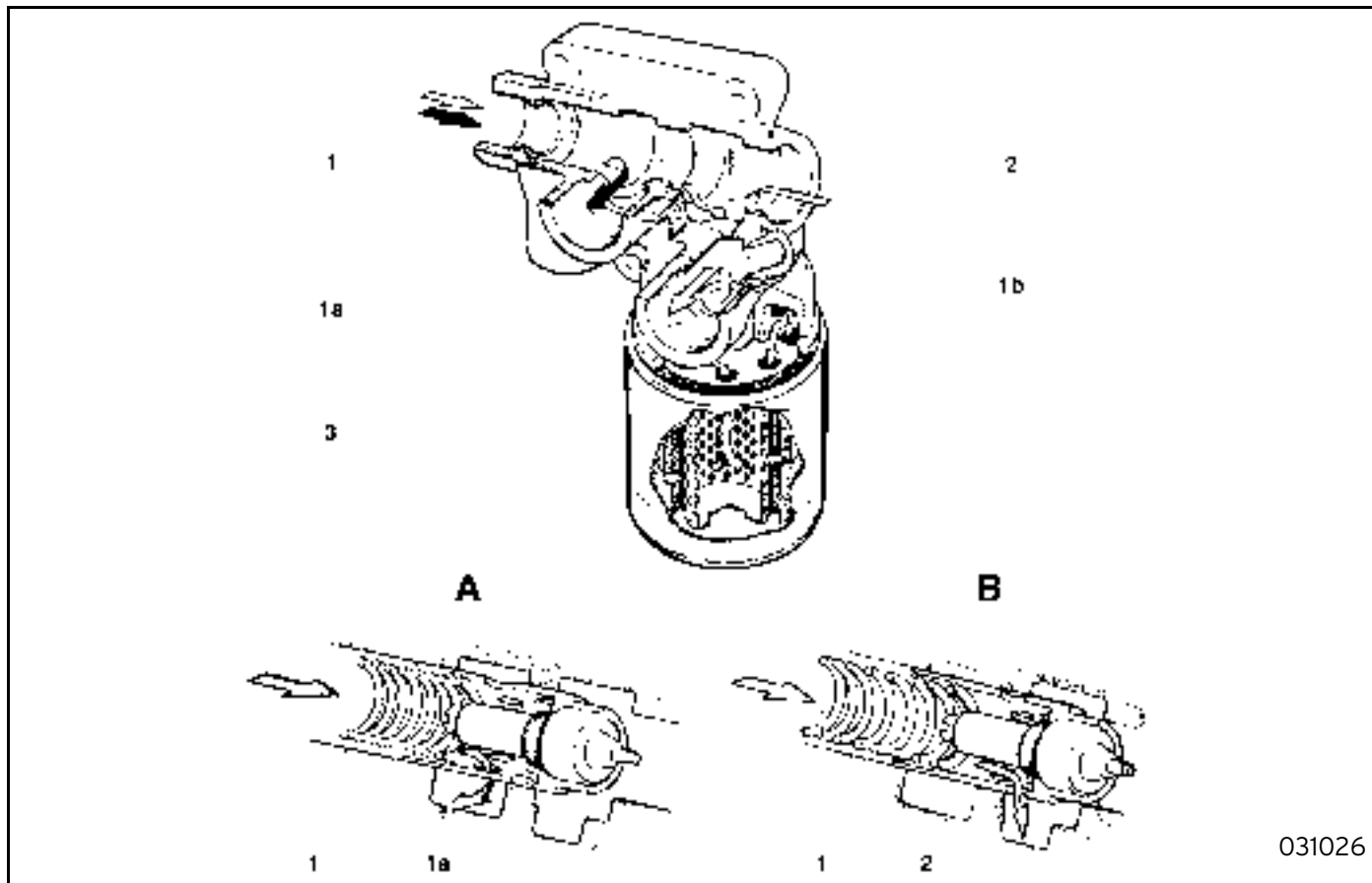
Fig. 23 - External circuit

Thermostatic valve

The lubrication system is equipped with a thermostatic valve that according to the oil temperature allows the oil passage through the heat exchanger. The thermostatic valve is located on the thermostatic body/filter seat.

The main checking data is:

Temperature (°C)	Stroke
80	start
95	9 mm
Max. stroke	11 mm



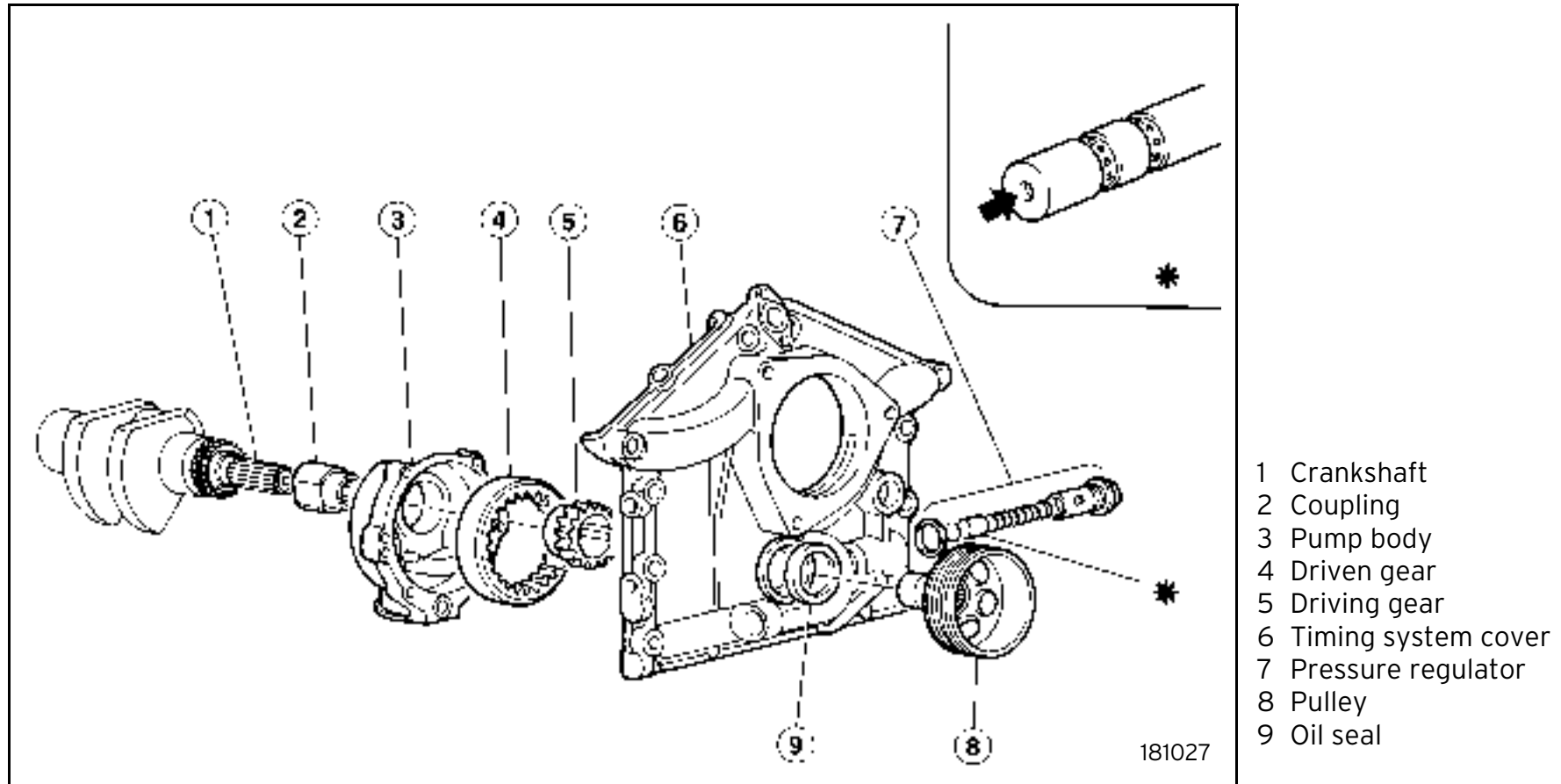
- 1 From oil pump : 1a - To oil radiator; 1b - From oil radiator
- 2 To filter
- 3 To engine
- A Valve open, oil path 1-1a-1b-2-3
- B Valve closed, oil path: 1-2-3

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Fig. 24 - Thermostatic valve

Oil pump check

- check the pump body and cover, replace the parts if there are scorings;
- clean suction and delivery carefully with a petroleum jet and compressed air;
- check the driving and driven gears; if they are in bad condition or worn replace them;
- check clearances;
- check that the relief valve piston moves properly in its seat;
- check the bearing.



- 1 Crankshaft
- 2 Coupling
- 3 Pump body
- 4 Driven gear
- 5 Driving gear
- 6 Timing system cover
- 7 Pressure regulator
- 8 Pulley
- 9 Oil seal

Fig. 25 - Oil pump



Check conditions of calibrated hole (arrow) and clean if required.

Level check and oil replacement

Check the oil level with the dipstick every 500 km, preferably with the engine cold. If the engine is hot, wait a few minutes to allow the oil to flow back to the sump.

Replace the oil when the engine is hot, draining it through the drain hole (A) in the bottom of the sump.

To have access to the engine oil filter remove the panel in the bottom of the car.

- remove the oil filter and replace it with a new one, after lubricating the seal with engine oil.
- fit the filter and tighten by hand.

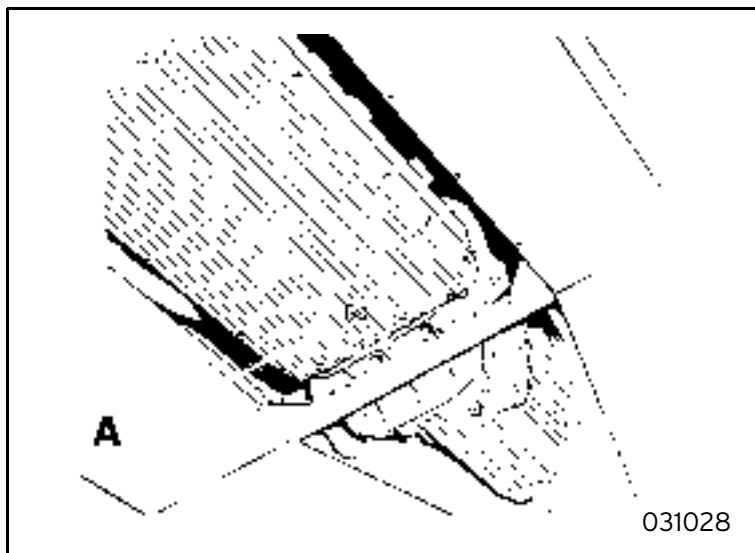


Fig. 26 - Engine oil drainage cap

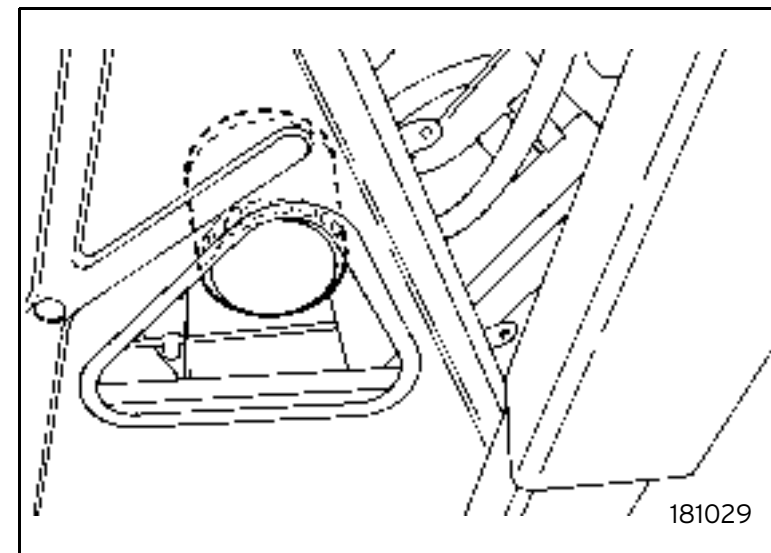
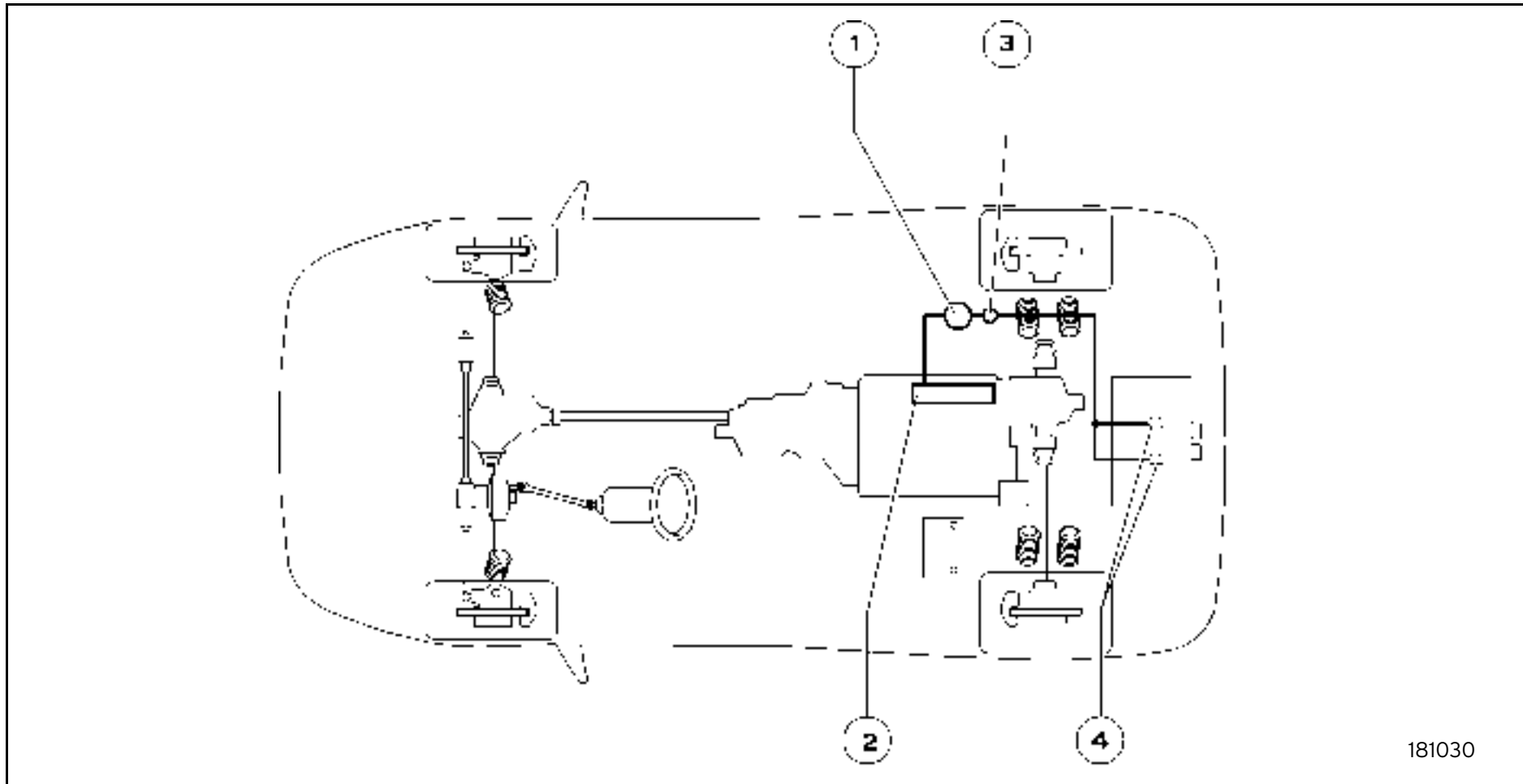


Fig. 27 - Engine oil filter

PNEUMATIC UTILITY CONNECTIONS

(EEC versions only)



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Fig. 28 - Pneumatic utility connections

- 1 Vacuum reservoir
- 2 Intake manifold block 7-12
- 3 ENCS system solenoid valve
- 4 ENCS system actuators