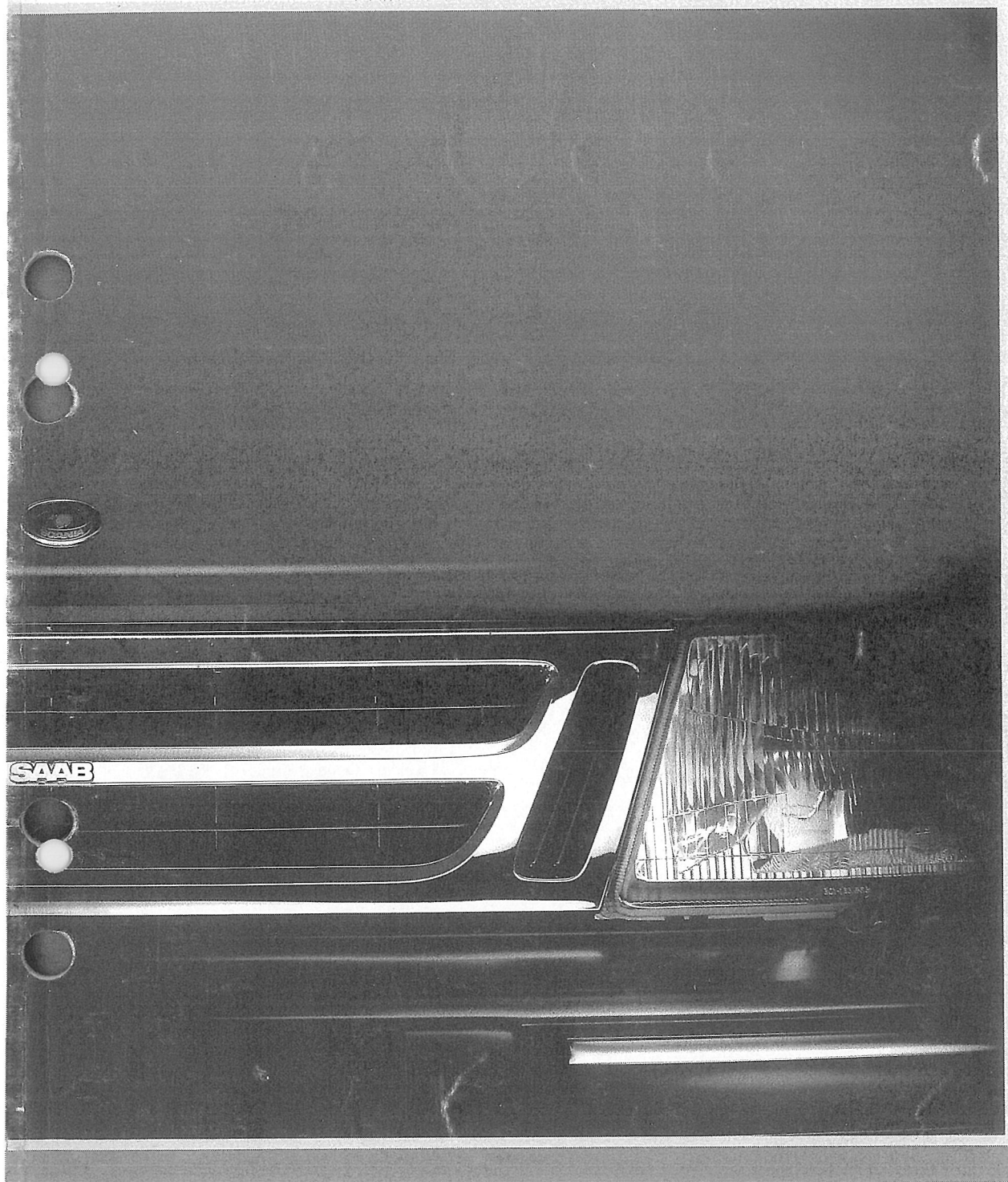


Saab 900

SERVICE MANUAL



SAAB

5:2 ABS braking system

M 1989 -



Units

The basic and derived units used throughout the Service Manual are in accordance with the SI system.

For users not familiar with the SI units, some non-Continental units are given in brackets after the respective SI unit.

The following symbols and abbreviations are used:

SI unit	Equivalent unit and symbol
mm	inch (in)
kg	pound (lb)
N	pound-force (lbf)
Nm	pound-force foot (lbf ft)
bar	pound-force per square inch (lbf/in ²) (Also abbreviated: psi)
l (litre)	US liquid quart (liq qt) (Also abbreviated: qts)
	US gallon (USgal)
°C	°F

Conversion factors

1 in = 25.4 mm	1 mm = 0.039 in
1 lbf = 4.45 N	1 N = 0.23 lbf
1 lbf ft = 1.36 Nm	1 Nm = 0.74 lbf ft
1 psi = 0.07 bar	1 bar = 14.5 lbf/in ²
1 liq qt = 0.95 l	1 l = 1.05 liq qt
1 US liq qt = 0.83 UKqt	1 USgal = 0.83 UKgal

Market codes

The codes refer to market specifications

AT	Austria	FR	France
AU	Australia	GB	Great Britain
BE	Belgium	GR	Greece
CA	Canada	IS	Iceland
CH	Switzerland	IT	Italy
DE	Germany	JP	Japan
DK	Denmark	ME	Middle East
ES	Spain	NL	Netherlands
EU	Europe	NO	Norway
FE	Far East	SE	Sweden
FI	Finland	US	USA

Technical data

Hydraulic unit

Make		ATE
Working voltage	V	10 - 14
Working temperature	°C (°F)	-30 to +80 (-22 to +176)
Pressures: Brake circuits	bar (psi)	0 - 180 (0 - 2610)
Accumulator	bar (psi)	140 - 180 (2030 - 2610)

Brake fluid reservoir

Reservoir capacity	litres (liq qt)	0.8 (0.84)
Total capacity of brake system	litres (liq qt)	1.2 (1.3)
Brake fluid specification		DOT 4
Number of chambers		3
No. 1 chamber		Static circuit
No. 2 chamber		Dynamic circuit (to pump)
No. 3 chamber		Dynamic circuit (return from servo)
Filter flow capacity	litres/min (l/liq qt)	0.5 (0.5)
Fluid level indicator resistance	ohm	10 (reservoir empty)
ABS-warning switch resistance	ohm	1 (reservoir full)

Pump

Type		Ball-valve
Pressure: Inlet side	bar (psi)	0.1 - 1.0 (0.45 - 14.5)
Delivery side	bar (psi)	140 - 180 (2030 - 2610)
Relief valve opening pressure	bar (psi)	210 (3045)
Power demand	W	180 (at 160 bar)
Maximum running time		2 min at a time followed by 10-min pause (pump must not be run dry)

Accumulator

Gas		Nitrogen
Gas pressure at 20°C (68°F)	bar (psi)	80 (1160)
Minimum gas pressure	bar (psi)	40 (580)
Fluid capacity	litres (liq qt)	0.25 (0.26)
Working pressure range	bar (psi)	135 - 190 (1958 - 2755)
Maximum pressure drop	bar (psi) 10 min	10 (145)

Pressure/warning-light switch

Pressure switch:		
Breaks circuit at	bar (psi)	180 ± 4 (2610 ± 58)
Makes circuit at	bar (psi)	140 ± 4 (2030 ± 58)
Warning-light switch:		
Breaks circuit at	bar (psi)	134 ± 2 (1943 ± 29)
Makes circuit at	bar (psi)	105 ± 2 (1523 ± 29)

Main valve

Maximum working pressure	bar (psi)	180 (2610)
Power rating at 12 V	W	35
Resistance	ohm	5 - 7

Solenoid valves

Maximum working pressure	bar (psi)	180 ± 40 (2610 ± 580)
Power rating at 12 V	W	25
Resistance	ohm	5 - 7
Flow capacity at 20°C and 100 bar	cm ³ /s (in ³ /s)	36 (2.2)

ECU

Working voltage range	V	7 - 18
Power rating	W	40
Working temperature range	°C (°F)	-40 to +80 (-40 to +176)

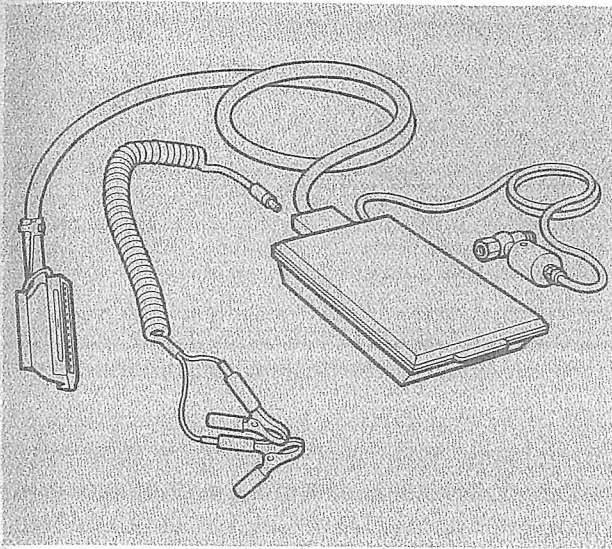
Wheel sensors

Working voltage range	V a.c.	0.15 - 0.70
Resistance	ohm	800 - 1400
No. of teeth		94
Wheel sensor - sensor wheel clearance	mm (in)	0.65 (0.026)

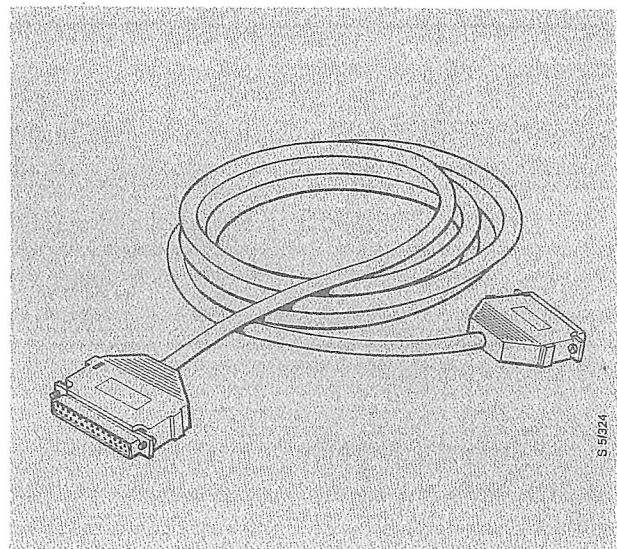
Tightening torques

Hydraulic unit	Nm (lbf ft)	26 ± 4 (19 ± 3)
Accumulator	Nm (lbf ft)	34 - 46 (25 - 34)
Pressure switch	Nm (lbf ft)	20 - 26 (15 - 19)

Special tools

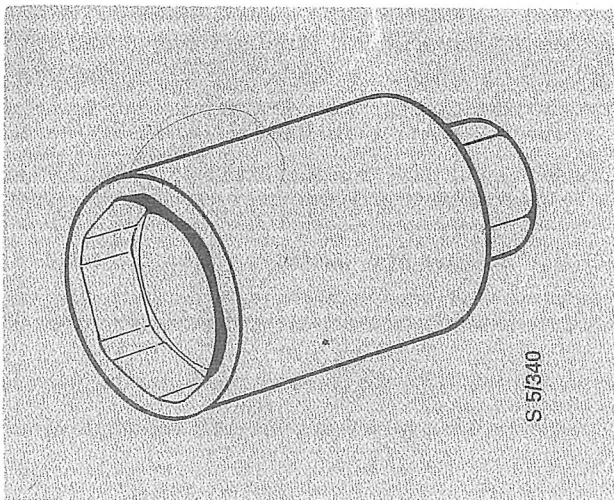


8996514 ABS-system tester

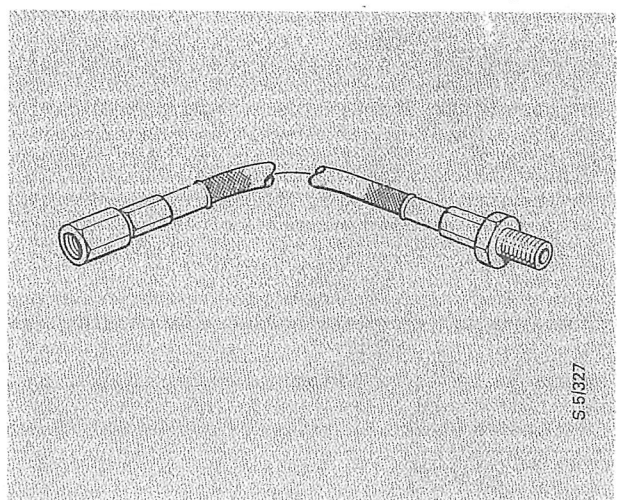


8996589 Extension lead, ECU to ABS-system tester

8996522 Pressure sensor (included with ABS-system tester)



8996571 Socket for removal/fitting of pressure switch



8996597 Adaptor hose for connecting pressure sensor to hydraulic unit



Technical description

General	500-1	Components	500-11
Principles of operation	500-5		

General

ABS brakes (Anti-lock Braking System) have been developed to provide optimum braking, with no loss of direction or stability, under widely varying conditions. The stopping distance of a car is influenced by a variety of factors, including weather conditions, road surface, prevailing traffic conditions, braking effort applied.

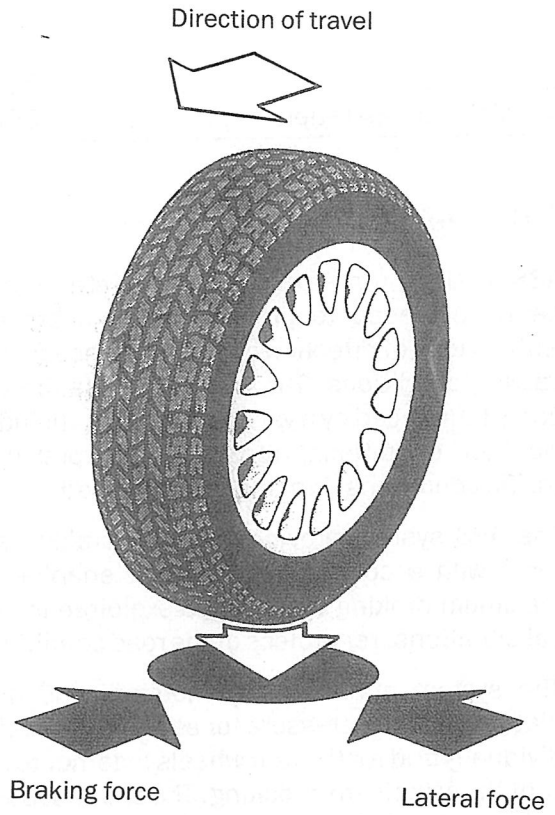
The ABS system provides modern braking systems with a control function that enables the maximum braking effect to be exploited in critical situations, regardless of the road conditions.

The system automatically monitors and modulates the brake pressure for each front wheel individually and for the rear wheels together to prevent the wheels from locking. The shortest possible stopping distance is therefore achieved without any loss of steering control.

The main advantages of the ABS system are as follows:

- No loss of directional stability on braking
- Steering control retained even when brakes hard on
- Shortest possible stopping distance
- Reduced tyre wear

To understand how the ABS system provides optimum braking without any loss of directional stability, we need to examine the forces acting on a wheel during braking.

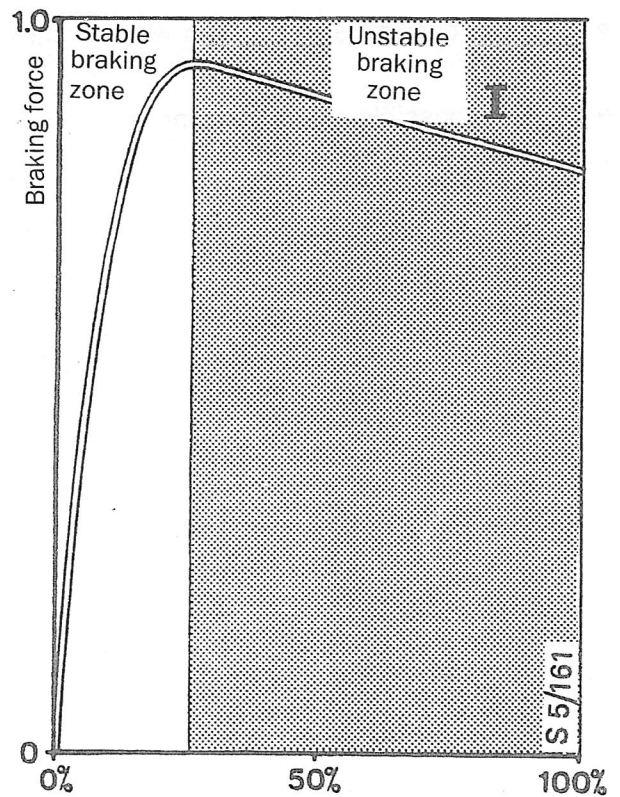


All the forces taken up by the tyre are either lateral forces or braking forces

On the adjacent chart, the curve (I) shows the relationship between braking force (expressed as a coefficient) and tyre slip (expressed as a percentage).

The braking force is equivalent to the coefficient of adhesion, i.e. the friction between the tyre and the road surface. Each application of a braking force gives rise to a certain degree of slip, ranging from 0% when the wheel is rolling freely to 100% when the wheel is locked.

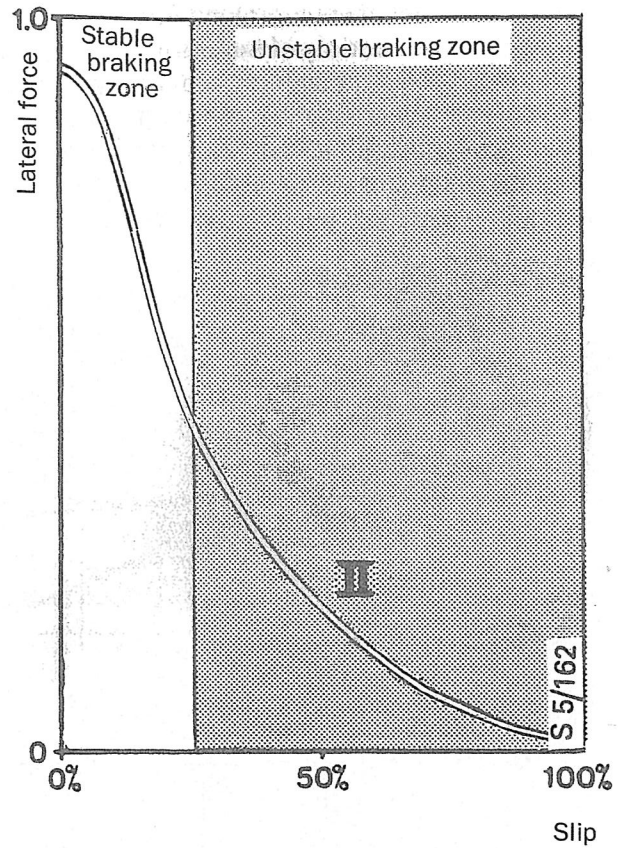
When the brake is first applied, the braking force increases sharply, but the degree of slip only gradually, up to a certain limit. Beyond that point, the braking force will decrease with increasing slip.



The maximum braking force (coefficient of adhesion) is reached at a point known as the limit of optimum slip.

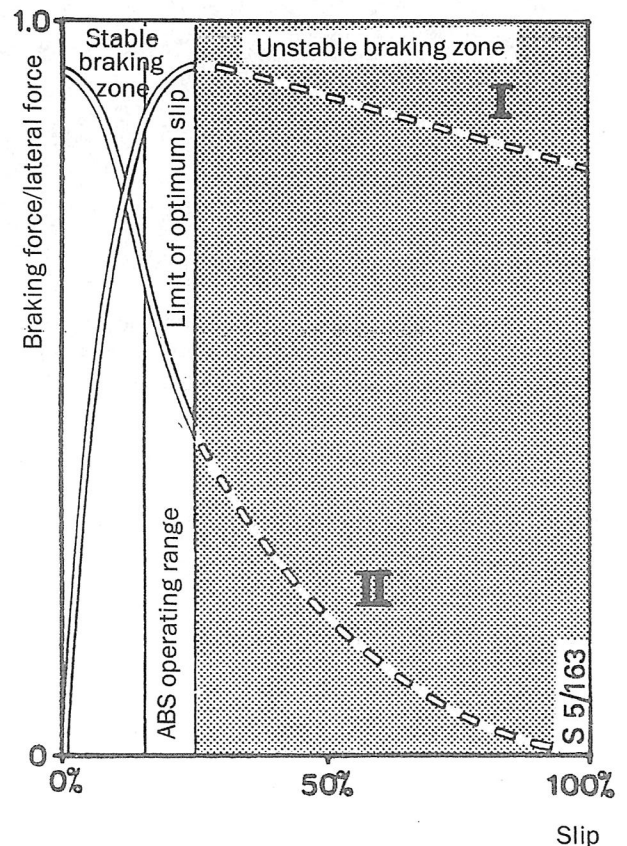
The section of the curve between 0% slip and the limit of optimum slip is known as the stable braking zone. The section of curve between the limit of optimum slip and 100% slip is known as the unstable braking zone, as stable braking cannot be achieved within this zone. This is because the wheel quickly becomes locked after the limit of optimum slip has been reached, unless the braking force is immediately reduced.

Slip also occurs when the tyre is called upon to transmit a lateral force (e.g. on cornering). Curve II on the adjacent chart shows lateral force as a function of slip. As can be seen, lateral force falls away sharply with increasing slip. At 100% slip, i.e. when the wheels have locked up, no lateral force remains for steering and the driver will no longer be able to control the vehicle.



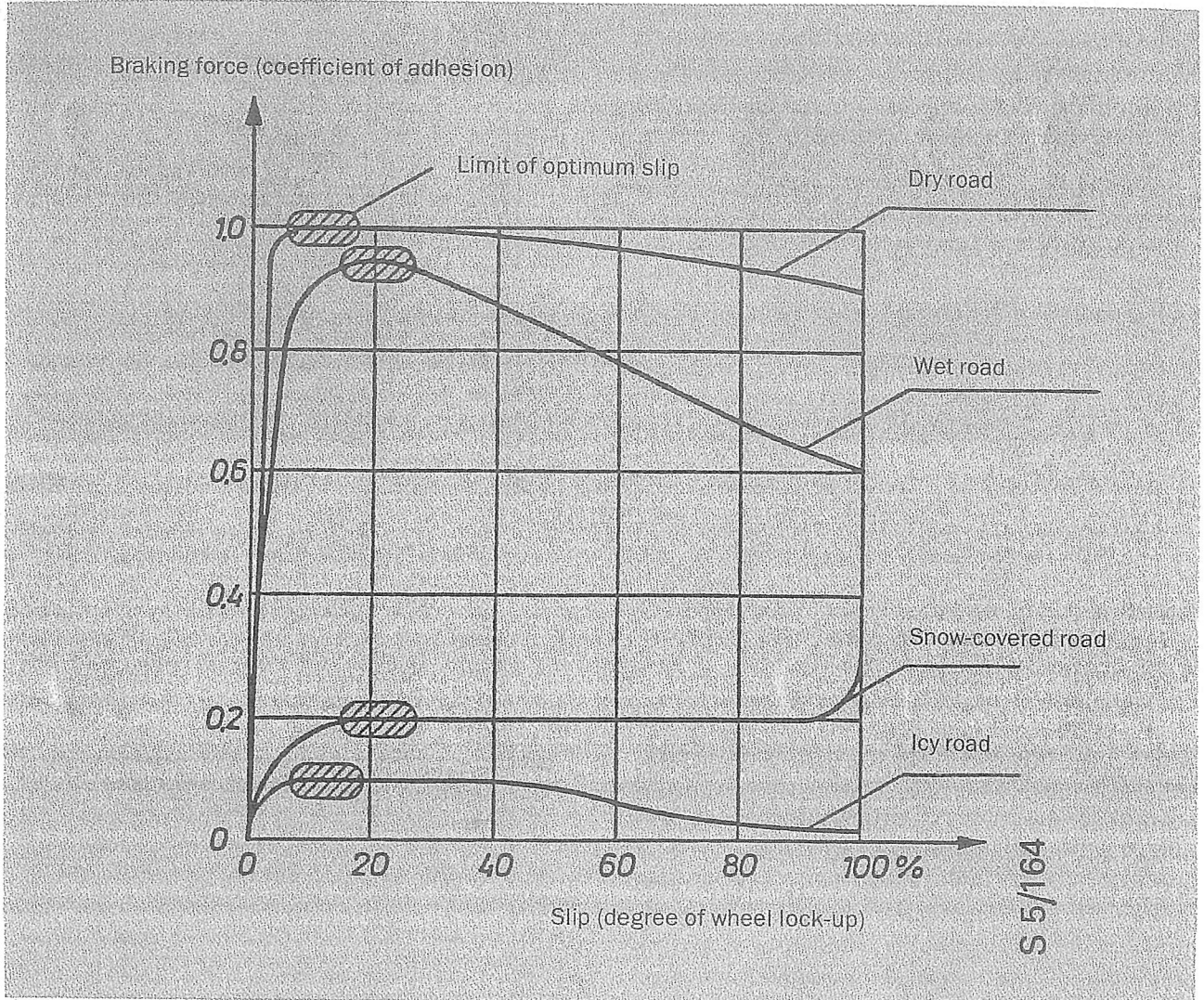
Both curves have been plotted on this next chart, which also shows the range within which the ABS system is operative. During braking, the system allows the braking force to increase to a point just before the limit of optimum slip and then prevents it from increasing further. The system modulates the hydraulic pressure to keep the braking force as close as possible to the optimum value (the limit of optimum slip) regardless of the pressure applied to the brake pedal.

Because the ABS system prevents the degree of slip from exceeding the limit of optimum slip, the car never enters the unstable zone. At the same time, some lateral force is preserved to ensure that steering control can be retained (curve II).



500-4 Technical description

The relationship between braking force and slip is influenced by a variety of factors including the properties of the road surface and the tyre type, tread pattern and pressures. Although variations in these factors will affect the precise points through which curves I and II are plotted, the basic shapes of the curves will not change.

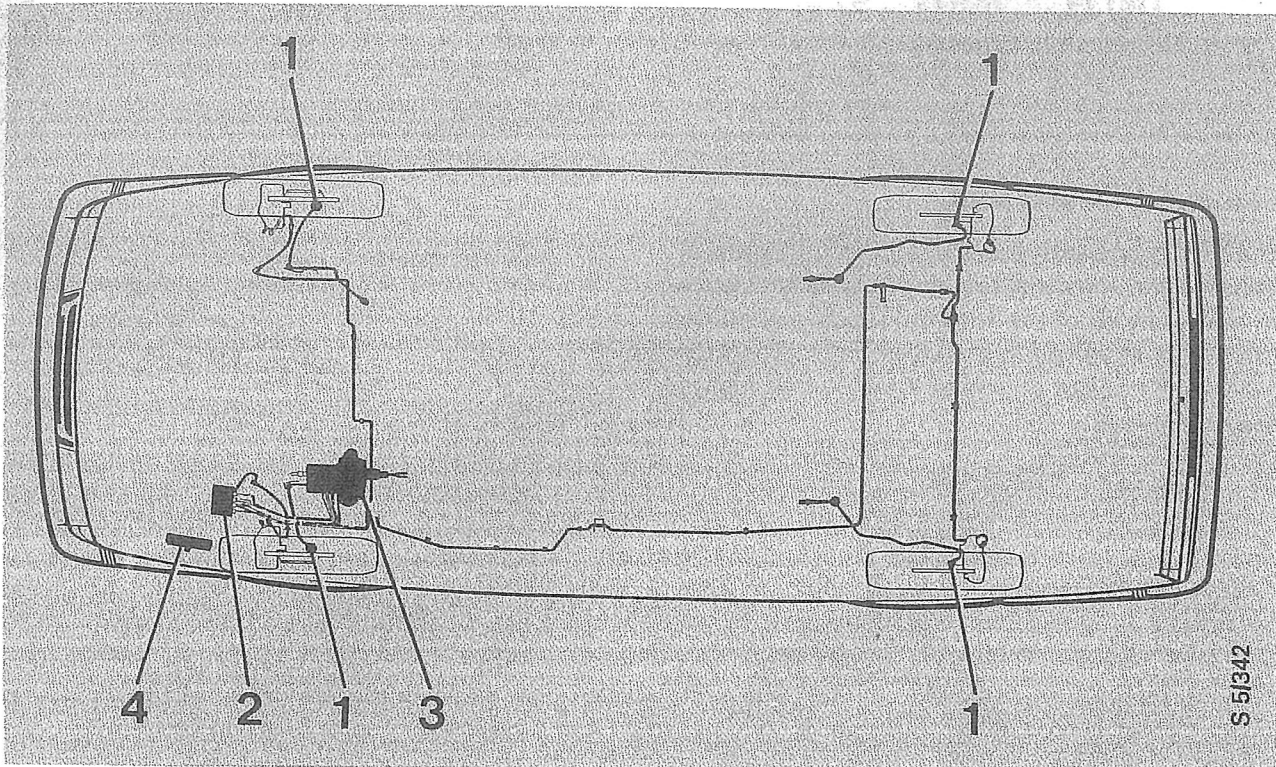


Graph showing coefficient of adhesion as a function of tyre slip (degree of wheel lock-up) for different road surfaces.

Principles of operation

The ABS system has four principal components:

- A set of four wheel sensors
- The valve block
- The hydraulic unit
- The electronic control unit (ECU)



Principal components of the ABS system

- 1 Wheel sensors
- 2 Valve block
- 3 Hydraulic unit
- 4 ECU

Saab's ABS system is a triple-circuit system (ABS + 3), with split circuits and individual monitoring and control for each front wheel and for the two rear wheels together.

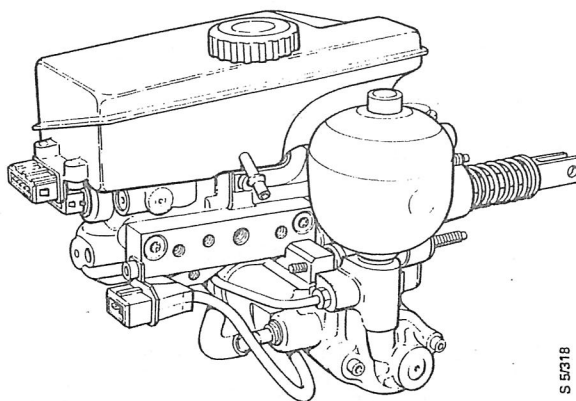
Signals from the four wheel sensors are sent to the ECU, which continuously monitors the speed, acceleration and deceleration of the wheels, the road speed and tyre slip. If a wheel is about to lock up, the ECU sends signals to the solenoid valves for the wheel concerned, thereby modulating the pressure in the brake circuit for the wheel to provide optimum braking effect and hence achieving the maximum coefficient of adhesion.

Apart from the electronically controlled features of the ABS system, there are two main differences between ABS brakes and the conventional braking system on a Saab 900:

- Triple-circuit system: individual circuits for each front wheel and one circuit for the rear wheels
- Brake servo unit hydraulically operated

Hydraulic unit

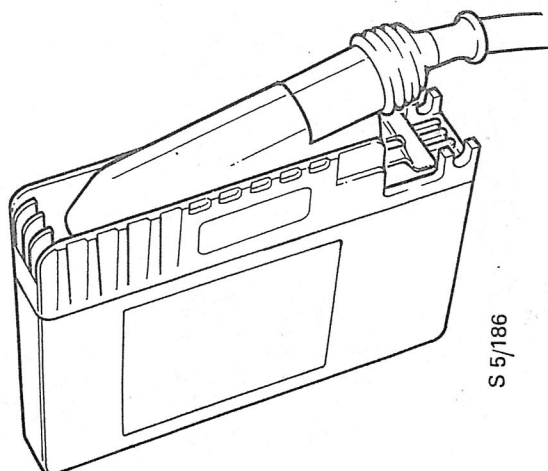
The hydraulic unit replaces the conventional master cylinder and vacuum-operated servo. This compact unit incorporates a master cylinder, an hydraulic servo cylinder, the brake fluid reservoir and an independent pump for hydraulic pressure.



S 5/318

Electronic control unit

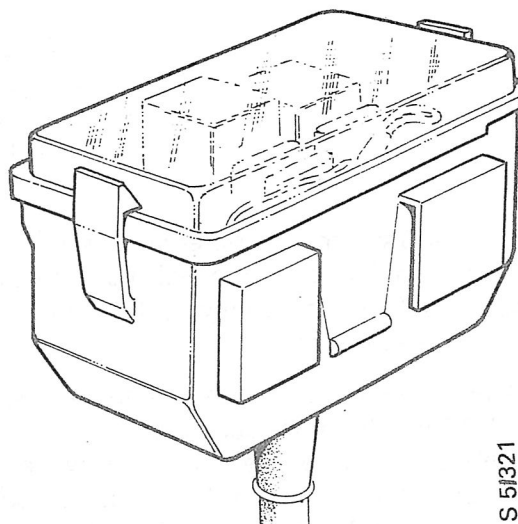
The ECU processes the signals from the wheel sensors and, on detecting any lock-up tendency in one or more of the wheels, sends signals to the solenoid valves in the valve block. The ECU module is housed on top of the LH wing, inside the engine bay.



S 5/186

Relay and fuse panel

The relays and fuses for the ABS system are housed in a special fuse panel, fitted beside the ECU. Inside the fuse panel are a system relay and fuse for the ECU, a relay and fuse for the pump motor, and an additional fuse for the ECU.



S 5/321

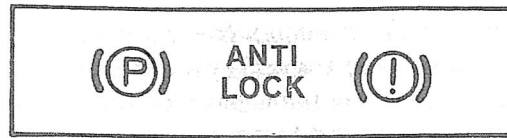
Brake-warning and ABS-warning lights

As on cars not equipped with ABS braking, the brake warning light will come on if the level in the fluid reservoir falls below the MIN mark. However, this light and the ABS warning light will both come on in the event of a pressure drop in the accumulator.

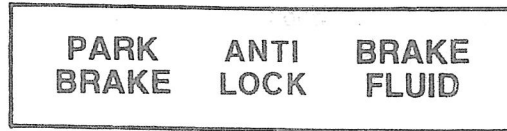
The ABS warning light will also come on:

- in the event of a further drop in the level of fluid in the reservoir
- in the event of a malfunction in the ECU
- in the event of a break in circuit continuity
- in the event of weak signals being received from the wheel sensors

The ABS system is always inoperative when the ABS warning light is on.



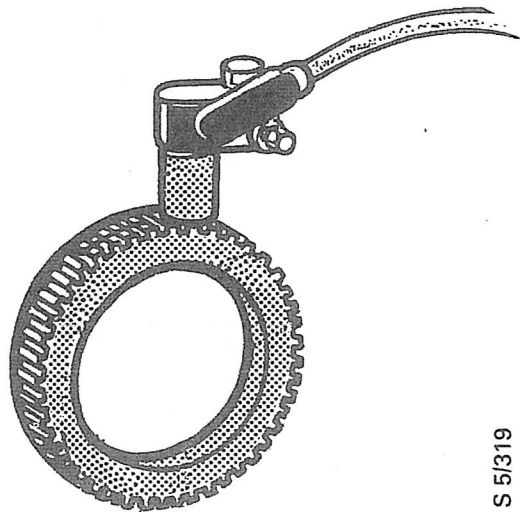
Or



S 5/341

Front wheel sensors and sensor wheels

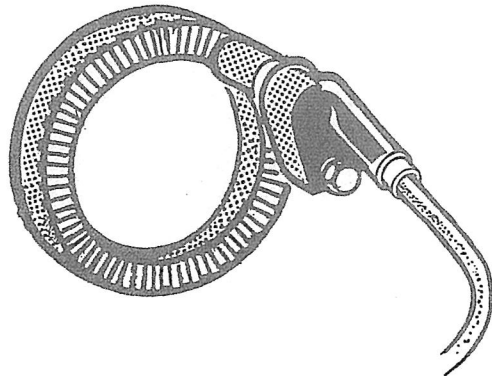
The front wheel sensors are orientated radially relative to the toothed sensor wheels and operate on the same principle as a generator. Each time a tooth on the rotating sensor wheel passes the sensor, it distorts a magnetic field, causing a signal to be sent to the ECU, which processes the signals to produce the control information it requires, such as wheel speed retardation and slip.



S 5/319

Rear wheel sensors and sensor wheels

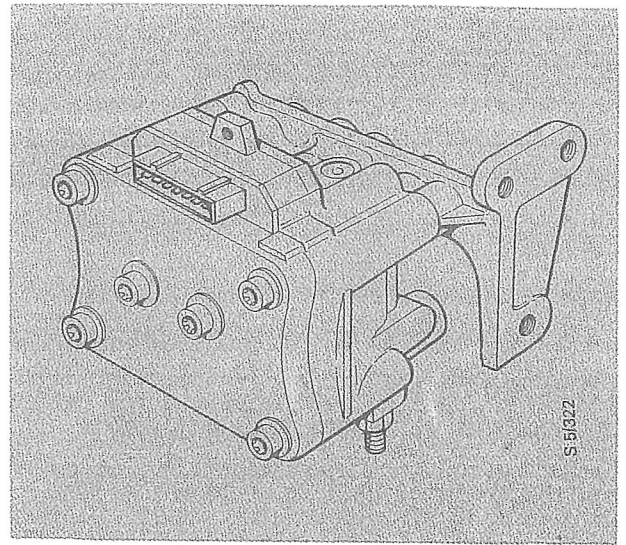
The rear wheel sensors are orientated axially relative to the toothed sensor wheels; the toothed wheels are therefore of a different design to those for the front wheels, although they operate in exactly the same way.



S 5/320

Valve block

The valve block modulates the pressure to the brake calipers when the ABS system is operative. The valve block contains six solenoid valves: three inlet valves and three outlet valves. Each brake circuit thus has one inlet and one outlet valve.



Overview of operating principles

- The brake servo unit is not vacuum operated but hydraulic. The hydraulic pressure is generated by an independent pump and stored in the accumulator.
- The central component of the ABS system is the hydraulic unit incorporating the brake servo unit and master cylinder.
- The front-wheel brakes are activated by a tandem plunger in the master cylinder.
- The rear-wheel brakes are activated via the servo cylinder by the pressure stored in the accumulator.
- The accumulator, comprising two chambers separated by a diaphragm, stores the energy generated by the pump in the form of pressure. Brake fluid acts on one side of the diaphragm and the other side is connected to a sealed chamber containing nitrogen. Fluid under pressure generated by the electric pump flows through a non-return valve to the diaphragm inside the accumulator. This causes the nitrogen to be compressed, creating the space required for storage of the hydraulic energy.
- The ABS system is supervised by an electronic control unit that detects any tendency for a wheel to lock up.
- A sensor at each wheel continuously senses the speed of rotation of the wheel.
- Each time a tooth on the sensor wheel passes the sensor, the magnetic field is distorted, causing an electric signal proportional to the speed of rotation of the wheel to be generated. These signals are transmitted continuously to the ECU, which processes the signals from the four sensors and computes a value known as the reference speed. The individual signals from each sensor (individual wheel rpm) are then compared with this reference speed.
- In the event of a tendency being detected for any of the wheels to lock up, the speed indicated by the signal from the sensor for that wheel will differ noticeably from the reference speed.
- The hydraulic pressure in the individual brake circuits is modulated by the solenoid valves in the valve block, which in turn are controlled by signals from the ECU.
- Automatic brake-pressure modulation continues until the ECU receives signals confirming that the speed of all the wheels is decreasing at the same rate; i.e., that the wheel speeds are the same as the reference speed.
- Up to 12 brake-pressure modulation cycles are possible per second.

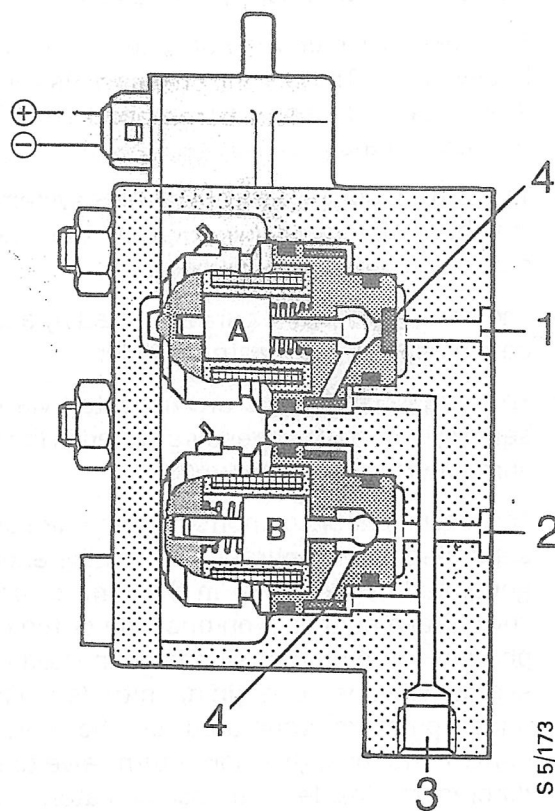
Safety overview

The logic system controlling the solenoid valves in the ABS system is such that the valves will assume their rest (de-energized) positions in the event of any disruption in their power supply. The ABS system will cease to operate the moment the ECU senses any departure from normal operating conditions; for instance:

- low fluid level in the reservoir
- low pressure in accumulator for servo cylinder
- break in continuity in any electrical circuit
- weak signals from wheel sensors
- malfunction in ECU

Any of these events will cause the ABS warning light to come on. In some conditions, e.g. drop in accumulator pressure or fall in fluid level in the reservoir, the brake warning light will also come on, as these affect braking performance, regardless of whether the ABS system is operative.

If the ABS system should become inoperative for any reason, all the solenoid valves will be de-energized and the braking system will operate in the same way as a conventional system. If the pressure in the accumulator and hence the servo cylinder should be lost, two separate, non-power-assisted brake circuits will always remain for application of the front-wheel brakes.

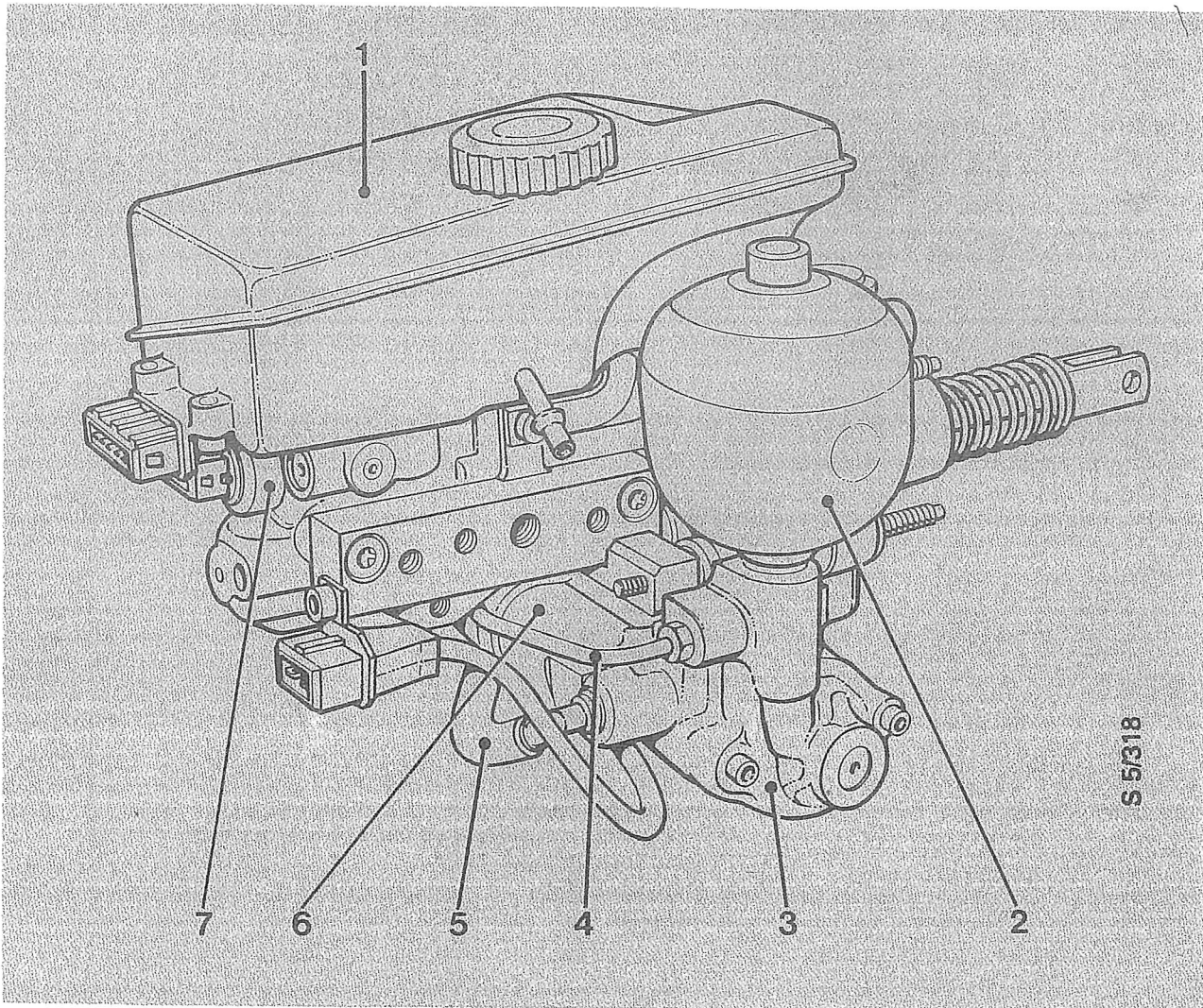


Valve block

- A Inlet valve
- B Outlet valve
- 1 From master cylinder
- 2 To brake fluid reservoir
- 3 To brake circuit
- 4 Filter

Components

Hydraulic unit



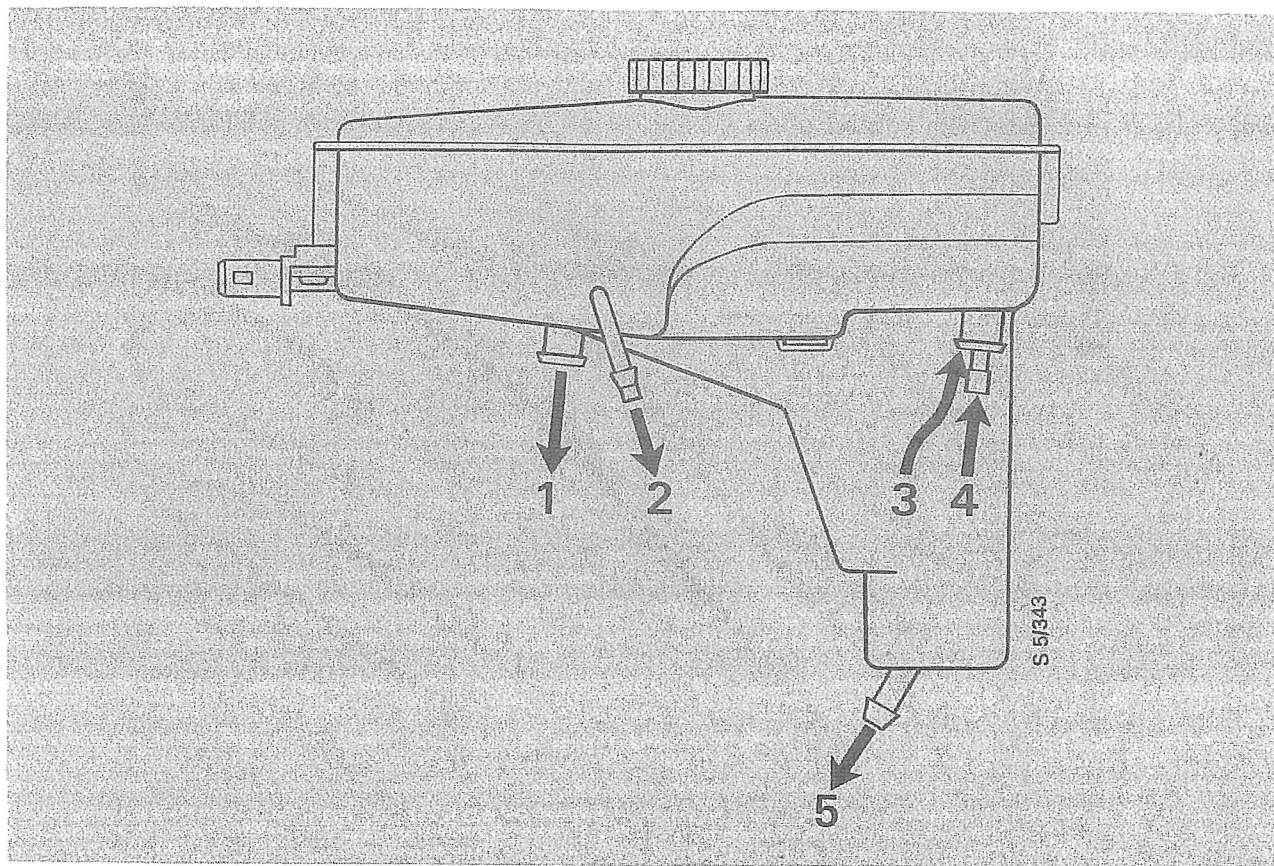
Hydraulic unit

- 1 Brake fluid reservoir
- 2 Accumulator
- 3 Pump
- 4 Pump delivery pipe
- 5 Pump inlet hose
- 6 Electric motor
- 7 Main valve

The following components are incorporated in the hydraulic unit:

- The servo cylinder, which provides power assistance to braking and brake pressure to the rear wheels
- The master cylinder, which operates on the same principle as a conventional brake master cylinder
- The main valve, which supplies brake fluid from the servo cylinder to the master cylinder during ABS-modulated braking

Brake fluid reservoir



Brake fluid reservoir

- 1 To master cylinder
- 2 To clutch cylinder(Manuals only)
- 3 From servo cylinder
- 4 From valve block
- 5 To pump

There are three chambers inside the reservoir:

- One for the master cylinder feeding the brake circuits to the front wheels
- One supplying fluid to the pump and thence to the circuit for the rear wheels and to the servo unit
- One for the clutch cylinder (manual cars only)

A safety function is incorporated in the design of the chambers. In the event of a leak in one of the front-wheel circuits, because the reservoir cannot be drained completely sufficient fluid will always remain to operate the rear-wheel brakes. If a leak occurs in the circuit for the rear wheels, it will still be possible to apply the front-wheel brakes, although without power assistance, therefore requiring greater pedal pressure.

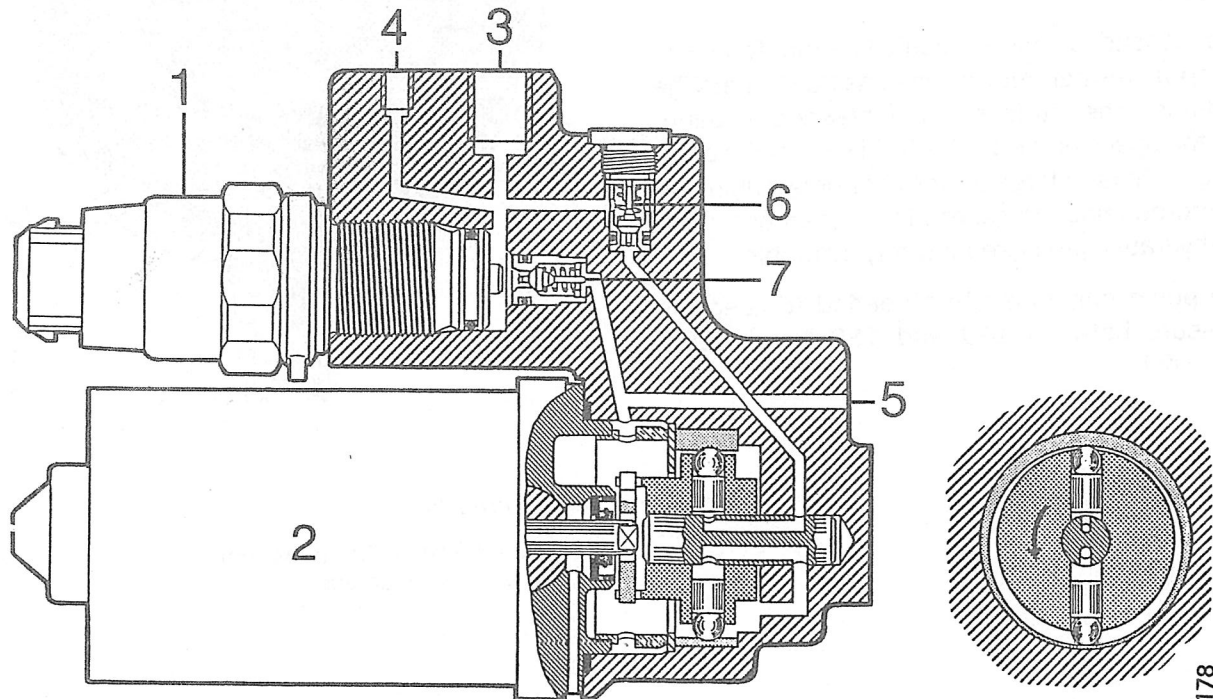
The return flow from the valve block, servo cylinder and master cylinder is directed to the second chamber, thereby damping the flow of fluid. This prevents any fluid with entrained air bubbles being drawn into the system.

The reservoir holds approximately 0.8 litre, but the fluid level must be kept between the MAX and MIN marks on the side of the reservoir. The reservoir is mounted on the hydraulic unit, the hydraulic connections between them consisting of two special rubber bushes. A hose also runs from the reservoir to the pump inlet. The filter cannot be replaced separately.

The reservoir incorporates a fluid level indicator, which switches on the brake warning light if the fluid level drops below the MIN mark. A further fall in the fluid level initiates a signal to the ECU, which cuts out the ABS system and switches on the ABS warning light.

Pump inlet hose

The hose from the reservoir to the pump is connected to the pump by means of a plastic elbow and a rubber bush.



S 5/178

Pump motor

- 1 Pressure switch
- 2 Pump motor
- 3 To accumulator
- 4 To servo cylinder
- 5 From fluid reservoir
- 6 Non-return valve
- 7 Relief valve

Electric motor

The motor for the pump is fitted with a two-pin electrical connector and is switched on and off by the pressure switch. It cannot be replaced separately, as it is an integral part of the pump unit.

Pump

The pump pumps brake fluid from the reservoir to the inlet at the bottom of the accumulator. It is secured by rubber mountings on the hydraulic unit and has a working pressure range of 140 - 180 bar (2030 - 2610 psi).

For safety reasons, the pump housing incorporates a relief valve that opens at 210 bar (3045 psi), releasing pressure to the inlet side of the pump.

The pump can be replaced only as a complete unit with the electric motor.

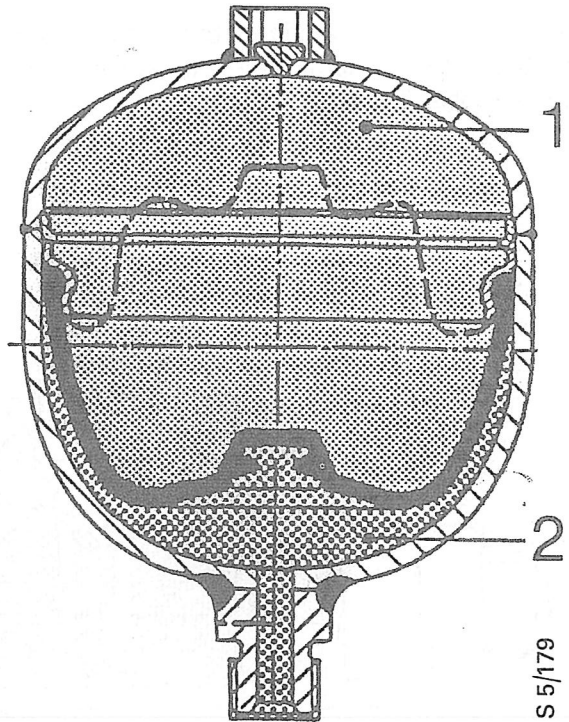
Accumulator

The accumulator, which is bolted onto the pump housing, comprises two chambers separated by a rubber diaphragm.

One of the chambers is sealed and charged with nitrogen to a nominal pressure of 80 bar (1160 psi) at 20°C (68°F). The lowest permissible pressure is 40 bar (435 psi); if the pressure falls below this value, the accumulator must be replaced.

The second chamber receives fluid from the pump via the non-return valve. As fluid enters the chamber, the nitrogen is compressed, expanding the space on the brake-fluid side of the diaphragm. Thus, a large quantity of brake fluid can be stored under pressure in this chamber, making hydraulic pressure instantly available.

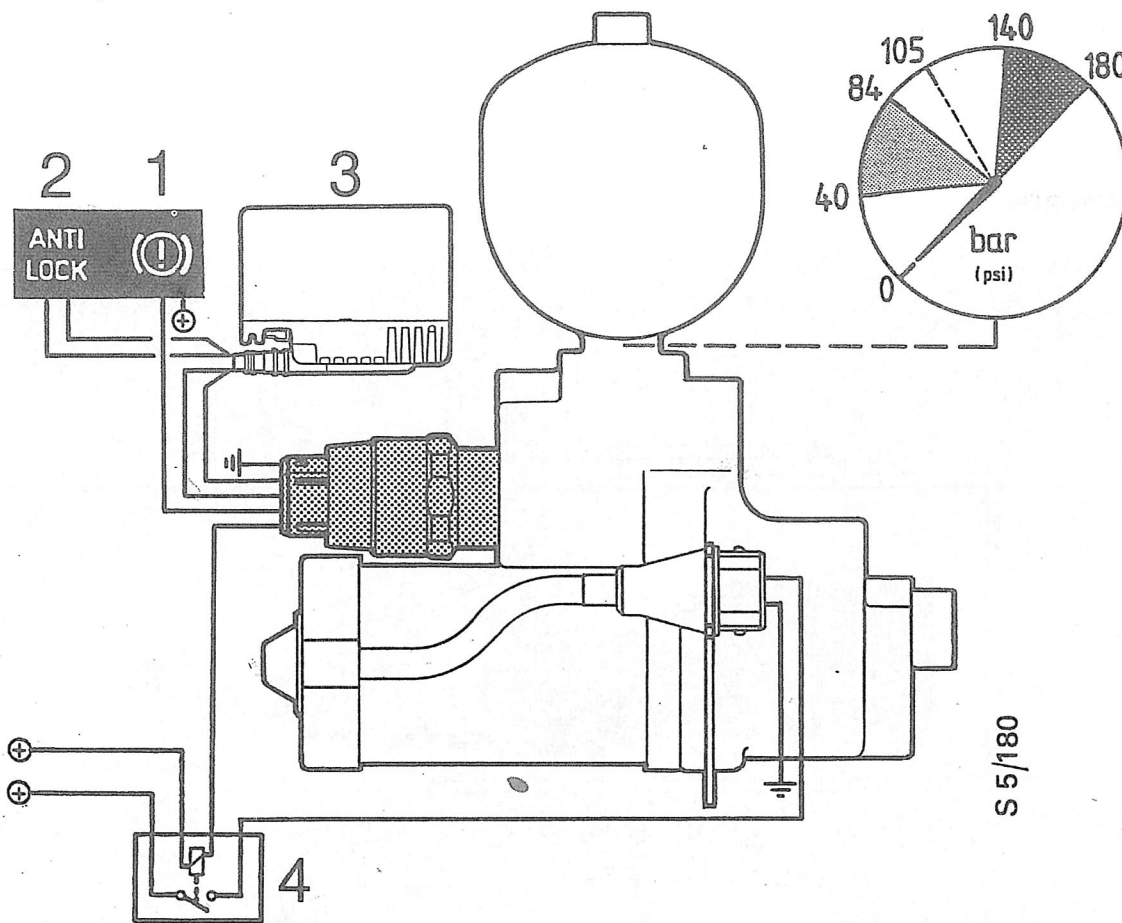
The pump only runs when needed to keep the pressure between 140 and 180 bar (2030 - 2610 psi).



Accumulator

- 1 Gas-filled chamber (nitrogen)
- 2 Brake-fluid chamber

Pressure switch



S 5/180

- 1 Brake warning light
- 2 ABS warning light
- 3 ECU
- 4 Pump motor relay

The pressure switch has two functions:

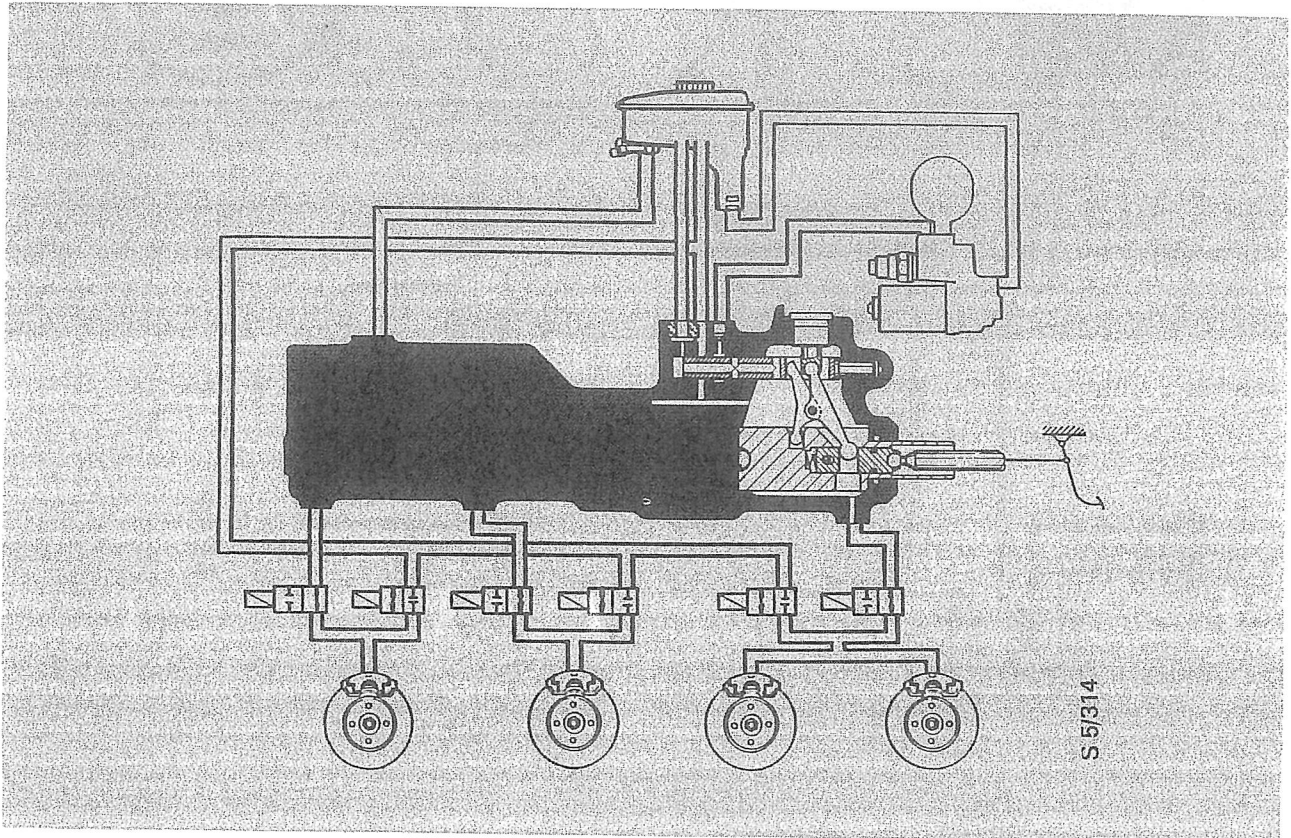
- To switch the pump motor on when the pressures falls to 140 bar (2030 psi) or to switch it off at 180 bar (2610 psi)
- To switch on the brake warning light if the accumulator pressure falls below 105 bar (1523 psi) and, at the same time, to cut out the ABS system and indicate this by switching on the ABS warning light.

The pressure switch is fitted inside the pump body and can be replaced separately.

Pump delivery pipe

The pressure in the pump delivery pipe, which links the pump to the servo cylinder, is the same as that in the accumulator.

Servo cylinder



Hydraulic unit and servo cylinder

The hydraulic servo cylinder replaces the conventional vacuum-operated brake servo and performs three functions:

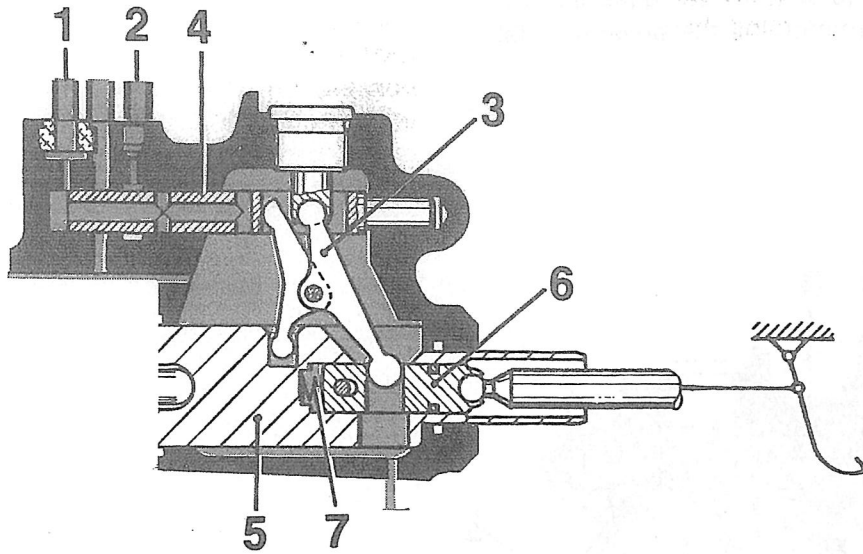
- To reinforce the driver's pedal effort
- To supply brake fluid to the circuit for the rear wheels
- Via the master valve, to supply brake fluid to the front-wheel circuits during ABS modulation



Hydraulic pressure is transmitted to the servo cylinder from the accumulator via the control valve. The servo cylinder thus provides power assistance proportional to the force applied to the brake pedal. The control valve is governed partly by pedal effort and partly by the pressure in the servo cylinder.

Because the brake circuit for the rear wheels is connected to the servo cylinder, the rear-wheel brakes are applied by the accumulator pressure built up in the servo cylinder via the control valve.

Brakes off

In the rest position (brakes off), the control valve is closed, shutting off the flow of fluid from the accumulator, and the return passage to the reservoir is open.



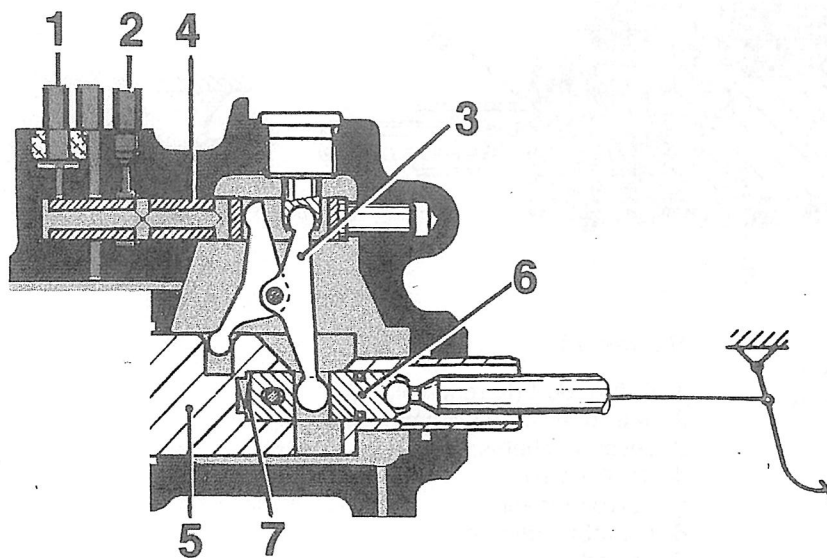
 = Accumulator pressure
 = Atmospheric pressure




Brakes off

- 1 Return port (to reservoir)
- 2 Inlet port (from accumulator)
- 3 Lever mechanism
- 4 Control valve
- 5 Servo plunger
- 6 Actuating plunger
- 7 Spring

Brakes applied (1)

As the brake pedal is depressed, the actuating plunger (6) and the lever mechanism (3) move forward, the lower balls moving towards each other and the upper ones apart. This causes the control valve (4) to open the inlet port (2) from the accumulator, and to close the port for the return passage (1). Resulting pressure builds up in the servo cylinder, forcing the servo plunger (5) forwards, thereby reinforcing the driver's pedal effort.



-  = Accumulator pressure
-  = Servo pressure
-  = Atmospheric pressure

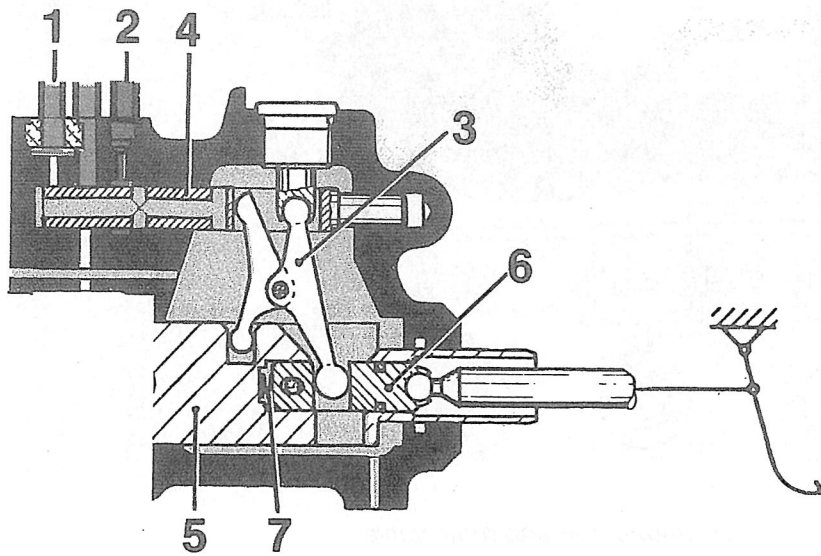
Brakes applied (1)




- 1 Return port (to reservoir)
- 2 Inlet port (from accumulator)
- 3 Lever mechanism
- 4 Control valve
- 5 Servo plunger
- 6 Actuating plunger
- 7 Spring

Brakes applied (2)

Pressure acts simultaneously between the servo plunger (5) and the actuating plunger (6), forcing the two components apart. The two lower ball joints are forced apart and the upper ones towards each other, thus closing the control valve inlet port (2) and keeping the port for the return passage (1) closed.

The control valve closes when the pressure acting on the actuating plunger develops a force equal to that applied to the pedal; the pressure in the servo cylinder is now proportional to the force applied to the pedal.



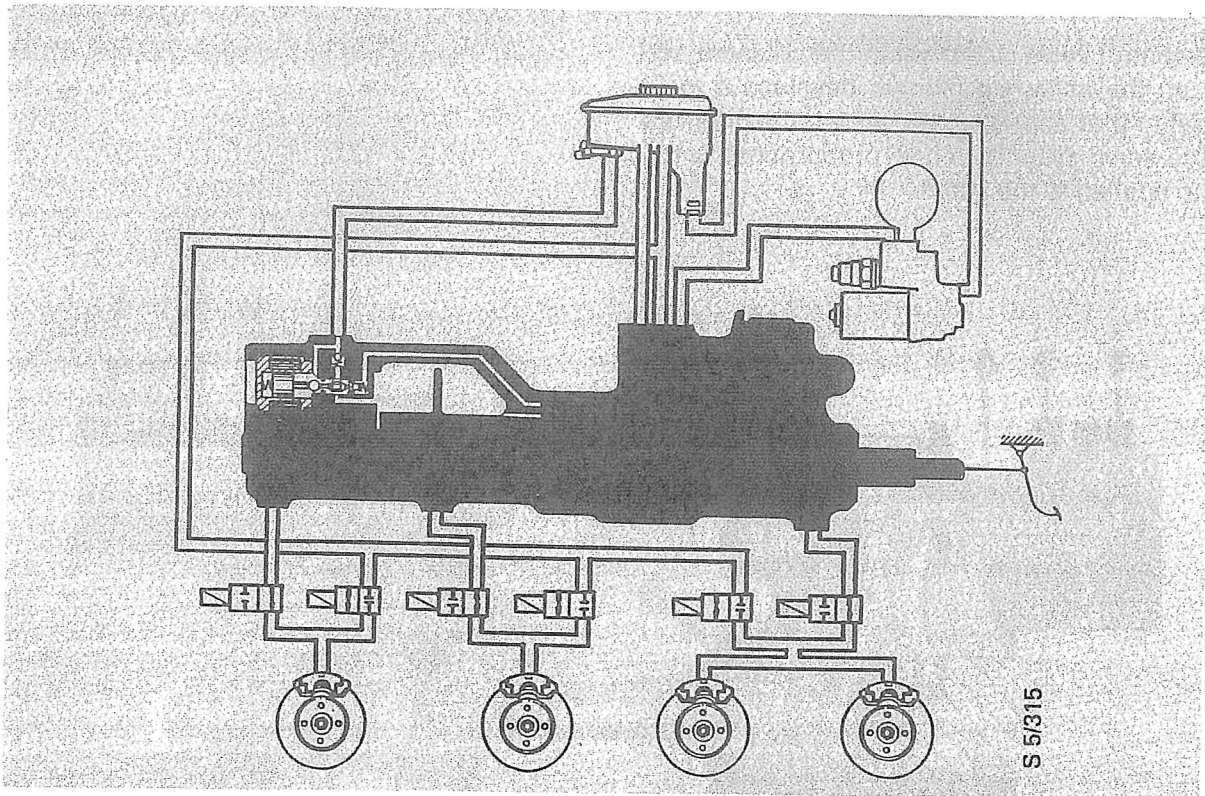
-  = Accumulator pressure
-  = Servo pressure
-  = Atmospheric pressure

Brakes applied (2)

- 1 Return port (to reservoir)
- 2 Inlet port (from accumulator)
- 3 Lever mechanism
- 4 Control valve
- 5 Servo plunger
- 6 Actuating plunger
- 7 Spring

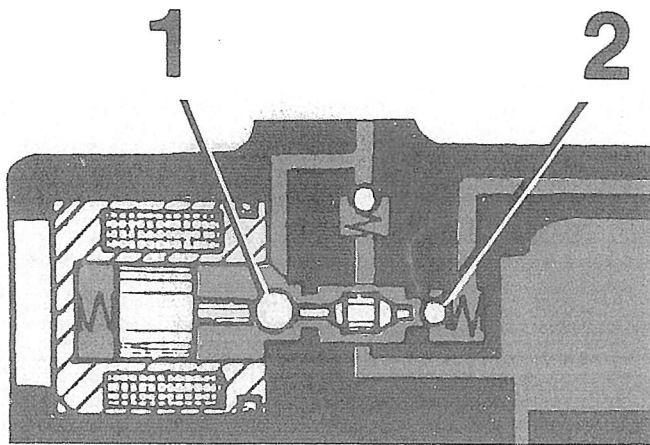
Main valve

The main valve is a solenoid valve fitted inside the master cylinder housing. The valve receives a signal from the ECU when ABS modulation cuts in.



Hydraulic unit and main valve

When ABS modulation ceases, the main valve closes the passage from the servo cylinder and opens the return passage to the reservoir.

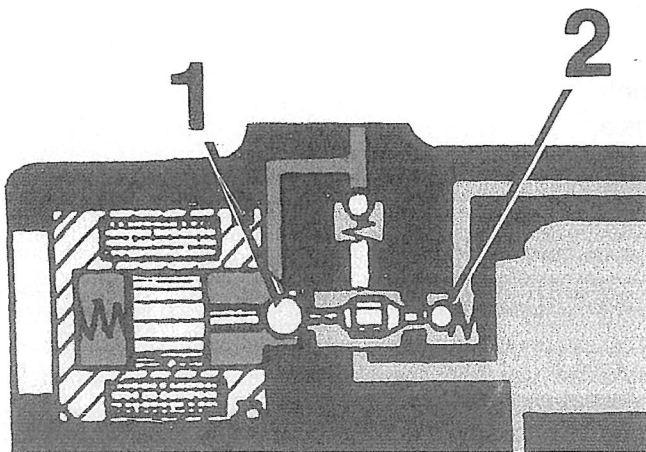


= Atmospheric pressure

Brakes off

- 1 Return passage to reservoir open
- 2 Passage from servo cylinder closed

When ABS modulation is initiated, the main valve opens the passage from the servo cylinder to the chamber behind the seals on the tandem plunger, at the same time closing the return passage to the reservoir. This allows a sufficient quantity of brake fluid to flow to the front-wheel circuits to replace the fluid returned to the reservoir via the outlet valves.



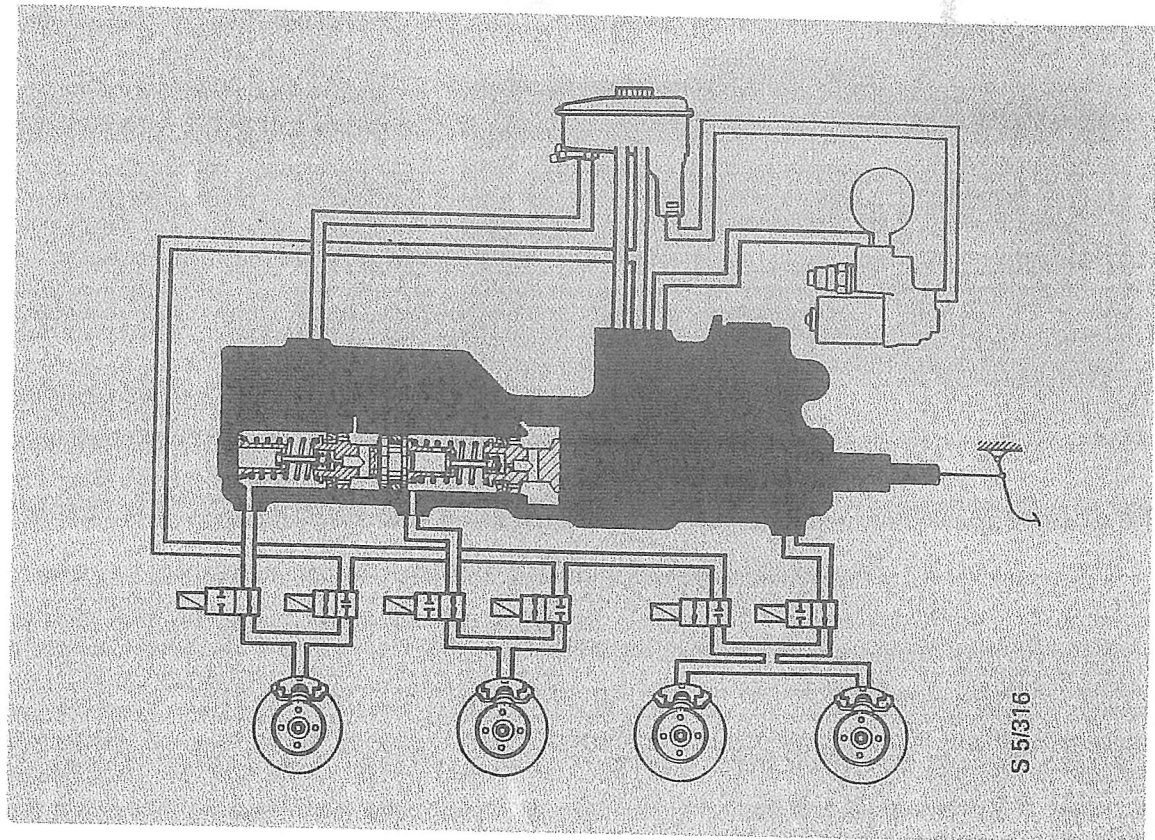
= Servo pressure
= Atmospheric pressure

ABS modulation

- 1 Return passage to reservoir closed
- 2 Passage from servo cylinder open

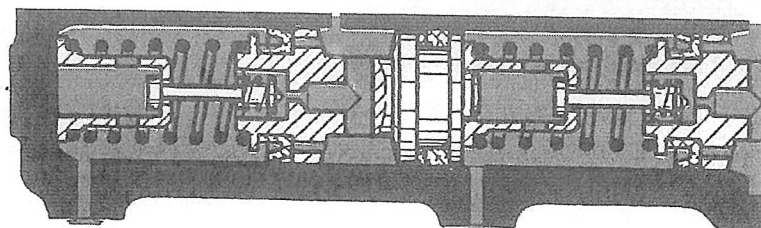
Master cylinder

The master cylinder is of the tandem type, serving two separate circuits for the front wheels.



Hydraulic unit and master cylinder

When the brakes are applied without any wheel-lock tendency, the master cylinder operates as a conventional master cylinder. A central valve in the cylinder admits brake fluid to the chamber in front of the plunger. When the brake pedal is depressed, this central valve closes.

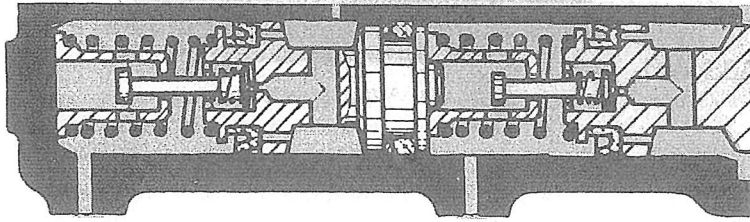



■ = Atmospheric pressure

Brakes off

Central valve open

On ABS-modulated braking, the chamber behind the seals is at the same pressure as that in front of the seals and in the servo cylinder. Brake fluid is thus forced back past the seals and into the valve block, whereupon the pressure to the wheel brakes is modulated.

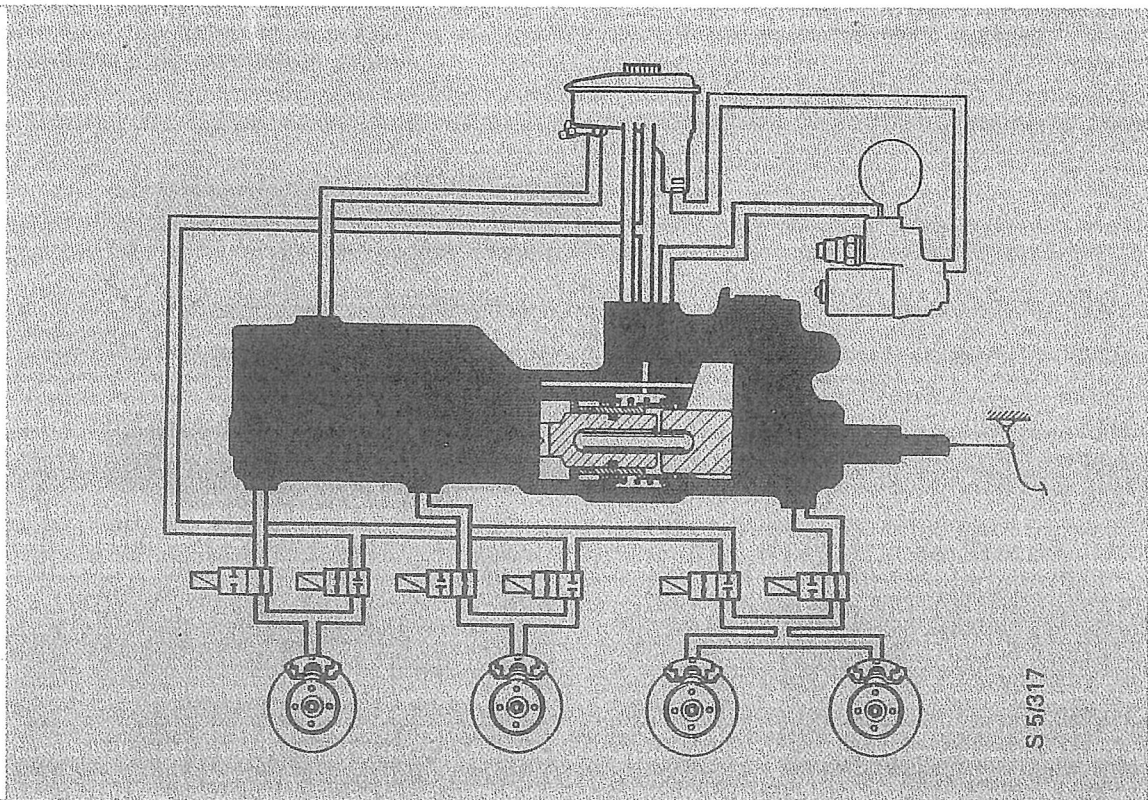


 = Servo pressure

ABS-modulated braking

Central valve closed

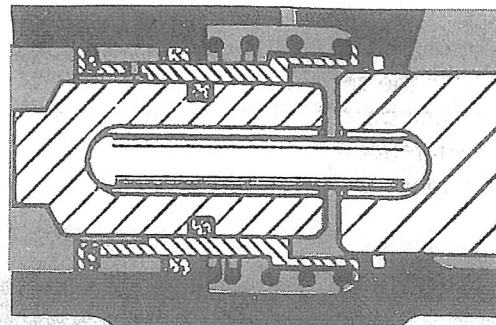
Positioning sleeve



Hydraulic unit and positioning sleeve

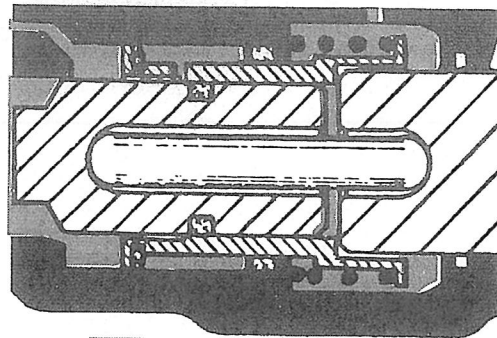
The pressure acting behind the seals also acts on the positioning sleeve, forcing back the sleeve, tandem plunger, servo plunger, actuating plunger and pedal pushrod. This backward movement, which can be felt in the brake pedal, ensures that sufficient pedal travel remains in the event of a leak in either of the front-wheel brake circuits.

In the absence of a positioning sleeve, the pedal would sink to the floor on initiation of ABS modulation.



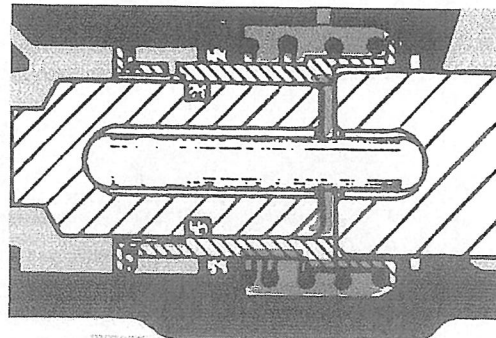
■ = Atmospheric pressure

Brakes off



■ = Atmospheric pressure

Brakes applied: no ABS modulation



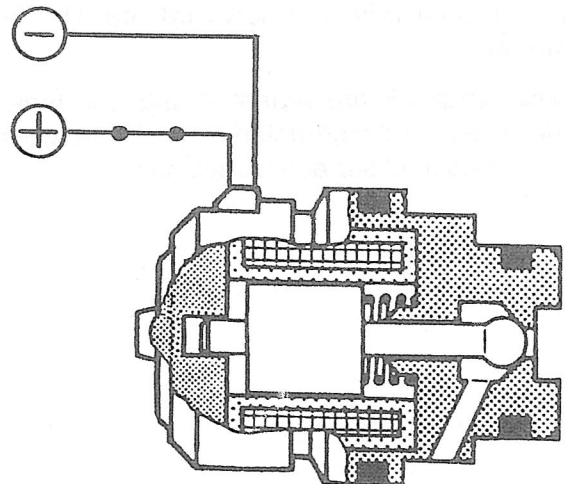
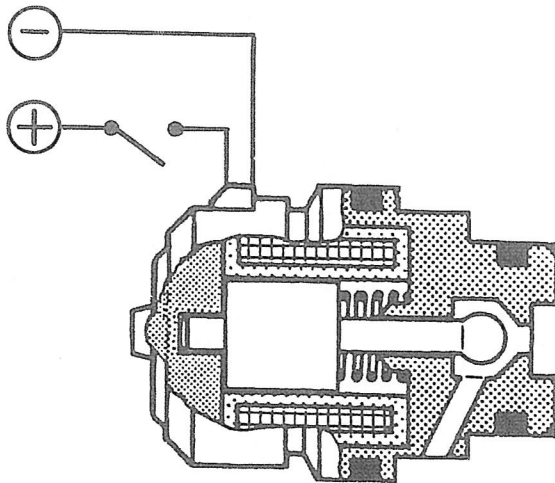
■ = Servo pressure
 ■ = Atmospheric pressure

Brakes applied: ABS modulation

Valve block

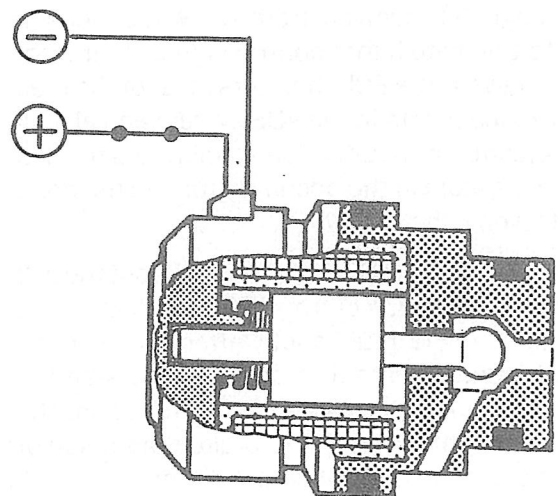
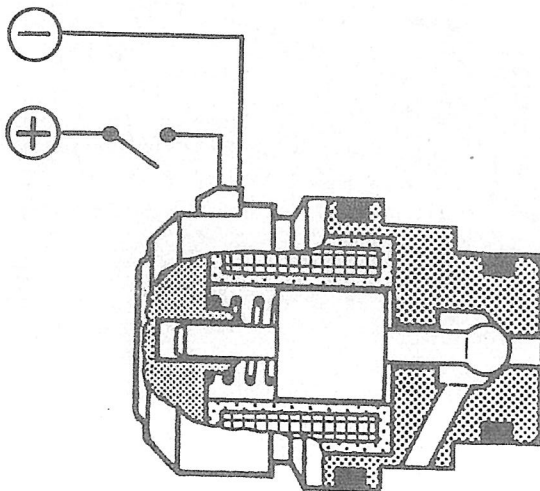
The valve block, mounted inside the engine bay on the LH wing, modulates the brake pressure to the wheel brakes during ABS-controlled braking.

There are six solenoid valves in the block: three inlet valves and three outlet valves. There is thus one outlet valve and one inlet valve for each circuit. When the brakes are off, the inlet valves are open and the outlet valves closed.



Inlet valve (normally open)
Open

Closed



Outlet valve (normally closed)
Closed

Open

When the ECU senses that a wheel is being retarded too much, it modulates the brake pressure to the wheel in three phases:

Phase 1: The ECU closes the inlet valve and opens the main valve. This prevents pressure being increased in the circuit to the wheel brake and allows brake fluid to flow upstream of the inlet valve for use in phase 3.

Phase 2: The ECU opens the outlet valve to release the pressure, thereby enabling the speed of rotation of the wheel to increase.

Phase 3: The ECU closes the outlet valve and opens the inlet valve, reducing the speed of rotation of the wheel. The 'used' fluid is replaced by fluid supplied from the servo cylinder via the main valve.

Phases 2 and 3 are repeated until the brake pedal is released or sufficient adhesion between the tyre and road surface is regained.

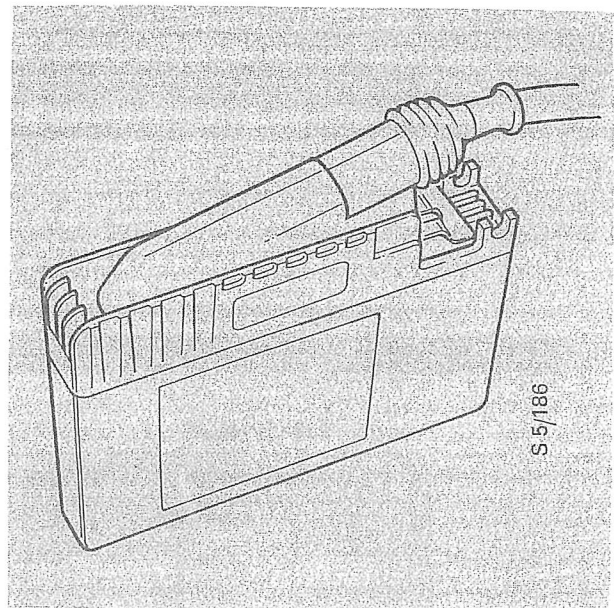
To ensure smooth braking, the valves open and close up to twelve times a second. In the event of a wire breaking or a short-circuit occurring, the valves will revert to their de-energized position, making conventional braking possible without ABS modulation.

Electronic control unit

The ECU, which receives power from the system relay, is a sealed module. No attempt must be made to open it.

The function of the ECU is to process the information (signals) received from the wheel sensors and to translate it into control signals to the solenoid valves. The ECU monitors most of the electrical components in the ABS system and also its own electronic circuitry. It also monitors the hydraulic pressure in the accumulator and the brake fluid level in the reservoir.

If a fault is detected, the ECU will cut out the ABS system, and switch on the ABS (Anti-lock) warning light. If the fault could affect the conventional braking system in the car, the standard brake warning light will also be switched on. This will occur if the level in the brake fluid reservoir drops too low or if the accumulator pressure falls outside the specified range.



The ECU will cut out the ABS system via the system relay on detecting a break in the circuit to the valve block, the main valve or wheel sensors. The ignition must be switched off and the fault rectified before the ABS warning light can be extinguished and the ABS system reactivated. Even if the fault has been rectified, the ABS warning light will remain on if the ignition has not been switched off.

The ABS system will also be inoperative if the level in the fluid reservoir falls too low or the hydraulic pressure drops below 105 bar (1523 psi). In either case, both the ABS warning light and the brake warning light will come on.

Weak signals from the wheel sensors will also cause operation of the ABS system to be suspended and the ABS warning light to come on. In such cases, when there is no system fault as such, as soon as the problem has been dealt with (e.g. topping up the fluid or restoring the hydraulic pressure) the system will become operative again and the ABS warning light will be extinguished.

When the ABS system is inoperative, the brake system will function like a conventional brake system.

The signals from the wheel sensors are processed by the ECU, which computes a reference speed for the vehicle. The individual signals are then compared with this reference speed. If any of the signals depart from this reference value, the modulating procedure will be activated, as follows:

Phase 1

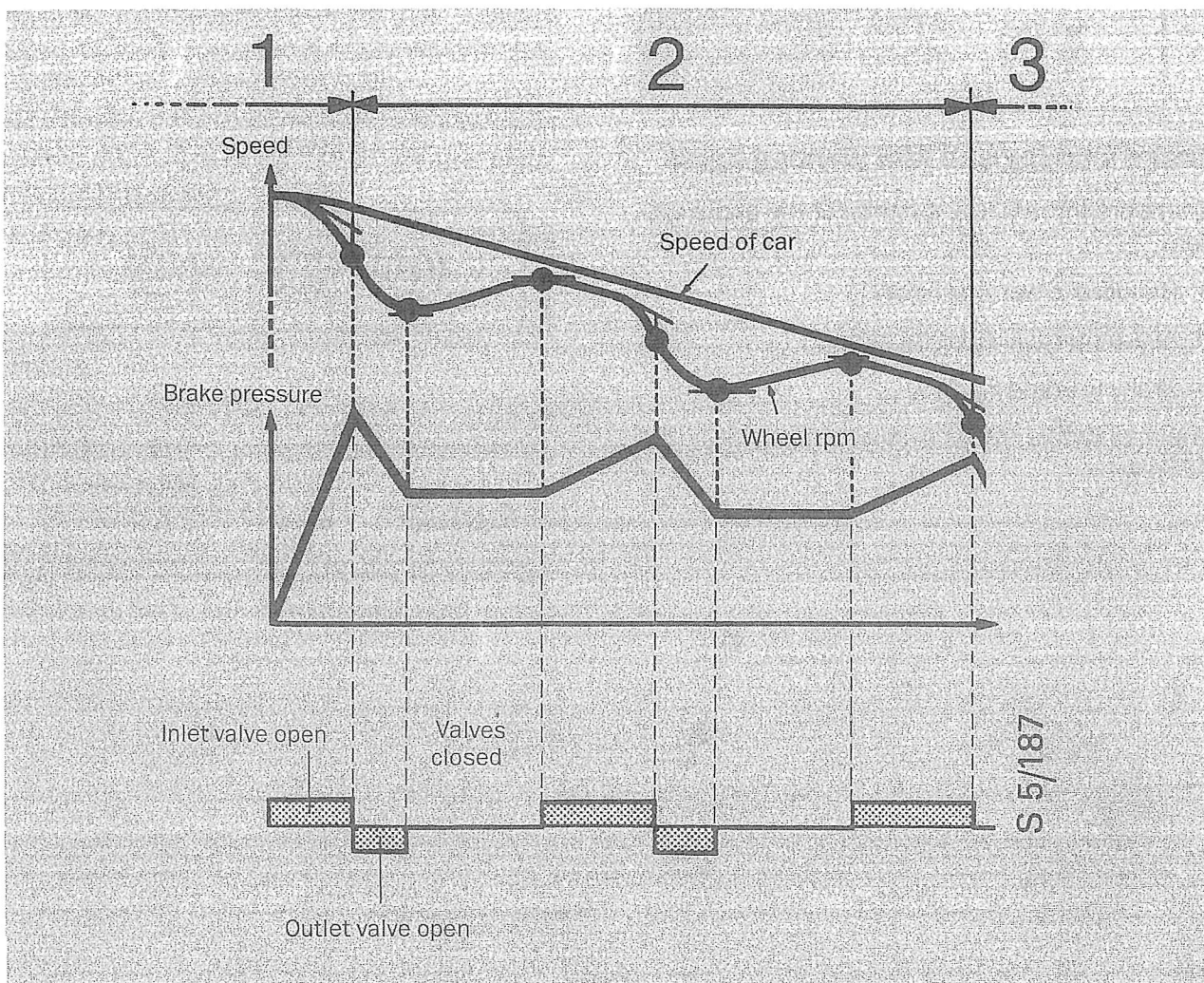
Lock-up tendency detected.
System prevents increase in brake pressure.

Phase 2

Initiation of ABS modulation.
Brake pressure reduced, held constant or increased, depending on increase or decrease in wheel rpm.

Phase 3

Tendency for wheel to lock gone.
Brake pressure increased depending on road adhesion checked in phase 2.

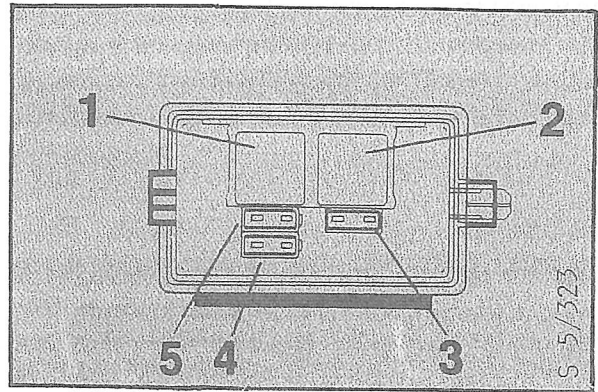


S 5/187

Relay and fuse panel

The relays and fuses for the ABS system are housed in a special fuse panel fitted alongside the ECU.

The fuse panel contains the system relay, with a fuse for the ECU, a relay and fuse for the pump motor and an additional fuse for the ECU.



Relay and fuse panel

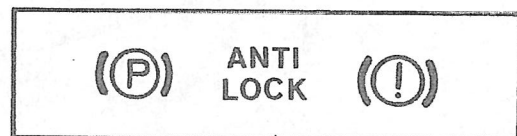
- 1 Relay, pump motor
- 2 Relay, ECU
- 3 Fuse, ECU (10 A, ABS)
- 4 Fuse, ECU (30 A, ABS)
- 5 Fuse, pump motor (30 A, Pump)

Brake warning and ABS warning lights

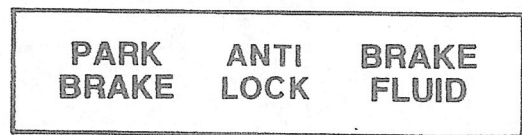
There are three warning lights for the brake system:

- Handbrake warning light (1)
- ABS (Anti-lock) warning light (2)
- Brake warning light (3)

The handbrake warning is not affected by the ABS system.



Or



1 2 3

S 5/341

Brake warning light on:

The brake warning light alone will come on if the level of fluid in the reservoir drops below the MIN mark.

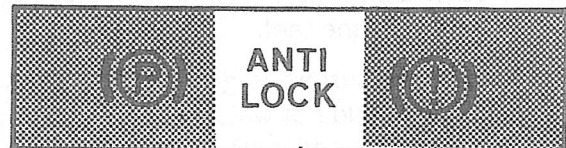
The brakes and ABS system will continue to operate normally.



ABS warning light on:

The ABS (Anti-lock) warning light alone will come on if the ECU detects a fault in the ABS system.

Conventional braking power will be available but the ABS system will be inoperative.



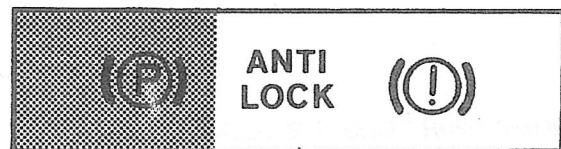
Brake warning and ABS warning lights both on:

If both of these lights are on, this indicates that the level in the fluid reservoir has dropped further or the pressure in the accumulator has dropped below 105 bar (1523 psi).

The ABS system will be inoperative but reduced braking effect will remain (i.e. greater pedal pressure required).

If the lights have come on because of insufficient fluid in the reservoir, leakage in one of the circuits is indicated. **The car must not be driven further until the fault has been found and rectified.**

If the lights have come on because of a pressure drop in the system, neither the power assistance nor the brake pressure to the rear wheels will be in proportion to pedal pressure. At worst, if no hydraulic pressure remains, there will be no power assistance and no rear-wheel braking. The front-wheel brakes will still operate normally but without power assistance.

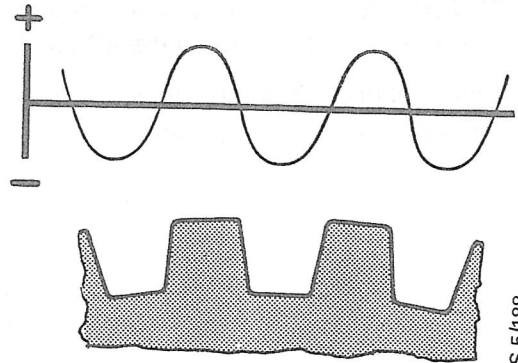
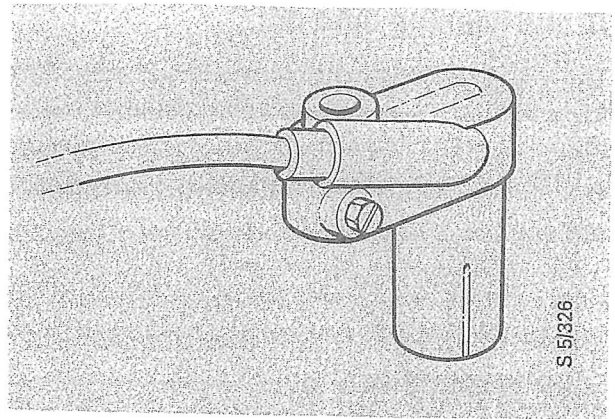


Wheel sensors

The wheel sensors operate on the generator principle, i.e. a current is induced in a conductor by distortion of the magnetic field surrounding it.

Distortion of the magnetic field around the sensor is caused by the toothed sensor wheel as it passes the sensor body: each time a tooth passes the sensor the magnetic field is reinforced. Each time a gap between the teeth passes the sensor, the magnetic field is weakened. Put simply, this means that positive (+) current is generated by each tooth and negative (-) current by each gap between the teeth.

Thus, alternating current is generated, the frequency and amplitude of which (the number of cycles per second and half the peak-to-peak value, respectively) will vary with the speed at which the sensor wheel is turning. From this signal, the ECU can deduce the speed of rotation of the wheel.



Sensor wheel

Front-wheel sensor and sensor wheel

Each sensor has a toothed sensor wheel, which is press-fitted onto the constant velocity joint. The sensor wheel cannot be removed.

The sensor is mounted vertically on the steering swivel member, i.e. orientated radially to the sensor wheel. The gap between the sensor and the sensor wheel can be adjusted by means of an adjusting sleeve and setscrew.

The sensor leads can be disconnected by means of a connector in the engine compartment.

Rear-wheel sensor and sensor wheel

Because the sensor is orientated axially relative to the sensor wheel, the design of the rear sensor wheels is different to that of the front ones. The sensor wheel is press-fitted onto the rear-wheel hub and cannot be removed.

The sensor leads can be disconnected by means of a connector underneath the rear seat.

ABS control: description of operation

The brake system can be in one of three conditions:

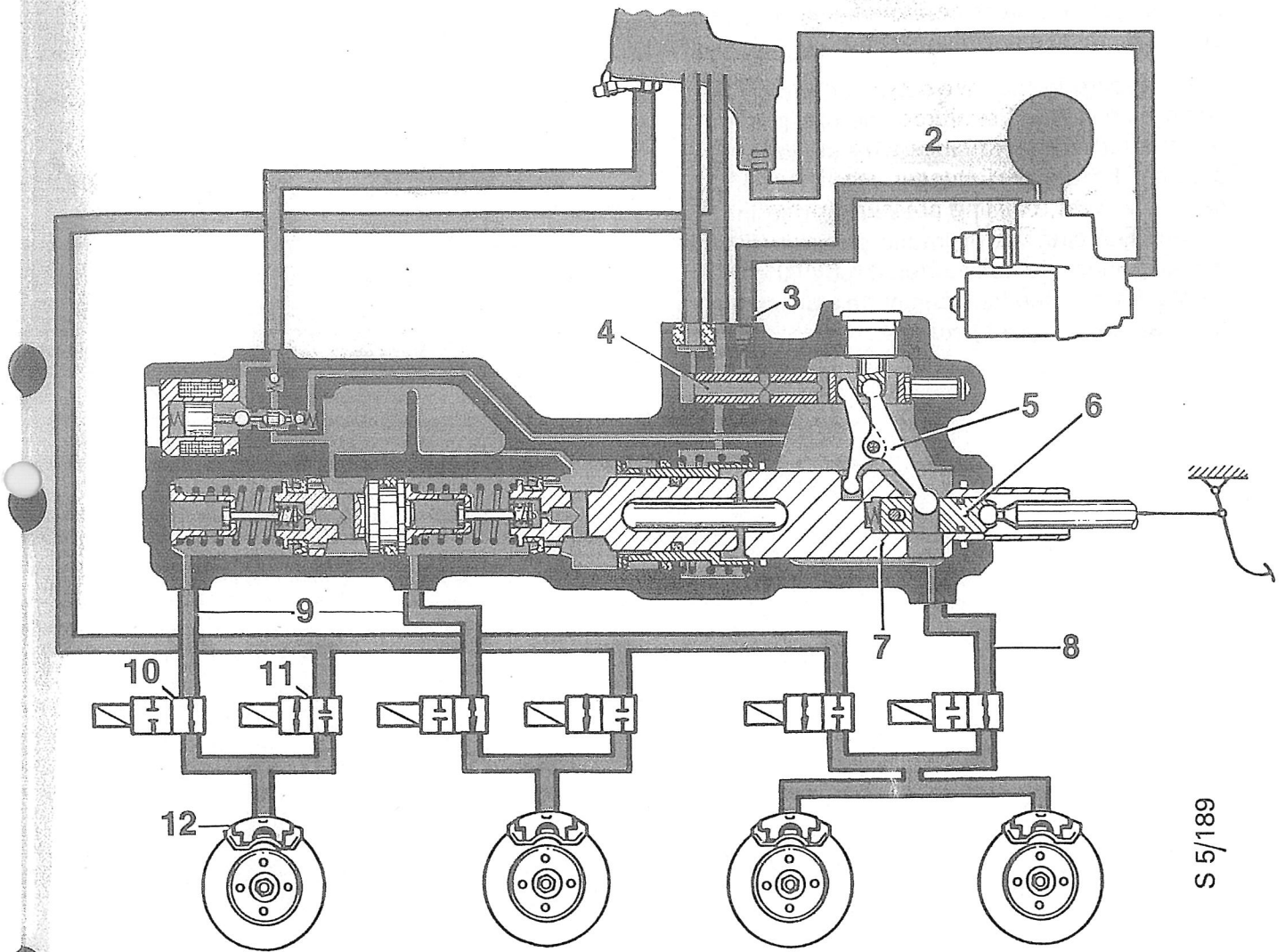
- 1 Brakes off
- 2 Brakes applied without ABS modulation
- 3 Brakes applied with ABS modulation

Brakes off

Hydraulic pressure is present between the accumulator and the control valve, keeping the feed passage between the accumulator and servo cylinder closed, and the return passage between the servo cylinder and fluid reservoir open.

The servo cylinder, master cylinder and other hydraulic components are all charged with fluid at atmospheric pressure.

The inlet and outlet valves in the valve block and the main valve are all in the rest (de-energized) position.



S 5/189

- = Accumulator pressure
- = Atmospheric pressure

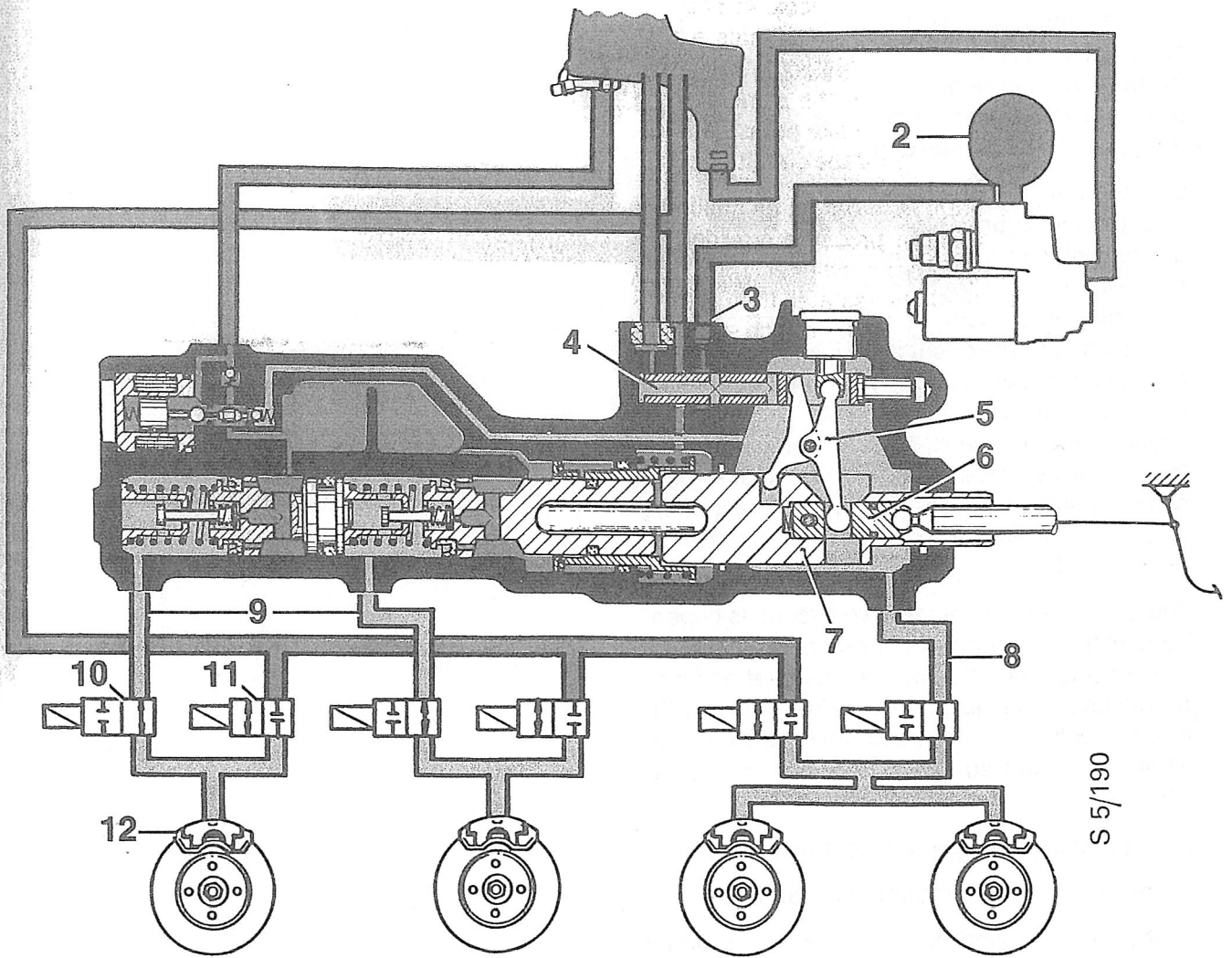
Brakes off

- 2 Accumulator
- 3 Pump delivery pipeconnection
- 4 Control valve
- 5 Lever mechanism
- 6 Actuating plunger
- 7 Servo plunger
- 8 Rear brake circuit
- 9 Front brake circuits
- 10 Inlet valve (in valve block)
- 11 Outlet valve (in valve block)
- 12 Brake caliper




Brakes applied without ABS modulation

When the brake pedal is applied and there is no tendency for any wheel to lock, the control valve admits hydraulic pressure from the accumulator proportional to the pedal pressure.

The pressure in the servo cylinder acts on the servo plunger and reinforces the braking force transmitted to the rear wheels. The servo plunger acts on the tandem plunger, which closes the central valves, causing pressure to rise in the front-wheel circuits. Hydraulic pressure to the wheel cylinders is transmitted through the valve block, in which the inlet and outlet valves are in the rest (de-energized) position.



S 5/190

-  = Accumulator pressure
-  = Master cylinder pressure (servo pressure)
-  = Atmospheric pressure

Brakes applied without ABS modulation

- 2 Accumulator
- 3 Pump delivery pipeconnection
- 4 Control valve
- 5 Lever mechanism
- 6 Actuating plunger
- 7 Servo plunger
- 8 Rear brake circuit
- 9 Front brake circuits
- 10 Inlet valve (in valve block)
- 11 Outlet valve (in valve block)
- 12 Brake caliper

Brakes applied with ABS modulation

ABS modulation is initiated when the system detects a tendency for a wheel to lock. As soon as the ECU detects from the input signals a tendency for a wheel to lock, it closes the inlet valve for the circuit in question. At the same time as the main valve opens, the brake pressure is reduced as the outlet valve for the circuit opens.

When ABS modulation is initiated, all braking is effected by accumulator pressure provided via the control valve in the servo cylinder. Thus, both front-wheel circuits will be isolated from the static pressure present in front of the tandem-plunger seals. The circuits are instead subject to dynamic pressure, caused by the brake fluid being forced past the seals to the chamber beyond, and thence to the valve block in which the pressure modulation takes place. The dynamic pressure also acts on the positioning sleeve, providing a nonpulsating reserve of pedal travel.

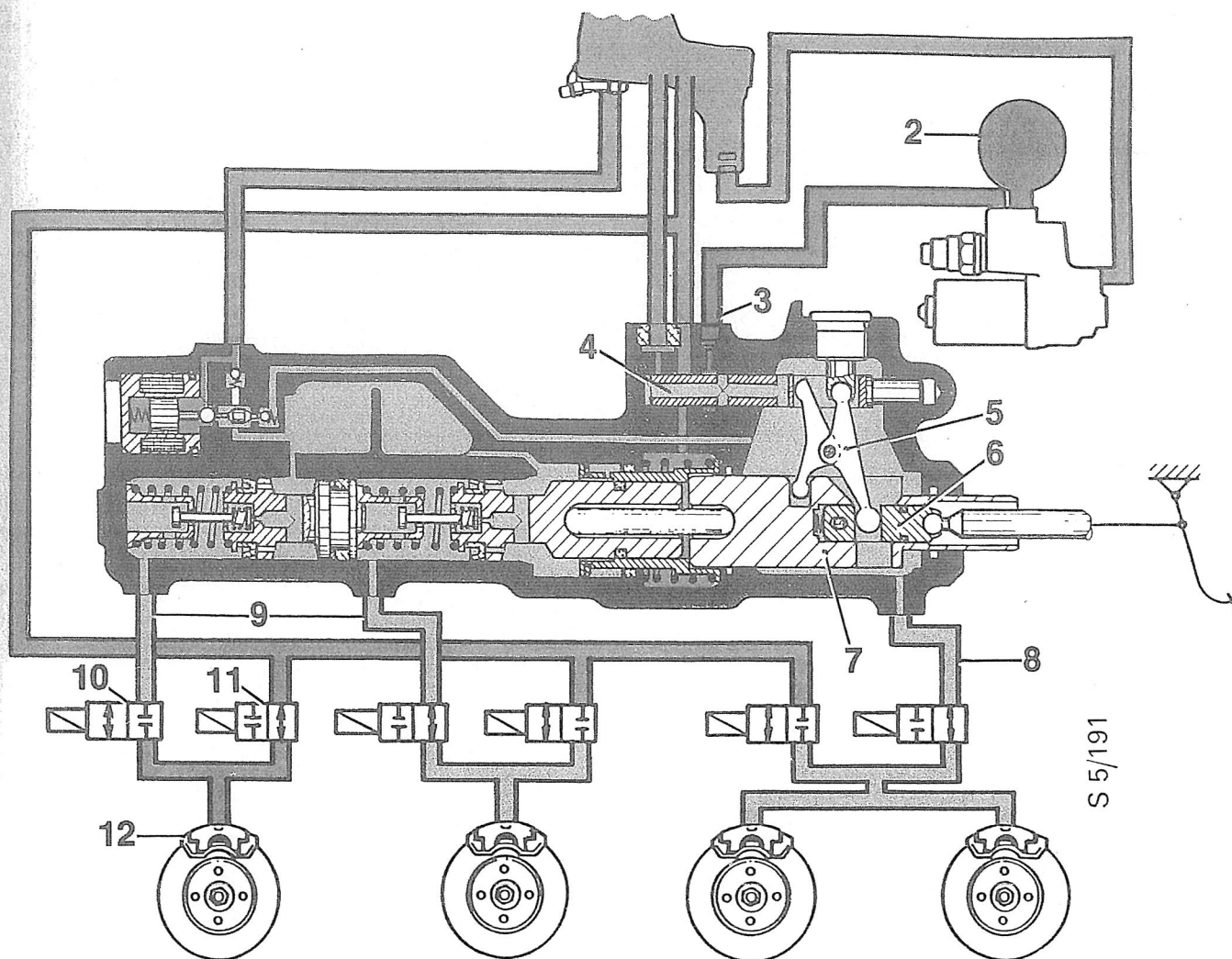
The pressure in the respective circuits is dependent on the retardation in wheel speed sensed by the sensors. The ECU controls the inlet and outlet valves so that maximum braking force (coefficient of adhesion) is maintained between the wheel and road surface (occurring at approx. 20% slip).

ABS-modulated braking will continue until:




- the car has been brought to a standstill
- the force applied by the driver to the brake pedal has been reduced to the level at which there is no danger of the wheels locking (determined by the relationship between braking force and the coefficient of adhesion).

Note that the pressure in the circuits can never exceed the pressure applied to the brake pedal by the driver.

The brake fluid returned to the reservoir via the outlet valves is replaced by fluid from the accumulator. The capacity of the accumulator is sufficient to ensure that the required quantity of pressurized brake fluid will always be available during ABS-modulated braking.



S 5/191

-  = Accumulator pressure
-  = Master cylinder pressure (servo pressure)
-  = Atmospheric pressure

Brakes applied with ABS modulation

- 2 Accumulator
- 3 Pump delivery pipeconnection
- 4 Control valve
- 5 Lever mechanism
- 6 Actuating plunger
- 7 Servo plunger
- 8 Rear brake circuit
- 9 Front brake circuits
- 10 Inlet valve (in valve block)
- 11 Outlet valve (in valve block)
- 12 Brake caliper



Component removal/fitting

Brake fluid reservoir	510- 1	Pump and motor unit	510-20
Hydraulic unit	510- 5	Valve block	510-23
Accumulator	510-12	ECU	510-26
Pressure switch	510-13	Wheel sensors	510-27
Pump delivery pipe	510-15		

Brake fluid reservoir

Caution!

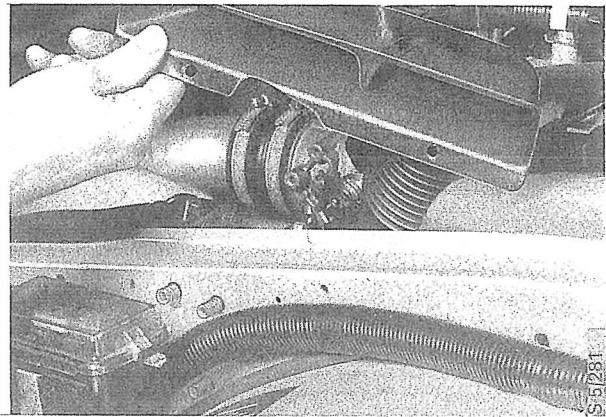
The system must be depressurized before work is started. To do this, with the ignition off depress the brake pedal about 20 times until positive resistance is felt in the pedal.

Caution!

Before starting work, thoroughly clean the surfaces around the reservoir to prevent dirt getting into the hydraulics.

To remove

- 1 Remove the air intake.

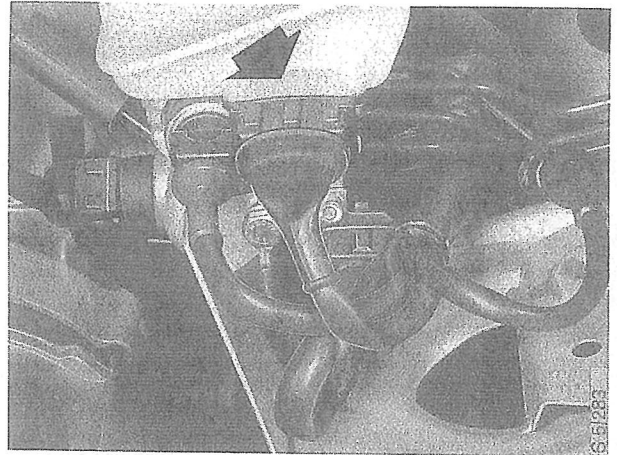


- 2 Remove the retaining bolt for the coolant expansion tank and move the tank out of the way.



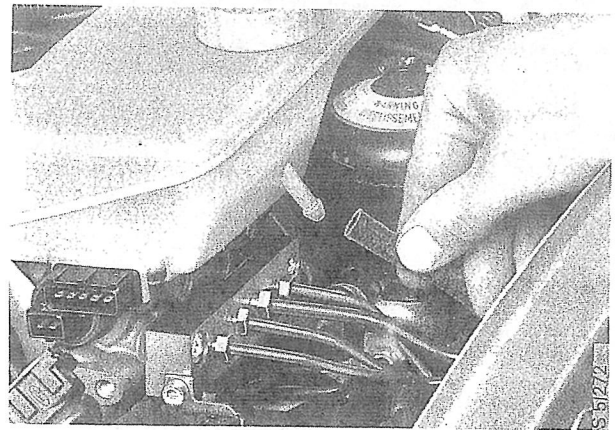
510-2 Component removal/fitting

- 3 Siphon off the fluid from the reservoir. Note that it will not be possible to empty the reservoir completely.
- 4 Unplug the electrical connector for the fluid level indicator on the reservoir.

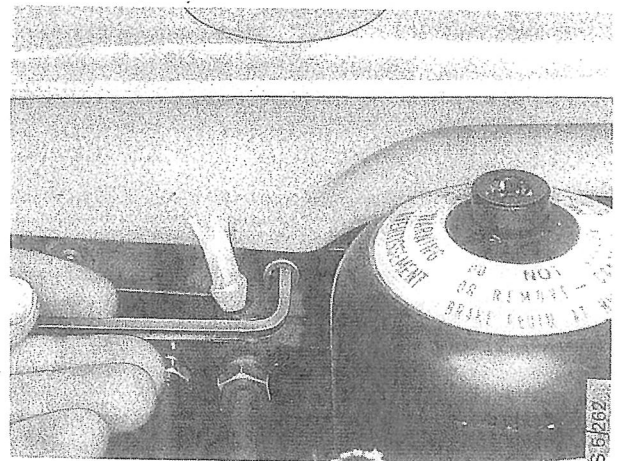


- 5 Manuals only: Disconnect the hose for the clutch cylinder and plug the end.

Take care not to lose any fluid from the hose. If fluid is lost, air may get into the clutch hydraulics.



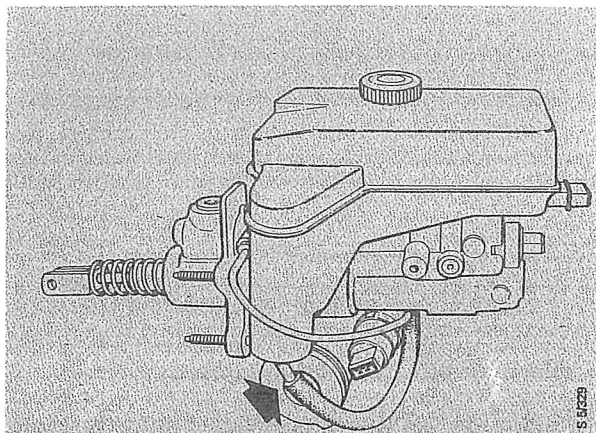
- 6 Undo the reservoir retaining screw.



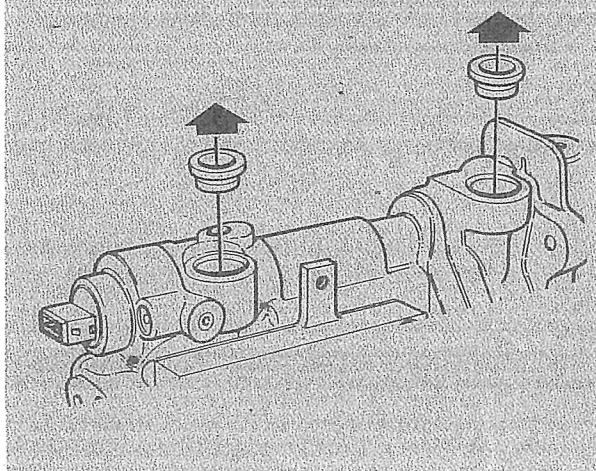
- 7 Lift the reservoir off the hydraulic unit by withdrawing it from the rubber bushes. Take care not to lose the spacer and 'O' ring on the rear connection.



- 8 Disconnect the pump feed hose from the reservoir.

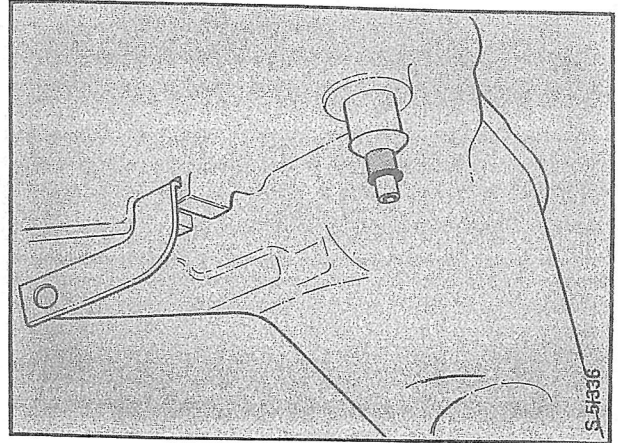


- 9 Remove the rubber bushes from the hydraulic unit.



To fit

- 1 Fit two new rubber bushes in the hydraulic unit.
- 2 Reconnect the pump feed hose to the reservoir.
- 3 Slide the spacer and 'O' ring onto the reservoir rear connection. Install the reservoir by pushing the connections into the rubber bushes in the hydraulic unit.



- 4 Tighten the reservoir retaining screw.
- 5 Manuals only: Reconnect the clutch feed hose to the reservoir. Make sure that fluid has not been lost from the hose.
- 6 Plug the electrical connector onto the fluid level indicator.
- 7 Move the coolant expansion tank back into place and tighten the bolt.
- 8 Refit the air intake.
- 9 Fill the reservoir with DOT 4 brake fluid.
- 10 Bleed the brake system.
For details refer to section 520.
- 11 Switch on the ignition and watch to see that the brake and ABS (Anti-lock) warning lights go off.
- 12 Test drive the car and verify that the brake system is working properly.

Hydraulic unit

Caution!

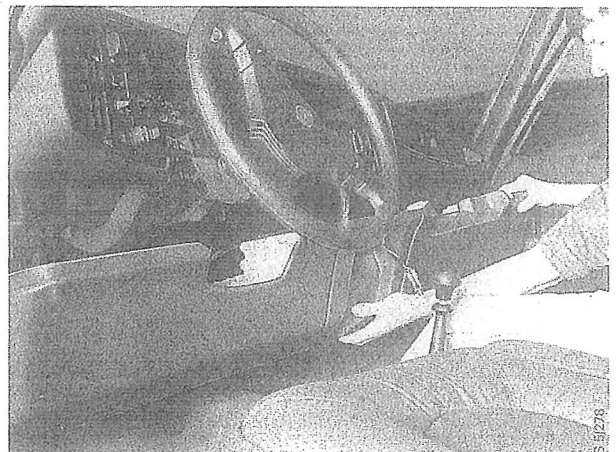
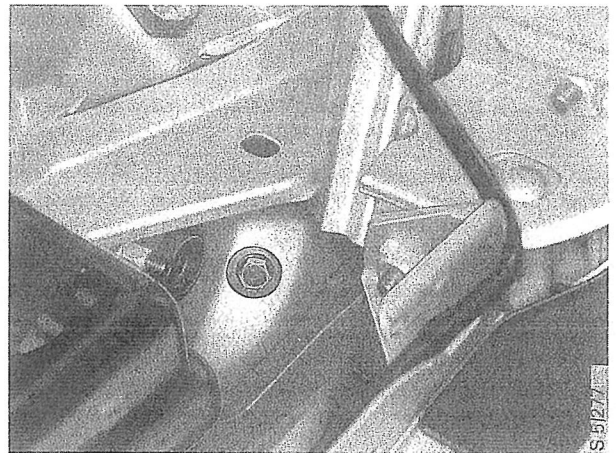
The system must be depressurized before work is started. To do this, with the ignition off depress the brake pedal about 20 times until positive resistance is felt in the pedal.

Caution!

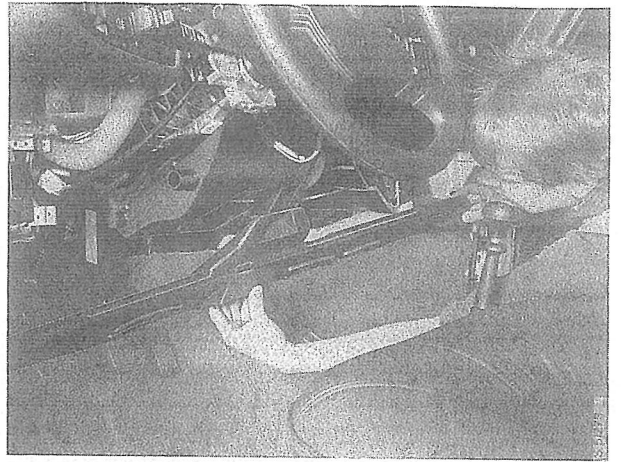
Before starting work, thoroughly clean the unit, connections and surrounding surfaces to prevent dirt getting into the hydraulics.

To remove

- 1 Remove the centre console.
- 2 Remove the padded trim panel from below the dash.



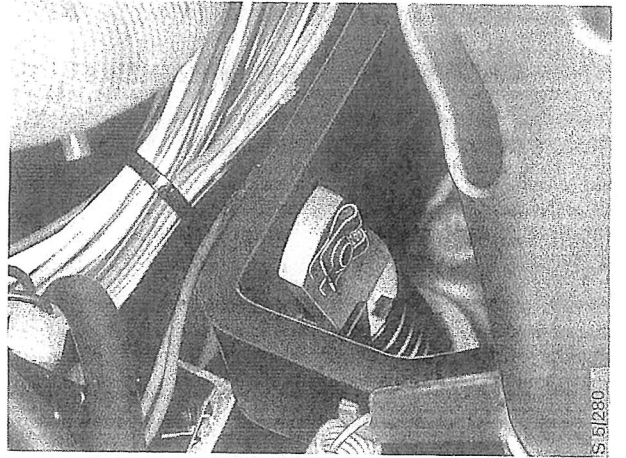
3 Remove the heater duct.



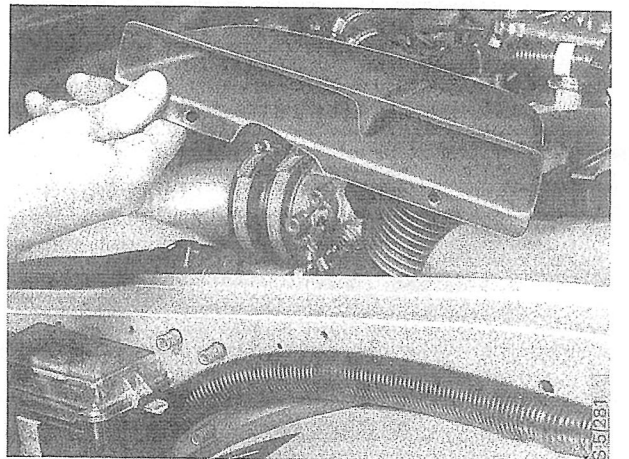
4 Remove the acoustic insulation from behind the pedal assembly.

5 Disconnect the LH defroster hose from the heater box.

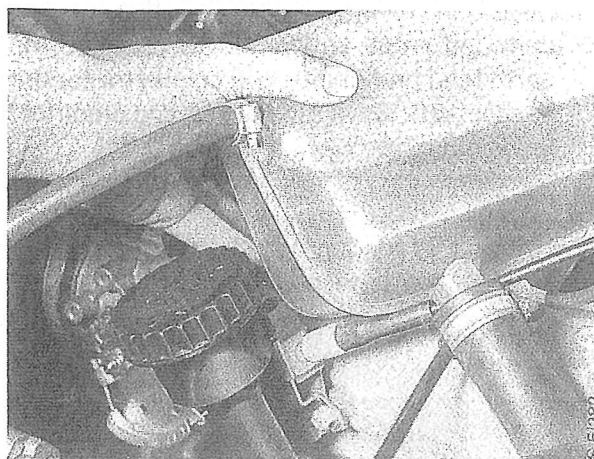
6 Remove the pin retaining clip and withdraw the pin from the hydraulic unit pushrod.



7 Remove the air intake.

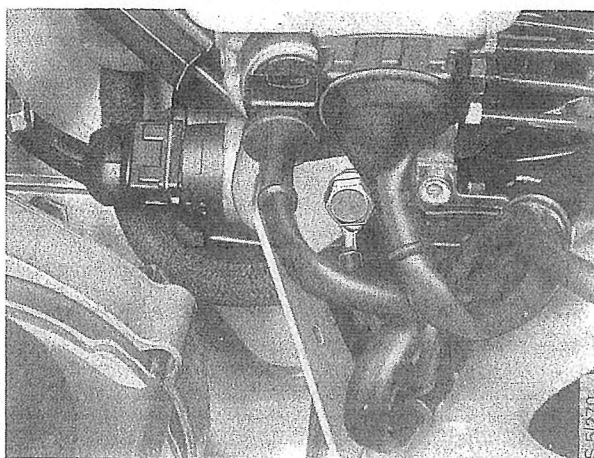
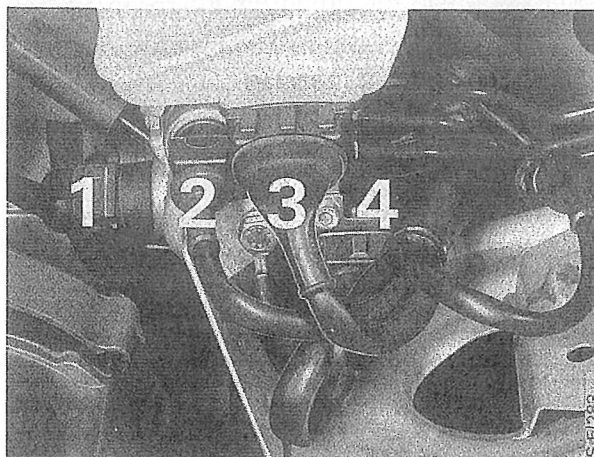


- 8 Remove the retaining bolt for the coolant expansion tank and move the tank out of the way.

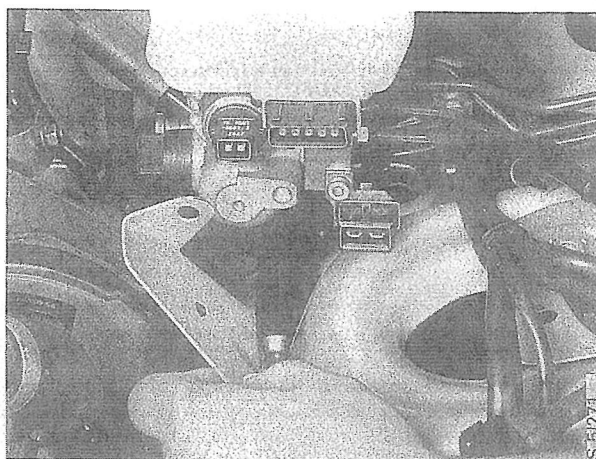


- 9 Unplug all electrical connectors from the hydraulic unit:

- pressure switch (1)
- main valve (2)
- fluid level indicator (3)
- pump motor (4)



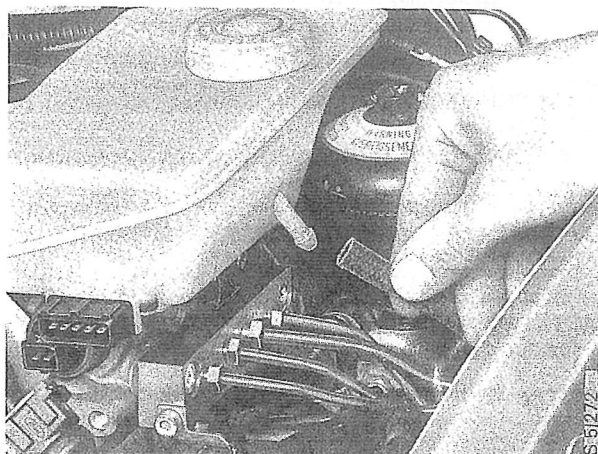
- 10 Unbolt the bracket between the hydraulic unit and front assembly. Disconnect the earth lead and unplug the connector for the sensor lead. Move the bracket and electrical leads out of the way.



- 11 Siphon off the fluid from the reservoir. Note that it will not be possible to empty the reservoir completely.

- 12 Manuals only: Unplug the hose for the clutch cylinder and plug the end.

Take care not to lose any fluid from the hose. If fluid is lost, air may get into the clutch hydraulics.

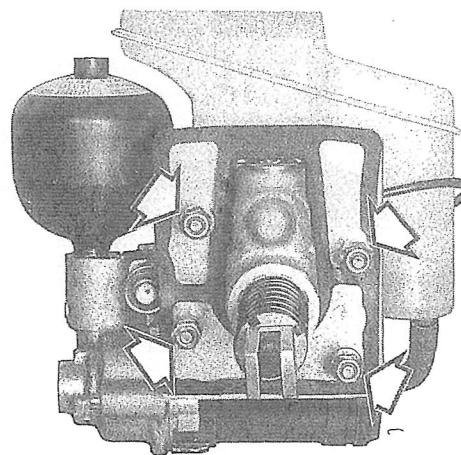


- 13 Label the brake pipes and the large-bore return pipe.

- 14 Disconnect the brake pipes and large-bore return pipe together, to avoid putting tension on the pipes.

Plug the ends of the pipes, and the openings in the hydraulic unit and valve block.

- 15 Undo the four securing nuts for the hydraulic unit on the bulkhead behind the pedal assembly.



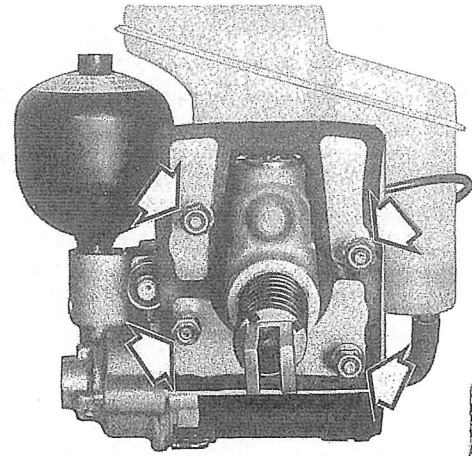
- 16 Lift out the hydraulic unit.

To fit

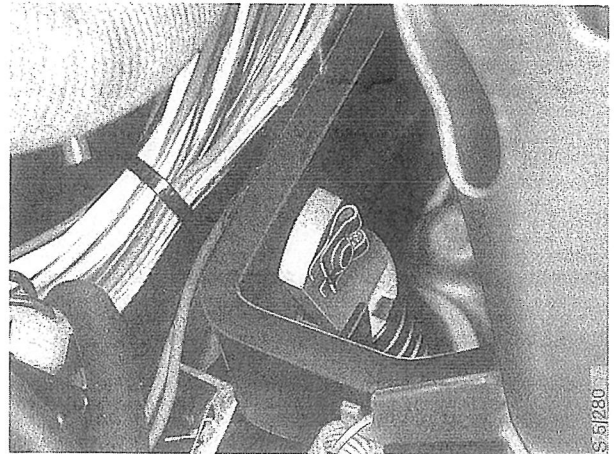
Note

On fitting the hydraulic unit, it is easy for the stop-light switch and cruise-control switch (if any) to be pushed in inadvertently. If so, use a pair of pliers to reset them.

- 1 Offer up the hydraulic unit and ensure that the pushrod is correctly aligned with the pedal assembly.



- 2 Reconnect the pushrod, fitting the pin and pin retaining clip.



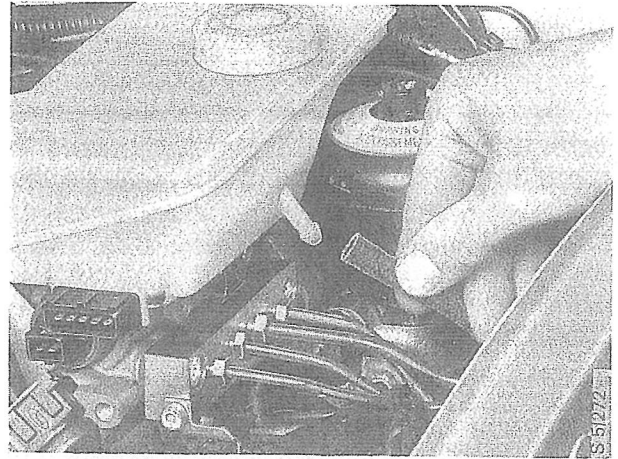
- 3 Tighten the hydraulic unit retaining nuts on the bulkhead behind the pedal assembly.

Tightening torque: 26 ± 4 Nm (19 ± 3 lbf ft)

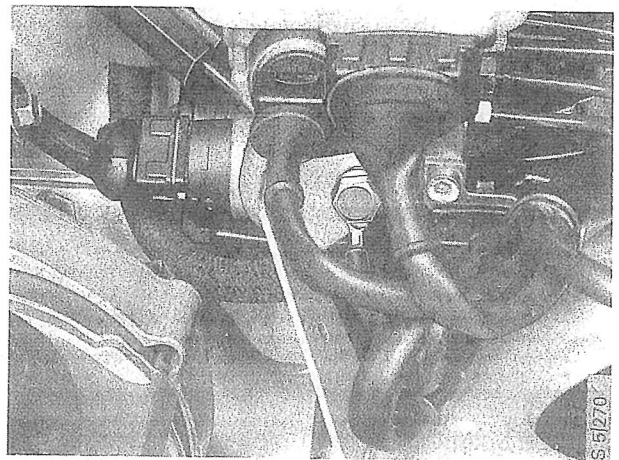
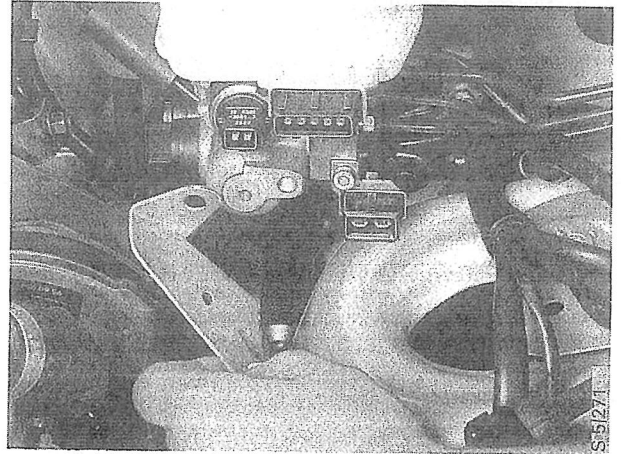
- 4 Connect the brake pipes and large-bore re-turn pipe.

510-10 Component removal/fitting

- 5 Manuals only: Reconnect the clutch feed hose to the reservoir. Make sure that fluid has not been lost from the hose.

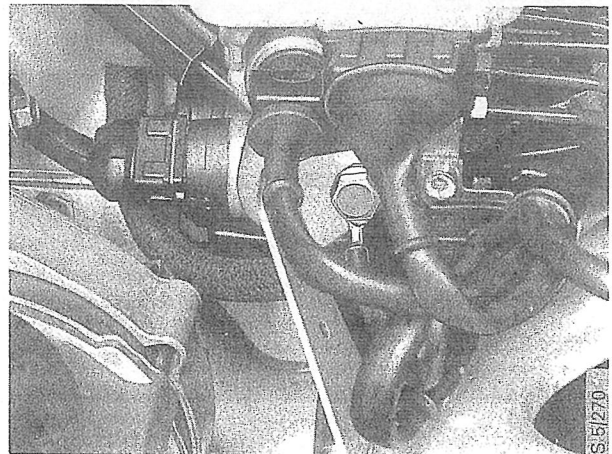
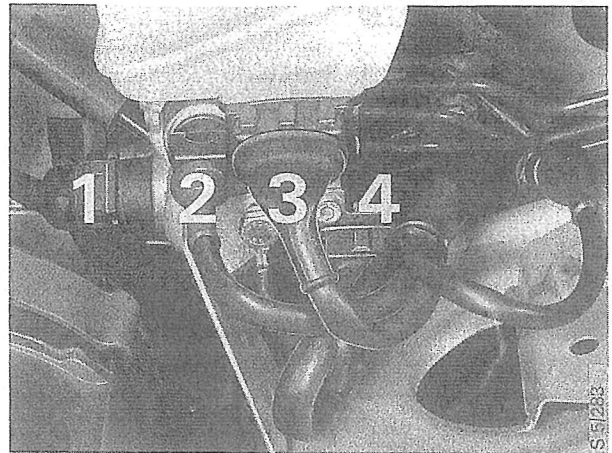


- 6 Plug on the sensor lead connector and fit the bracket between the hydraulic unit and front assembly. Remember to secure the earth lead on the top bolt.



7 Reconnect all the electrical leads:

- pressure switch (1)
- main valve (2)
- fluid level indicator (3)
- pump motor (4)



- 8 Move the coolant expansion tank back into place and tighten the bolt.
- 9 Refit the air intake.
- 10 Fill the reservoir with DOT 4 brake fluid.
- 11 Switch on the ignition and check that the pump is working.
- 12 Bleed the brake system.
For details refer to section 520.
- 13 Inspect the brake system for leaks and check that the brake and ABS (Anti-lock) warning lights go off.
- 14 Reconnect the LH defroster hose.
- 15 Fit the acoustic insulation behind the pedal assembly.
- 16 Refit the heater duct.
- 17 Refit the padded trim panel under the dash.
- 18 Refit the centre console.
- 19 Test drive the car and verify that the brakes and clutch are working properly.

Accumulator

Caution!

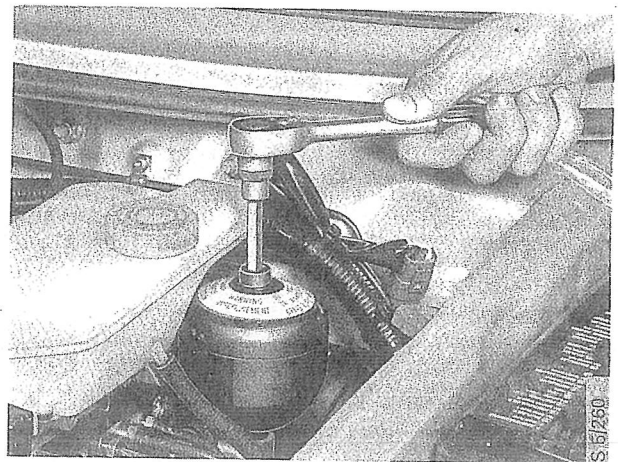
The system must be depressurized before work is started. To do this, with the ignition off depress the brake pedal about 20 times until positive resistance is felt in the pedal.

Caution!

Before starting work, thoroughly clean the accumulator, connections and surrounding surfaces to prevent dirt getting into the hydraulics.

To remove

- 1 Remove the accumulator (8-mm Allen key).



To fit

- 1 Fit a new 'O' ring on the accumulator.
- 2 Fit the accumulator.
Tightening torque: 34 - 46 Nm (25 - 34 lbf ft)
- 3 Switch on the ignition and watch to see that the brake and ABS (Anti-lock) warning lights go off.
- 4 Test drive the car and verify that the brake system is working properly.

Pressure switch

Caution!

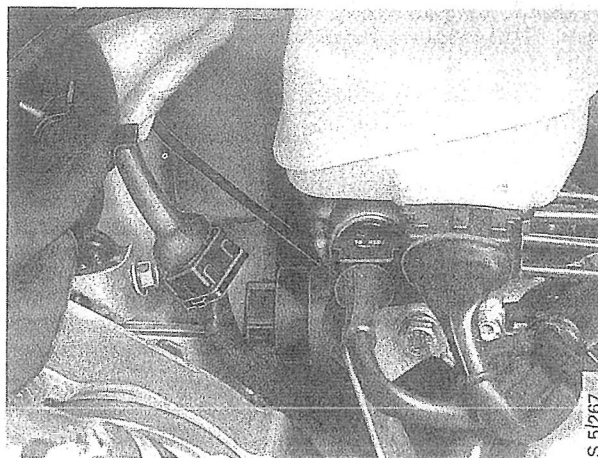
The system must be depressurized before work is started. To do this, with the ignition off depress the brake pedal about 20 times until positive resistance is felt in the pedal.

Caution!

Before starting work, thoroughly clean the surfaces around the pressure switch to prevent dirt getting into the hydraulics.

To remove

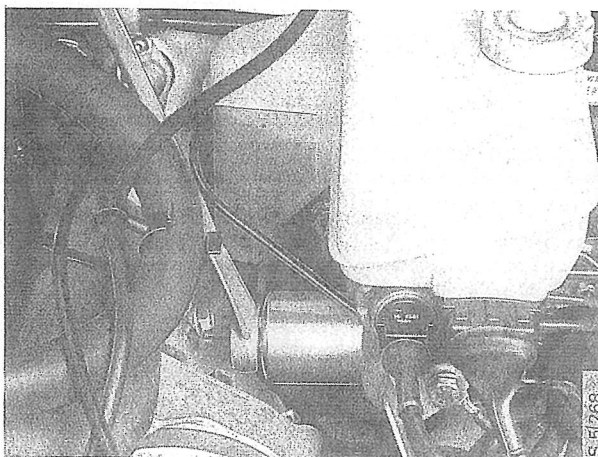
- 1 Remove the rubber damper from the pump delivery pipe.
- 2 Unplug the electrical connector from the pressure switch.



- 3 Fit special tool 8996571 and unscrew the switch.

Hint

If the switch is difficult to undo, insert a suitable brace between the pump body and the hydraulic unit.



To fit

- 1 Fit a new 'O' ring and screw in the pressure switch.

Tightening torque:

20 - 26 Nm (15 - 19 lbf ft)

- 2 Plug the connector onto the pressure switch.
- 3 Fit the rubber damper onto the pump delivery pipe.
- 4 Switch on the ignition and watch to see that the brake and ABS (Anti-lock) warning lights go off.
- 5 Inspect the brake system for leaks.
- 6 Test drive the car and verify that the brake system is working properly.

Pump delivery pipe

Caution!

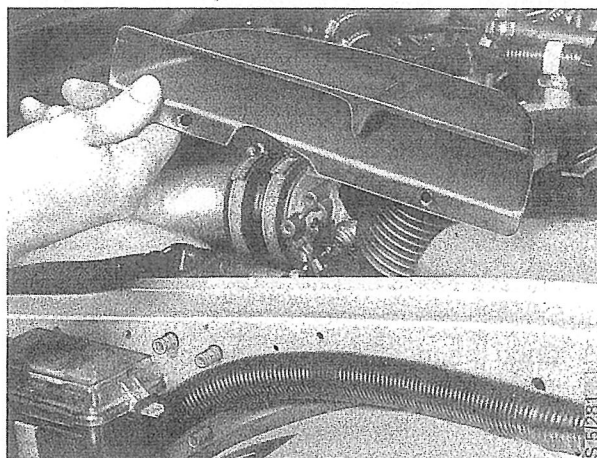
The system must be depressurized before work is started. To do this, with the ignition off depress the brake pedal about 20 times until positive resistance is felt in the pedal.

Caution!

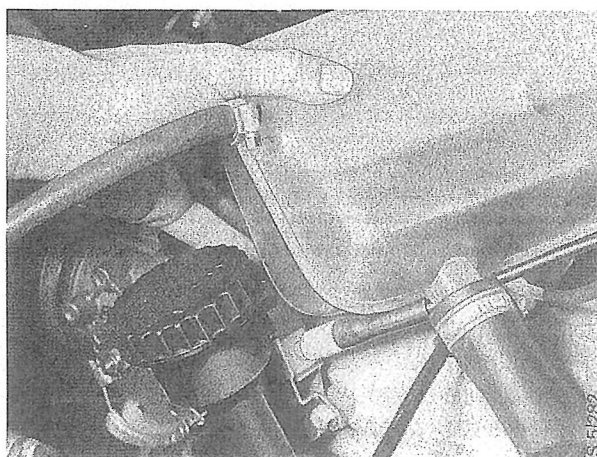
Before starting work, thoroughly clean the unit, connections and surrounding surfaces to prevent dirt getting into the pump delivery pipe.

To remove

- 1 Remove the air intake.

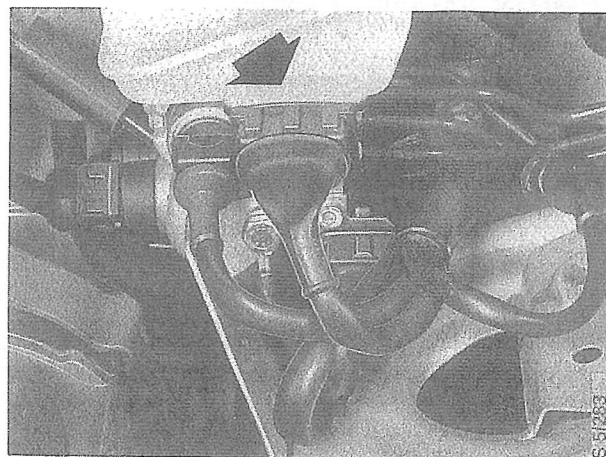


- 2 Remove the retaining bolt for the coolant expansion tank and move the tank out of the way.



- 3 Siphon off the fluid from the reservoir. Note that it will not be possible to empty the reservoir completely.

- 4 Unplug the electrical connector for the fluid level indicator on the reservoir.

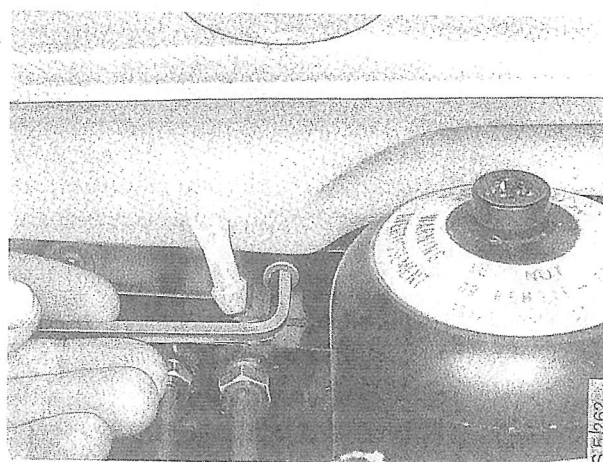


- 5 Manuals only: Disconnect the hose for the clutch cylinder and plug the end.

Take care not to lose any fluid from the hose. If fluid is lost, air may get into the clutch hydraulics.



- 6 Undo the reservoir retaining screw.

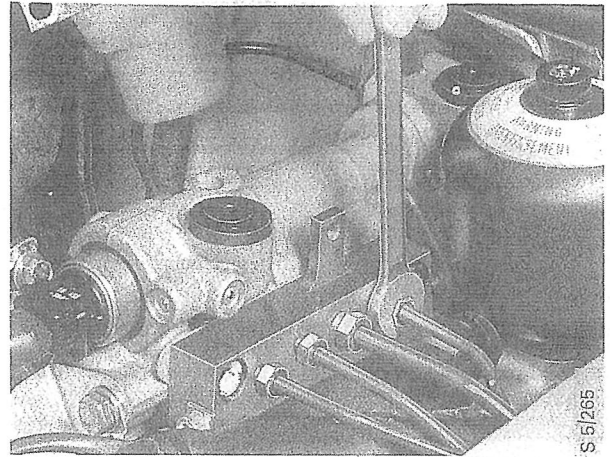


- 7 Lift the reservoir off the hydraulic unit by withdrawing it from the rubber bushes. Take care not to lose the spacer and 'O' ring on the rear connection.

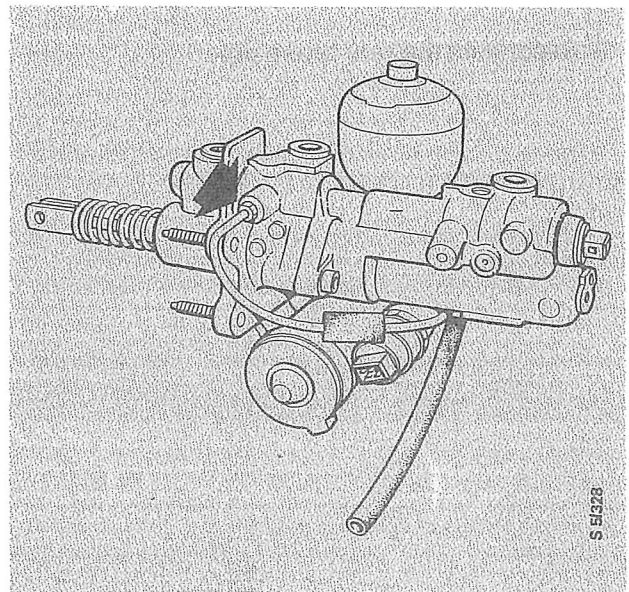
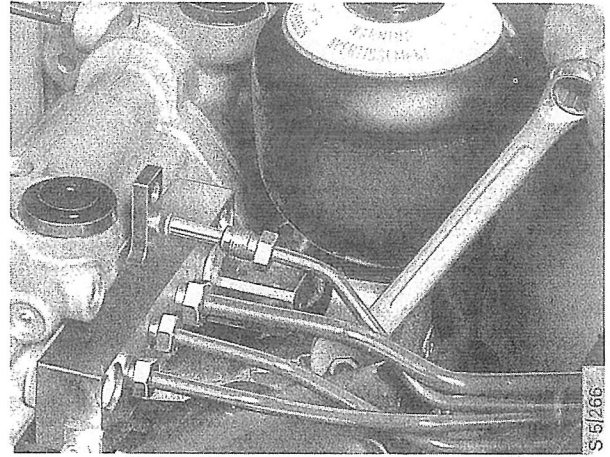
Plug the holes in the rubber bushes in the hydraulic unit.



- 8 Disconnect the rear brake pipe on the hydraulic unit to gain better access to the pump delivery pipe coupling. Plug the end of the brake pipe and the opening in the hydraulic unit.

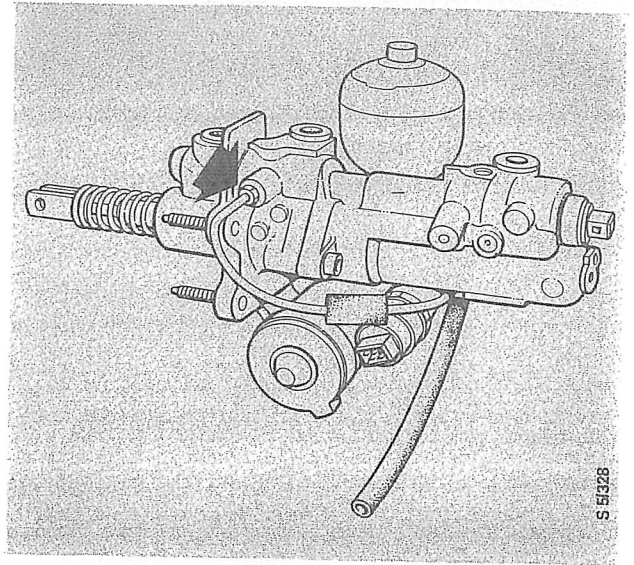
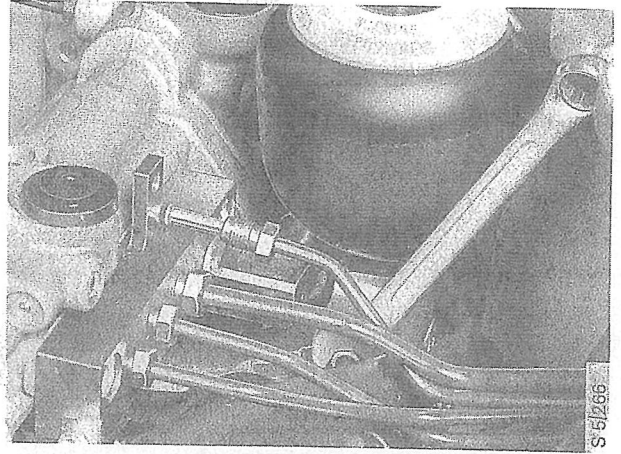


- 9 Remove the pump delivery pipe. Plug the two openings for the pipe in the unit.

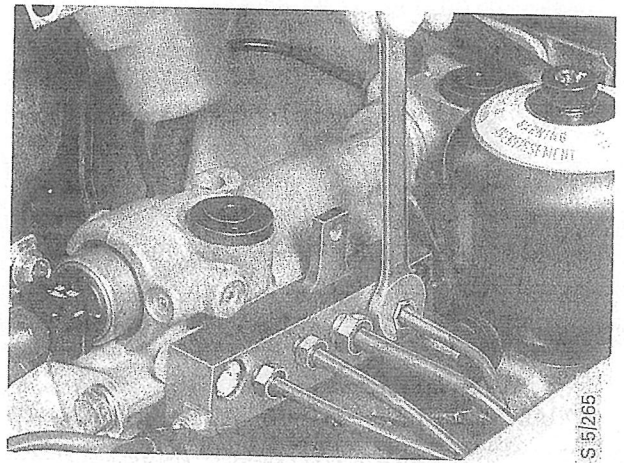


To fit

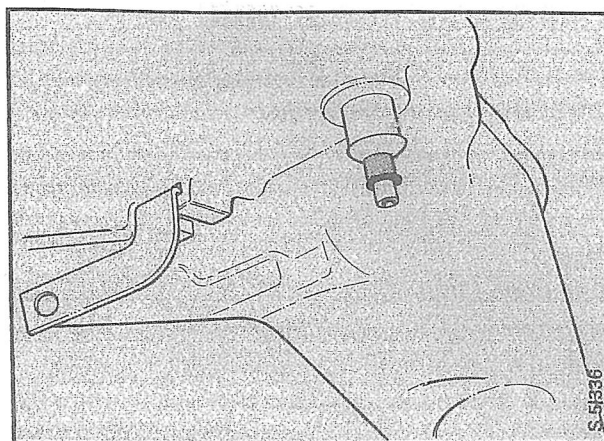
- 1 Fit the pump delivery pipe.



- 2 Reconnect the rear brake pipe.



- 3 Slide the spacer and 'O' ring onto the reservoir rear connection. Install the reservoir by pushing the connections into the rubber bushes in the hydraulic unit.



- 4 Tighten the reservoir retaining screw.
- 5 Manuals only: Reconnect the clutch feed hose to the reservoir. Make sure that fluid has not been lost from the hose.
- 6 Plug the electrical connector onto the fluid level indicator.
- 7 Move the coolant expansion tank back into place and tighten the bolt.
- 8 Refit the air intake.
- 9 Fill the reservoir with DOT 4 brake fluid.
- 10 Bleed the brake system.
For details refer to section 520.
- 11 Switch on the ignition and watch to see that the brake and ABS (Anti-lock) warning lights go off.
- 12 Test drive the car and verify that the brake system is working properly.

Pump and motor unit

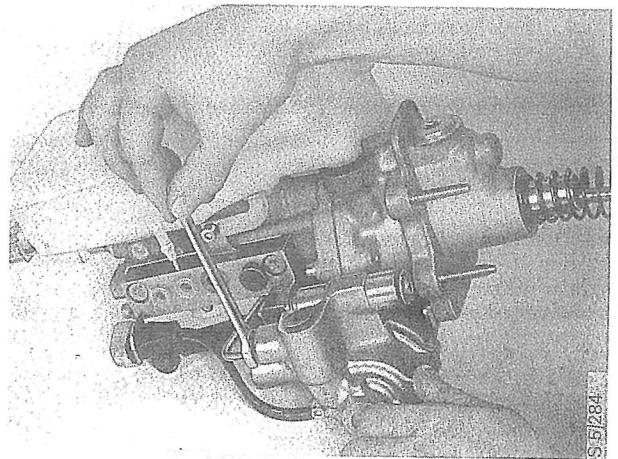
The pump and motor unit cannot be removed with the hydraulic unit in the car.

Hint

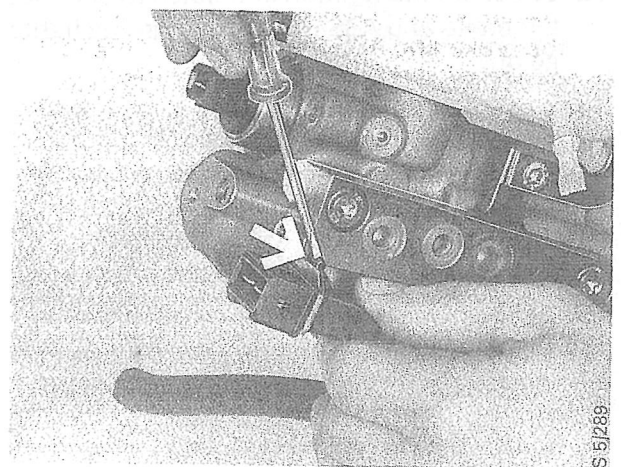
It is a good idea to remove the accumulator before the hydraulic unit is removed from the car. Plug the opening in the pump body.

To remove

- 1 Disconnect the pump delivery pipe from the pump unit.
Plug the open end of the pipe.

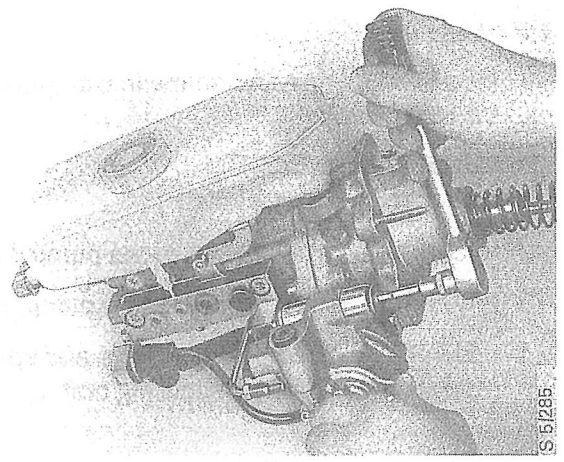


- 2 Prise back the catch and unplug the electrical connector.

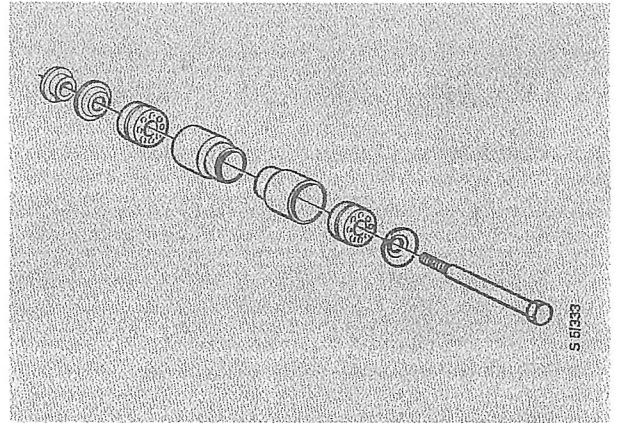


- 3 Disconnect the inlet hose from the pump unit.

- 4 Undo the securing screw at the front of the pump unit.



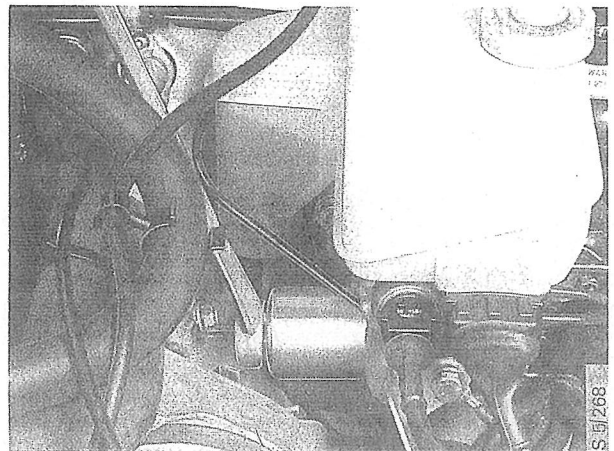
Note the order for reassembling the dampers, washers and spacer.



- 5 Disengage the pump and motor unit from its rear mounting.
- 6 Remove the pressure switch. Use special tool 89 96 571.

Hint

If the switch is difficult to undo, insert a suitable brace between the pump body and the hydraulic unit.



S 5/284

S 5/268

S 5/285

S 5/233

S 5/268

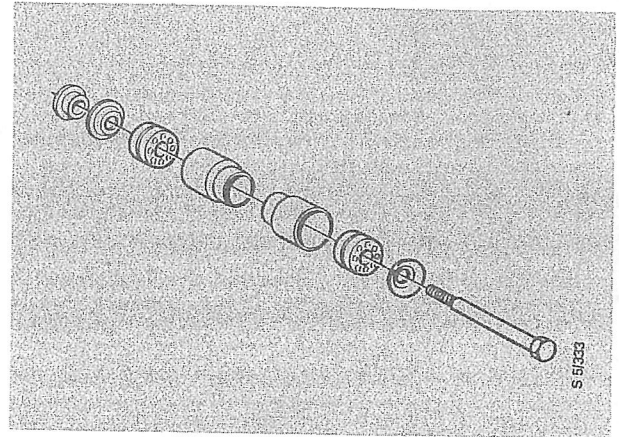
To fit

- 1 Fit a new 'O' ring and screw in the pressure switch.

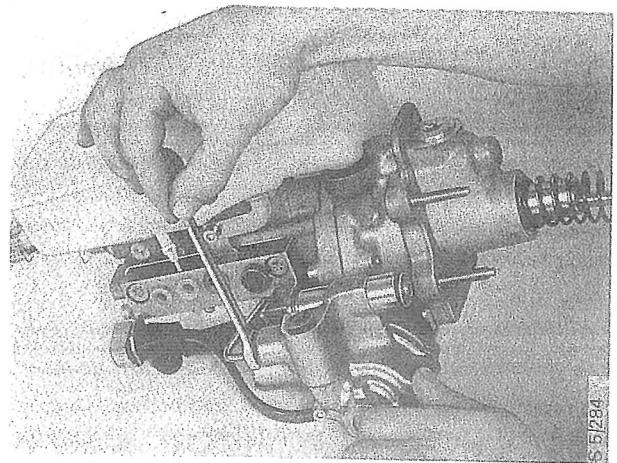
Tightening torque:

20 - 26 Nm (15 - 19 lbf ft)

- 2 Reconnect the inlet hose to the pump unit.
- 3 Engage the rear mounting on the pump unit.
- 4 Assemble the dampers, washers and spacer (as shown) and fit the securing bolt.



- 5 Plug on the electrical connector.
- 6 Reconnect the pump delivery pipe to the pump unit.



Refit the hydraulic unit in the car. Fit the accumulator.

Tightening torque:

34 - 46 Nm (25 - 34 lbf ft)

Valve block

Caution!

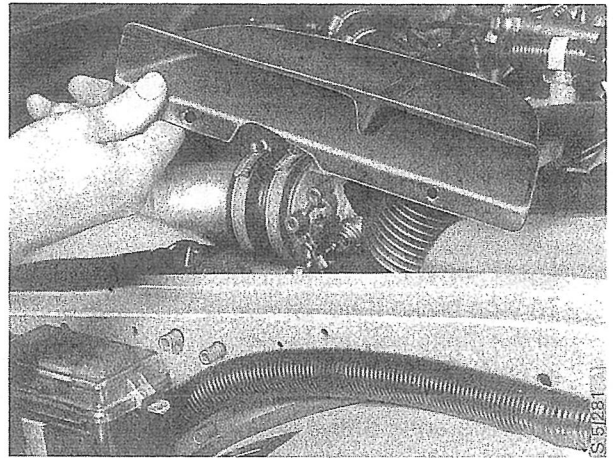
The system must be depressurized before work is started. To do this, with the ignition off depress the brake pedal about 20 times until positive resistance is felt in the pedal.

Caution!

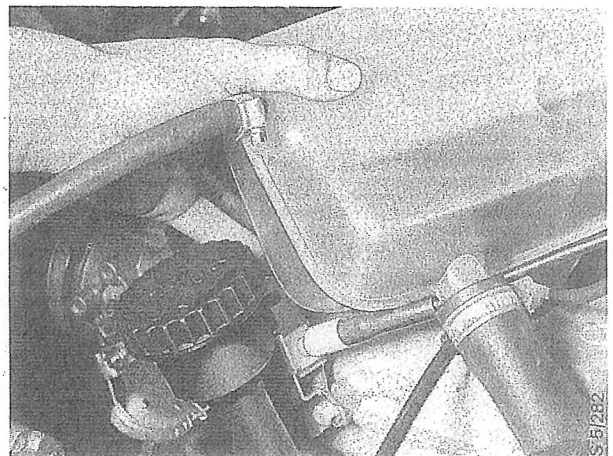
Before starting work, thoroughly clean the valve block, connections and surrounding surfaces to prevent dirt getting into the hydraulics.

To remove

- 1 Remove the air intake.



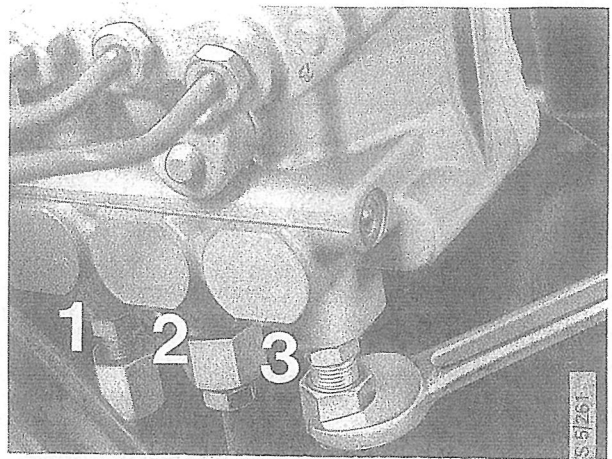
- 2 Remove the retaining bolt for the coolant expansion tank and move the tank out of the way.



- 3 Siphon off the fluid from the reservoir. Note that it will not be possible to empty the reservoir completely.
- 4 Unplug the electrical connector on the valve block.

5 Disconnect the brake pipes from the underside of the valve block:

- (1) front left (nearest wing)
- (2) rear (middle)
- (3) front right (nearest engine)



6 Disconnect the brake pipes and the large-bore return pipe from the valve block.

Hint

Place a rag under the valve block connections to prevent brake fluid getting onto the paintwork.

Undo the nut on the cover underneath the pipes.

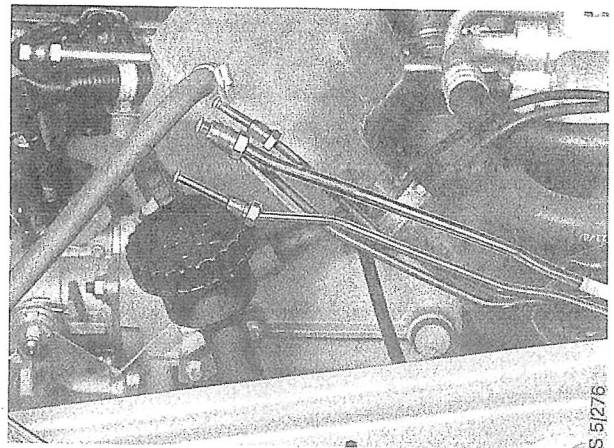
Slacken off the connections at the hydraulic unit to avoid stressing the pipes.

7 Withdraw the brake pipes and return pipe from the valve block.

Hint

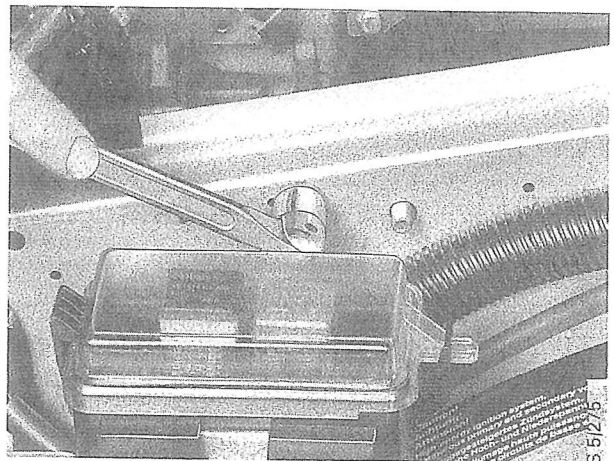
To stop brake fluid escaping, raise the ends of the pipes and lightly tighten down the connections to the hydraulic unit.

Plug the ends of the brake pipes and return pipe, and the openings in the valve block.



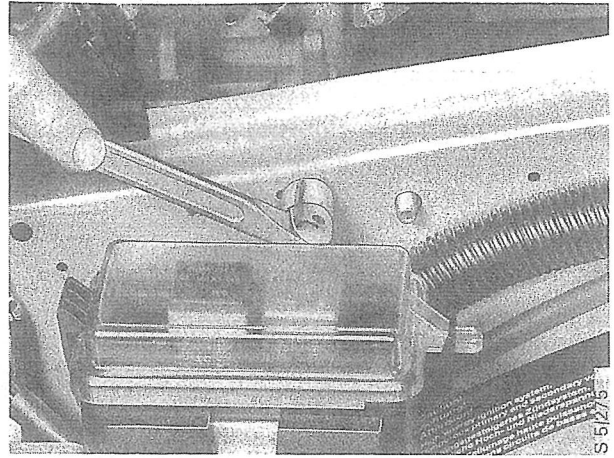
8 Snip through the tie securing the wiring loom to the valve block.

9 Remove the three nuts and lift off the valve block.

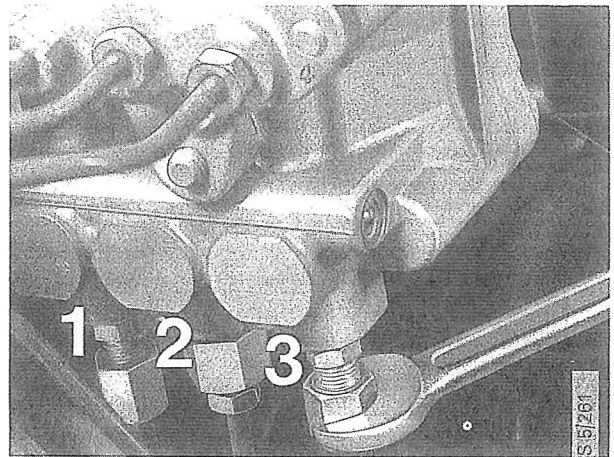


To fit

- 1 Lift the valve block into position and tighten the three nuts.



- 2 Reconnect the brake pipes to the underside of the valve block:
 - (1) front left (nearest wing)
 - (2) rear (middle)
 - (3) front right (nearest engine)



- 3 Secure the wiring loom to the valve block by means of a cable tie.
- 4 Slacken off the connections at the hydraulic unit.

Connect the brake pipes and return pipe to the valve block. Tighten the fittings.

Fit the cover for the underside of the pipes to the wing.

- 5 Plug on the connector for the valve block.
- 6 Move the coolant expansion tank back into place and tighten the bolt.
- 7 Refit the air intake.
- 8 Fill the reservoir with DOT 4 brake fluid.
- 9 Bleed the brake system.
For details refer to section 520.
- 10 Inspect the brake system for leaks. Switch on the ignition and check that the brake and ABS (Anti-lock) warning lights go off.
- 11 Test drive the car and verify that the brake system is working properly.

Electronic control unit

Note

The ECU must not be exposed to high temperatures. Always remove it from the car before starting any arc welding, stove drying, etc.

To remove

- 1 Unscrew the ECU from the LH wing inside the engine bay.
- 2 Lift up the ECU module and unplug the connector.

To fit

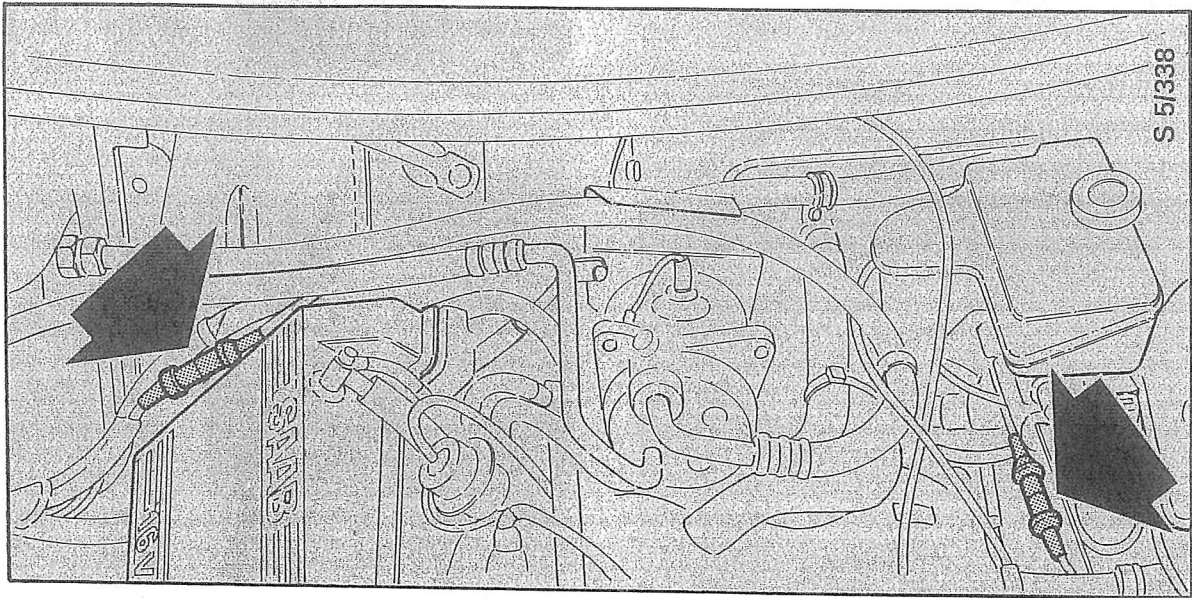
- 1 Plug the connector onto the module.
- 2 Screw the ECU module into place.

Wheel sensors

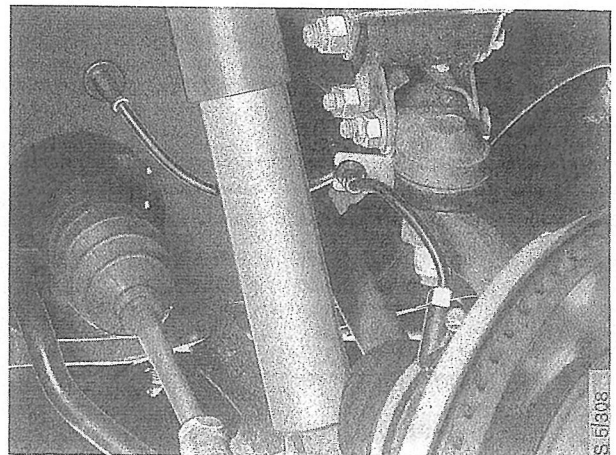
To remove

Front-wheel sensors

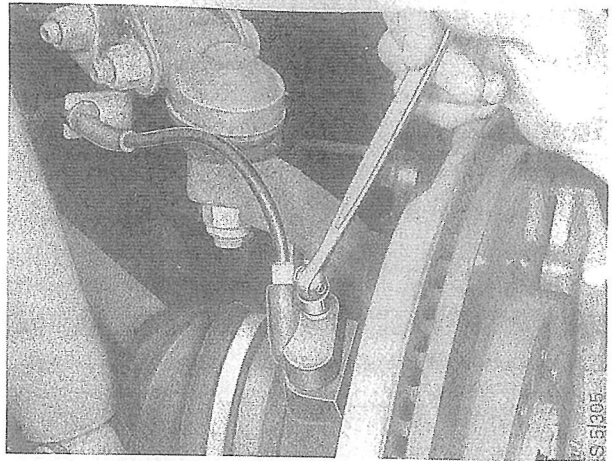
- 1 Unplug the sensor lead connector (one for each wheel) inside the engine bay by pushing the halves together and twisting (bayonet fitting).



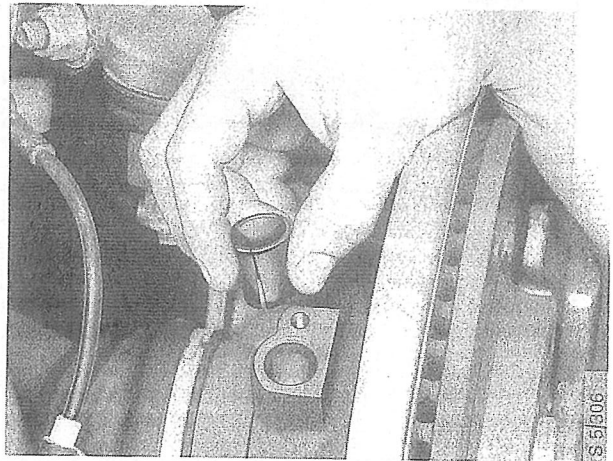
- 2 Raise the front of the car and remove the road wheel.
- 3 Withdraw the sensor lead from the guide and pull it through the rubber grommet in the wheel arch.



- 4 Undo the screw and remove the sensor.

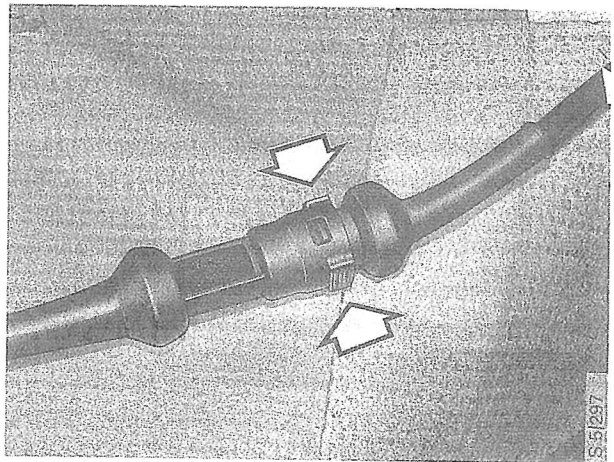


Note the plastic sleeve that is fitted to prevent corrosion between the steering swivel member and the sensor.



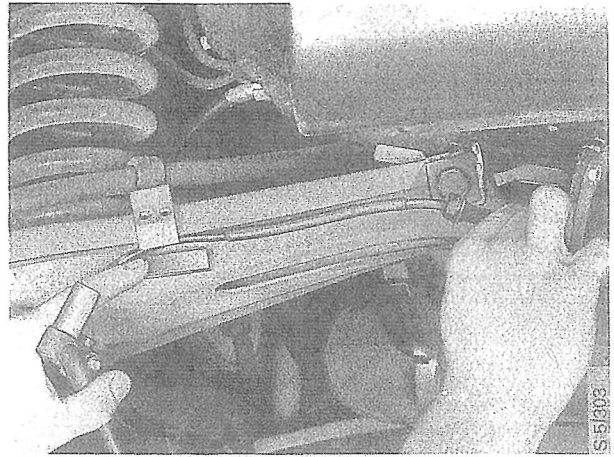
Rear-wheel sensors

- 1 Unplug the sensor lead connector (one for each rear wheel) located under the rear seat by pushing the halves together and twisting (bayonet fitting).

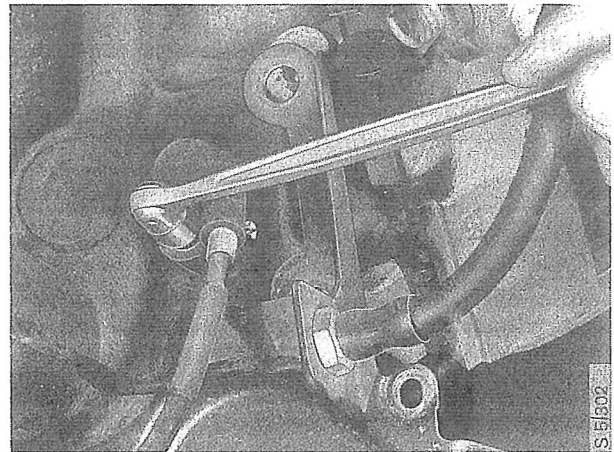


- 2 Raise the car and remove the road wheel.
- 3 Pull the sensor lead through the rubber grommet in the floor.

- 4 Undo the clip securing the handbrake cable to the suspension arm.
Note the position of the distance piece.



- 5 Release the sensor lead from the guide on the back of the suspension arm.
- 6 Undo the screw and remove the sensor.



510-30 Component removal/fitting

The following items must be carried out before the new wheel sensor is fitted.

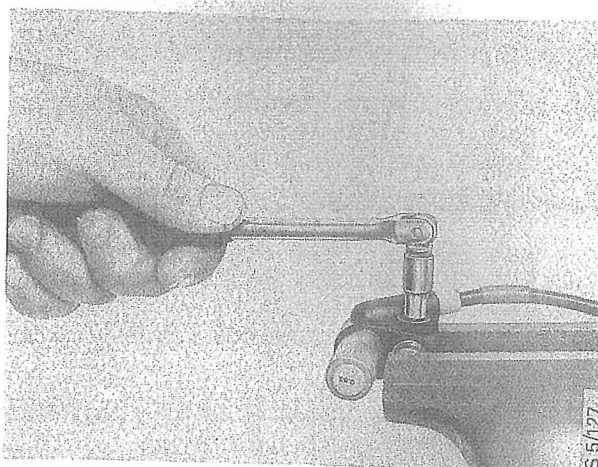
Note

To secure the sensor in the vice, grip the adjusting sleeve in the jaws. Never clamp the sensor body itself as this can distort it.

- Undo the setscrew and transfer the adjusting sleeve to the new sensor. Check that the sleeve slides freely: if necessary, polish the surface with a piece of fine emery cloth. Clean the surface thoroughly and lubricate lightly before fitting the sleeve.
- Use a wire brush to remove all traces of the old fibre spacer from the end of the sensor. Clean the surface with a rag (if required, moistened with a little petrol/gasoline).
- Remove any traces of fibre or dirt from inside the sensor housing. Spin the sensor wheel slowly and remove any fibre remains or dirt from between the teeth. At the same time, inspect for signs of damage.
- Glue a new fibre spacer onto the end of the sensor.
Spacer thickness: 0.65 mm

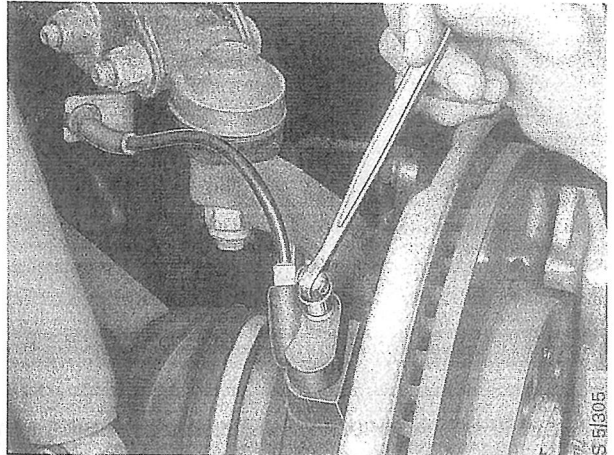
Note

Once the sensor with the new fibre spacer has been pushed out towards the sensor wheel, the road-wheel hub must not be rotated before the sensor has been secured in its correct position. If the hub is rotated prematurely, the sensor wheel will tear the spacer, causing the sensor to be set incorrectly. Offset the adjusting sleeve half-a-turn to bring the setscrew to a new position.

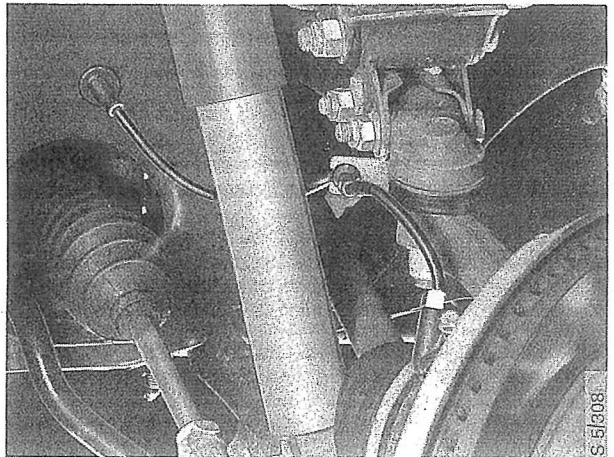


To fit**Front-wheel sensors**

- 1 Fit the sensor, tightening the retaining screw.



- 2 Press the sensor body gently against the sensor wheel and tighten the setscrew.
- 3 Insert the sensor lead through the grommet in the wheel arch and secure it in the guide.

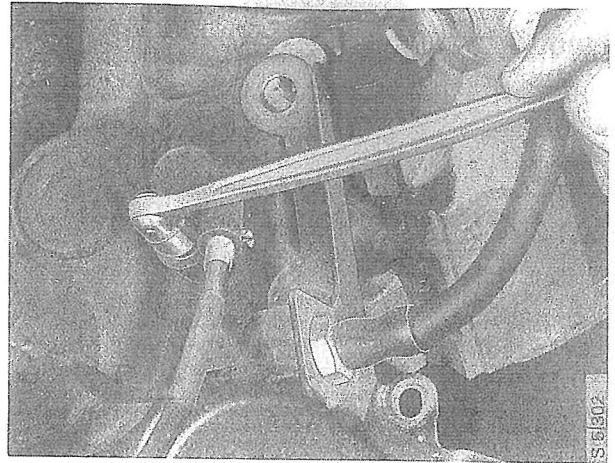


- 4 Reconnect the sensor lead connector inside the engine compartment.
- 5 Fit the road wheel.

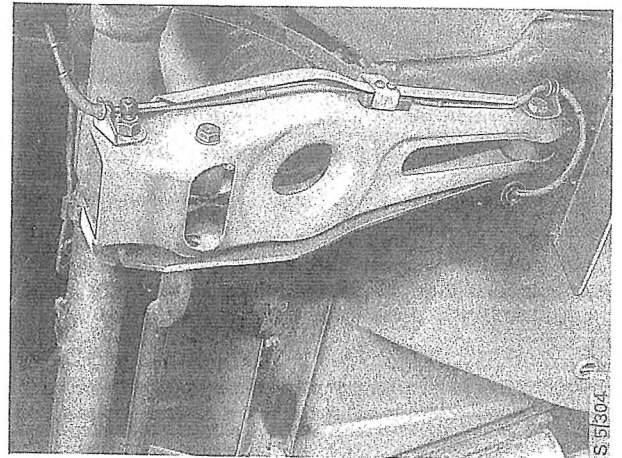
After fitting, ensure that the sensor lead cannot chafe against any of the components when the wheel is at full lock.

Rear-wheel sensors

- 1 Fit the sensor, tightening the retaining screw.



- 2 Press the sensor body gently against the sensor wheel and tighten the setscrew.
- 3 Fit the clip for the handbrake cable onto the suspension arm.
Note the position of the distance piece.



- 4 Insert the sensor lead through the grommet in the floor and secure it to the suspension arm.
- 5 Reconnect the sensor lead connector under the rear seat.
- 6 Fit the road wheel.

Bleeding the brake system

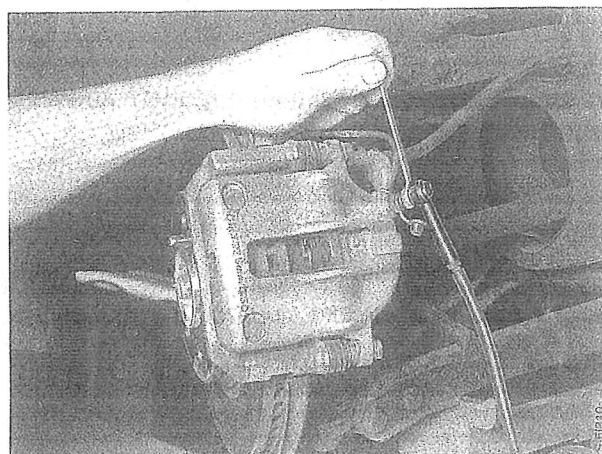
Note

The front-wheel brake circuits must be bled first.

Front-wheel brake circuits

If required, a bleeder unit can be used for the front brake circuits.

- 1 Top up, as necessary, with DOT 4 brake fluid.
- 2 Connect a length of transparent hose to the bleed nipple on the RH front brake caliper. Place the other end of the hose in a suitable receptacle.



- 3 Have a helper depress the brake pedal as you undo the nipple.

With the pedal down to the floor, tighten the nipple and then release the pedal.

Repeat this operation until no air bubbles are visible in the hose.

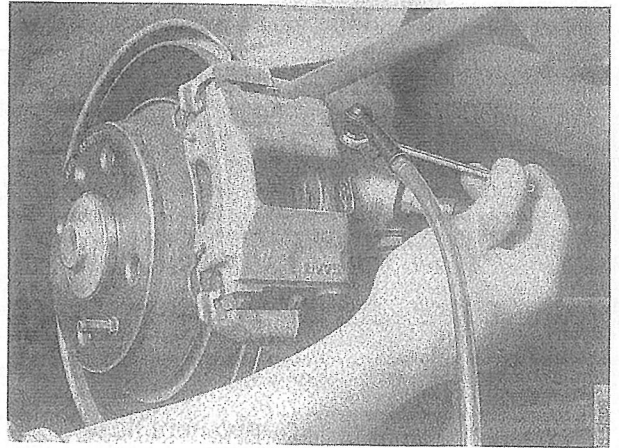
Repeat steps 2 and 3 to bleed the circuit for the LH front wheel.

Rear-wheel brake circuit

Note

The front-wheel brake circuits must be bled first.

- 1 Top up the reservoir, as required, with DOT 4 brake fluid.
- 2 Connect a length of transparent hose to the bleed nipple on one of the rear brake calipers. Place the other end of the hose in a suitable receptacle.



- 3 Have a helper switch on the ignition and depress the brake pedal.

Caution

The pump motor must not run for more than two minutes at a time. After the motor has been running, leave it to cool for ten minutes before restarting it.

- 4 Undo the brake nipple and draw off brake fluid until no bubbles are visible in the tube.

To bleed the remainder of the circuit to the other wheel, repeat steps 2, 3 and 4.

- 5 Top up the brake fluid to bring the level up to the MAX mark on the side of the reservoir.

Changing the brake fluid

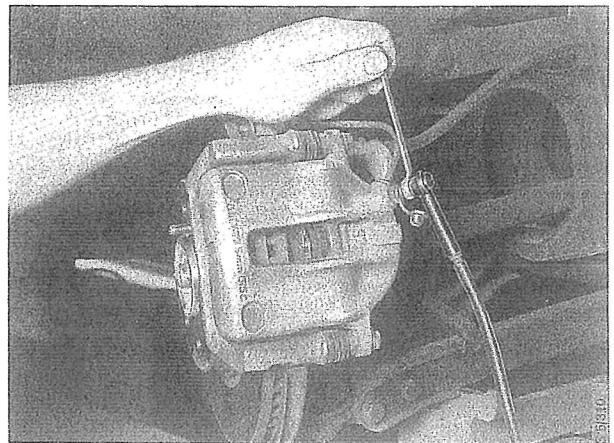
All brake fluid deteriorates after a time through oxidation and absorption of water. This lowers the boiling point of the fluid, which may therefore vaporize during prolonged hard braking. The result can be sudden brake failure. It is therefore essential that the brake fluid is changed regularly at the specified intervals (see the Maintenance Programme in Section 1:2 of the Service Manual).

Caution

To avoid possible brake failure, all old brake fluid must be drained from the system. The fluid capacity of the brake system is approx. 1.2 litre (1.3 liq qt).

If required, a bleeder unit can be used for the front brake circuits.

- 1 Siphon off the fluid from the reservoir. Note that it will not be possible to empty the reservoir completely.
- 2 Top up with DOT 4 brake fluid.
- 3 Connect a length of transparent hose to the bleed nipple on the RH front brake caliper. Place the other end of the hose in a measuring cylinder or other graduated receptacle.



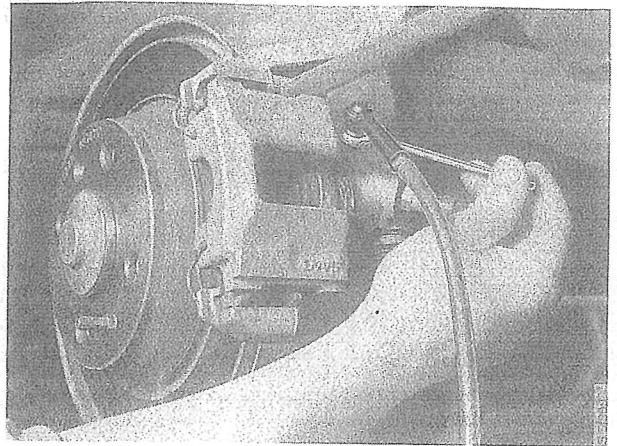
- 4 Have a helper depress the brake pedal as you undo the nipple. With the pedal down to the floor, tighten the nipple and then release the pedal.

Repeat the procedure until approx. 0.5 litres (0.5 liq qt) has been drained off.

To drain the circuit for the LH front wheel: repeat steps 3 & 4, except this time drain off approx. 0.1 litre (0.1 liq qt) of fluid.

530-2 Changing the brake fluid

- 5 Connect a length of transparent hose to the bleed nipple on one of the rear brake calipers. Place the other end of the hose in a suitable receptacle.



- 6 Have a helper switch on the ignition and depress the brake pedal.

Caution

The pump motor must not run for more than two minutes at a time. After the motor has been running, leave it to cool for ten minutes before restarting it.

- 7 Open the bleed nipple until approx. 0.1 litre (0.1 liq qt) of fluid has been drained off.

Repeat steps 5, 6 and 7 to drain the remainder of the circuit to the other wheel.

- 8 Fill up with brake fluid to bring the level up to the MAX mark on the side of the reservoir.

ABS-system tester

Technical data	590- 1	Selecting the ABS-system version . . .	590-15
Technical description	590- 2	Test mode	590-16
Quick checks	590- 8	Valve test mode	590-18
Connecting the tester to the car . . .	590-11	Monitor mode	590-22
Connecting the pressure sensor . . .	590-13	Error codes	590-26
Checking the accumulator gas pressure	590-14	Fault-diagnosis routines	590-27

Technical data

Casing

The casing of the tester unit is made of impact and oil-resistant plastic and incorporates a hinged cover over the display and control panel.

Display

Specially designed LCD display having 56 segments.

Control panel

Special oil-resistant design incorporating three membrane switches.

Microprocessor

Eight-bit single-chip microprocessor with analogue/digital converter and 4 K internal storage.

Power consumption

Approx. 170 mA in ready mode.

Connection to the ABS-system ECU

Connection between the ECU and the car's wiring loom is made using a two-way (male/female) 35-pin connector.

Power supply

The power supply for the tester is taken direct from the battery via a lead fitted with crocodile clips.

Pressure sensor

A pressure sensor can be connected to the ABS accumulator for measuring hydraulic pressure.

Technical description

General

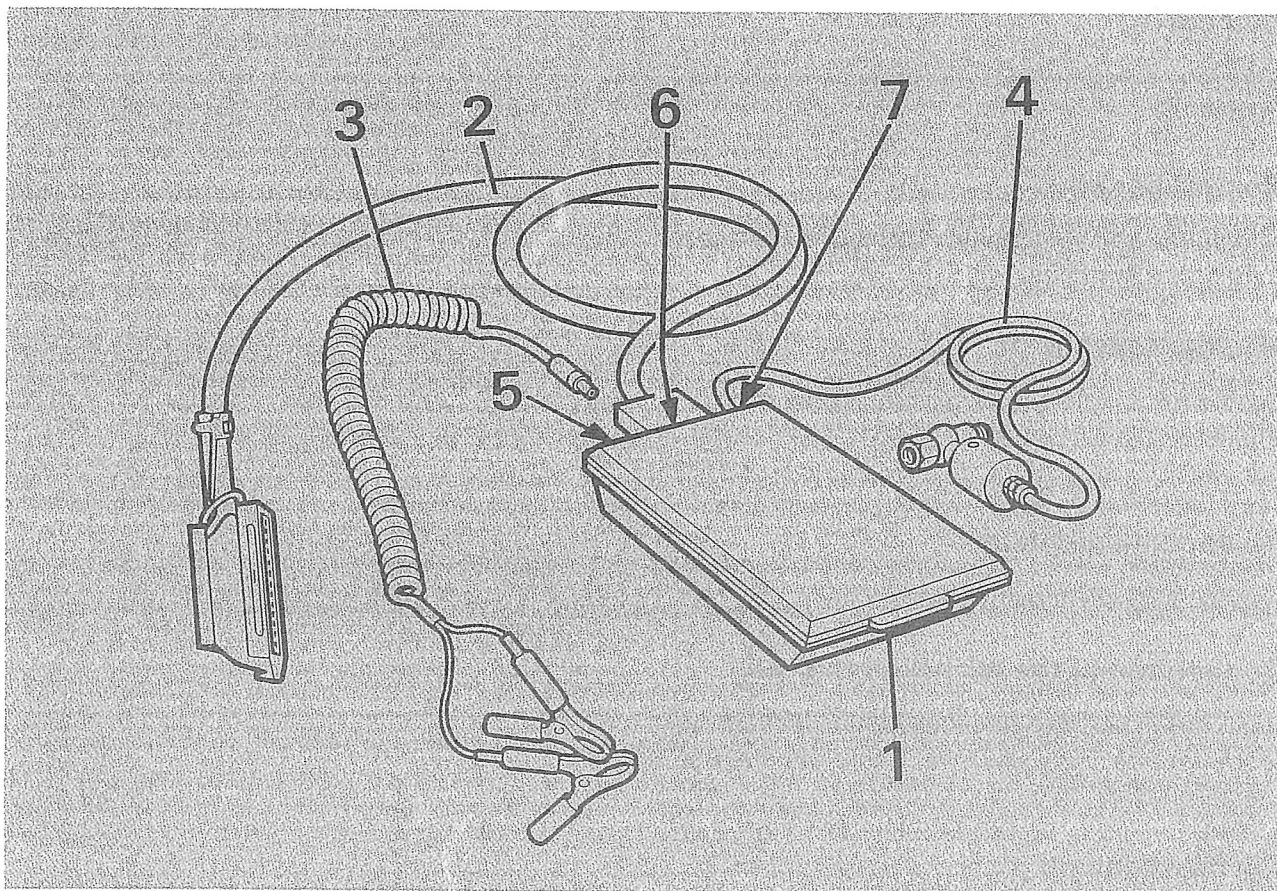
The Saab ABS-system tester has been developed for efficient servicing and fault-diagnosis work on the Saab ABS braking system.

The equipment comprises the following components:

- Tester
- Test lead with a two-way 35-pin connector
- Power supply lead
- Pressure sensor with connecting lead

The tester can be used for three different sets of tests:

- a Automatic testing of each wheel sensor and lead, and of the hydraulic pressure in the system (Test Mode)
- b Manual valve testing (Valve Test Mode)
- c Manual testing of each wheel sensor and lead, and of the hydraulic pressure in the brake system (Monitor Mode)



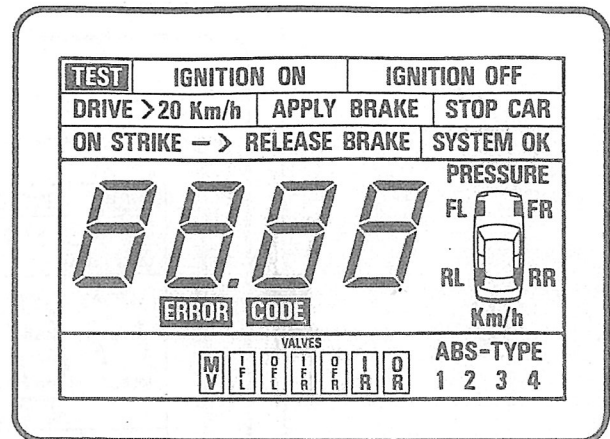
ABS-system tester

- 1 Tester unit
- 2 Test lead with two-way 35-pin connector
- 3 Power supply lead
- 4 Pressure sensor with connecting lead
- 5 Port for power supply
- 6 Port for test lead
- 7 Port for pressure-sensor lead

Tester display

The display is divided into three zones:

- Test prompts
- Measured values and error codes, with overview of test items
- Valve and ABS-version monitor



Test prompts

Displays driving instructions for the operator during testing.

(Details of individual prompts are given on page 590-5.)

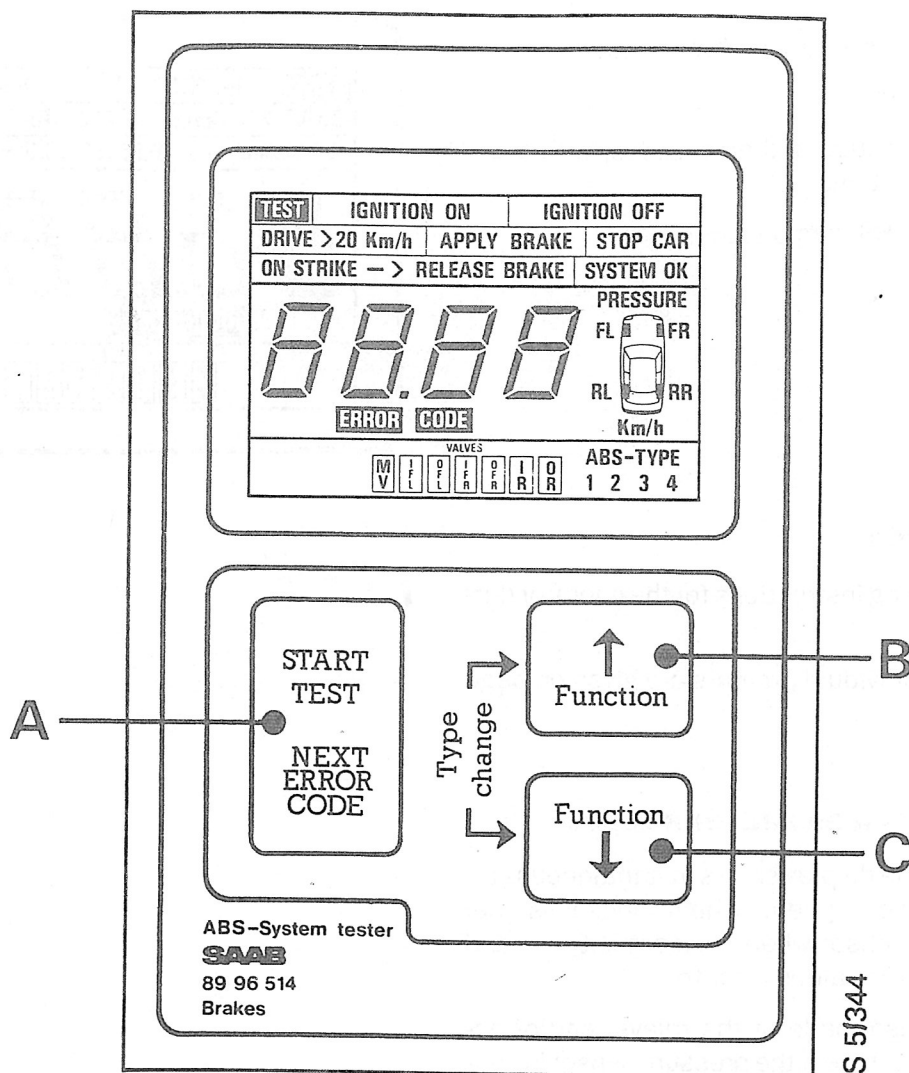
Measured values and error codes

This part of the display shows instantaneous values for wheel speed, wheel sensor signal amplitude, sensor-wheel eccentricity - and which wheel the values refer to.

A check is also made of the relays, and of accumulator pressure if the pressure sensor is connected. Error codes are displayed at the end of the run.

Valve monitoring

The valves operating during the test are indicated as is the ABS-system version selected.



Control panel

There are three buttons of the membrane-switch type on the control panel:

Button **A** is used to start the test cycle and to run through the error codes.

Button **B** is used to select the program that measures wheel-sensor signal strength, tests the operation of the wheel sensors and measures accumulator pressure (if pressure sensor connected).

Button **C** is used to select the program that measures sensor wheel eccentricity, to test the operation of the wheel sensors and to measure accumulator pressure (if pressure sensor connected).

Buttons **B** and **C** can be depressed simultaneously to select the ABS-system version.

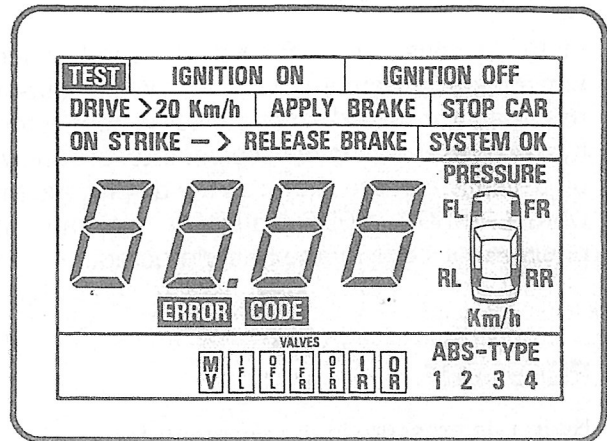
Test prompts

Note

The test prompts do not appear in the order shown on the display but vary with the test being run.

TEST

The program starts the test



IGNITION ON

Turn the ignition key to the drive position

ON STRIKE -> IGNITION OFF

If brake pedal pulsates or pedal travel is greater than normal: switch off ignition within 10 seconds.

If the pedal neither pulsates nor sinks to the floor, leave the ignition on and wait 20 seconds for the next prompt.

DRIVE > 20 km/h

Drive the car at a speed greater than 20 km/h (13 mph) but less than 30 km/h (19 mph)

APPLY BRAKE

Press down hard on the brake pedal immediately

STOP CAR

Take your foot off the accelerator and let the car coast. Light braking using handbrake only is permissible.

RELEASE BRAKE

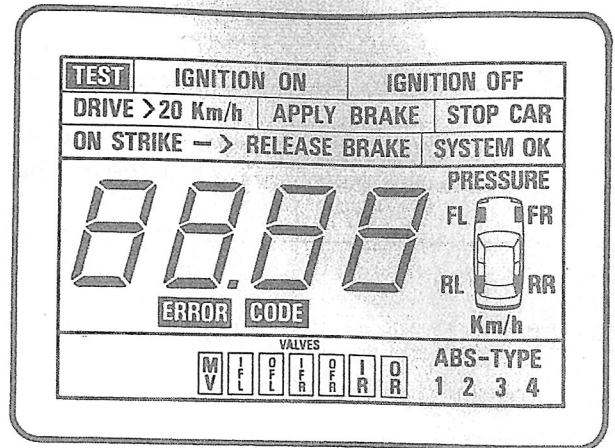
Foot off brake. **No** braking permissible

SYSTEM OK

Test completed: no fault found.

Signal values and error codes

Instantaneous values for wheel speed, wheel sensor signal amplitude, sensor wheel out-of-round and, if the pressure sensor is connected, hydraulic pressure in the accumulator are shown on the display. Also shown on the display are the words ERROR CODE followed by the alphanumeric code for the fault detected.



PRESSURE

Hydraulic pressure in the accumulator

FR

Front Right wheel

FL

Front Left wheel

RL

Rear Left wheel

RR

Rear Right wheel

Valve Test Mode

M
V

Main Valve

I
F
L

Inlet Front Left (left front inlet valve)

O
F
L

Outlet Front Left (left front outlet valve)

I
F
R

Inlet Front Right (right front inlet valve)

O
F
R

Outlet Front Right (right front outlet valve)

I
R

Inlet Rear (rear inlet valve)

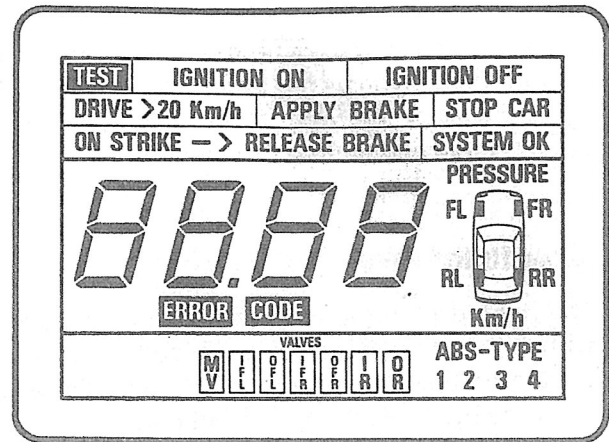
O
R

Outlet Rear (rear outlet valve)

ABS-TYPE

1234

Indicates the ABS-system version selected



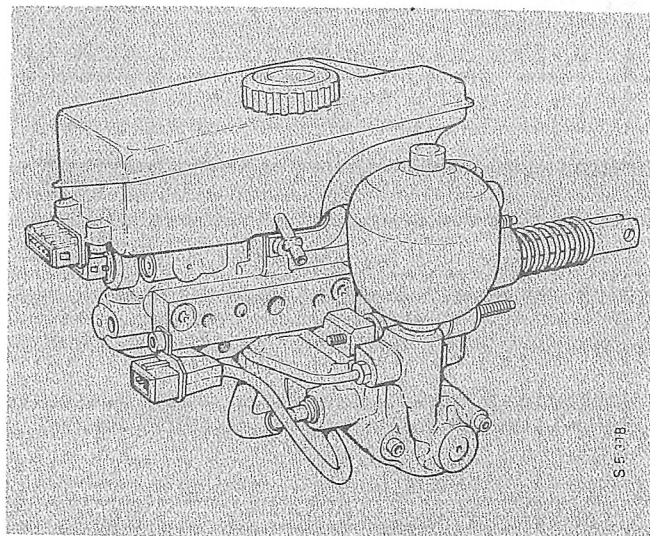
Quick checks

Although the ABS-system tester is the most important fault-diagnosis aid available for the ABS system, always perform the following quick checks before connecting the tester.

Brake fluid level

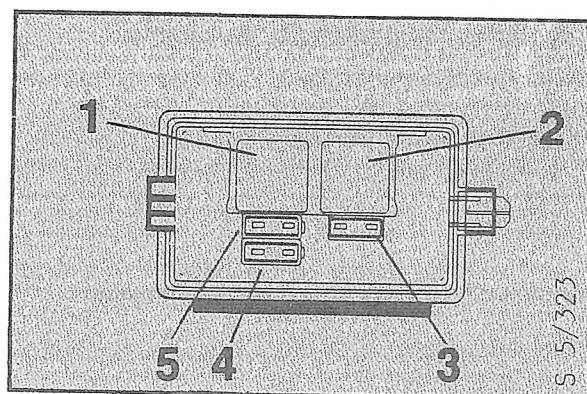
The fluid level in the reservoir must be checked with the accumulator fully charged with fluid. Switch on the ignition and check the fluid level after the hydraulic pump has cut out.

Top up, as necessary, with DOT 4 brake fluid to bring the level up to the MAX mark on the side of the reservoir.



Fuses

Inspect all the fuses in the fuse panel adjacent to the ABS-system ECU.

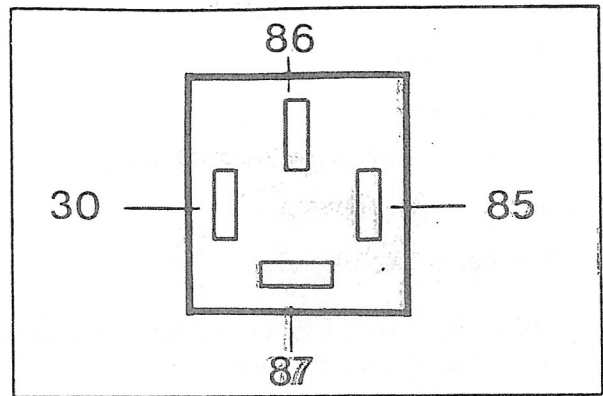


Relay and fuse panel

- 1 Relay, pump motor
- 2 Relay, ECU
- 3 Fuse, ECU (10 A, ABS)
- 4 Fuse, ECU (30 A, ABS)
- 5 Fuse, pump motor (30 A, Pump)

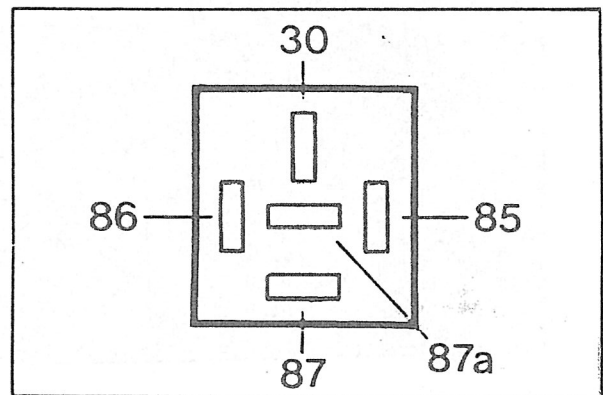
Relays

Check that the relay for the ECU and the relay for the pump motor have been fitted correctly.



Relay for pump motor

- 86 Voltage via fuse (10 A ABS)
- 85 Earth via pressure switch (accumulator pressure 140 bar)
- 87 Output to pump and ECU pin 32
- 30 Voltage via fuse (30 A Pump)



Relay for ECU

- 30 Output to ECU pins 3 and 20
- 85 Earth
- 87a Earth
- 87 Voltage via fuse (30 A ABS)
- 86 Output to ECU pin 8

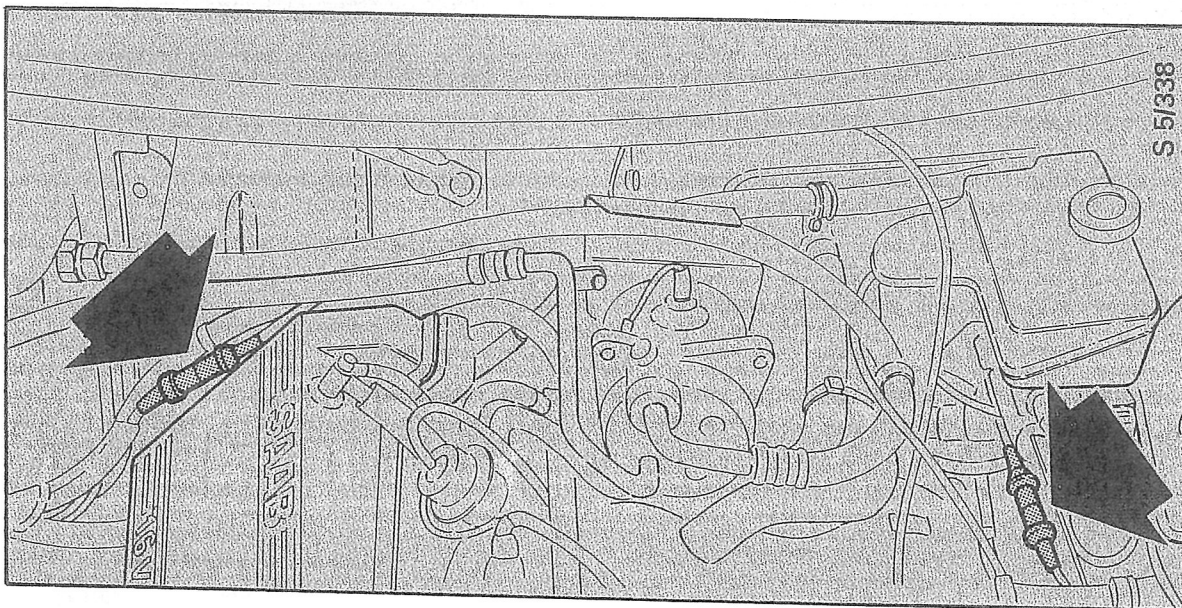
Electrical connections

Check all electrical connections:

- Pressure switch
- Master valve
- Fluid level indicator switch on reservoir
- Electric motor for pump
- Connector on valve block

Also check that the sensor lead connectors are making good contact:

- Both connectors in engine compartment
- Both connectors under rear seat



Earthing points

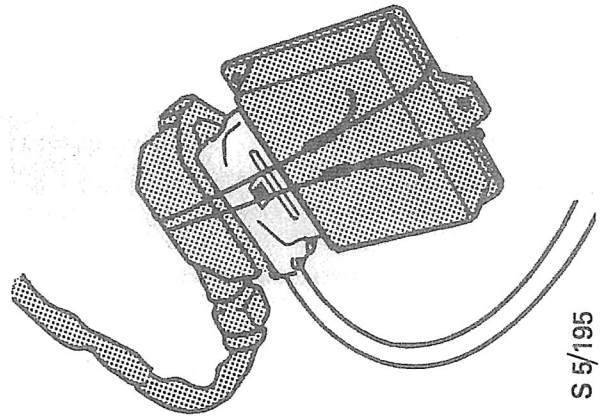
Check all earthing points:

- On LH wheel arch
- On bracket between hydraulic unit and front assembly

Connecting the tester to the car

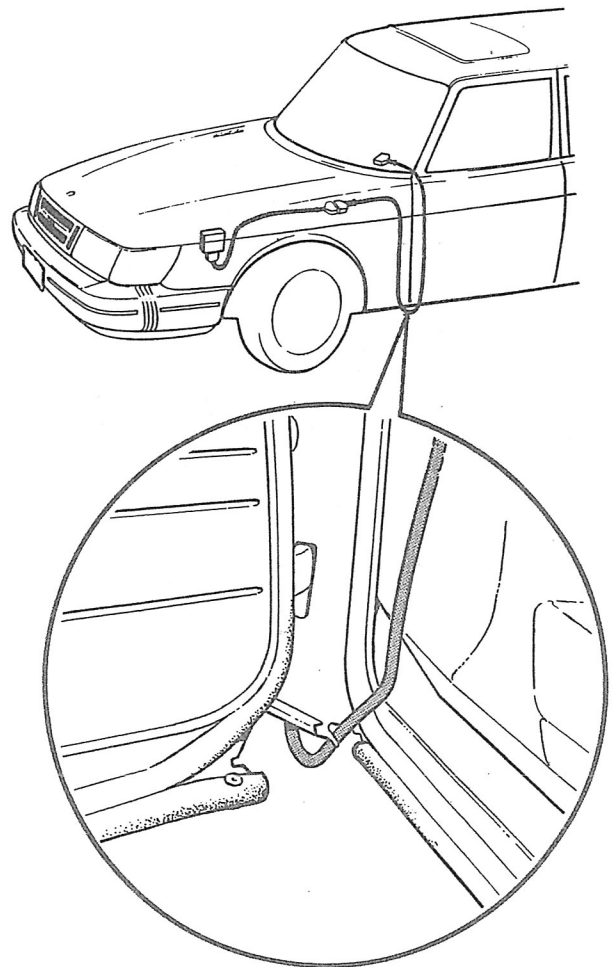
- 1 Switch off the ignition.
- 2 Remove the ECU.
- 3 Connect the tester lead between the ECU and the ABS wiring loom by means of the two-way 35-pin connector.

Secure the connector by fitting a strap round the ECU and connectors.



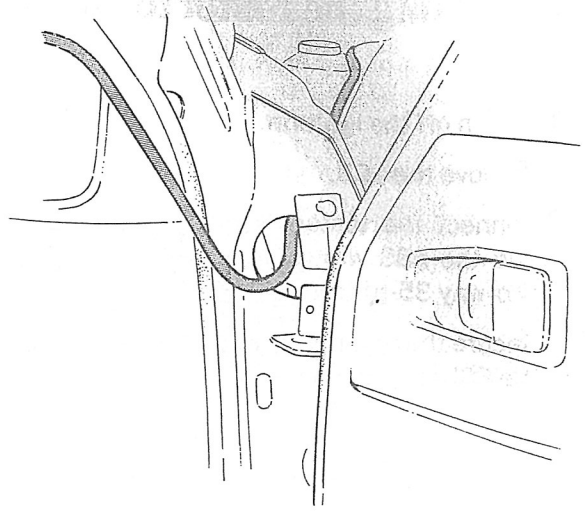
Run the test lead down between the LH wheel arch and A pillar and then into the car via the bottom corner of the door opening.

Connect the lead to the tester.



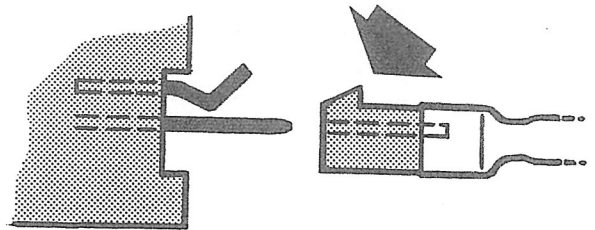
- 4 Connect the power supply lead to the battery (negative terminal first).

Run the lead through the opening in the RH 'A' pillar and connect it to the tester.



Note

Ensure that the connector is installed the right way round. If the connector is fitted upside down, the tester will be seriously damaged.



The tester will now automatically select ABS-type 1.

Caution

Always switch off the ignition before unplugging the test-lead connector from the ECU. Failure to do so can result in the ECU being destroyed.

Connecting the pressure sensor

It is not necessary to connect the pressure sensor unless a pressure-related fault is suspected.

Caution

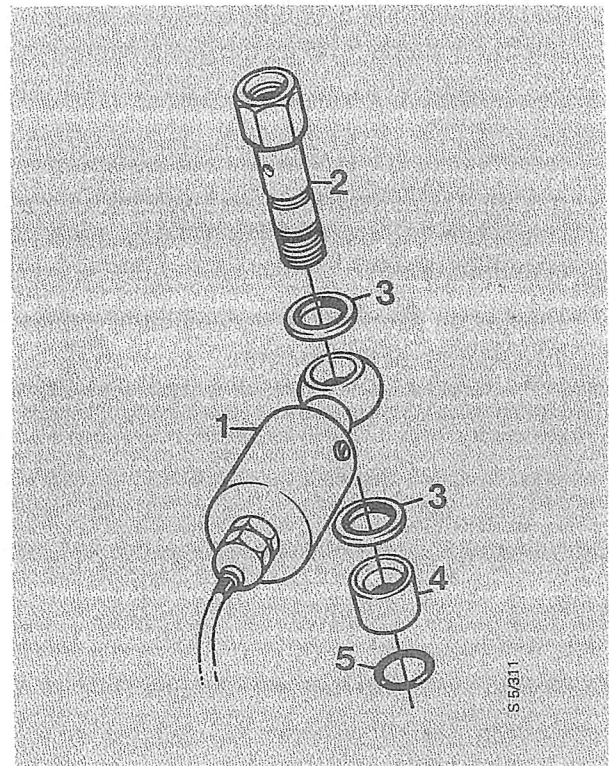
The system must be depressurized before work is started. To do this, with the ignition off depress the brake pedal about 20 times until positive resistance is felt in the pedal.

To connect the pressure sensor

- 1 Remove the accumulator.
- 2 Connect hose 89 96 597 to the connection for the accumulator on the hydraulic unit.
- 3 Connect the pressure sensor to the hose.
- 4 Connect the accumulator to the pressure sensor.

Tightening torque:

34 - 46 Nm (25 - 34 lbf ft)



- 5 Connect the pressure sensor lead to the tester.

To disconnect the pressure sensor

Caution

The system must be depressurized before work is started. To do this, with the ignition off depress the brake pedal about 20 times until positive resistance is felt in the pedal.

To disconnect the pressure sensor, reverse the procedure for connecting it.

- 1 Pressure sensor
- 2 Fitting with groove for 'O' ring
- 3 Washer
- 4 Sleeve
- 5 'O' ring

Checking the accumulator gas pressure

Connect the tester and pressure sensor as detailed on pages 590-11 and 590-13.

- 1 Set the tester so that PRESSURE is shown on the display.
- 2 Switch on the ignition and let the pump run until the ABS (Anti-lock) warning light goes off.
- 3 Switch off the ignition.
- 4 Pump the brake pedal and watch the display on the tester. Each time the pedal is pressed, the hydraulic pressure in the brake system drops.

The moment the hydraulic pressure has fallen to the same level as the gas pressure in the accumulator, the value 0 will appear on the display.

Note the value shown on the display immediately before the 0 value appears. This value denotes the gas pressure in the accumulator (bar).

The gas pressure in the accumulator should be between 40 and 80 bar.

Caution

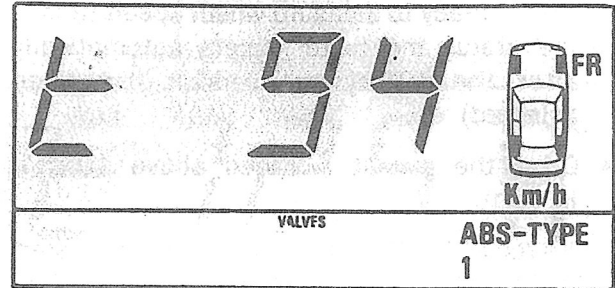
If the value is below 40 bar, fit a new accumulator.

Selecting the ABS-system version

As soon as the tester is powered up, it automatically selects ABS-type 1. This is the system version with a 94-tooth sensor wheel, fitted to all 1989 and earlier models.

The letter 't' (teeth) is shown on the display followed by the figure '94', indicating the number of teeth on the sensor wheel. (Note that some testers will display the figure '96'.)

"ABS-type 1" indicates the automatically chosen system.



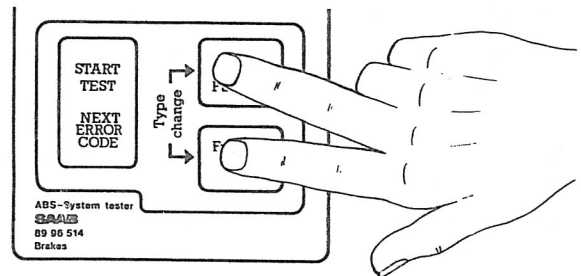
Selection of an alternative ABS-system version must be made within four seconds of power up by pressing the two function buttons simultaneously.

The following ABS versions are in use:

ABS type

- 1 = Sensor wheel with 94 teeth
- 2 = Sensor wheel with 46 teeth
- 3 = Not used
- 4 = Not used

A couple of seconds after the ABS version has been selected, the tester will automatically switch to Monitor Mode (manual test cycle).



Test mode

The tests in this mode are the same as those in Monitor Mode, except that here the tester switches automatically from one test to the next.

To enter Test Mode:

- Make sure that the tester is in the Monitor Mode, ready to measure wheel speed (this is the status the tester enters automatically after the ABS-system version has been selected)
- Drive the car at a speed above 10 km/h (6 mph).

Press the START TEST button. TEST will now start to flash on the display, indicating that the Test Mode has been initiated.

If the tester does not enter the Test Mode, remain in Monitor Mode and check the wheel sensor signal amplitude for each wheel.

For accurate test results, the car must be driven for at least three minutes at a speed of about 70 km/h (42 mph). The test results will not be affected by the car stopping and starting in response to traffic conditions. The test cycle for each wheel takes about two seconds; testing the accumulator pressure takes a bit longer (approx. four seconds) because the relays are also checked.

The tester will bleep each time a fault is detected.

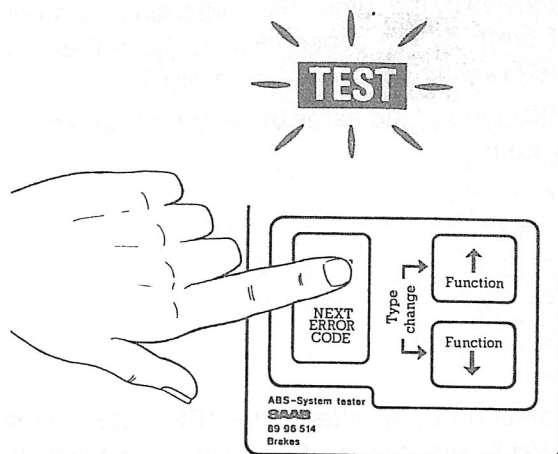
Rectify any faults by locking up the error code in the fault-diagnosis routine.

Testing will continue until the tester is switched off or the START TEST button is pressed for about three seconds.

To read the test results:

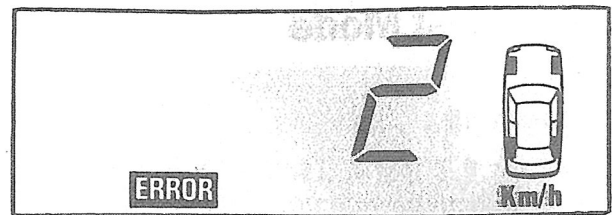
- 1 Stop the car. **Do not** switch off the ignition.
- 2 Wait until the display indicates FR, FL, RL or RR and press the START TEST button.

If no faults have been detected, the display will read SYSTEM OK.

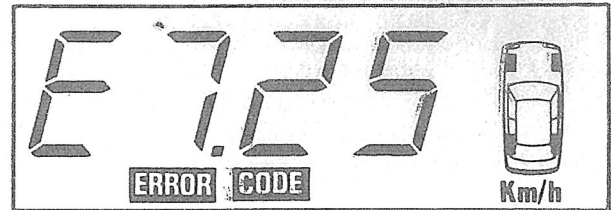


SYSTEM OK

If any faults have been detected, ERROR will appear on the display followed by a figure indicating the number of faults found.



To read the error codes, press the NEXT ERROR CODE button and the error codes will be displayed. Press the button again to read each successive error code.



If several error codes are displayed together they must be investigated and rectified in the following order:

E002	EE24	E001	E033
E422	EE25	E009	E034
E523	E011	E010	E035
E624	E008	E015	E132
E725	E320	E016	PRES
EE22	E014	E017	
EE23	E032	E018	

To return to Monitor Mode, press one of the function buttons.

Valve Test Mode

Warning

During this test you will need to stop the car abruptly several times. If possible, use roads that are deserted or where traffic is very light.

Remember to use your mirror and to give clear signals of your intentions.

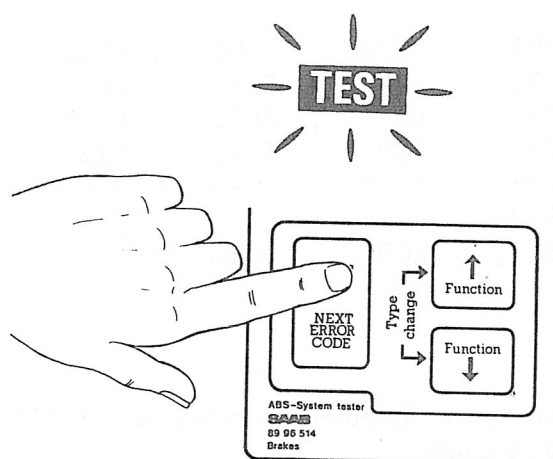
To enter the Valve Test Mode:

- Make sure that the tester is in Monitor Mode (entered automatically by the tester after the ABS-system version has been selected)
- The car must be at a standstill with the engine running.

Press one of the FUNCTION buttons to enter the Valve Test Mode. (The ABS (Anti-lock) warning light on the instrument panel will come on and remain on throughout the test sequence.)

Press the START TEST button. TEST will now flash on the display, indicating that the test sequence has been initiated.

The tester will bleep each time a fault is detected.



Inlet valves

The valves are tested in the following order:

IFL	=	Inlet Front Left
IFR	=	Inlet Front Right
IR	=	Inlet Rear

Note

When the rear inlet valve (IR) is to be tested, choose a place to stop the car where it can remain parked whilst the remaining valves are tested.

During this test, the following prompts will appear on the display in the order shown:

DRIVE > 20 km/h

Drive the car at a speed above 20 km/h (13 mph) but not over 30 km/h (19 mph).

STOP CAR and RELEASE BRAKE

Foot off the accelerator and let the car coast. Do not touch the brake pedal: use the handbrake if you need to slow the car down. Depress the clutch pedal (manuals only) and be ready to brake when APPLY BRAKE appears on the display (after the road speed has dropped to about 18 km/h or 11 mph).

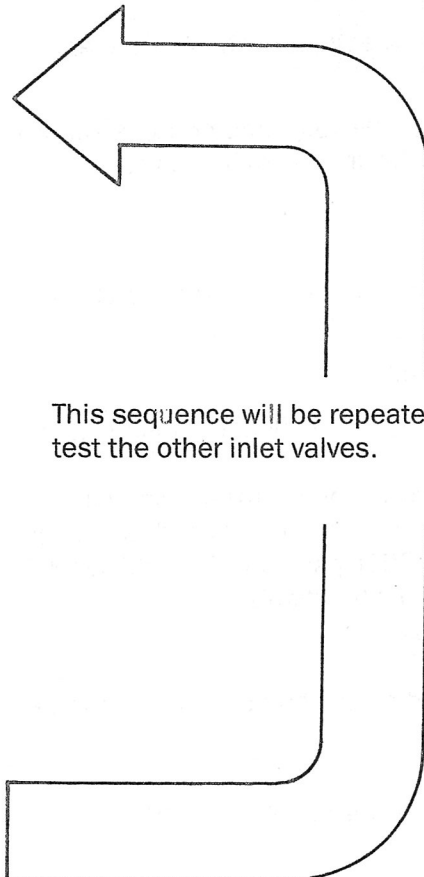
APPLY BRAKE

Press down hard on the brake pedal as soon as the text appears. (The tester will measure the wheel retardation as the car slows from 15 to 13 km/h.)

RELEASE BRAKE

As soon as the car has stopped, release the brake pedal. Do not touch the brake pedal again.

When the test sequence for the inlet valves has been completed, the tester will automatically continue the next sequence, i.e. testing the outlet valves and main valve.



This sequence will be repeated automatically to test the other inlet valves.

Outlet valves and main valve

The outlet valves and main valve are tested in the following order:

- OR = Outlet Rear (rear outlet valve)
- OFR = Outlet Front Right
- OFL = Outlet Front Left
- MV = Main valve

Note

During testing of the main valve (MV) the brake pedal will pulsate strongly.

Before starting the test:

- The car must be at a standstill with the engine switched off.

During this test, the following prompts will appear on the display in the order shown:

IGNITION ON

Switch on the ignition (turn key to drive position)

RELEASE BRAKE

Do not touch the brake pedal. Braking is **not** allowed.

(After about five seconds, the pump will have raised the pressure in the accumulator to approx. 180 bar (2610 psi) and RELEASE BRAKE will disappear from the display.)

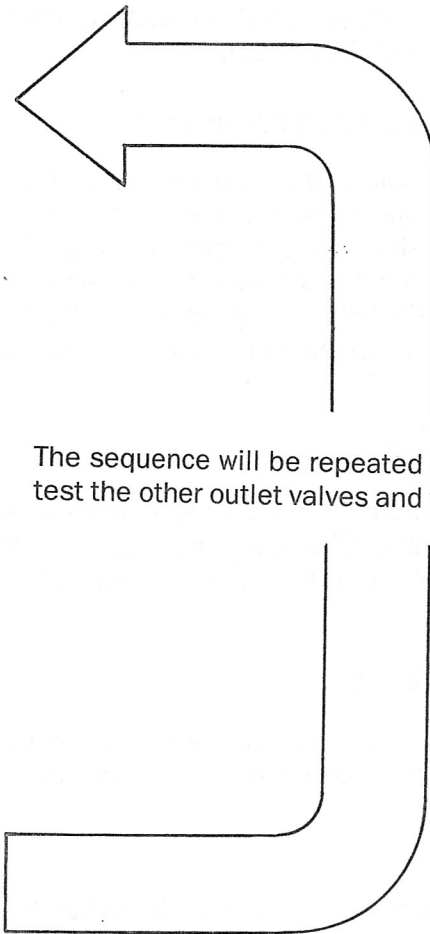
APPLY BRAKE

Press down hard on the brake pedal as soon as the text appears.

ON STRIKE → and IGNITION OFF
(Both flashing)

The pedal should pulsate or there should be excessive pedal travel when the pedal is depressed. If so, switch off the ignition within 10 seconds to send an acknowledgement to the tester. If the pedal does not respond as described, do not switch off the ignition. Wait about 20 seconds for the next prompt (RELEASE BRAKE) to appear on the display.

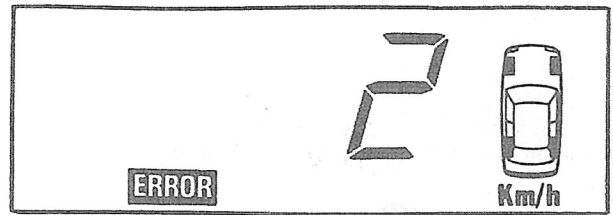
If no faults have been detected, the display will read SYSTEM OK.



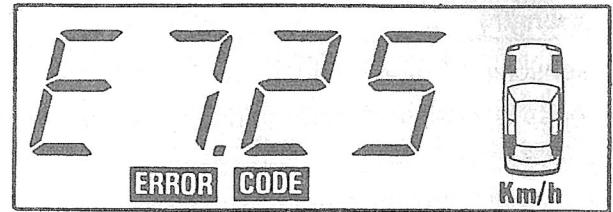
The sequence will be repeated automatically to test the other outlet valves and the main valve.

SYSTEM OK

If any faults have been detected, ERROR will appear on the display followed by a figure indicating the number of faults found.



To read the error codes, press the NEXT ERROR CODE button and the error codes will be displayed. Press the button again to read each successive error code.



If several error codes are displayed together they must be investigated and rectified in the following order:

E002	EE24	E001	E033
E422	EE25	E009	E034
E523	E011	E010	E035
E624	E008	E015	E132
E725	E320	E016	PRES
EE22	E014	E017	
EE23	E032	E018	

To return to Monitor Mode, press one of the function buttons.

Monitor mode

After the tester has been powered up and the ABS-system version selected, the tester will automatically enter the Monitor Mode.

The following tests can now be performed:

- Wheel speed
- Wheel sensor signal amplitude (signal strength)
- Sensor wheel eccentricity (out-of-round)
- Wheel-sensor circuit continuity and function check
- Accumulator pressure (if pressure sensor connected)

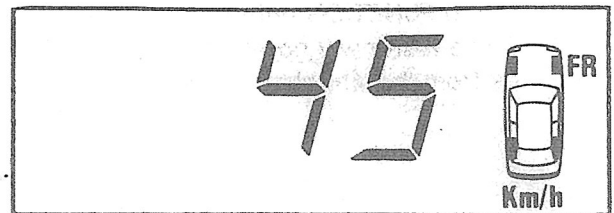
The tester will bleep each time a fault is detected.

Road-wheel speed

This test must be carried out with the car being driven at a steady speed.

Km/h will appear on the display together with a number, indicating the speed of the wheel in km/h.

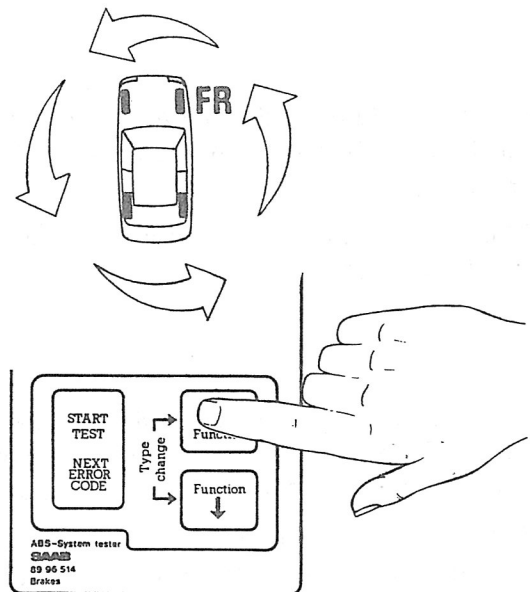
FR on the display indicates that the front right wheel is being tested.



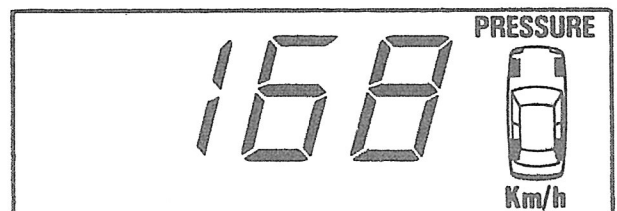
To test the speed of the other wheels, press the top FUNCTION button. The wheels will now be tested in an anticlockwise sequence, as shown.

(The test can also be performed in a clockwise sequence - press the bottom FUNCTION button.)

The values should be roughly the same for all four wheels.



If the pressure sensor is connected, PRESSURE will appear on the display together with a value indicating the accumulator pressure in bar (this is the working pressure of the brake system).

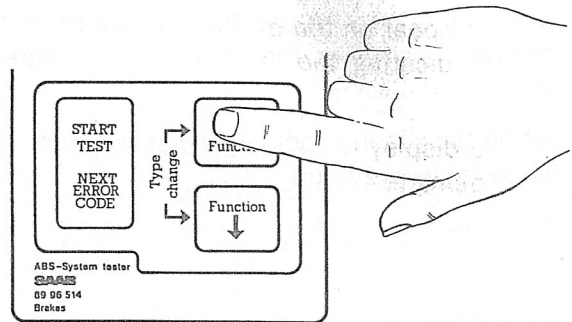


Some of the valve segments may flash during this test; this is quite normal and can be disregarded.

Wheel-sensor signal amplitude

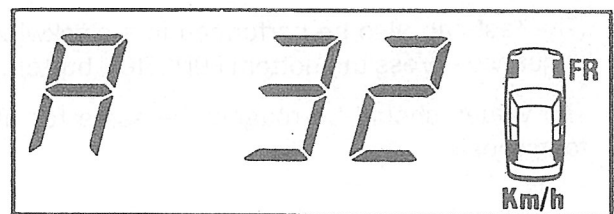
This test must be carried out with the car being driven at a steady speed.

Press the top FUNCTION button for about three seconds. The tester will now measure the signal amplitude from the wheel sensors.



The letter A (amplitude) will appear on the display followed by a value proportional to the signal voltage.

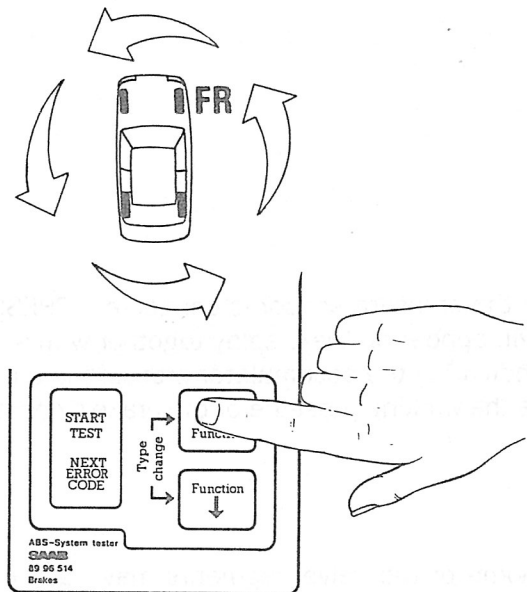
FR on the display indicates that the front right wheel is being tested.



To test the speed of the other wheels, press the top FUNCTION button. The wheels will now be tested in an anticlockwise sequence, as shown.

(The test can also be performed in a clockwise sequence - press the bottom FUNCTION button.)

The values for the different wheels should not vary by more than about 20%.



If the pressure sensor is connected, PRESSURE will appear on the display together with a value indicating the accumulator pressure in bar (this is the working pressure of the brake system).

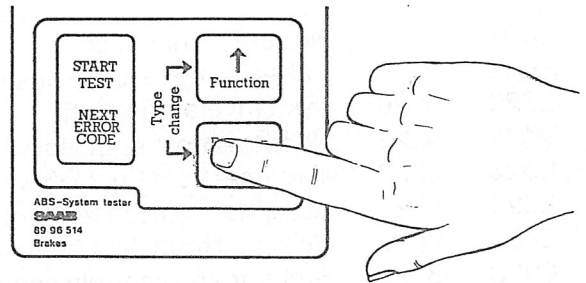


Press the top FUNCTION button for about three seconds and the tester will revert to the test cycle for measuring wheel speed.

Sensor-wheel eccentricity

For this test the car must be driven at a speed of between 40 and 45 km/h (25 - 30 mph) for a minimum period of 60 seconds.

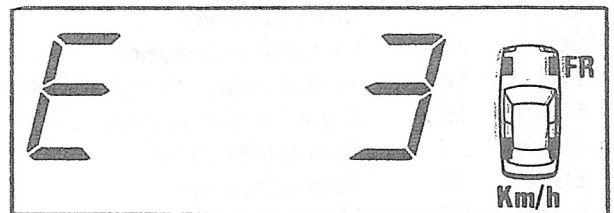
Press the bottom FUNCTION button for three seconds to initiate this test.



The letter E (eccentricity) will appear on the display together with a number indicating the ratio of amplitude variation to maximum amplitude during one revolution of the wheel.

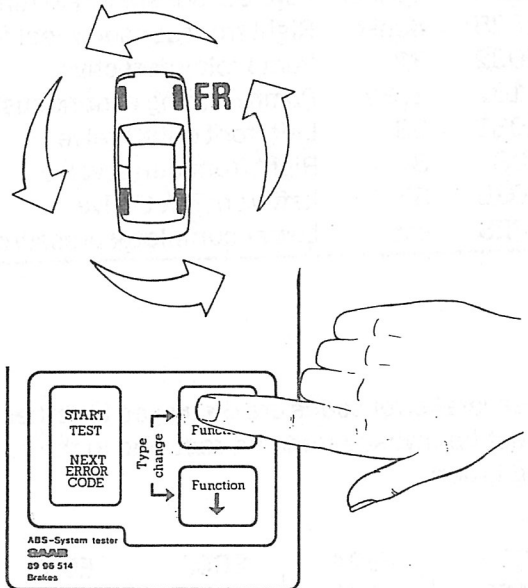
This value should not be higher than 6.

FR on the display indicates that the front right wheel is being tested.

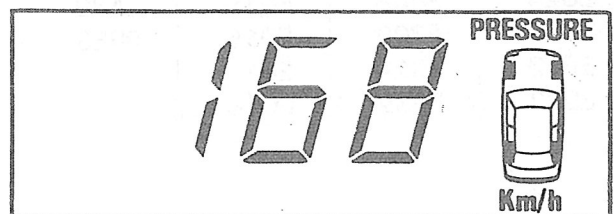


To test the speed of the other wheels, press the top FUNCTION button. The wheels will now be tested in an anticlockwise sequence, as shown.

(The test can also be performed in a clockwise sequence - press the bottom FUNCTION button.)



If the pressure sensor is connected, PRESSURE will appear on the display together with a value indicating the accumulator pressure in bar (this is the working pressure of the brake system).



Press the top FUNCTION button for about three seconds and the tester will revert to the test cycle for measuring wheel speed.

Error codes

The tester uses the following error codes:

Error code	ECU pin no	Malfunction indicated	Action, see page
E001	1	No earth connection	590-27
E002	2	Battery voltage low or absent	590-28
E320	3, 20	System relay function	590-29
E422	4, 22	No signal from right rear wheel sensor	590-30
E523	5, 23	No signal from front left wheel sensor	590-30
E624	6, 24	No signal from left rear wheel sensor	590-30
E725	7, 25	No signal from right front wheel sensor	590-30
E008	8	System relay-control signal missing	590-31
E009	9	Brake fluid level low: hydraulic pressure low	590-32
E010	10	ECU defective	590-32
E011	11	No earth connection	590-33
E014	14	Pump relay/pressure switch defective	590-34
E015	15	Right front inlet valve	590-35
E016	16	Rear outlet valve	590-35
E017	17	Rear inlet valve	590-35
E018	18	Main valve	590-35
EE22	Sensor	Right rear sensor wheel runout	590-36
EE23	Sensor	Left front sensor wheel runout	590-36
EE24	Sensor	Left rear sensor wheel runout	590-36
EE25	Sensor	Right front sensor wheel runout	590-36
E032	32	Pump relay defective	590-37
E132	1, 32	Pump running continuously	590-38
E033	33	Left front outlet valve	590-35
E034	34	Right front outlet valve	590-35
E035	35	Left front inlet valve	590-35
PRES	ext	Low accumulator pressure	590-39

If several error codes are displayed together they must be investigated and rectified in the following order:

E002	EE24	E001	E033
E422	EE25	E009	E034
E523	E011	E010	E035
E624	E008	E015	E132
E725	E320	E016	PRES
EE22	E014	E017	
EE23	E032	E018	

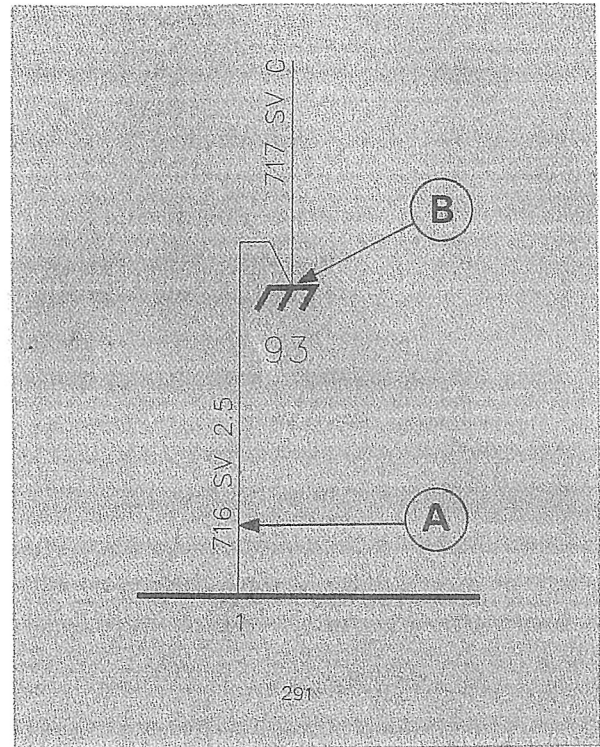
Fault-diagnosis routines

Error code: **E001**

Malfunction indicated: No earth between ECU pin 1 and earthing point 93.

Action:

- A Check the wiring between ECU pin 1 and earthing point 93.
- B Check that good earth obtained at earthing point 93.



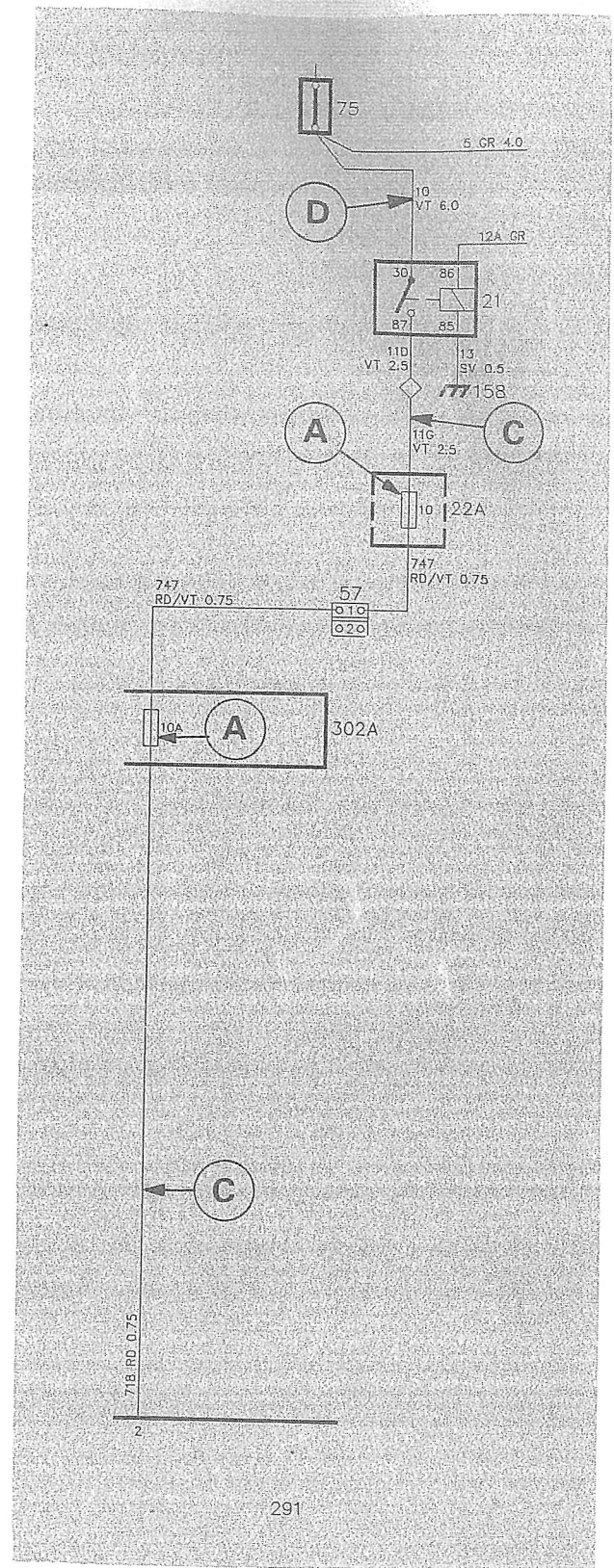
590-28 ABS-system tester

Error code: **E002**

Malfunction indicated: Battery voltage low at ECU pin 2

Action:

- A Check the 10A (ABS) fuse in the ABS fuse panel (302A), and fuse 10 in the fuse panel (22A).
- B Check that the battery voltage is higher than 10V.
- C Check the wiring between ECU pin 2 and terminal 87 in the ignition switch relay (21)
- D Check the wiring between terminal 30 in the ignition switch relay (21) and connector 75.



Error code: **E320**

Malfunction indicated: Defective system relay (292)

Action:

A Check the signals from the wheel sensors by driving the car with the tester in Monitor Mode.

Note the signal from all sensors. A break in sensor-circuit continuity can trigger error code E320 (indicated on the display by a speed value of 0 being shown for the wheel in question).

Rectify any faults following the procedure given for error code E422, E523, E624 or E725.

B Check the valves by running the tester in the Valve-Test Mode. A brake in valve-circuit continuity can trigger error code E320.

C Check the 30 A (ABS) fuse and the 30 A (PUMP) fuse in the ABS fuse panel (302A).

D Check the wiring from ECU pins 3 and 20 to pin 30 on the system relay (292).

E Check the wiring between connector 75 and pin 87 on the system relay (292).

F Check the wiring between earthing point 93 and pin 87 A on the system relay (292).

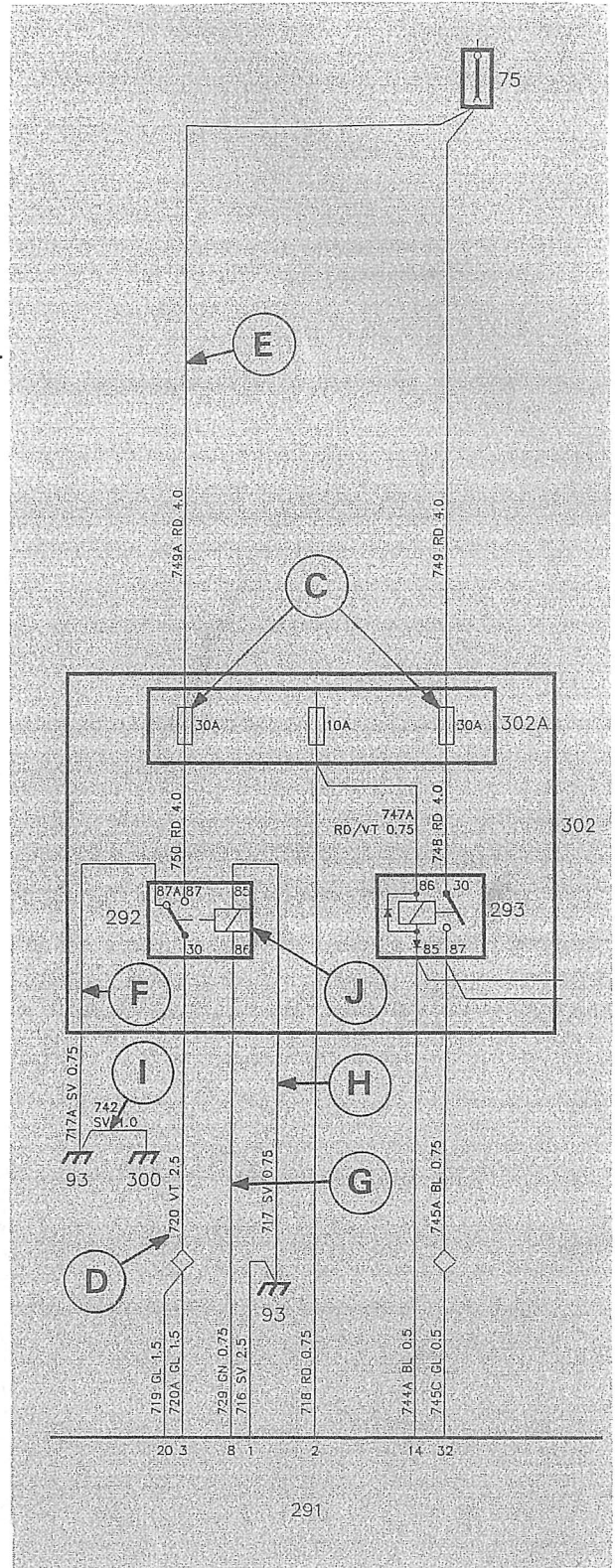
G Check the wiring between ECU pin 8 and pin 86 on the system relay (292).

H Check the wiring between earthing point 93 and pin 85 on the system relay (292).

I Check the wiring between earthing point 93 and earthing point 300.

J Check the system relay for a break or short-circuit between pins 85 and 86.

K Fit a new system relay.

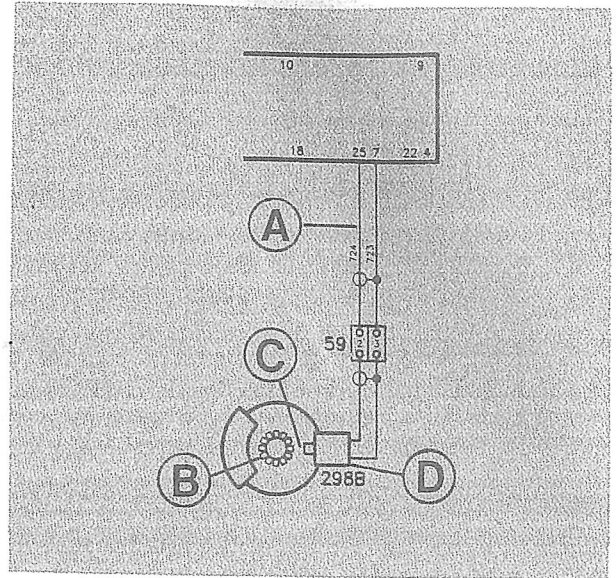


Error code: **E725**

Malfunction indicated: No wheel-sensor signal to ECU pins 7 and 25.

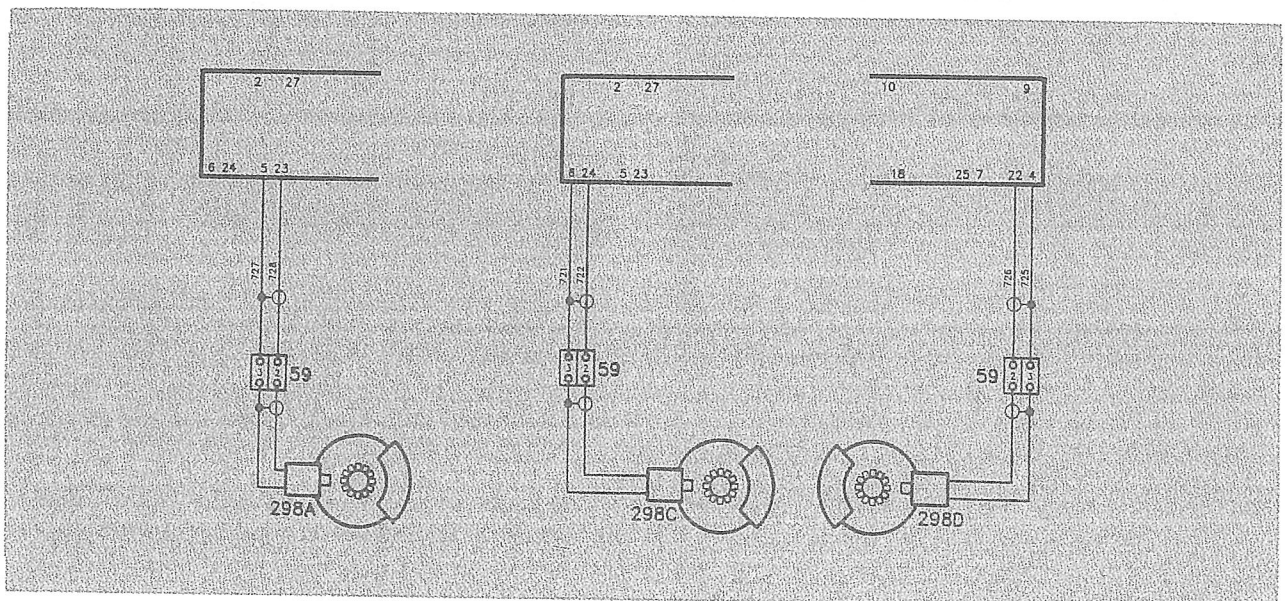
Action:

- A Check the wiring from ECU pins 7 and 25 to the wheel sensor (298B).
- B Check the right front sensor wheel.
- C Check the gap between the sensor wheel and sensor.
- D Fit a new wheel sensor.



Similarly:

Error Code	Sensor wheel	ECU	Wheel sensor
E422	Right rear	Pins 4 & 22	298D
E523	Left front	Pins 5 & 23	298A
E624	Left rear	Pins 6 & 24	298C



Error code: **E008**

Malfunction indicated: Main relay - control signal missing

Action:

A Check the signals from the wheel sensors by driving the car with the tester in Monitor Mode.

Note the signal from all sensors. A break in circuit continuity from a sensor can trigger error code E008 (indicated on the display by a speed value of 0 being shown for the wheel in question).

Rectify any faults following the procedure given for error code E422, E523, E624 or E725.

B Check the valves by running the tester in the Valve-Test Mode. A break in valve-circuit continuity can trigger error code E008.

C Check the 30 A (ABS) fuse in the ABS fuse panel (302A).

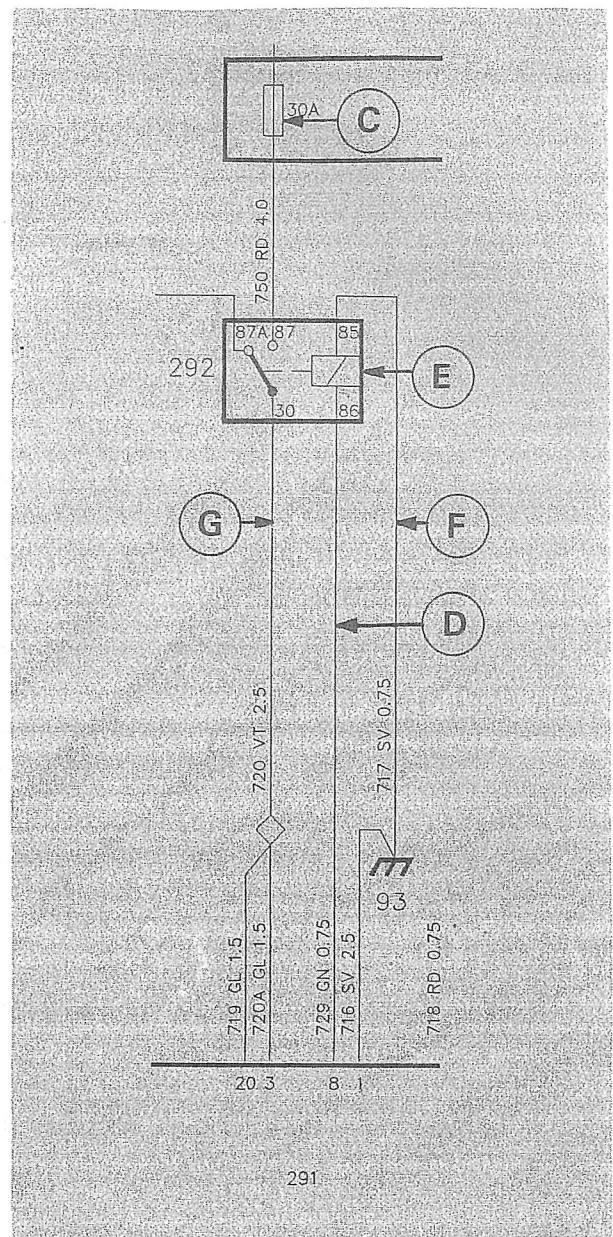
D Check for a short-circuit or break in the wiring between ECU pin 8 and pin 86 on the system relay (292).

E Check the system relay for a break or short-circuit between pins 85 and 86.

F Check circuit continuity or for short-circuit between pin 85 on the system relay and earthing point 93.

G Check the wiring from ECU pins 3 and 20 to pin 30 on the system relay (292).

H Fit a new ECU.



Error code: **E009**

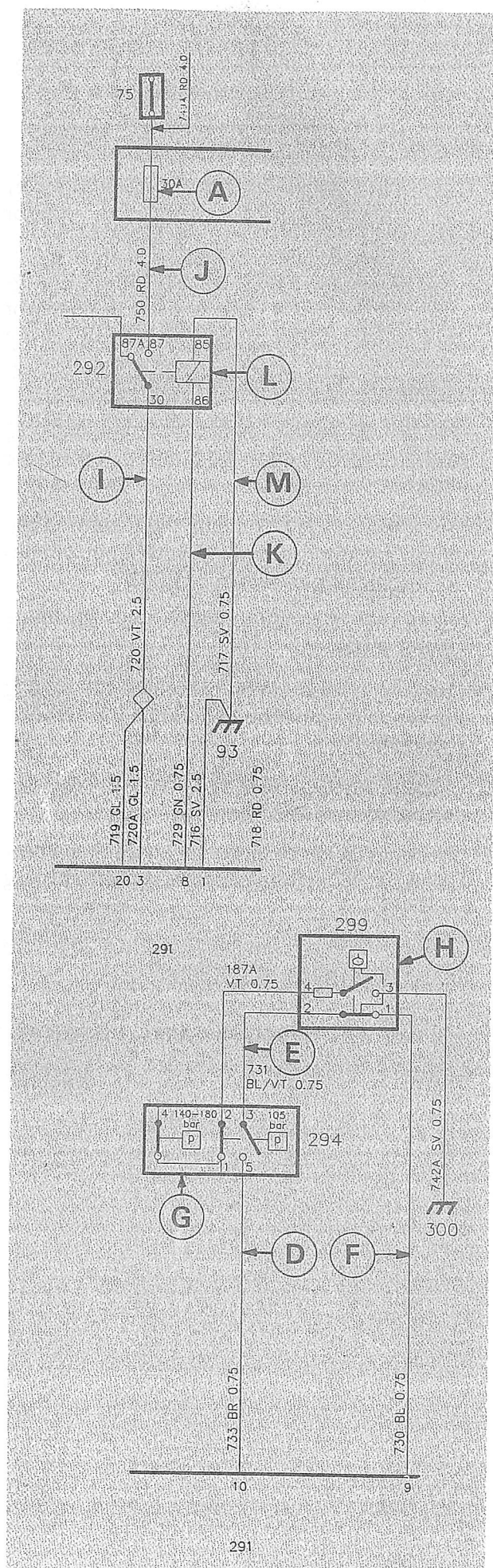
Malfunction indicated: Fluid level low; hydraulic pressure low

Error code: **E010**

Malfunction indicated: Defective ECU

Action:

- A Check the 30A (ABS) fuse in the ABS fuse panel (302A).
- B Check the valves by driving the car with the tester in Valve Test Mode.
- C Check the wheel-sensor signals by driving the car with the tester in Monitor Mode.
- D Check for a break or short-circuit in wiring between ECU pin 10 and pin 5 of the pressure switch (294).
- E Check for a break or short-circuit in the wiring between pin 3 on the pressure switch (294) and pin 2 on the fluid level indicator (299).
- F Check for a break or short-circuit in the wiring between pin 1 of the fluid level indicator (299) and ECU pin 9.
- G Check the function of the pressure switch (294). Contacts 3 and 5 should be closed when the pressure is above 105 bar.
- H Check the function of the fluid level indicator (299).
- I Check the wiring from ECU pins 3 and 20 to pin 30 on the system relay (292).
- J Check the wiring between connector 75 and pin 87 on the system relay (292).
- K Check for a break or short-circuit in the wiring between ECU pin 8 and pin 86 on the system relay (292).
- L Check for a break or short-circuit between pins 85 and 86 on the system relay.
- M Check for a break or short-circuit in the wiring between pin 93 of the system relay and earthing point 93.
- N Fit a new ECU.

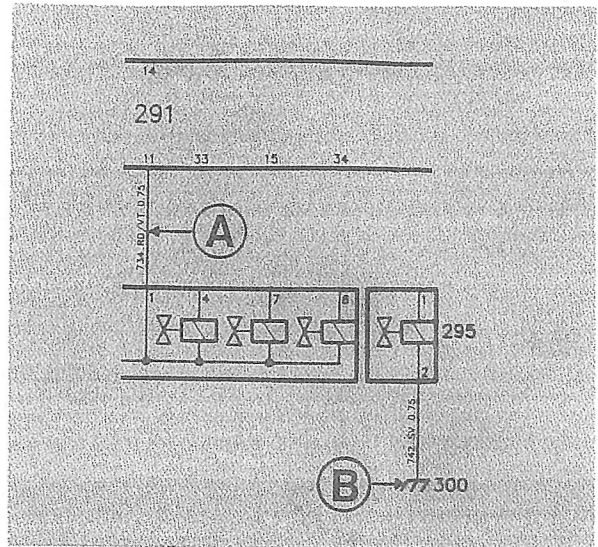


Error code: **E011**

Malfunction indicated: No continuity between ECU pin 11 and earthing point 300 on the hydraulic unit.

Action:

- A Check the wiring between ECU pin 11 and pin 1 on the valve block connector (296).
- B Check that good earth is available at the earthing point (300) on the hydraulic unit.



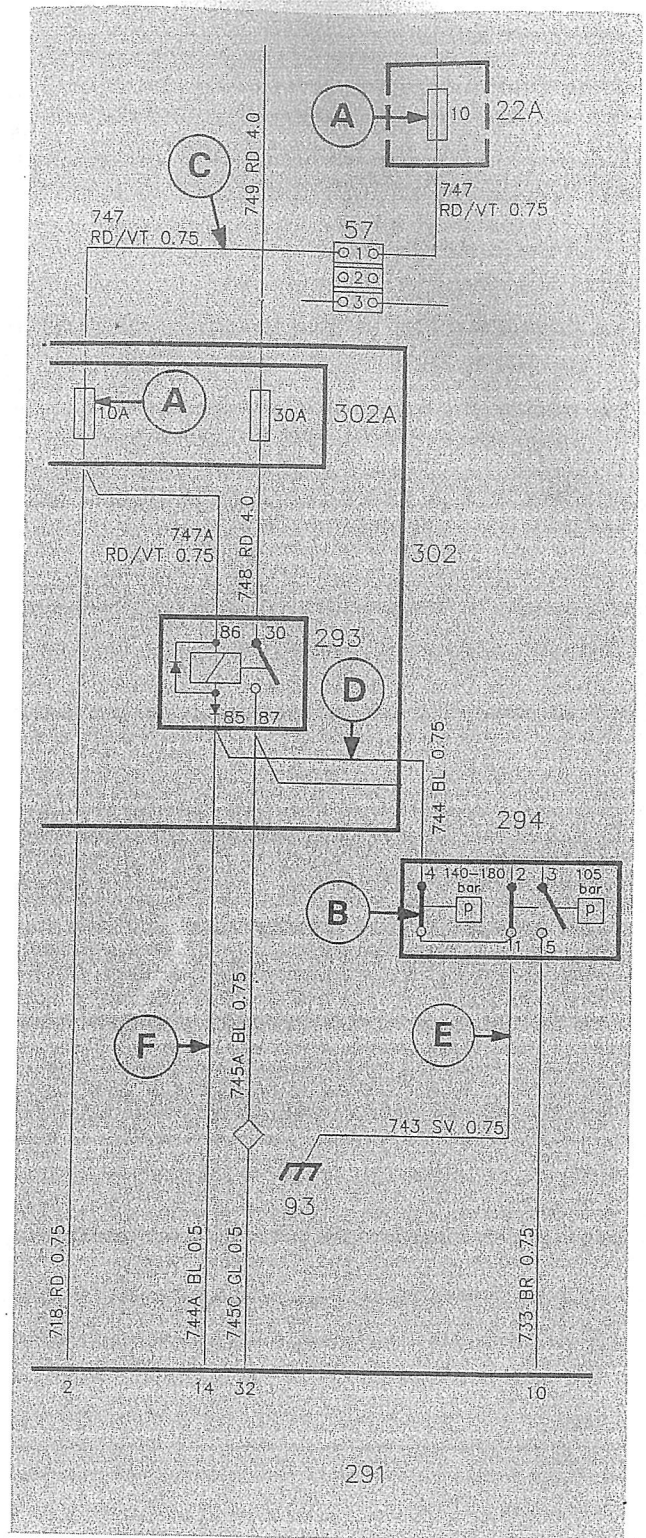
Error code: **E014**

Malfunction indicated: Defective pump/pressure switch relay

This error code can only be triggered if ECU terminal 14 has sensed continuous pump operation for more than 90 seconds during testing.

Action:

- A Check the 10A (ABS) fuse in the ABS fuse panel (302A) and fuse 10 in the main fuse panel (22A).
- B If the pressure is below 140 bar (2030 psi), check that the switch between terminals 1 and 4 on the pressure switch (294) is closed.
- C Check the wiring between connector 75 and pin 86 on the pump relay (293).
- D Check the wiring between pin 85 on the pump relay (293) and pin 4 on the pressure switch (294).
- E Check the wiring between pin 1 on the pressure switch (294) and earthing point 93.
- F Check the wiring between pin 85 on the pump relay (293) and ECU pin 14.
- G Fit a new pump relay (293).

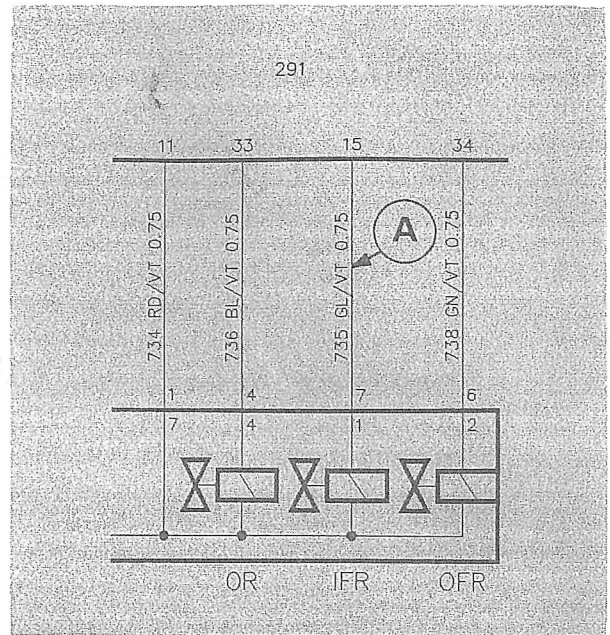


Error code: **E015**

Malfunction indicated: IFR valve inoperative

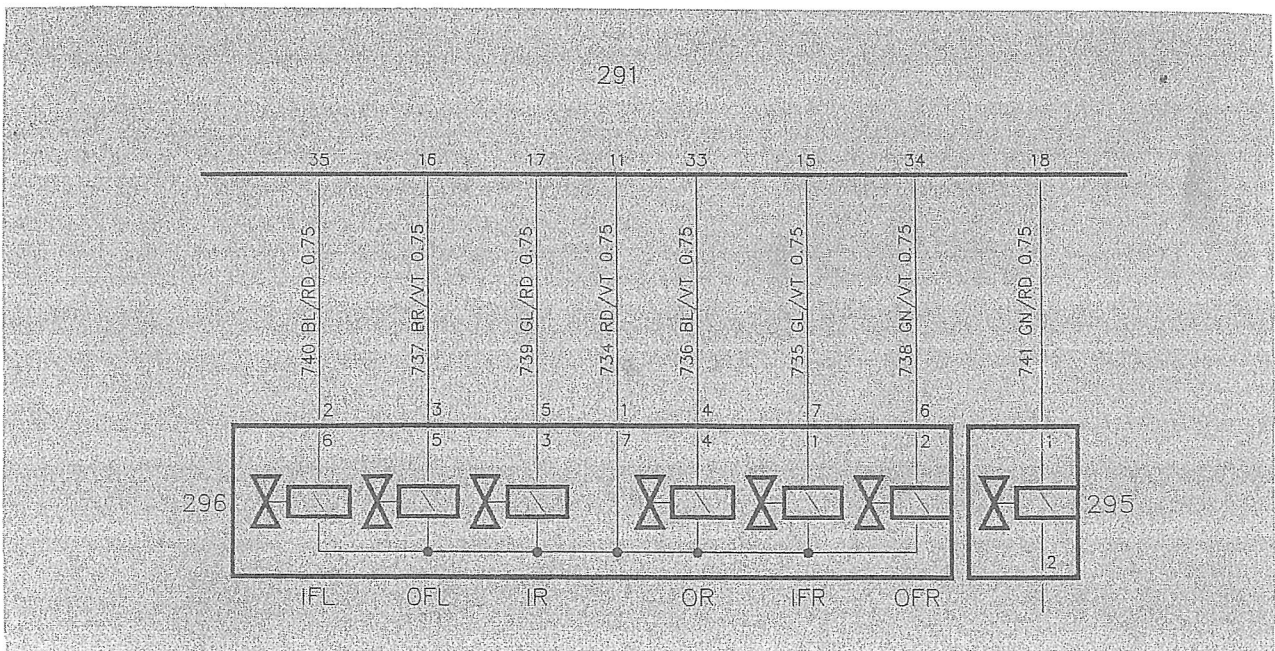
Action:

- A Check the wiring between pin 7 on the IFR valve and ECU pin 15.
- B Fit a new valve block.



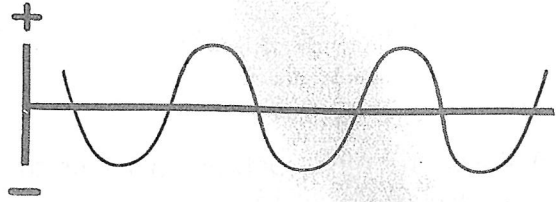
Similarly:

Error code	Valve	ECU pin no	Valve block connector
E016	OR	33	Pin 4
E017	IR	17	Pin 5
E018	MV	18	Main valve connector pin 1
E033	OFL	16	Pin 3
E034	OFR	34	Pin 6
E035	IFL	35	Pin 2



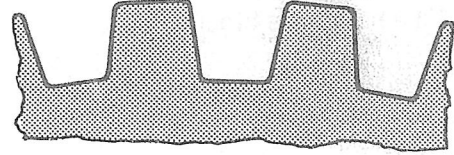
Error code: **EE25**

Malfunction indicated: Sensor wheel runout.
(Amplitude variation during one revolution out of spec.)



Action:

A Fit a new sensor wheel on the right front wheel.



S 5/188

Similarly:

Error code Sensor wheel

- EE22** Right rear
- EE23** Left front
- EE24** Left rear

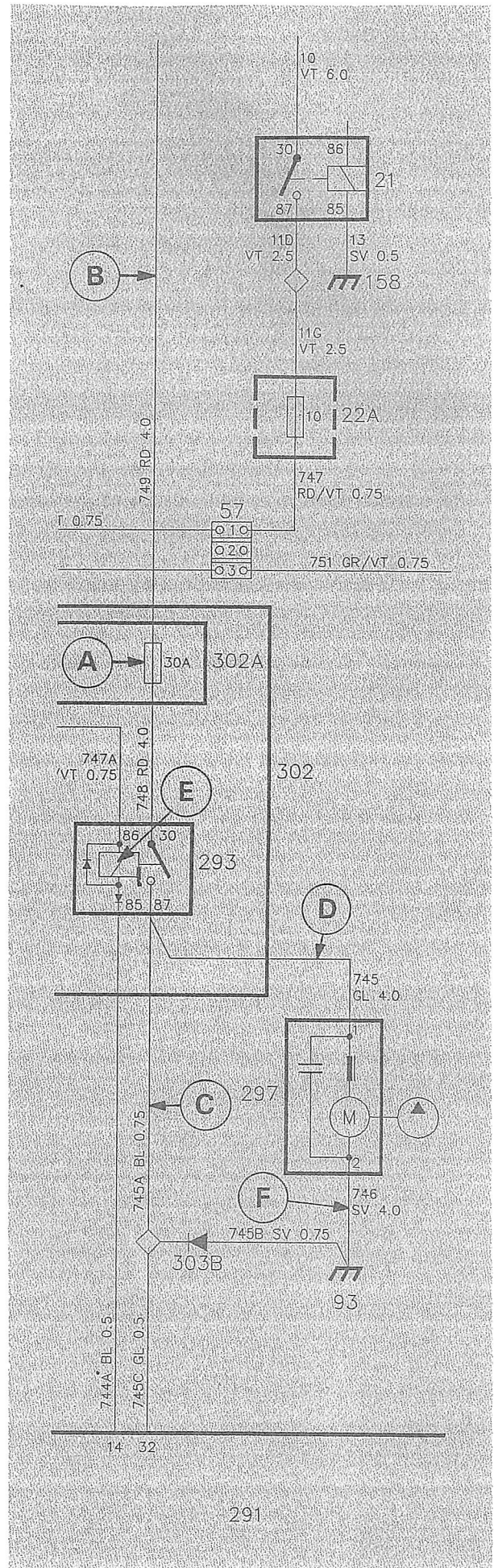
Error code: **E032**

Malfunction indicated: Defective pump relay (293)

This error code can be triggered only if the signal level at terminals 14 and 32 has been the same for more than 40 seconds during testing.

Action:

- A Check the 30 A (pump) fuse in the ABS fuse panel (302A).
- B Check the wiring between connector 75 and pin 30 on the pump relay (293).
- C Check the wiring between ECU pin 32 and pin 87 on the pump relay (293).
- D Check the wiring between pin 87 on the pump relay (293) and pin 1 on the pump motor (297).
- E Check continuity between pins 85 and 86 on the pump relay.
- F Check the wiring between pin 2 on the pump motor and earthing point 93.
- G Fit a new pump relay (293).



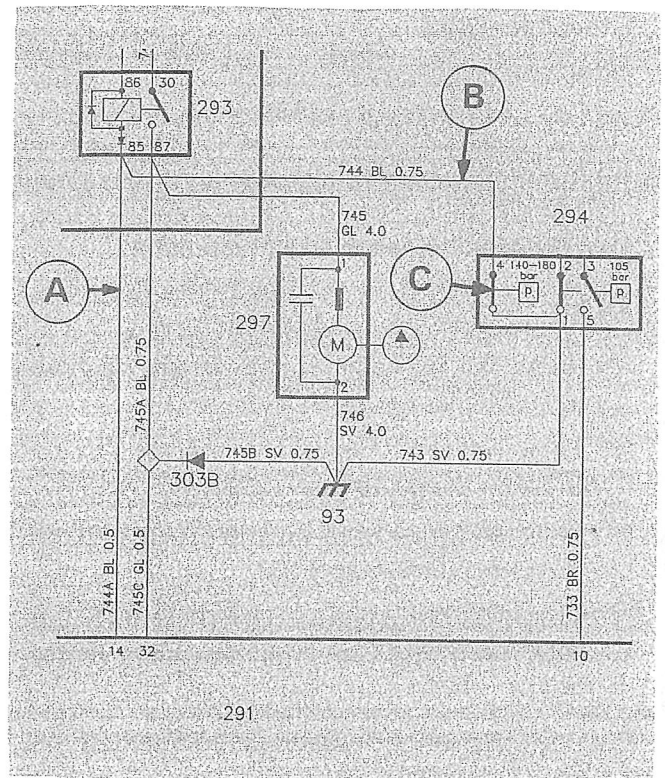
Error code: **E132**

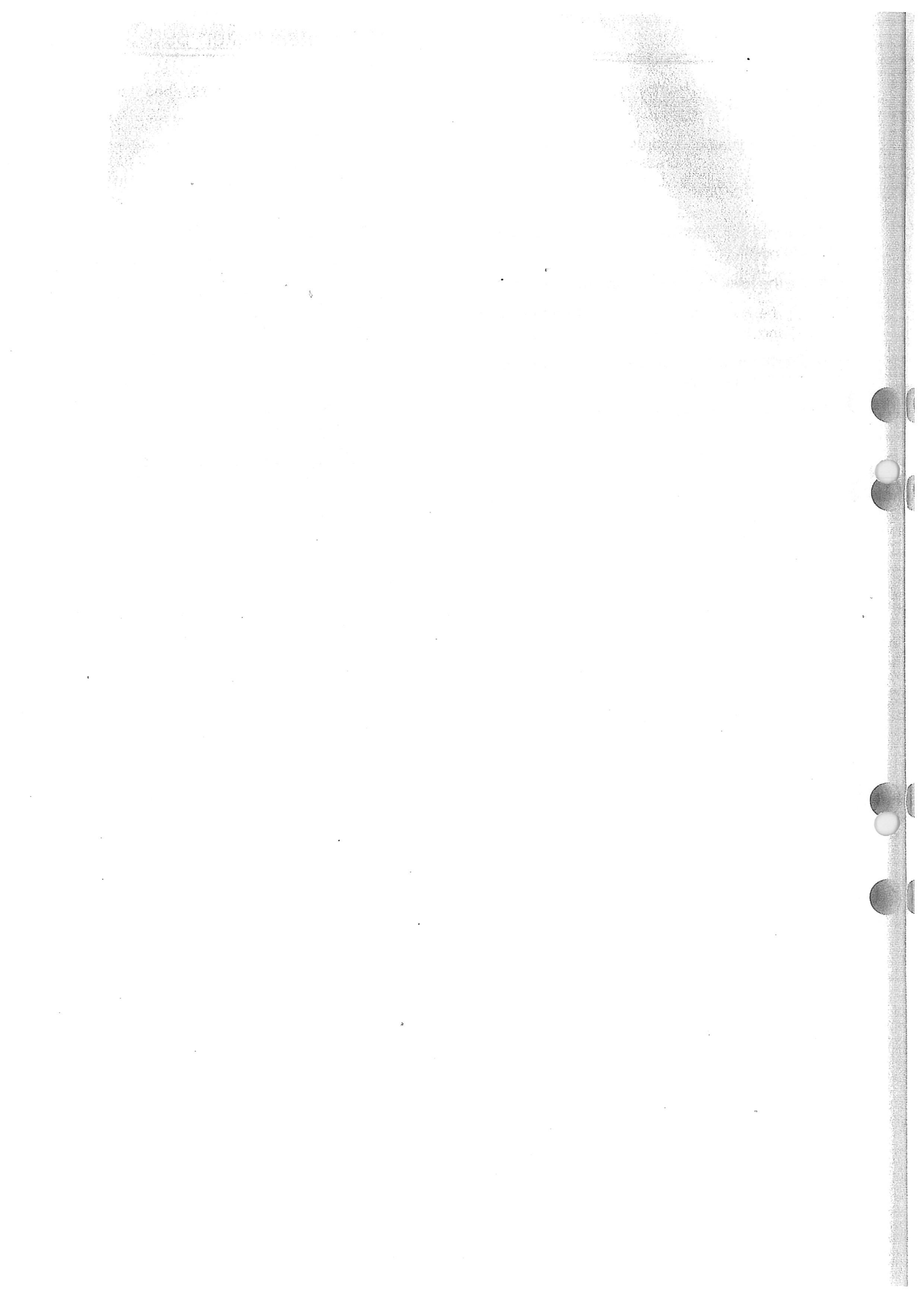
Malfunction indicated: Hydraulic pump running continuously

This error code can be triggered only if ECU terminal 32 has been energized for more than 90 seconds during testing.

Action:

- A Check for a short-circuit in wiring between ECU pin 14 and pin 85 on the pump relay (293).
- B Check for a short-circuit in the wiring between pin 85 on the pump relay (293) and pin 4 on the pressure switch.
- C If the pressure is higher than 180 bar (2611 psi), check that the switch between pins 1 and 4 on the pressure switch (294) is open.
- D Fit a new pump relay (293).





Alphabetical section guide

ABS (ANTI-LOCK) warning light	500-29	Sensor wheels	500-30
ABS brakes: general	500- 1	Sensor-wheel eccentricity (out-of-round)	590-25
ABS modulation	500-1	Servo cylinder	500-16
ABS-system tester	590- 1	Signal amplitude (strength)	590-24
Accumulator pressure	590-14	Solenoid valves	500-25
Accumulator		Special tools	105- 1
Removal/fitting	510-12	Technical data	025- 1
Bleeding the brake system	520- 1	Technical description	
Brake fluid reservoir		General	500- 1
Removal/fitting	510- 1	Principles of operation	500- 5
Brake fluid		Components	500-11
Changing	530- 1	Test Mode	590-16
Brake warning light	500-29	Valve block	
ECU		Removal/fitting	510-23
Removal/fitting	510-26	Valve-Test Mode	590-18
Error codes	590-26	Wheel sensors	
Fault-diagnosis routines	590-27	Removal/fitting	510-27
Fuse and relay panel	500-28	Wheel speed	590-23
Hydraulic unit			
Removal/fitting	510- 5		
Main valve	500-20		
Master cylinder	500-22		
Monitor Mode	590-22		
Positioning sleeve	500-23		
Pressure switch			
Removal/fitting	510-13		
Pump and motor unit			
Removal/fitting	510-20		
Pump delivery pipe			
Removal/fitting	510-15		
Pump inlet hose	500-13		
Pump motor	500-13		





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