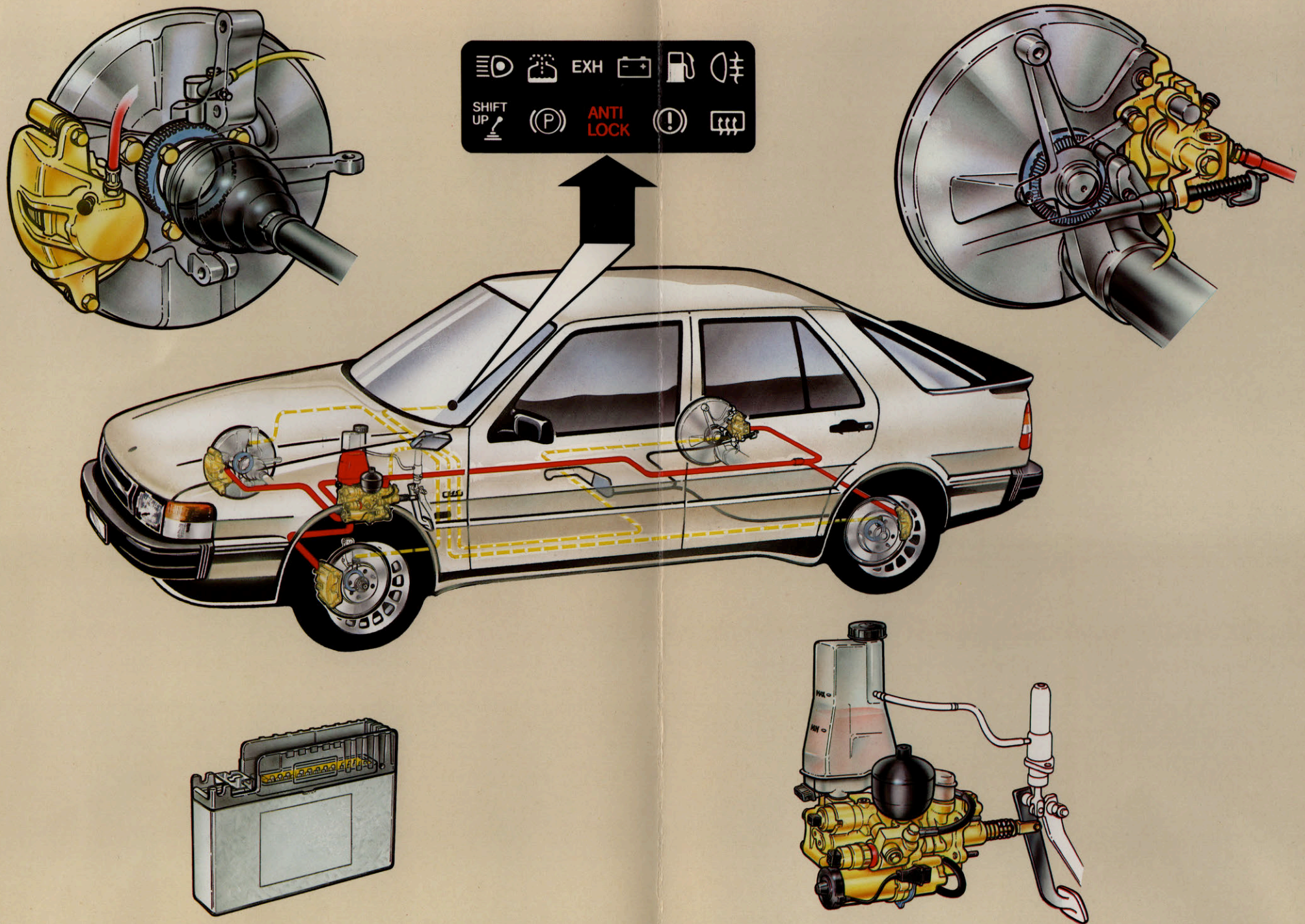
SAAB

9000

SERVICE MANUAL

5:2 Anti-lock Braking System (ABS)

M 1988


EXH
SHIFT UP
ANTI LOCK

SAAB 9000

SERVICE MANUAL

5:2 Anti-Lock Braking

M 1987

Units

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

As a supplement to these, a number of other units are specified within brackets.

The following symbols for the various units have been used in this issue:

SI unit	Supplementary unit unit
mm	in
kg	lb
N	lbf
Nm	lbf ft
bar	psi
l	qt (US)
°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 psi
1 qt = 0,95 l	1 l = 1,05 qt

Production: Technical Publications, Saab-Scania, Trollhättan, Sweden

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Technical Data

Hydraulic unit

Make		ATE
Brake fluid specification		DOT 4
Working voltage	V	10-14
Working temperature range	°C (°F)	-30 - +80 (-22 - +176)
Pressure: brake circuits accumulator	bar (psi) bar (psi)	0-180 (0-2610) 140-180 (2030-2610)

Brake fluid reservoir

Capacity	litre (liq qt)	0.8 (0.84)
Number of chambers No. 1 chamber 2 3		3 Static circuit Dynamic circuit (pump) Dynamic circuit (return from servo)
Flow through filter	litre/min	0.5

Filler cap, brake fluid reservoir

Fluid level indicator resistance	ohm	10 (float at lowest point)
ABS-warning switch	ohm	1 (float at highest point)

Hydraulic pump

Type		Ball-valve
Pressure: inlet side delivery side	bar (psi) bar (psi)	0.1-1.0 (1.45-14.5) 140-180 (2030-2610)
Relief valve opening pressure	bar (psi)	210 (3045)
Power demand	W	180 at 160 bar (2320 psi)

Hydraulic accumulator

Pressure of gas-filled chamber at 20°C (68°F)	bar (psi)	80 (1160)
Capacity	litre (liq qt)	0.25 (0.26)
Working pressure range	bar (psi)	135-190 (1956-2755)
Maximum pressure loss	bar (psi) per 10 min	10 (145)

Pressure switch and 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)

Master valve

Maximum working pressure	bar (psi)	180 (2610)
Power rating at 12 V	W	35
Coil resistance	ohm	2-5

Solenoid valves

Maximum working pressure	bar (psi)	180+40 (2610+580)
Capacity at 20°C (68°F) and 100 bar (1450 psi)	cm^3/s (in^3/s)	36 (2.2)
Power rating at 12 V	W	25
Resistance	ohm	5-7

ECU

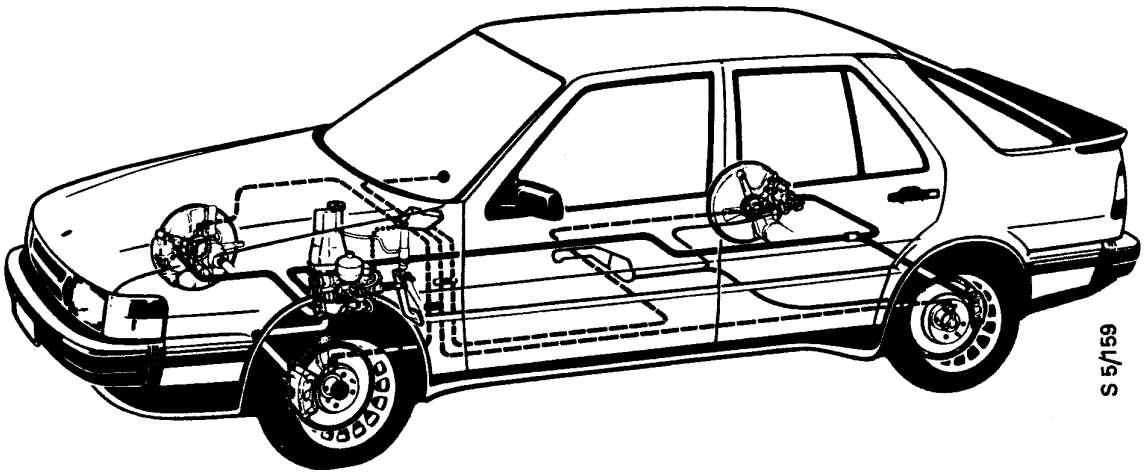
Working voltage	V	7-18
Power rating	W	40
Working temperature range	°C (°F)	-40 - +80 (-40 - +176)

Wheel sensors

Resistance	ohm	800-1400
Working voltage	V a.c.	0.15-0.70

Tightening torques

Pressure switch	Nm (lbf ft)	20-26 (15-19)
Hydraulic accumulator	Nm (lbf ft)	34-46 (25-34)
Pump delivery hose	Nm (lbf ft)	16-24 (12-18)
Brake fluid reservoir	Nm (lbf ft)	4-6 (3-4)
Pump unit	Nm (lbf ft)	7-9 (5-7)



General

The ABS anti-lock braking system has been developed to enable optimum braking to be achieved under widely varying conditions. Only very rarely can a driver correctly assess all the factors influencing the stopping distance of his vehicle, such as weather conditions, the nature of the road surface, prevailing traffic conditions, suitable brake-pedal pressure, etc.

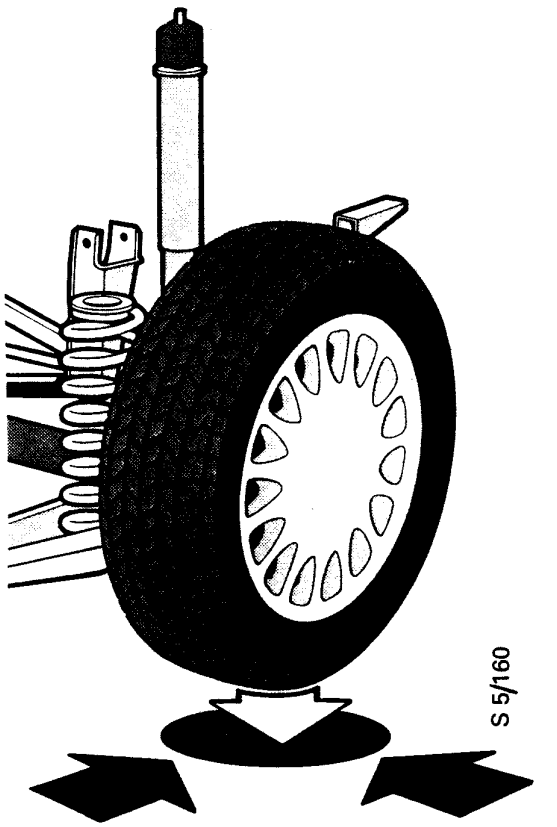
The ABS system provides modern braking systems with a control function that enables the maximum braking effect to be exploited in critical situations and in the most widely varying road conditions.

The system monitors and controls automatically the braking force for each front wheel individually and for the rear wheels as a pair, preventing the wheels from locking. In consequence, full steering control (steerability) is maintained during braking and the shortest possible stopping distance achieved.

The main advantages of the ABS system are as follows:

- No loss of directional stability on braking
- Steering control retained even when brakes fully applied
- Shortest possible stopping distance achieved

To illustrate the way in which the ABS system provides optimum braking without any loss of directional stability, let us consider the forces acting on the wheel during braking.



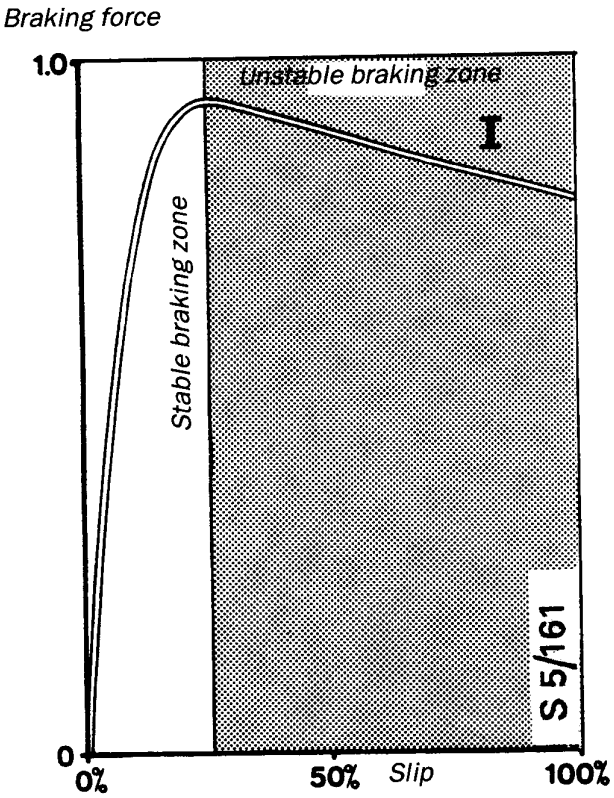
All of the forces taken up by the tyre are either lateral forces or braking forces

On the adjacent chart, the curve (I) shows the relation between the 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.

The application of a braking force gives rise to a certain degree of slip, which ranges from 0% when the wheel is rolling freely to 100% when the wheel is locked.

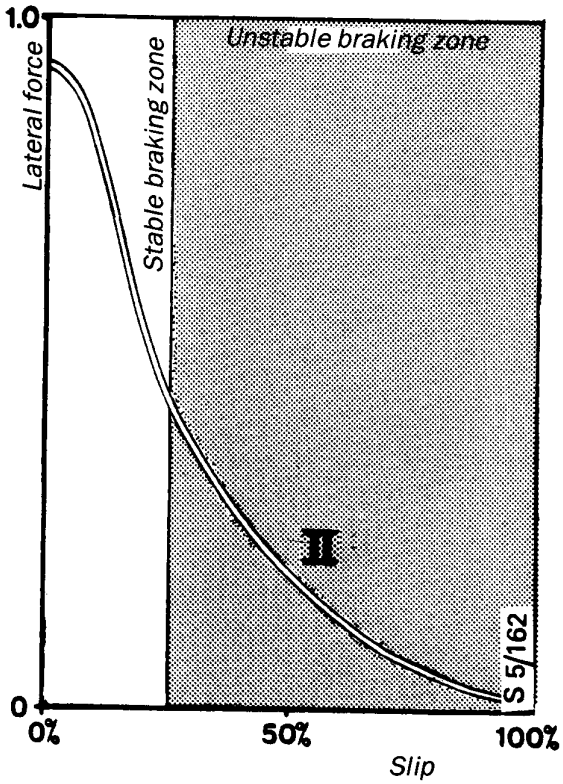
When the brake is first applied, the braking force increases sharply and the degree of slip gently until a certain maximum value is reached. Thereafter, the braking force decreases with increasing slip.



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.**

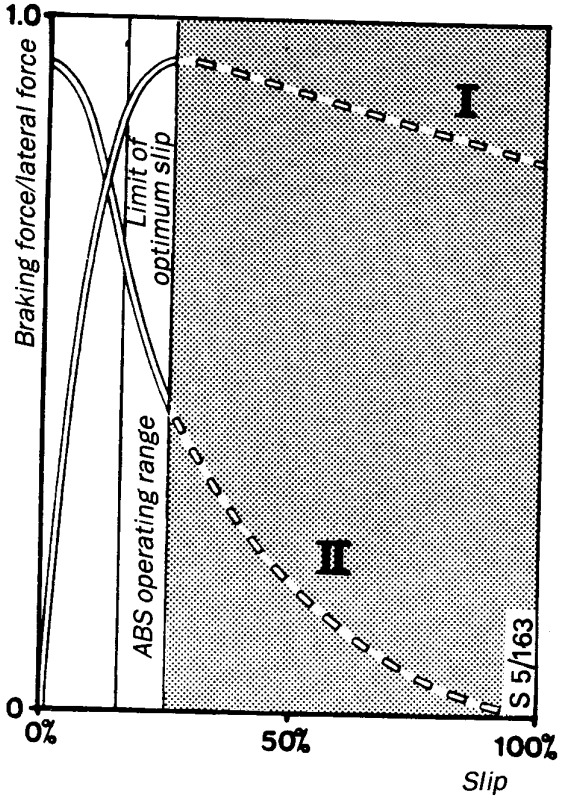
The section of curve between the limit of optimum slip and 100% slip is known as the **unstable braking zone,** as stable braking cannot be achieved within this zone. This is because the wheel quickly becomes locked after the limit of optimum slip has been reached, unless the braking force is reduced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

When the tyre is called upon to transmit a lateral force (such as on cornering) this also gives rise to slip. Curve II on the adjacent chart shows lateral force as a function of slip. As can clearly be seen, the lateral force falls away sharply with increasing slip. When the wheels have locked (100% slip), no lateral force remains for steering and the driver will no longer be able to control the vehicle.

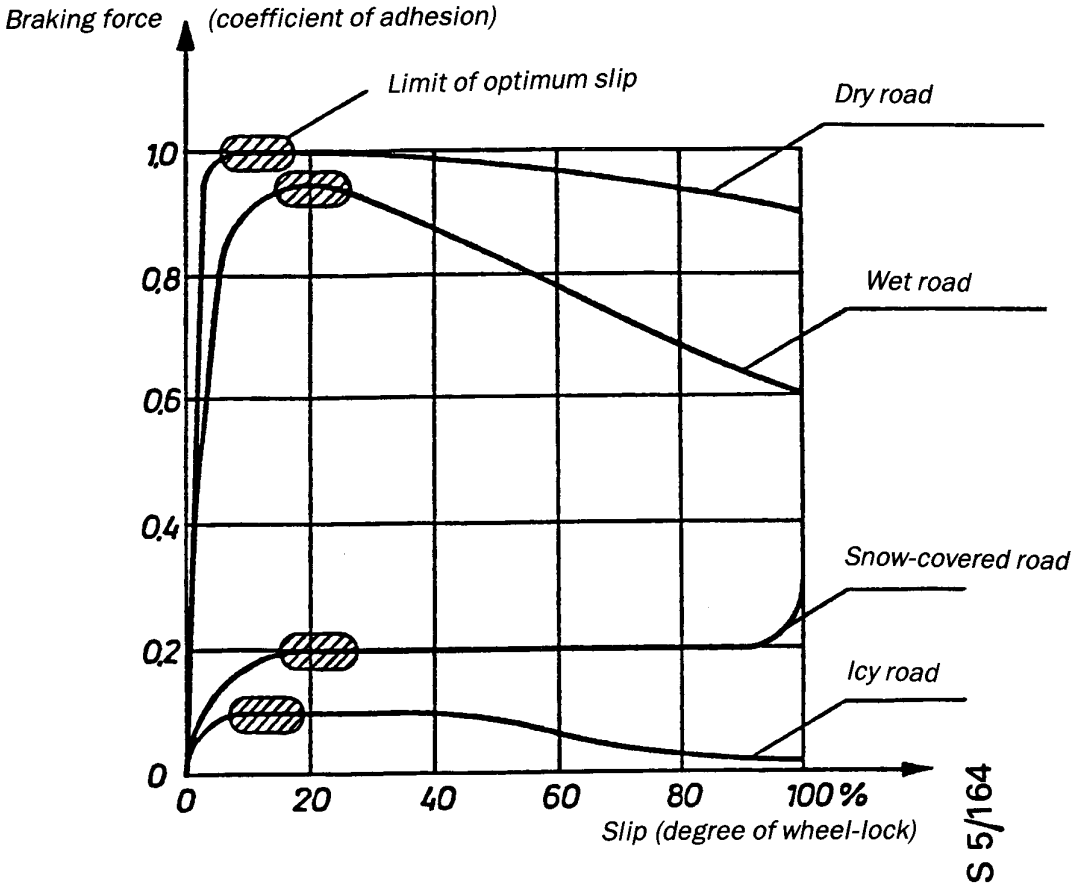


The chart on the right shows curves I and II and also the ABS operating range. During braking, the system allows the braking force to increase to a point just before the limit of optimum slip and then prevents it from increasing further. The system modulates the hydraulic pressure such that the braking force is held at a level as close as possible to the optimum value (the limit of optimum slip) regardless of how hard the driver's foot depresses the brake pedal.

Thus, the ABS system prevents the degree of slip from exceeding the limit of optimum slip and entering the unstable zone. At the same time, some lateral force is retained to ensure that there is no loss of steering control (curve II).



The curve showing the relation between braking force and slip is obviously influenced by numerous factors, including the properties of the road surface and the tyre type, tread pattern and pressures. Although variations in these factors will affect the 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) for different surfaces

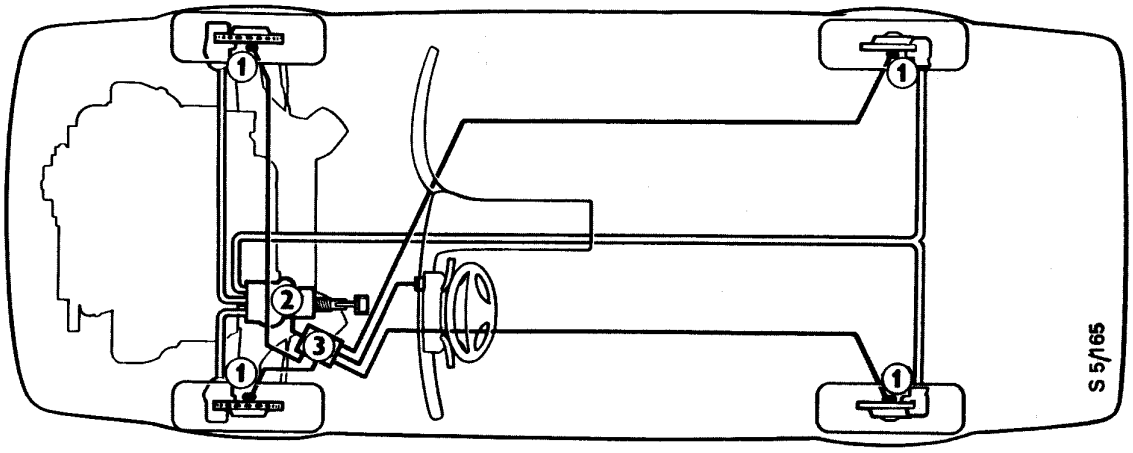
The Saab 9000 ABS system Overview

The braking system comprises three principal parts:

A set of four wheel sensors (1)

The hydraulic unit (2)

The electronic control unit (ECU) (3)



ABS system
1 Wheel sensors
2 Hydraulic unit
3 ECU

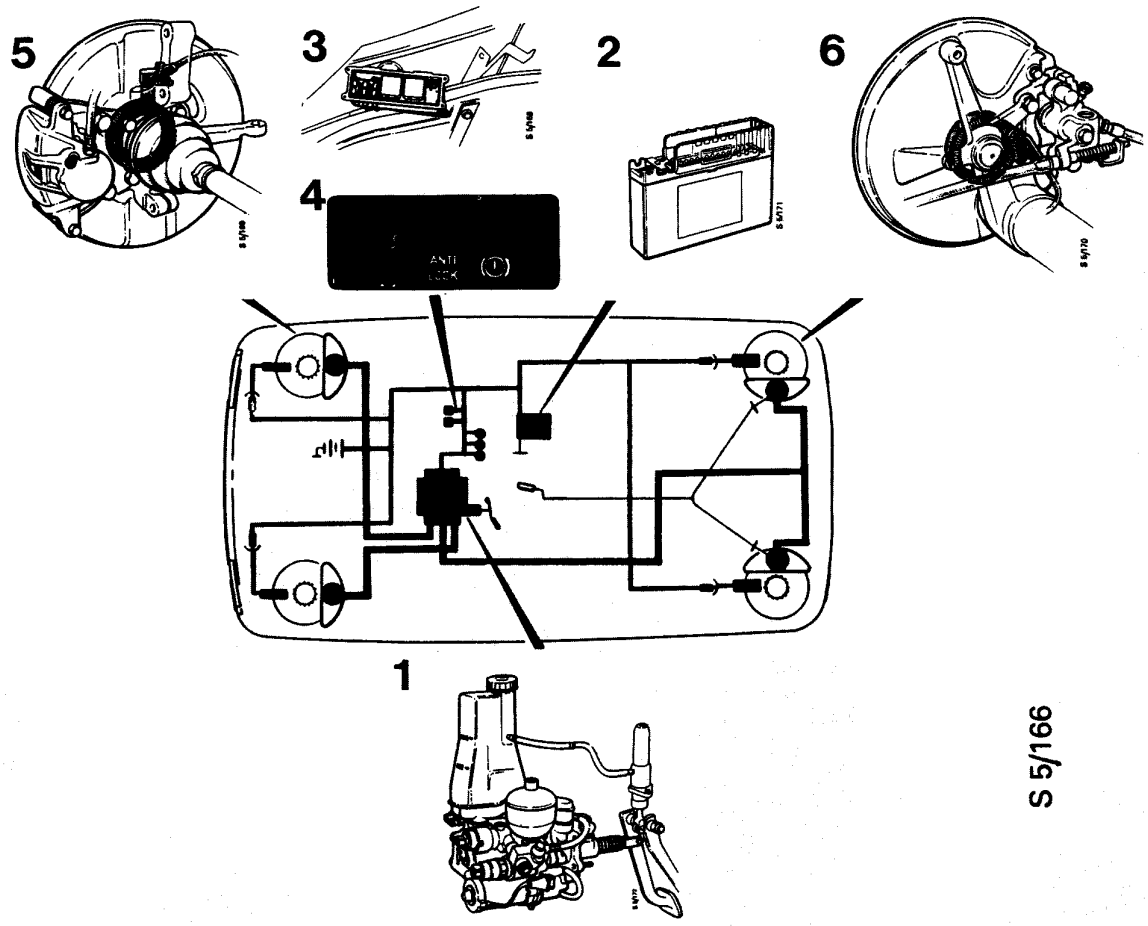
The braking system on the Saab 9000 is a triple-circuit system, with split circuits and individual monitoring and control for each front wheel and for the two rear wheels together.

Signals from the four wheel sensors are sent to the ECU, which computes at a given instant the wheel speed, acceleration and deceleration, the road speed and tyre slip. If a wheel is about to lock, the ECU will send signals to the solenoid valves for the wheel concerned, whereupon the pressure in the brake circuit for the wheel will be modulated to ensure that the optimum braking effect, and thus the maximum coefficient of adhesion, is achieved.

Apart from the electronically controlled features of the ABS system, there are two main differences between the basic braking system on cars fitted with ABS brakes and those fitted with the conventional braking system for the Saab 9000:

- A triple split-circuit system with individual circuits for the left front wheel, the right front wheel and the two rear wheels together.
- The brake servo unit is hydraulically operated instead of being operated by the depression in the inlet manifold.

Description of components



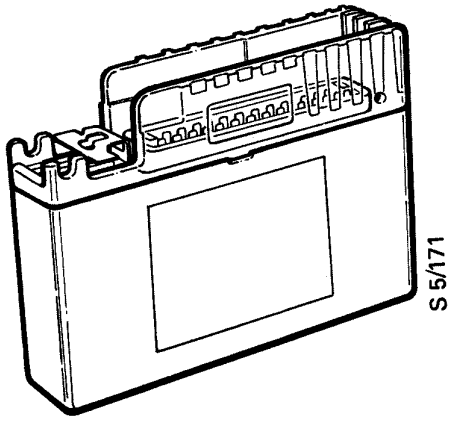
Main components of the ABS system
1 Hydraulic unit
2 Electronic control unit (ECU)
3 Relay and fuse holder
4 Brake-warning and ABS-warning lights
5 Front wheel sensor and sensor wheel
6 Rear wheel sensor and sensor wheel

Hydraulic unit

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

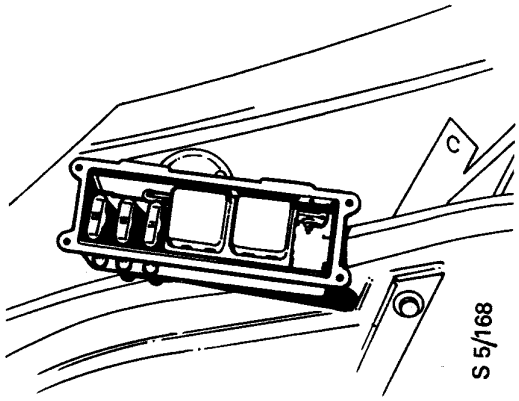
Electronic control unit

The ECU processes the signals from the wheel sensors and, on detecting any wheel-lock tendency in one or more wheels, controls the operation of the solenoid valves in the valve block. The ECU module is fitted beside the ECU module for the fuel-injection system, behind the false bulkhead panel on the LH side of the engine compartment.



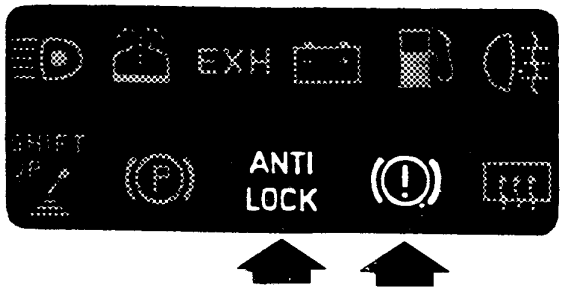
Relay and fuse holder

The relays and fuses for the ABS system are housed in a special holder containing a system relay and fuse for the ECU, a motor relay and fuse for the pump motor in the hydraulic unit, and an additional fuse for the ECU.



Brake-warning and ABS-warning lights

As on cars not equipped with ABS braking, the brake warning light will come on if the level of fluid in the brake fluid reservoir should fall too low. However, this light will also come on with the ABS-warning light if the pressure in the accumulator should fall too low.



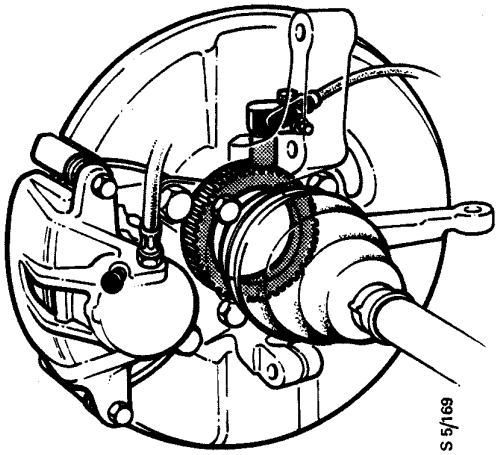
The ABS-warning light will also come on:

- if the level of fluid in the brake fluid reservoir should fall even further
- in the event of a malfunction in the ECU
- in the event of a break in continuity in the circuitry
- 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.

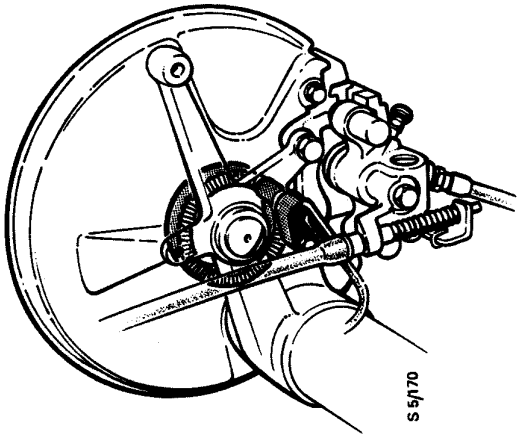
Front wheel sensors and sensor wheels

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 rpm, retardation and slip.



Rear wheel sensors and sensor wheels

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



Principles of operation - a synopsis

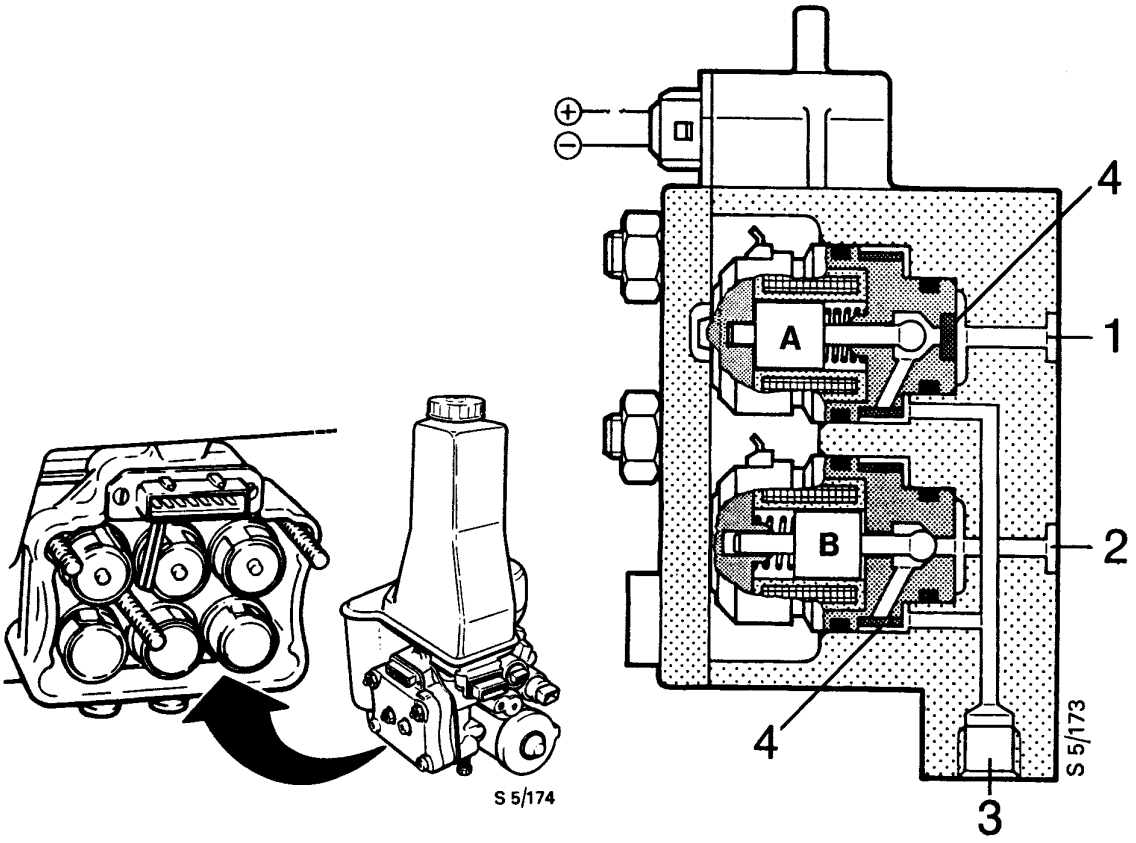
- The brake servo unit is not vacuum operated but hydraulic. The hydraulic pressure is generated by an independent power source and stored in an accumulator.
- The central component of the ABS system is the hydraulic unit incorporating the brake servo unit and master cylinder.

- 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 hydraulic accumulator.
- The hydraulic accumulator, comprising two chambers separated by a diaphragm, stores the energy generated 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 tendencies for a wheel to lock.
- 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 will continue 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 aspects - a synopsis



A = Inlet valve *B = Outlet valve*

1 From master cylinder
2 To brake fluid reservoir
3 To brake circuit
4 Filter

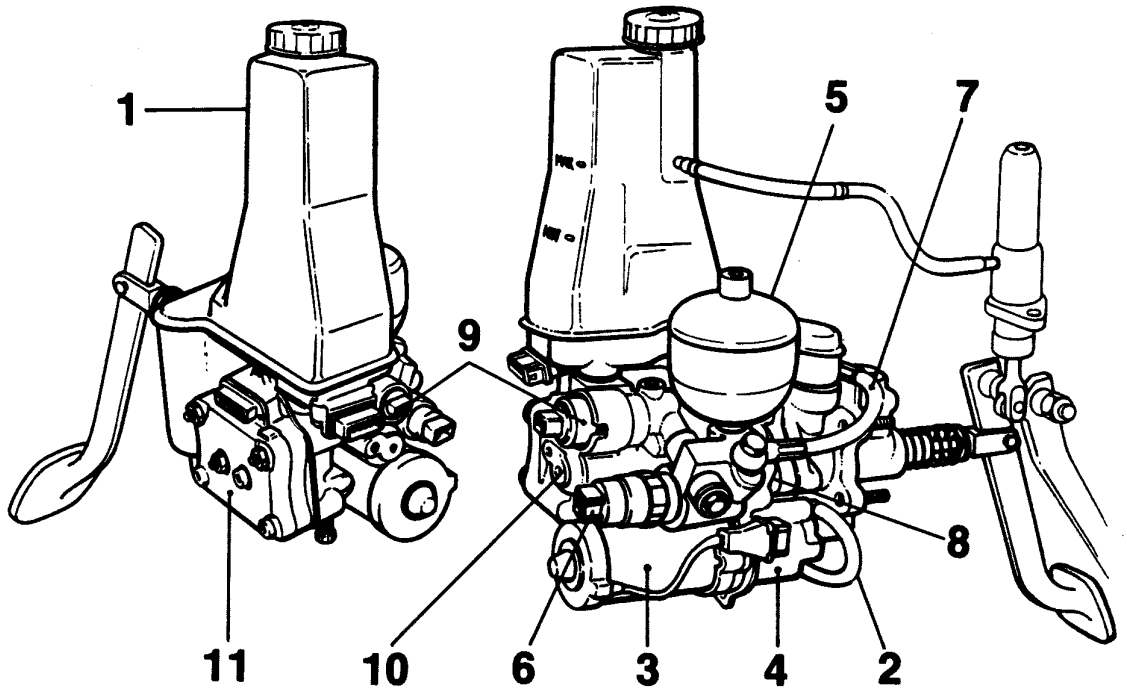
The logic system controlling the solenoid valves in the ABS system is such that the valves will assume their rest (de-energized) positions in the event of any disruption of their power supply. The ABS system will cease to operate the moment the ECU senses any departure from normal operating conditions;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

- Low fluid level in brake fluid reservoir
- Low pressure in hydraulic accumulator for servo cylinder
- Break of 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.

If a condition arises that affects the braking system regardless of whether the ABS system is operating (e.g. insufficient pressure in hydraulic accumulator for servo cylinder or low brake fluid level), the standard brake warning light will come on. In the event of the ABS system being switched off, all the 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 non-power-assisted brake circuits will always remain for application of the front-wheel brakes.

Description of component operation



Hydraulic unit

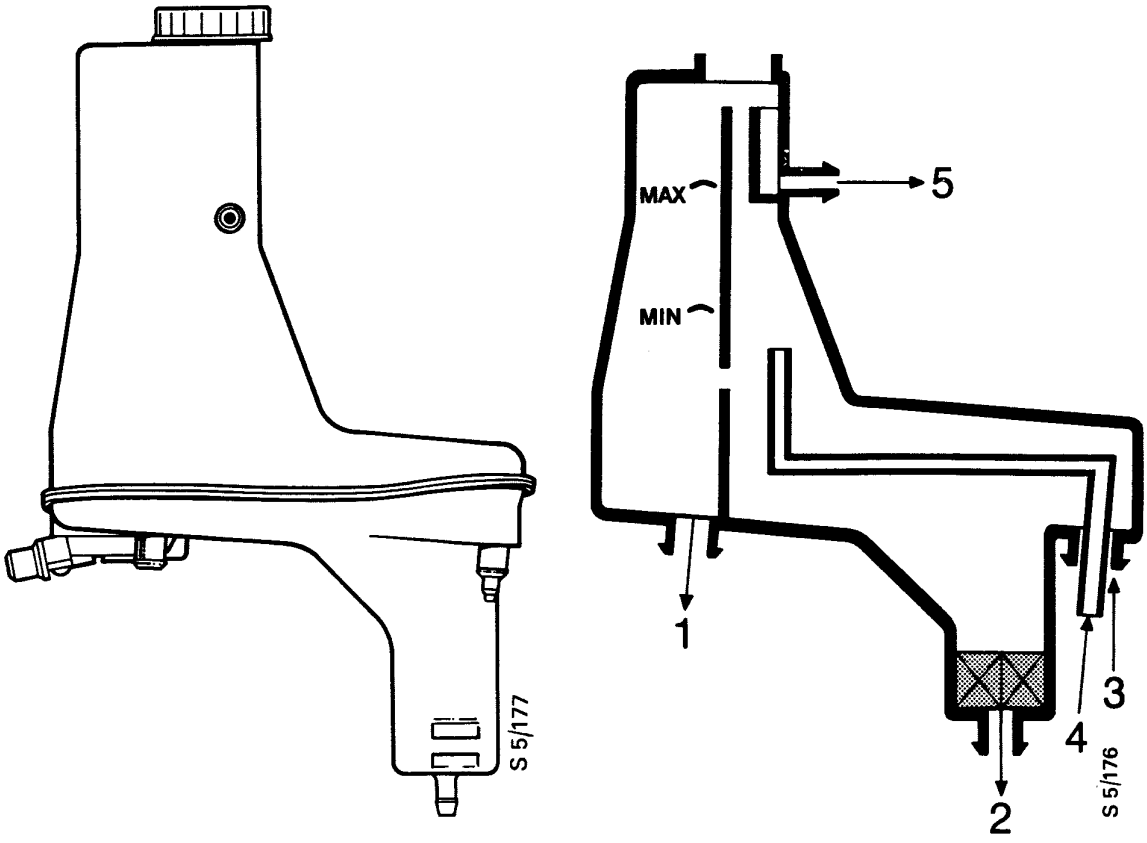
1 Brake fluid reservoir
2 Hose, reservoir to pump inlet
3 Electric motor
4 Hydraulic pump
5 Accumulator
6 Pressure switch
7 Pump delivery hose
8 Servo cylinder
9 Master valve
10 Master cylinder
11 Valve block

Hydraulic unit

The hydraulic unit incorporates the following components:

- **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 master cylinder
- **The master valve,** which supplies brake fluid from the servo cylinder to the master cylinder during ABS braking
- **The valve block,** which modulates the pressure to the brake calipers during ABS braking

Brake fluid reservoir



Brake fluid reservoir

1 To master cylinder
2 To pump
3 From servo cylinder
4 From valve block
5 To clutch cylinder

The reservoir has three chambers:

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

A safety function is incorporated in the two brake fluid chambers: in the event of a leak occurring in the circuits to the front wheels, the reservoir cannot be drained completely, so a reserve sufficient for the rear wheel circuit will always remain, to ensure that the rear wheel brakes can always be applied. In the event of leakage in the circuit for the rear wheel brakes, it will still be possible to apply the front-wheel brakes, although power assistance will be lost and greater pedal pressure will be required to apply the brakes.

The flow of fluid from the valve block, brake servo unit and master cylinder is returned to the second chamber, thereby arresting flow of the fluid. In this way, brake fluid with entrained air bubbles is prevented from being drawn into the system.

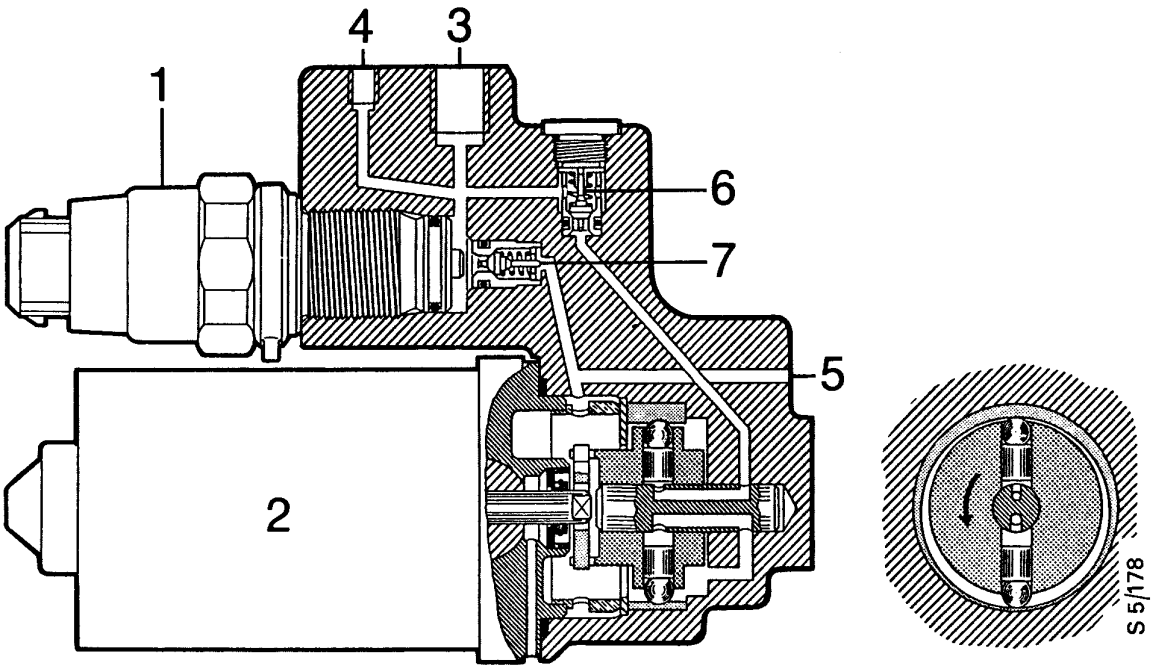
The reservoir holds approximately 0.8 litre but the fluid level must be kept between the MAX and MIN marks on the side of the reservoir. The reservoir is mounted on the hydraulic unit and the hydraulic connections between them are by means of two special bushes. A hose also runs from the reservoir to 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 too low. A further fall in the fluid level will initiate a signal to the ECU, which will switch off the ABS system and switch on the ABS warning light.

The electrical leads to the reservoir are connected via a five-pin connector.

Pump inlet hose

This hose, which runs between the reservoir and the hydraulic pump, is connected to the pump by means of a plastic elbow secured to the pump by a retaining clip.



Electric motor, hydraulic pump

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

Electric motor

The motor for the hydraulic pump is switched on and off by the pressure switch. The motor is fitted with a two-pin electrical connector and can be replaced as a unit complete with the pump.

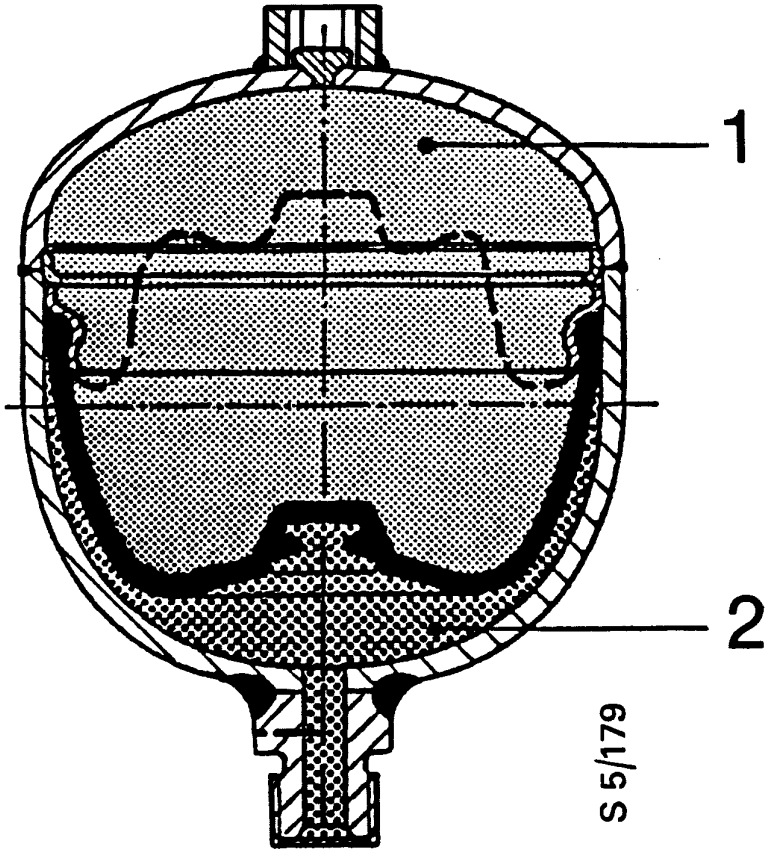
Hydraulic pump

The hydraulic pump pumps brake fluid from the reservoir to the inlet at the bottom of the pressure accumulator. The pump, which is secured by rubber mountings on the hydraulic unit, has a working pressure of between 140 and 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 hydraulic pump can be replaced only as a complete unit with the electric motor.

Hydraulic accumulator



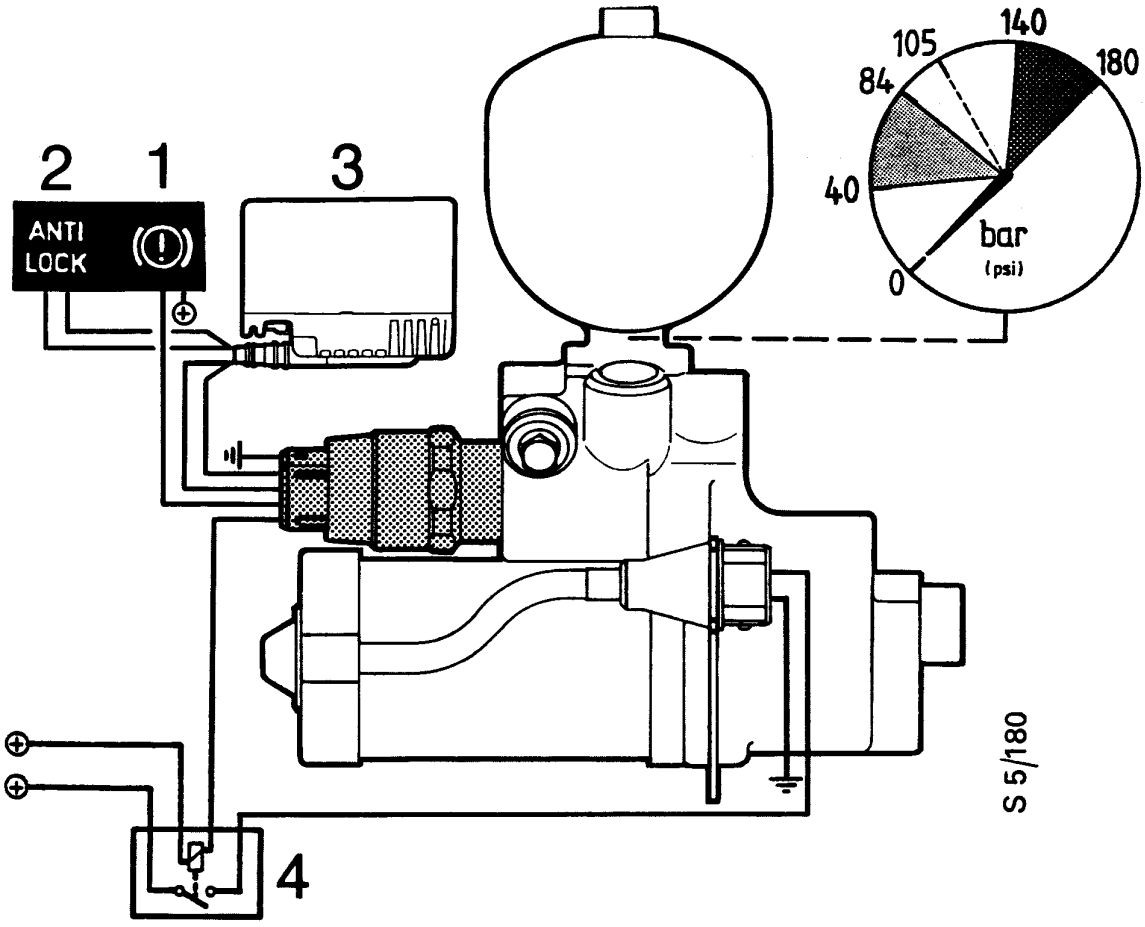
Hydraulic accumulator

1 Gas-filled chamber - nominal pressure of 84 bar (1218 psi)
2 Pressure chamber

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 84 bar (1218 psi). The lowest permissible pressure is 40 bar (580 psi); if the pressure should fall below this value, the accumulator must be replaced. The second chamber receives brake fluid from the hydraulic pump.

Brake fluid is pumped through the non-return valve into the accumulator. This compresses the nitrogen, expanding the space on the brake-fluid side of the diaphragm. Thus, a large quantity of brake fluid can be stored under pressure, giving two main advantages: hydraulic pressure is instantly available and the pump only needs to run during the period required to maintain the pressure at between 140 bar (2030 psi) and 180 bar (2610 psi).

Pressure switch



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 pressure falls to 140 bar (2030 psi) and 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 switch off the ABS system and indicate this by switching on the ABS-warning light.

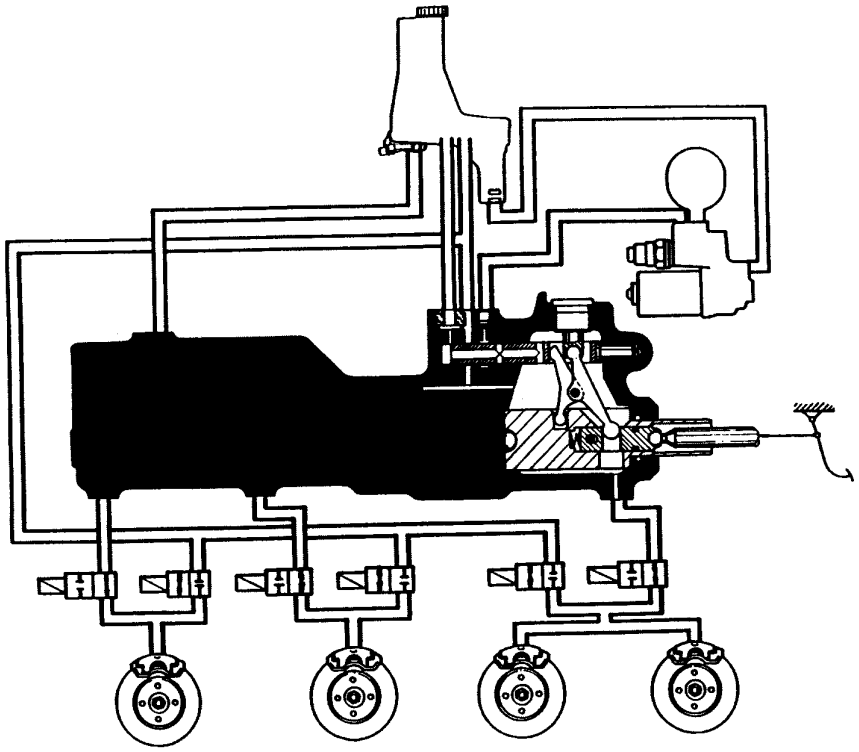
The electrical leads are connected via a five-pin connector.

The pressure switch is fitted inside the pump housing underneath the hydraulic accumulator and can be replaced separately.

Pump delivery hose

The pressure in the pump delivery hose, 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:

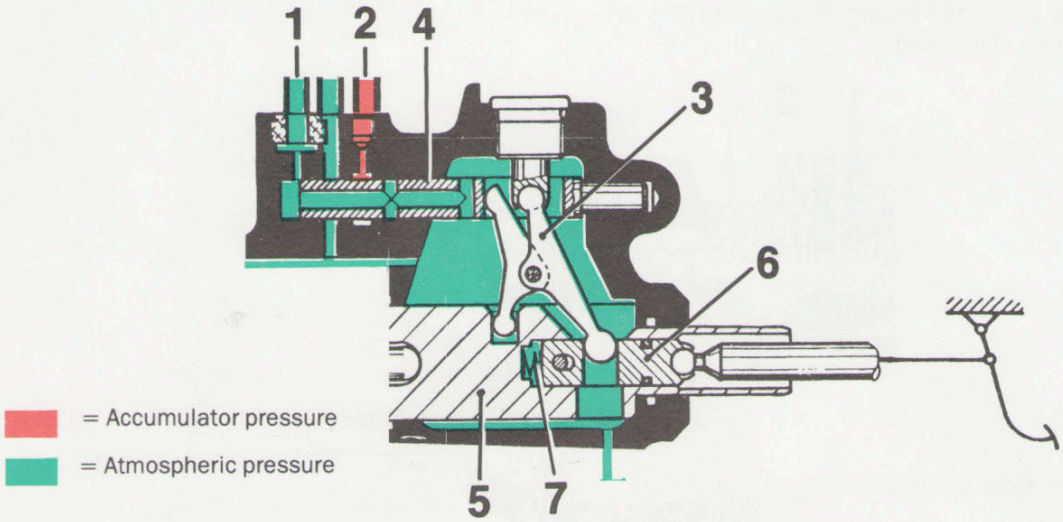
- To reinforce the driver's pedal effort
- To supply brake fluid to the circuit for the rear wheels
- To supply brake fluid via the master valve to the brake circuits for the front wheels during ABS braking.

Hydraulic pressure is transmitted to the servo cylinder from the accumulator via the control valve. Thus, the power assistance provided by the servo cylinder is 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, application of the rear-wheel brakes is 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.

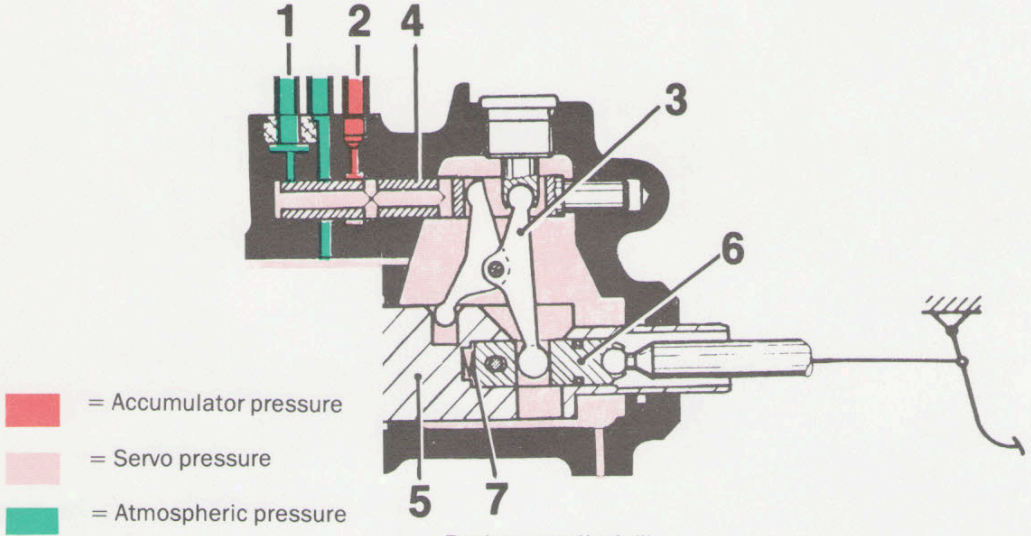


Brakes off

1 Return to reservoir
2 From accumulator
3 Lever mechanism
4 Control valve
5 Servo plunger
6 Actuating plunger
7 Spring

Brakes applied (I)

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) for the passage from the accumulator, and to close the port for the return passage. Resulting pressure builds up in the servo cylinder, forcing the plunger (5) forwards, thereby reinforcing the driver's pedal effort.



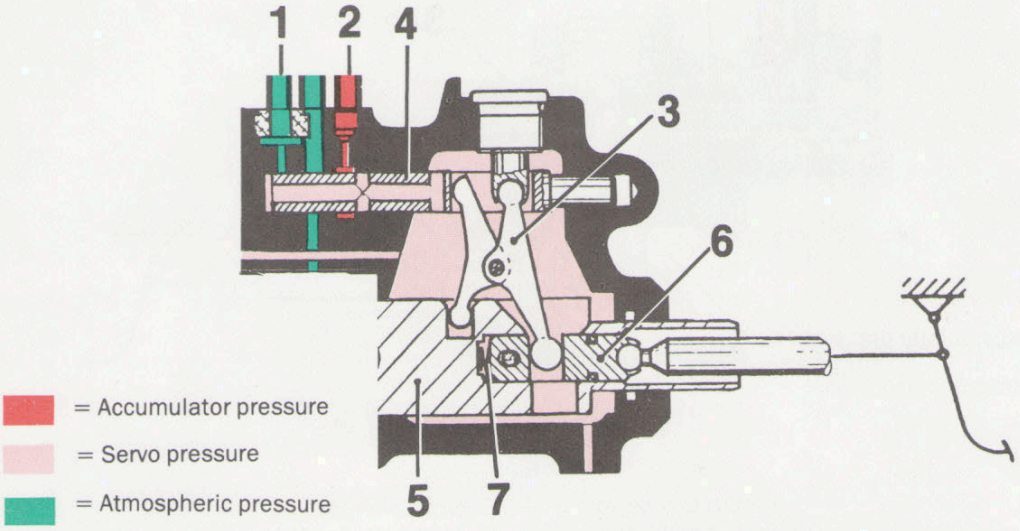
Brakes applied (I)

1 Return to reservoir
2 From accumulator
3 Lever mechanism
4 Control valve
5 Servo plunger
6 Actuating plunger
7 Spring

Brakes applied (II)

The pressure acts simultaneously between the servo plunger and the actuating plunger, forcing the two components apart. The two lower ball joints are forced apart and the upper ones moved towards each other, thus closing the control valve inlet port 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, whereby the pressure in the servo cylinder will be proportional to the force applied to the pedal.



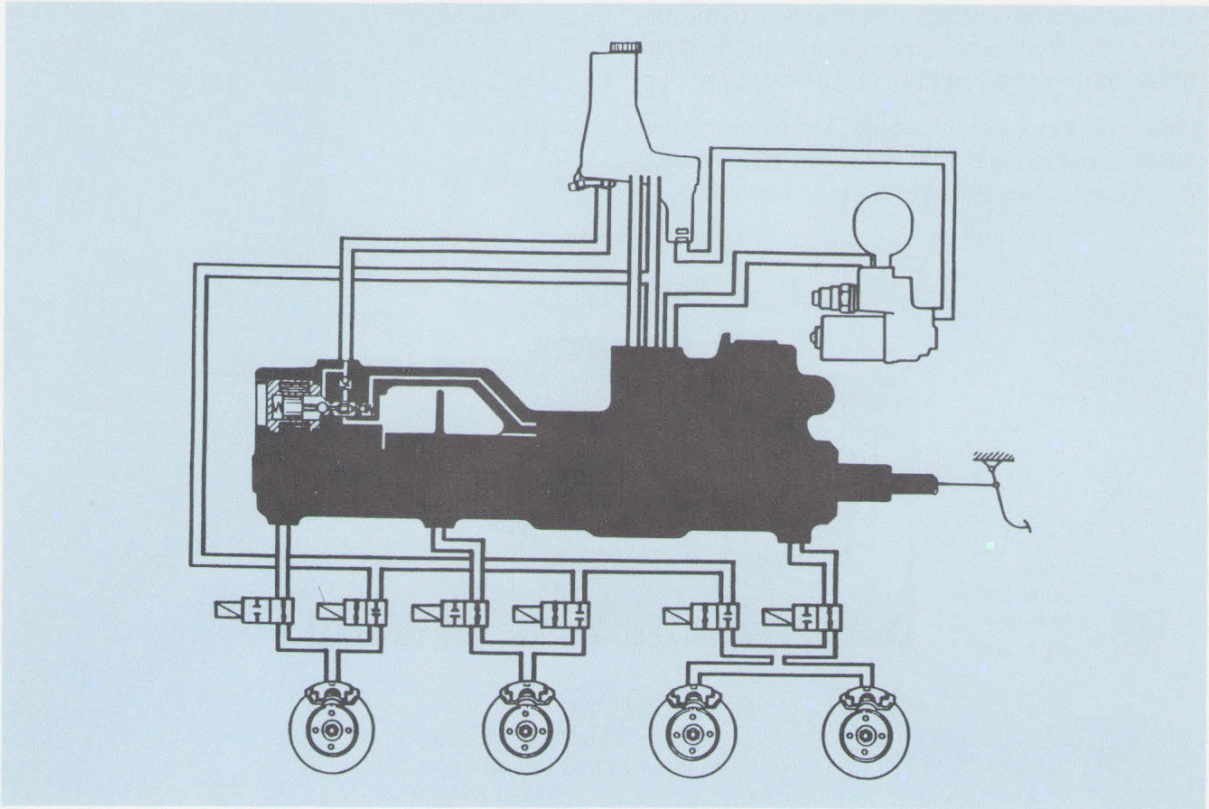
Brakes applied (II)

1 Return to reservoir
2 From accumulator
3 Lever mechanism
4 Control valve
5 Servo plunger
6 Actuating plunger
7 Spring

The servo cylinder can be replaced only as a complete unit with the master cylinder and valve block.

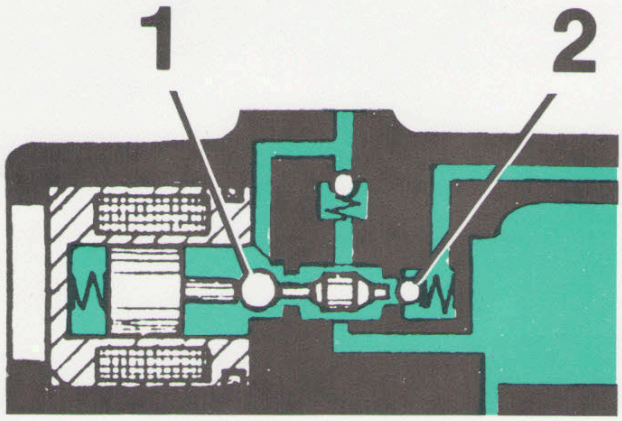
Master valve

The master valve is a solenoid valve fitted inside the master cylinder housing.



Hydraulic unit and master valve

Brakes off

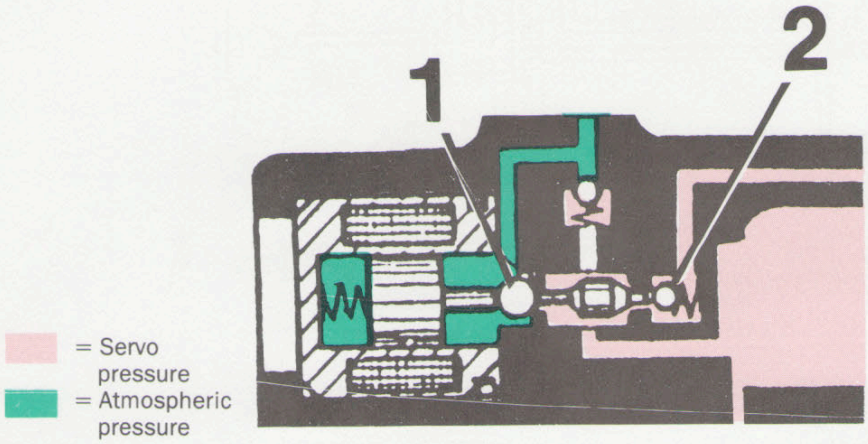


= Atmospheric pressure

Brakes off
1 Passage to reservoir open
2 Passage from servo cylinder closed

When ABS modulation is initiated, the master 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 brake fluid reservoir. This allows a sufficient quantity of brake fluid to flow to the circuit for the front wheels to replace the fluid returned to the reservoir via the outlet valves.

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

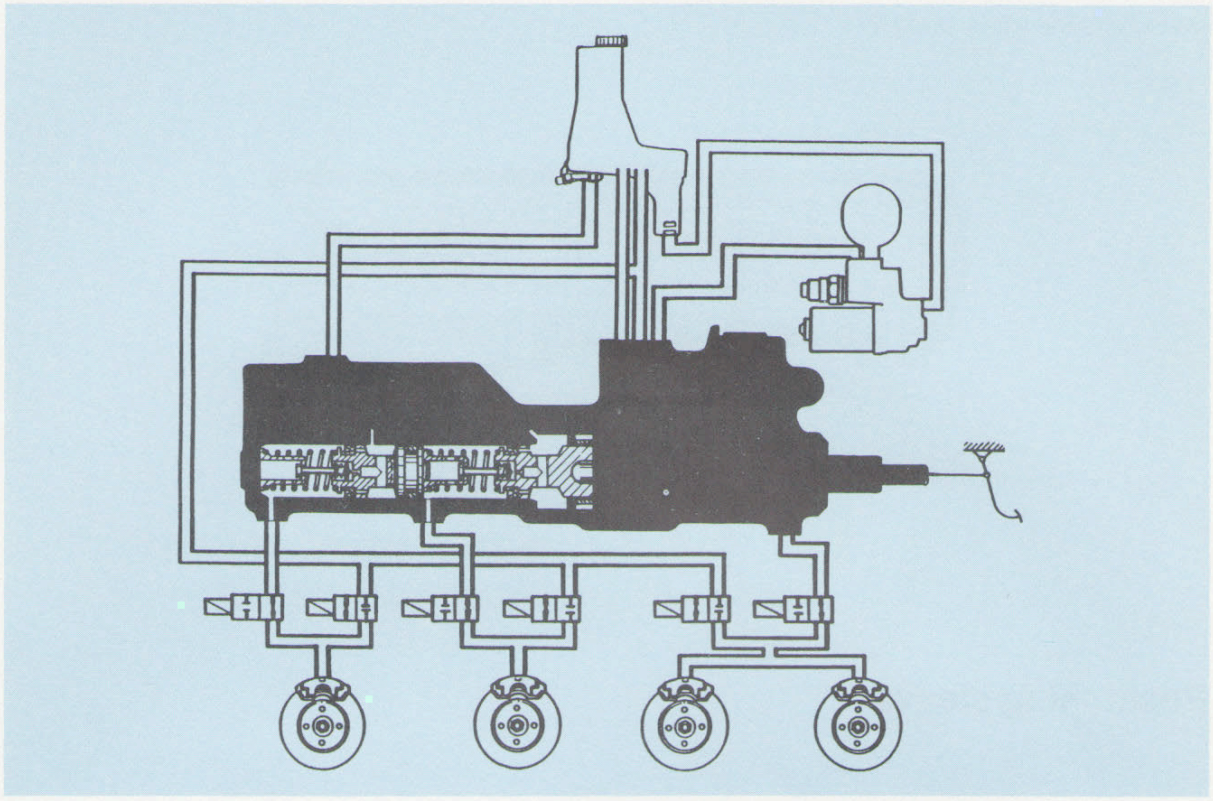


ABS modulation
1 Passage to reservoir closed
2 Passage from servo cylinder open

The master valve cannot be replaced separately.

Master cylinder

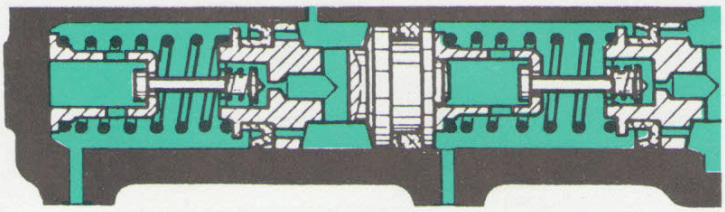
The master cylinder is of the tandem type, serving two separate circuits for the front wheels.



Hydraulic unit and master cylinder

When the car brakes are applied and there is no tendency for any wheel to lock, the master cylinder operates in the same way as a conventional master cylinder.

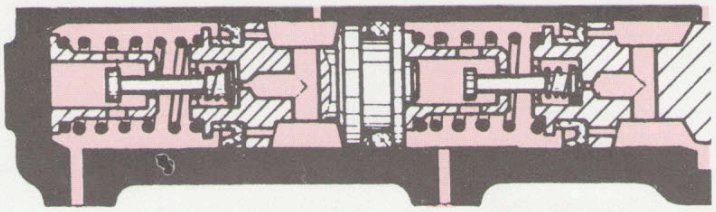
A central valve in the master cylinder admits brake fluid to the chamber in front of the plunger. When the brake pedal is depressed, the valve closes.



Brakes off
Valve open

= Atmospheric pressure

During braking with ABS control, the chamber behind the plunger 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, which will now modulate the pressure to the wheel brakes.

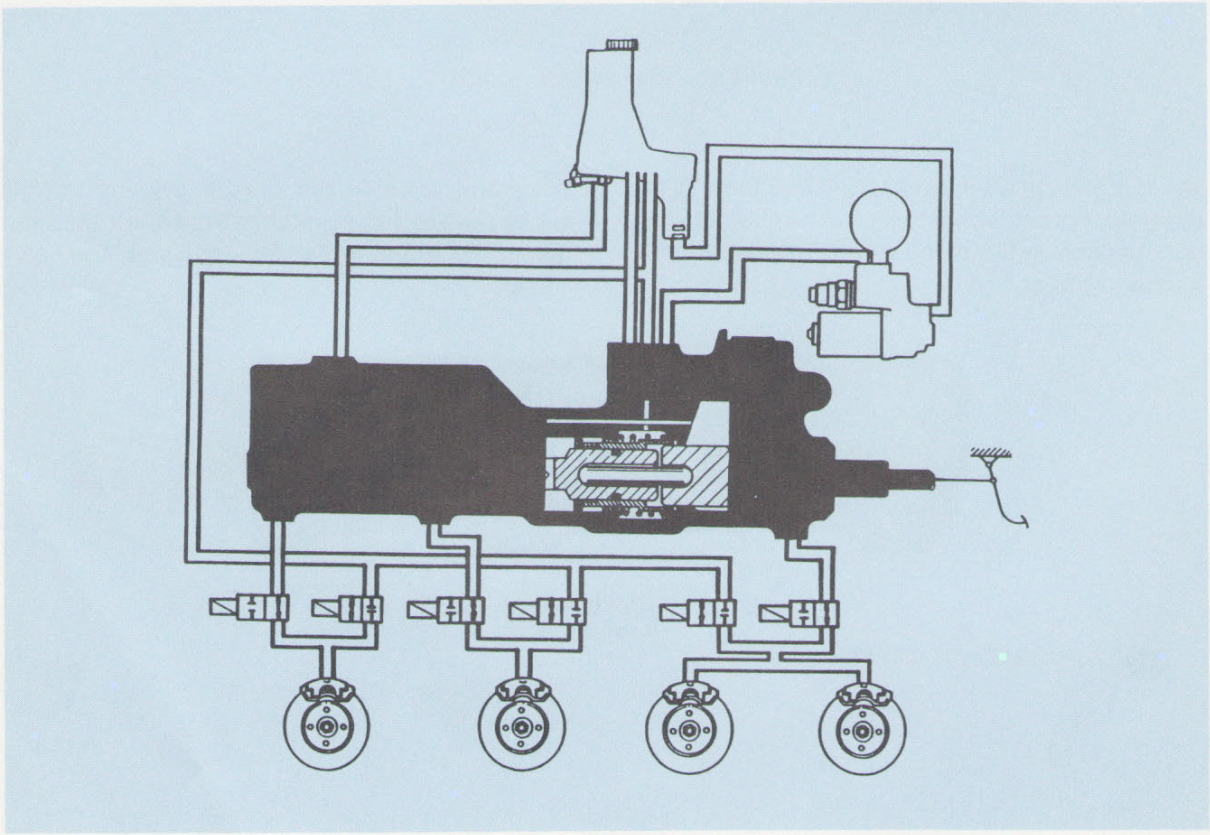


= Servo pressure

Brake applied (with ABS control)

Valve closed

Positioning sleeve

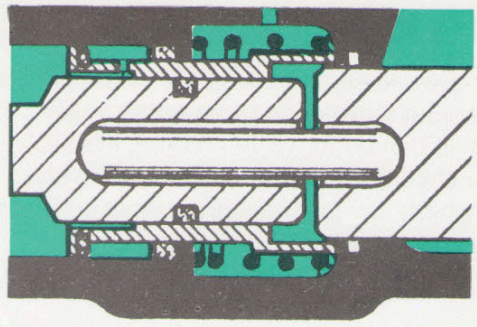


Hydraulic unit and positioning sleeve

The pressure acting behind the seals also acts on the positioning sleeve, causing the positioning sleeve and also the tandem plunger, servo plunger, actuating plunger and pedal pushrod to be forced back. 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 brake circuits for the front wheels.

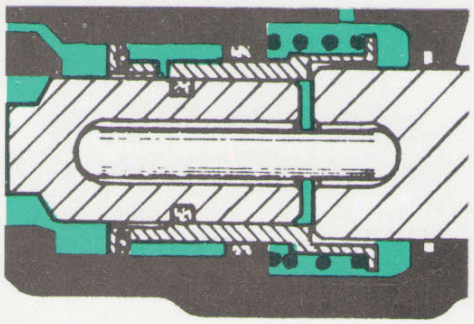
In the absence of a positioning sleeve, the pedal would be floored on initiation of ABS modulation.

The master cylinder cannot be replaced separately.



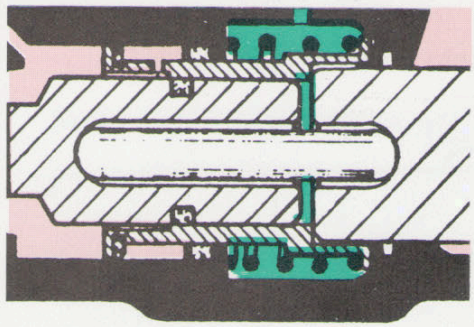
= Atmospheric pressure

Brakes off



= Atmospheric pressure

Brake applied (without ABS control)



= Servo pressure

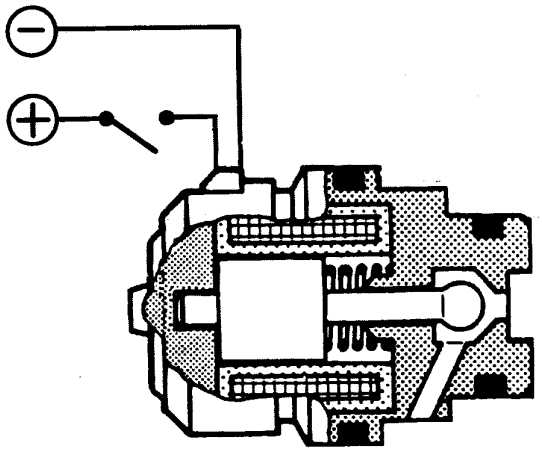
= Atmospheric pressure

Brake applied with ABS control

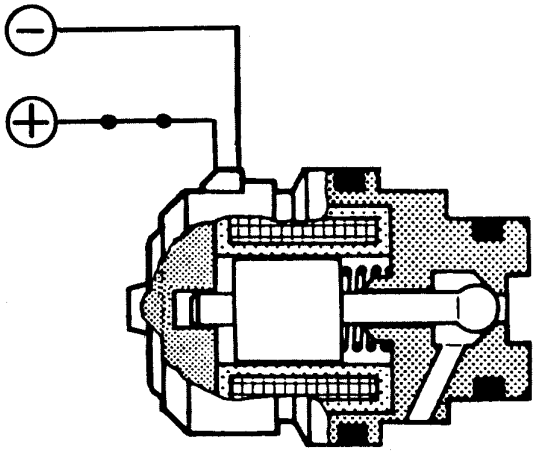
Valve block

The valve block comprises six solenoid valves: three inlet valves and three outlet valves. Thus there is one outlet valve and one inlet valve for each circuit. When the brake is off (valves de-energized), the inlet valves are open and the outlet valves closed.

Inlet valve (normally open)

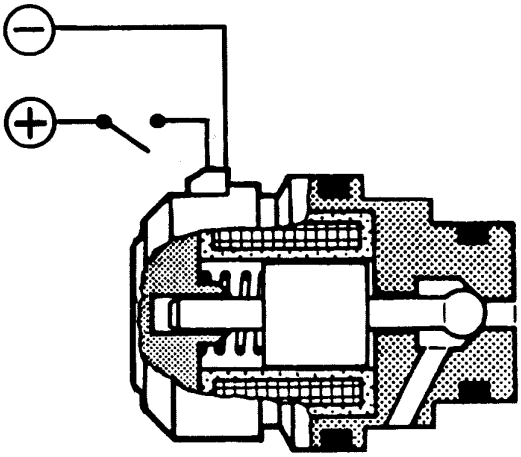


Open

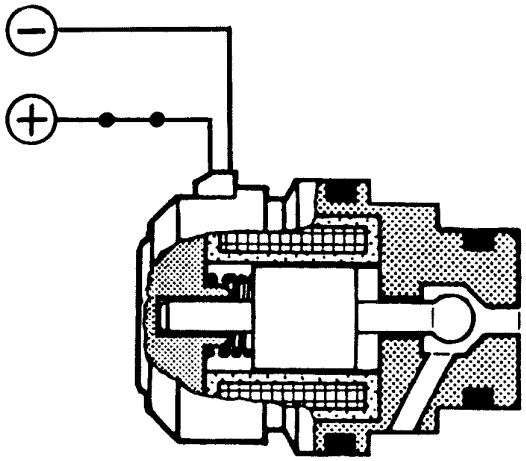


Closed

Outlet valve (normally closed)



Closed



Open

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

A It closes the inlet valve and opens the master valve. This prevents pressure being increased in the circuit to the wheel brake and also allows brake fluid to flow upstream of the inlet valve for use in phase C.

B It opens the outlet valve to release the pressure, thereby enabling the speed of rotation of the wheel to increase.

C It 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 master valve.

Phases B and C 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 the de-energized position and normal braking will be possible.

The valve block, which is secured to the master cylinder by means of three studs, cannot be replaced separately.

Electronic control unit

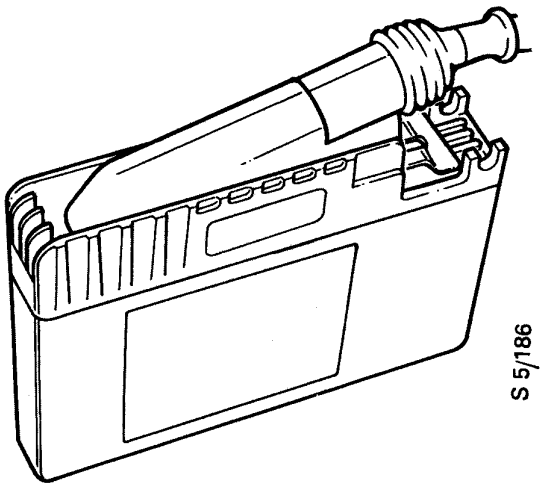
The ECU, which receives power from the system relay, is a sealed unit and no attempt must be made to open it.

The function of the ECU is to process the information (signals) received from the wheel sensors and to translate it into command signals for the solenoid valves in the hydraulic unit.

The ECU monitors most of the electrical components in the ABS system and also monitors itself for any faults in the electronic circuitry.

Other functions performed by the ECU include checking of the hydraulic pressure in the accumulator and of the fluid level in the brake fluid reservoir.

On detecting a fault in the ABS system, the ECU will suspend operation of the ABS system partially or totally. In either case, the ABS-warning light will be switched on. If the nature of the malfunction is such that it can affect the normal braking of the car, the brake-warning light will also be switched on. This will occur if the level of fluid in the brake fluid reservoir falls too low or if the pressure of brake fluid in the accumulator falls below the preset limit.



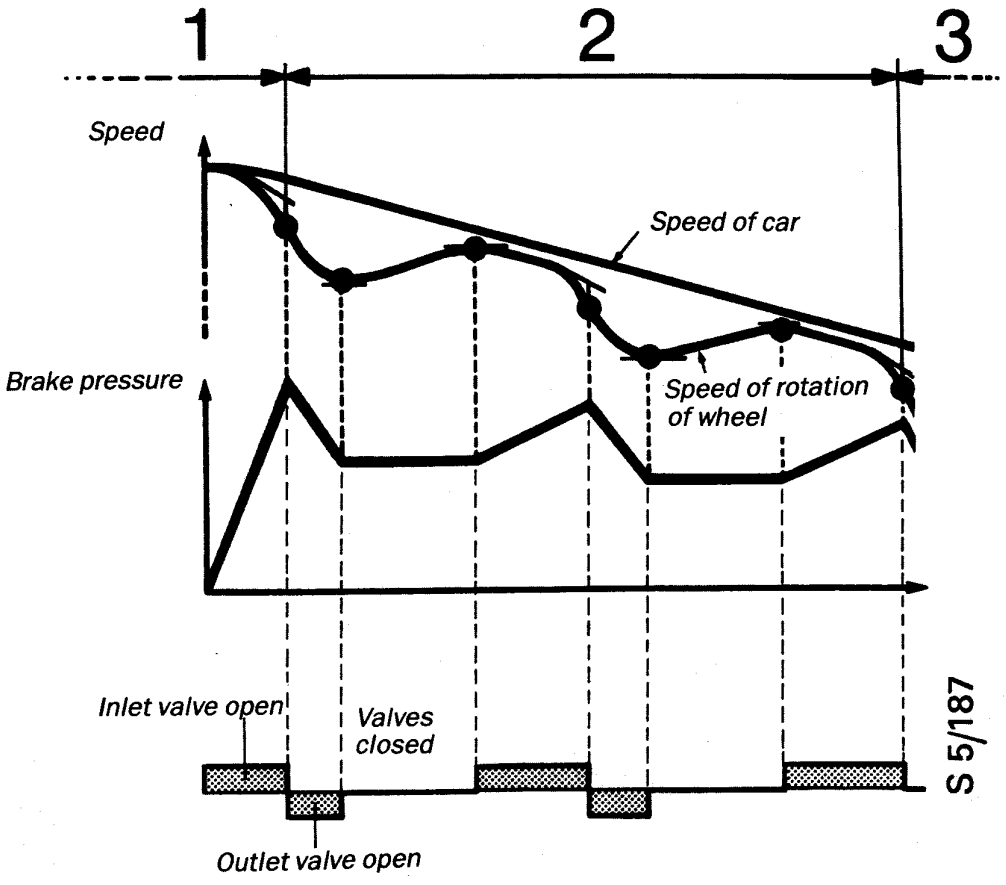
ABS control will be switched off totally if the ECU detects a break in a circuit to the valve block, master valve or sensors. Switching off of ABS control is done by the system relay. Before the ABS-warning light can be extinguished and the ABS system reactivated, the fault must be remedied and the ignition switched off. Even though the fault may have been remedied, unless the ignition has been switched off the warning light will remain on.

Operation of the ABS system will be partly suspended if the fluid level in the brake fluid reservoir falls too low or if the hydraulic pressure in the accumulator falls 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 partially suspended and the ABS-warning light to come on. When operation of the system has only been partially suspended, the ABS system will be reactivated and the ABS-warning light switched off as soon as the cause has been dealt with - for instance, replenishing the brake fluid or reinstating pressure in the accumulator.

When the ABS system is inoperative, the brake system will operate in the same way as a conventional 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 and in the event of a signal departing from this value, the ABS system will perform the following cycles to control the wheel concerned.



1: Tendency for wheel to lock detected.
Increase in brake pressure prevented.

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

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

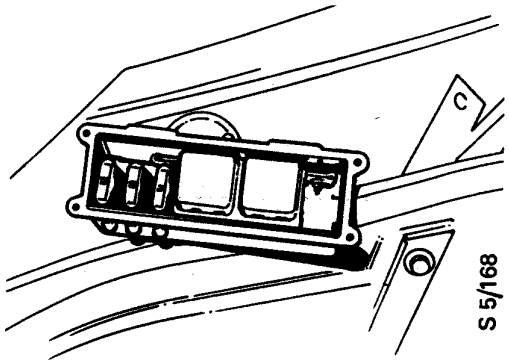
N.B.
The ECU must be removed from the car before any arc welding is done. Unplugging the connector is not enough. Similarly, owing to the high temperature involved, the ECU must be removed before stove-drying of paintwork.

Relay and fuse holder

The relays and the fuses for the ABS system are housed in a special module fitted behind the false bulkhead panel.

The module holds the system relay, with a 30 A fuse for the ECU, a motor relay with an integrated diode and a 30 A fuse for the pump motor, and a 10 A fuse for the ECU.

Power to the ECU and thence to the hydraulic unit is supplied through the system relay, and to the motor for the hydraulic pump from the motor relay.

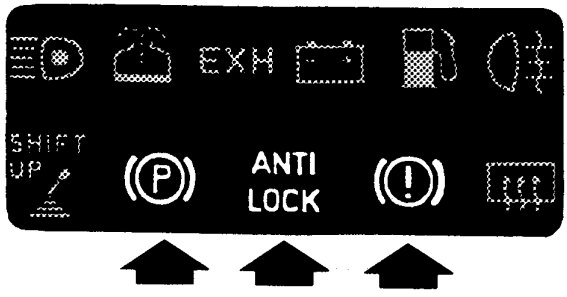


Brake-warning and ABS-warning lights

The car is fitted with three warning lights:

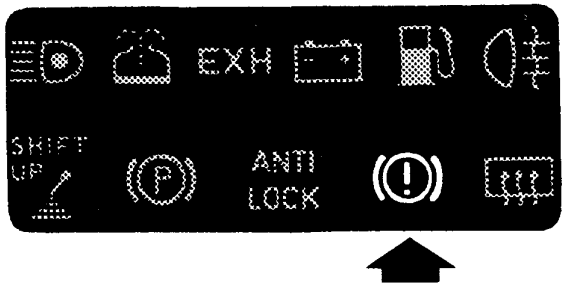
- Handbrake warning light
- Brake-warning light (low brake fluid level or accumulator pressure)
- ABS-warning light

The handbrake warning light is not affected by the ABS system.



Brake-warning light on:

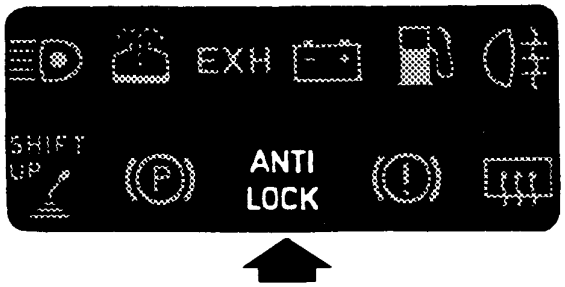
The brake-warning light alone will come on in the event of a fall in the fluid level in the brake fluid reservoir. The brakes and ABS system will continue to operate normally.



ABS-warning light on:

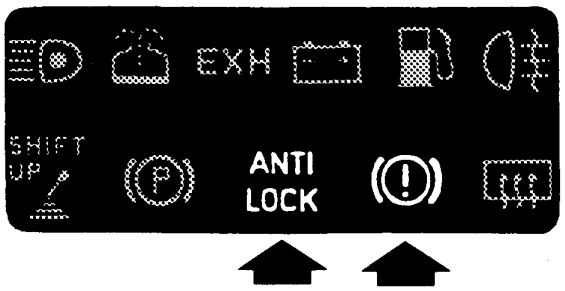
The ABS-warning light alone will come on if the ECU detects a malfunction in the ABS system (for further details, refer to the section, 'Electronic control unit').

The ABS system will no longer be operative but the brakes will still operate normally.



Brake-warning and ABS-warning lights both on:

When both of these lights are on, either the fluid level in the brake fluid reservoir has dropped below the MIN mark or the hydraulic pressure in the accumulator has fallen below 105 bar (1523 psi). The ABS system will now be inoperative but the brakes will still work, albeit with **a reduced braking effect.**



If the warning lights are on at the same time because of a low fluid level, leakage in one of the circuits is indicated. The car must not be driven further until the fault is found and remedied.

If the warning lights are on at the same time because of low hydraulic pressure: a fall in the hydraulic pressure will result in the power assistance and the brake pressure to the rear-wheel brakes no longer being proportional to the effort applied to the brake pedal. At worst, if no hydraulic pressure remains, there will be no power assistance and no rear-wheel braking. However, the front-wheel brakes will still operate normally but without power assistance.

When the ignition is switched on, the ABS-warning light will also come on for about two seconds while the ECU checks the system.

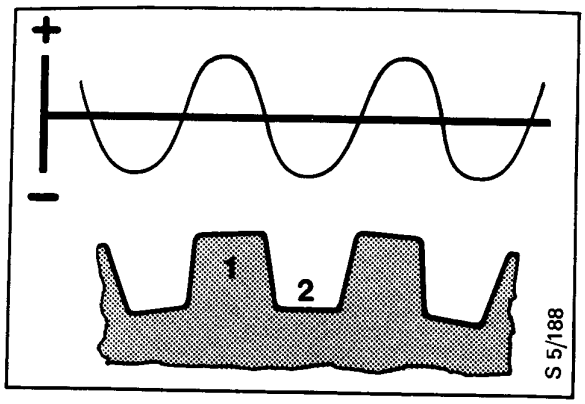
Wheel sensors

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 created by the toothed sensor wheel as it passes the sensor body: each time a tooth passes the sensor the magnetic field is reinforced and then decreased as a gap between the teeth follows.

Somewhat simplified, it can be said 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.



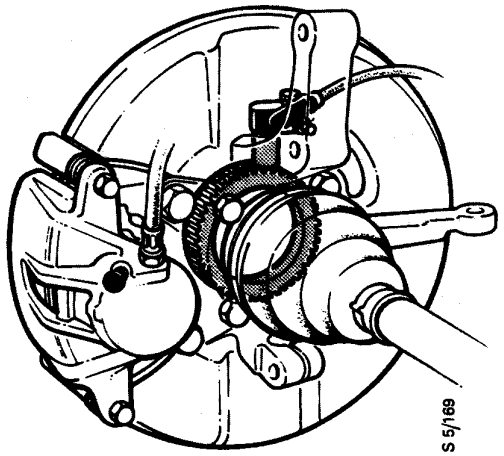
1 Tooth
2 Gap

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 fitted vertically on the steering swivel member. The distance between the sensor and the sensor wheel can be adjusted by means of an adjusting screw.

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

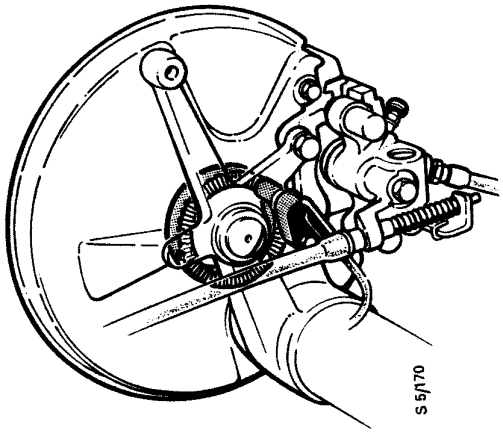


Front-wheel sensor

Rear-wheel sensor and sensor wheel

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

The sensor leads can be disconnected at the connector underneath the rear seat.



Rear-wheel sensor

Description of operation of the ABS system

The brake system can be in one of three conditions:

1 Brakes off

2 Brakes applied without ABS control

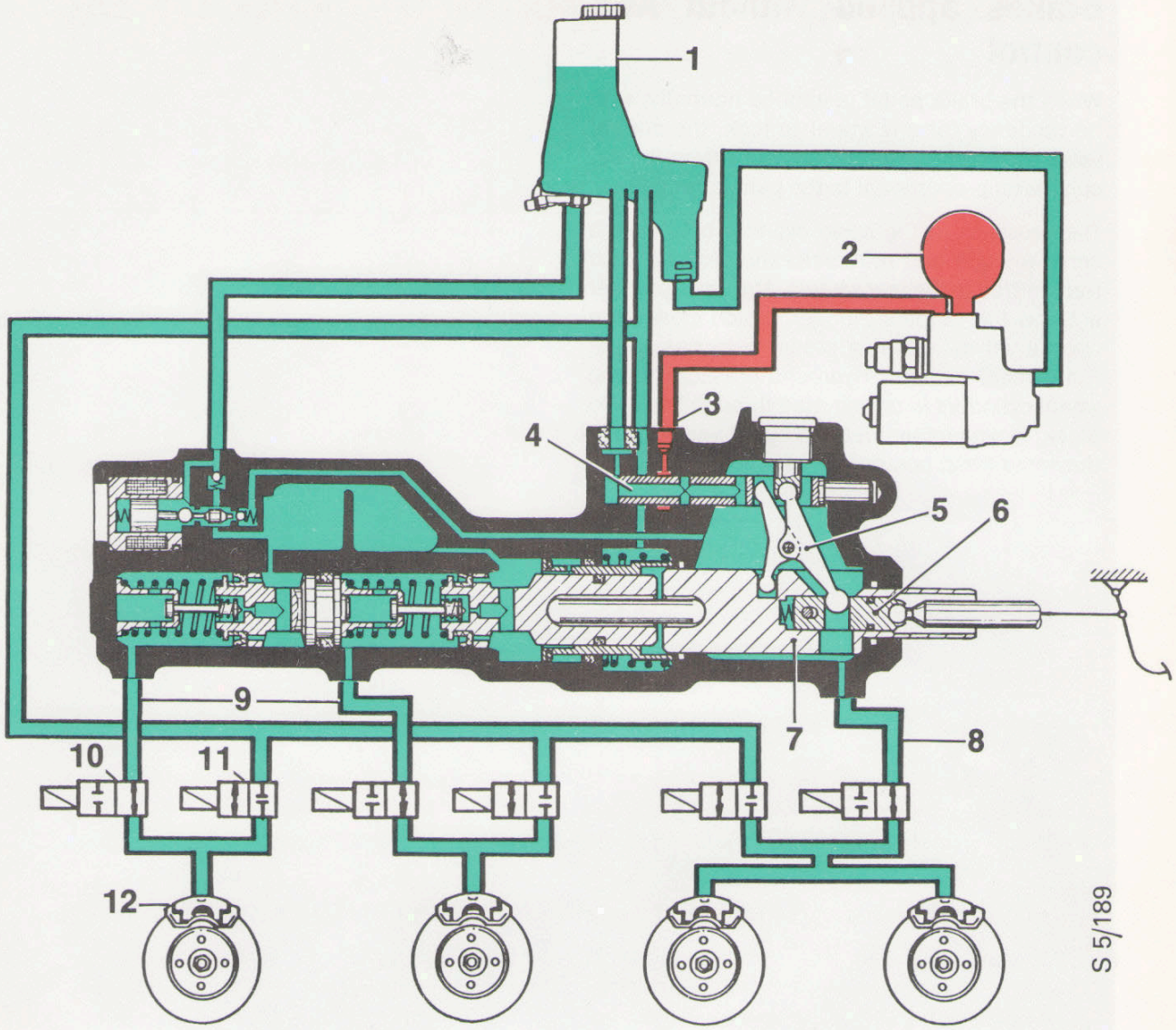
3 Brakes applied with ABS control

Brakes off

Hydraulic pressure is present between the accumulator and the control valve, which keeps 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 brake fluid at atmospheric pressure.

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



= Accumulator pressure

= Atmospheric pressure

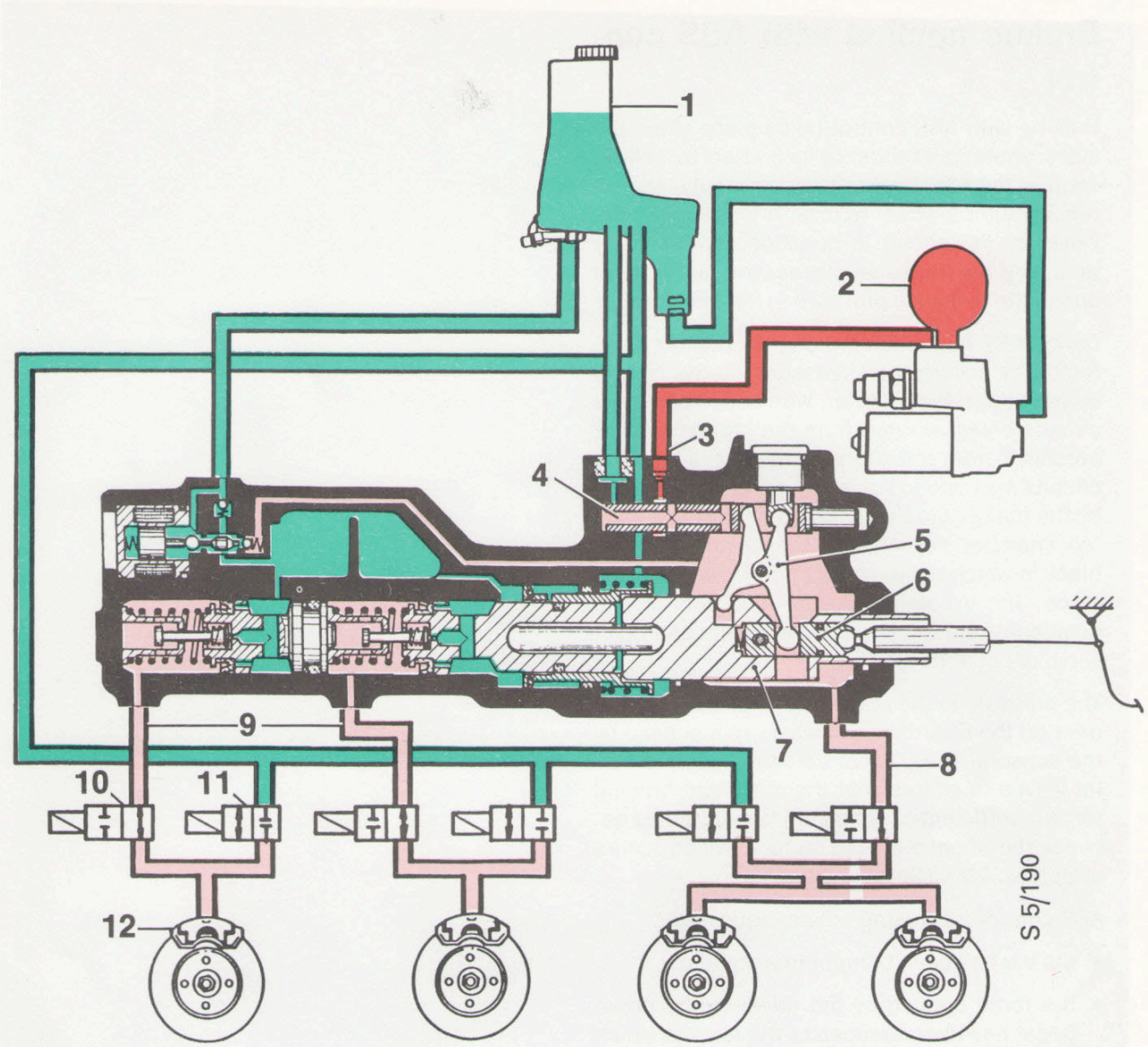
Condition 1: brakes off

1 Brake fluid reservoir
2 Accumulator
3 Coupling, pump delivery hose
4 Control valve
5 Lever mechanism
6 Actuating plunger
7 Serv o plunger
8 Rear brake circuit
9 Front brake circuits
10 Inlet valve
11 Outlet valve
12 Wheel brake

Brakes applied without ABS control

When the brake pedal is applied normally, with no tendency for any wheel to lock, the control valve will admit 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 same (rest) position as in condition 1.



= Accumulator pressure

= Master cylinder pressure (servo pressure)

= Atmospheric pressure

Condition 2: brakes applied without ABS control

1 Brake fluid reservoir
2 Accumulator
3 Coupling, pump delivery hose
4 Control valve
5 Lever mechanism
6 Actuating plunger
7 Serv o plunger
8 Rear brake circuit
9 Front brake circuits
10 Inlet valve
11 Outlet valve
12 Wheel brake

Brakes applied with ABS control

Braking with ABS control takes place 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, the master valve closes, the outlet valve opens the hydraulic pressure in the circuit falls.

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

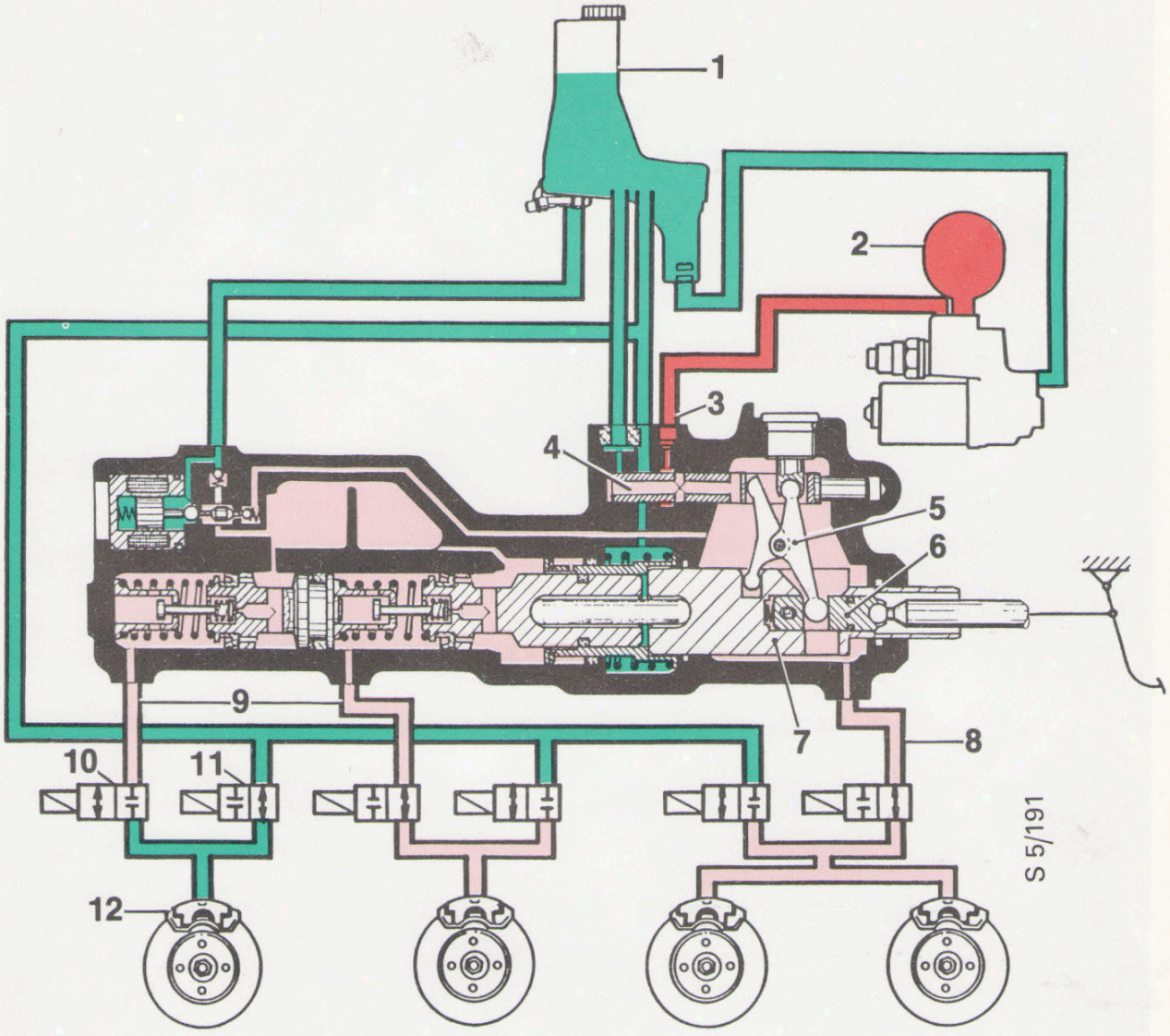
The pressure in the respective circuits is dependent on the retardation in wheel rpm sensed by the sensors. The ECU controls the inlet and outlet valves to ensure that the maximum braking force (coefficient of adhesion) is maintained between the wheel and road surface (which occurs at approx. 20% slip).

ABS-controlled 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 relation between the 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 which is designed to ensure that a sufficient quantity of pressurized brake fluid will always be available during ABS-controlled braking.



= Accumulator pressure

= Master cylinder pressure (servo pressure)

= Atmospheric pressure

Condition 3: braking with ABS control

1 Brake fluid reservoir
2 Accumulator
3 Coupling, pump delivery hose
4 Control valve
5 Lever mechanism
6 Actuating plunger
7 Servo plunger
8 Rear brake circuit
9 Front brake circuits
10 Inlet valve
11 Outlet valve
12 Wheel brake

Removal and fitting

N.B.

- Before starting any work on th e hydraulic unit, thoroughly clean the surfaces of the unit, all connections and the area around the unit to prevent ingress of dirt into the system.
- When replacing any component of the hydraulic unit, always renew all existing 'O' rings and rubber seals.
- Lubricate all new 'O' rings with unused brake fluid before fitting.

To replace the pressure switch (hydraulic unit in situ)

To remove

1 Remove the battery, battery shelf and fuel filter to provide access to the hydraulic unit.

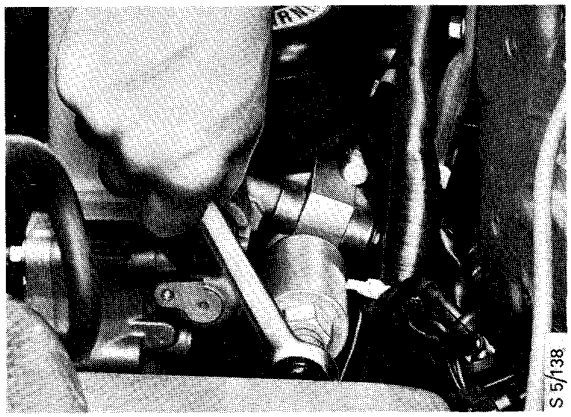
Caution

The system must be depressurized before work proceeds further. To do this, depress the brake pedal about twenty times until positive resistance is felt in the pedal.

2 Unplug the electrical connectors on the pressure switch, master valve, fluid level indicator and valve block.

Remove the steady bar and disconnect the earth lead from the master cylinder.

3 Remove the pressure switch using a 36-mm socket.



To fit

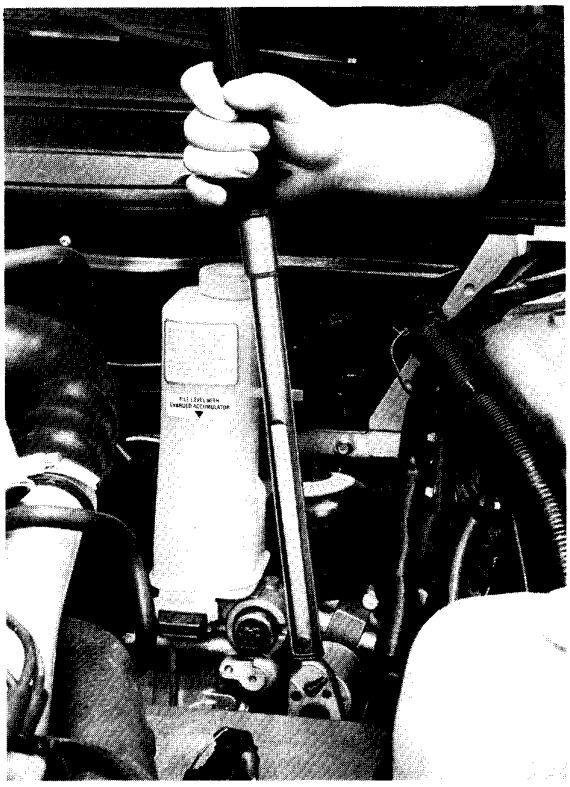
1 Fit the pressure switch

Tightening torque: 20-26 Nm (15-19 lbf ft)

2 Reconnect the electrical leads to the valve block, pressure switch, master valve and fluid level indicator.

3 Fit the steady bar and reconnect the earth lead to the master cylinder.

4 Test the system.



To replace the hydraulic accumulator (hydraulic unit in situ)

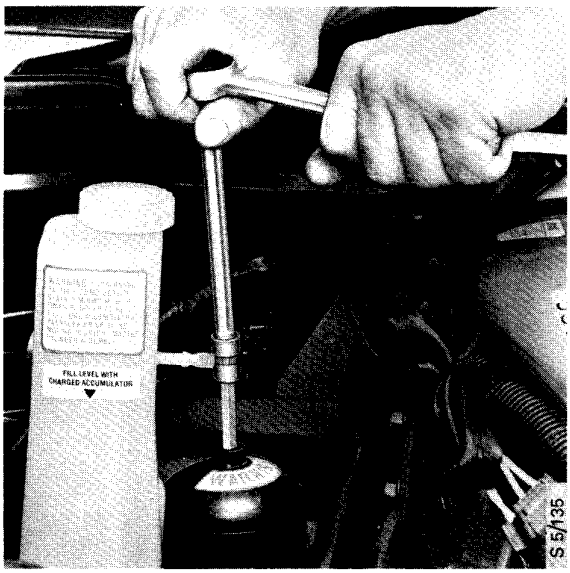
1 Disconnect the battery leads and remove the battery.

Caution

The system must be depressurized before work proceeds further. To do this, depress the brake pedal about twenty times until positive resistance is felt in the pedal.

2 Slacken the fixings for the fuel filter on the battery shelf and move the filter to one side.

3 Remove the hydraulic accumulator.



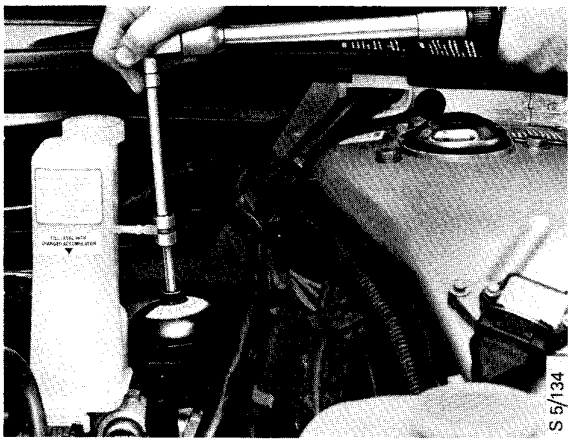
To refit

1 Fit new 'O' ring and then refit the hydraulic accumulator.

Tightening torque: 34-46 Nm (25-34 lbf ft)

2 Refit the fuel filter and battery and reconnect the battery leads.

3 Test the system.



To remove the hydraulic unit

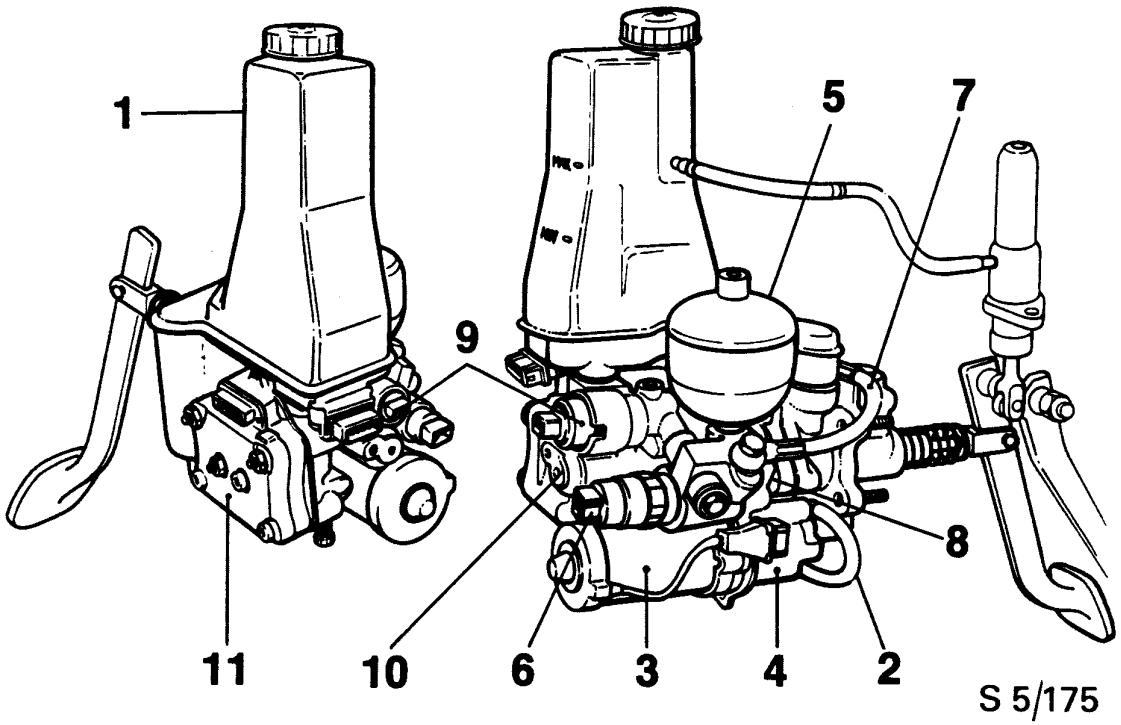
1 Disconnect the battery leads and remove the battery.

Caution

The system must be depressurized before work proceeds further. To do this, depress the brake pedal about twenty times until positive resistance is felt in the pedal.

N.B.

- Before starting any work on the hydraulic unit, thoroughly clean the surfaces of the unit, all connections and the area around the unit to prevent ingress of dirt into the system.
- When replacing any component of the hydraulic unit, always renew all existing 'O' rings and rubber seals.
- Lubricate all new 'O' rings with unused brake fluid before fitting.

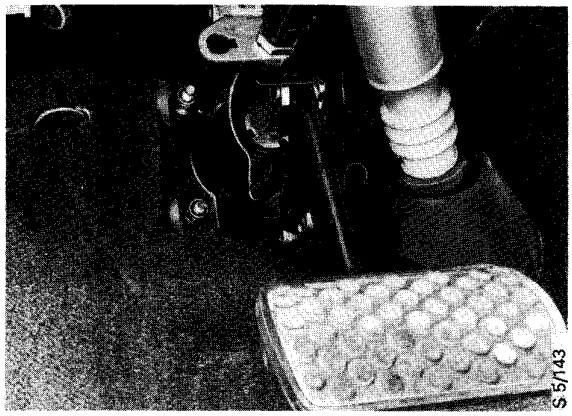


Hydraulic unit

1 Brake fluid reservoir
2 Hose, reservoir to pump inlet
3 Electric motor
4 Hydraulic pump
5 Accumulator
6 Pressure switch
7 Pump delivery hose
8 Servo cylinder
9 Master valve
10 Master cylinder
11 Valve block

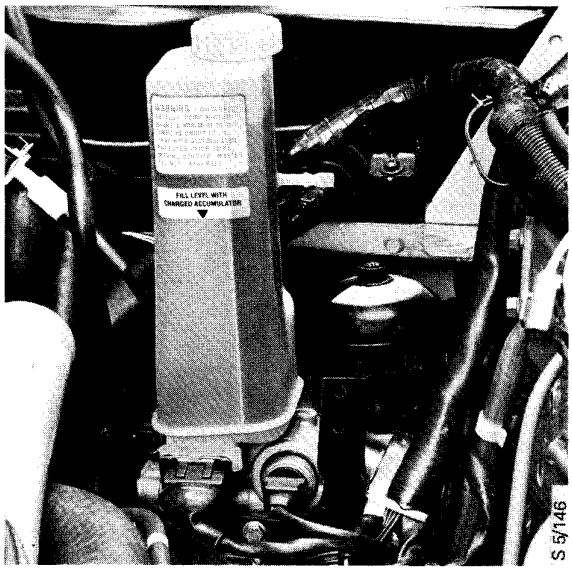
2 Remove the trim panel (five screws)

3 Remove the pin retaining clip and the clevis pin from the linkage between the pedal and pushrod.



4 To clear the way for removal of the hydraulic unit:

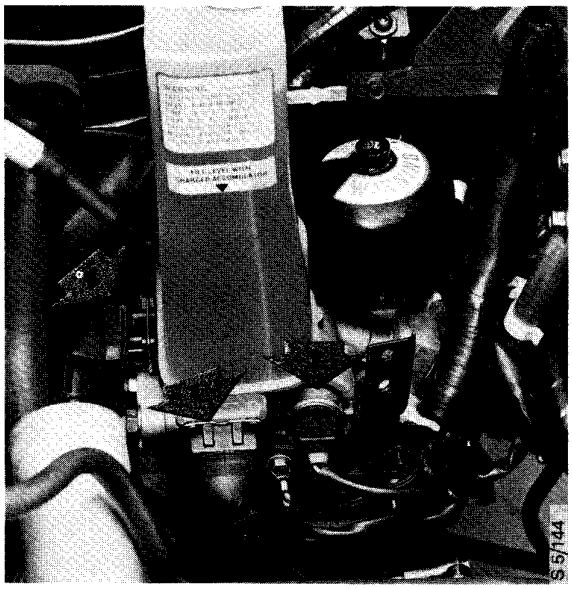
- Undo the clips for the wiring loom on the battery shelf and remove:
- The junction box complete with electrical leads from the battery shelf
- The fuel filter
- The battery shelf
- The rubber duct between the inlet manifold and throttle housing



5 Unplug the electrical connectors on the following:

- Fluid level indicator on brake fluid reservoir (1)
- Master valve (2)
- Pressure switch (3)
- Valve block (4)

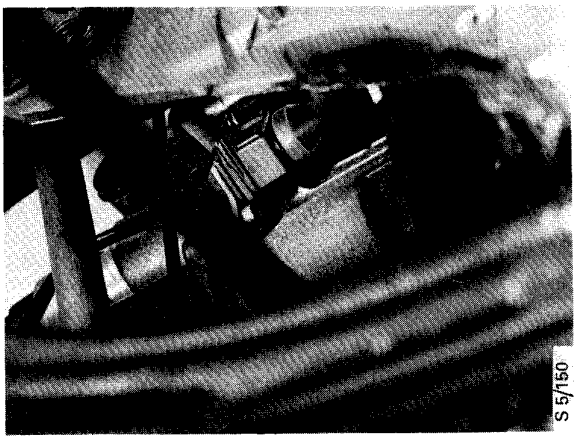
Detach the wiring loom from the steady bar, disconnect the earth lead and remove the steady bar from the master cylinder (5)



6 Siphon the brake fluid from the reservoir. Cars with manual gearbox: disconnect the hose to the clutch cylinder.

7 Raise the car and remove the left front wheel. Remove both sections of the wing liner.

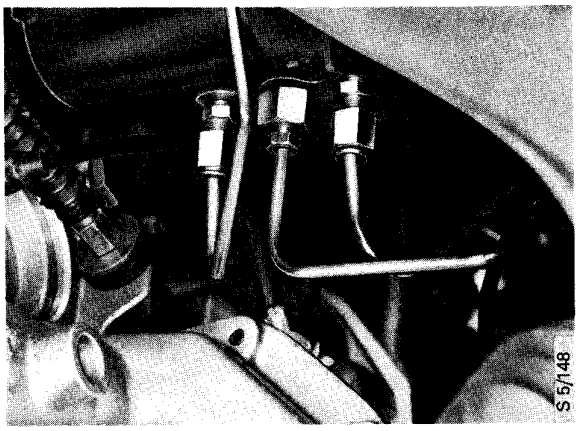
8 Unplug the connector for the pump motor on the hydraulic unit.



Electrical connector for pump motor (viewed from below)

N.B.
Clean the brake pipe connecti ons at the valve block using a degreasing agent and blow clean with an air gun.

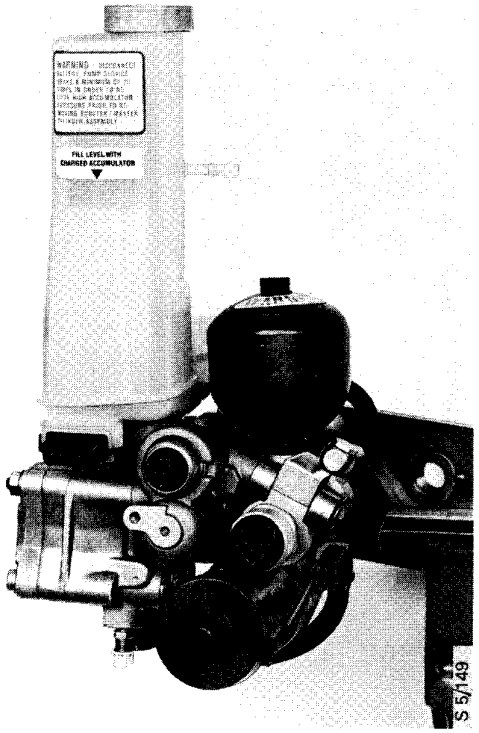
9 Disconnect the brake pipes from the valve block and cap the ends of the pipes and the ports in the block.



10 Remove the four nuts securing the hydraulic unit to the bulkhead and lift the unit out of the car.

To dismantle the hydraulic unit

Before removing any hydraulic unit component, secure the unit in fixture 87 90 51 or an equivalent device, which should be clamped in a vice.

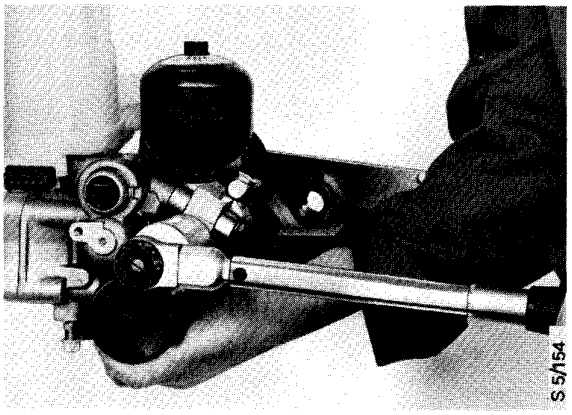


N.B.
Before dismantling any component, clean the connections thoroughly using a degreasing agent and blow clean with an air gun

Pressure switch

Use a 36-mm socket to remove the pressure switch.

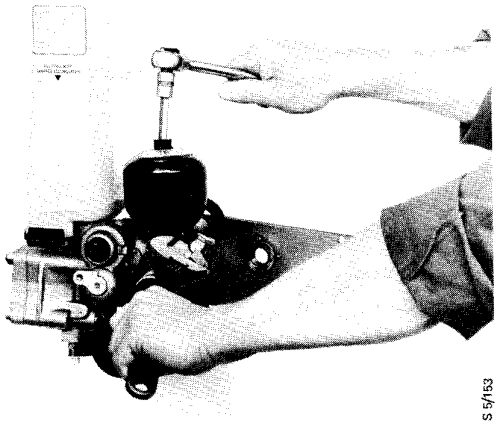
Tightening torque on refitting: 20-26 Nm (15-19 lbf ft).



Hydraulic accumulator

To remove

Use a ratchet handle and an 8-mm hex bit adaptor. Prevent the pump housing from turning by gripping with an adjustable spanner.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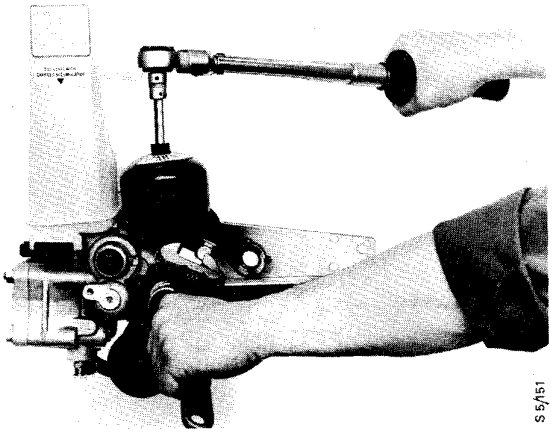
To fit

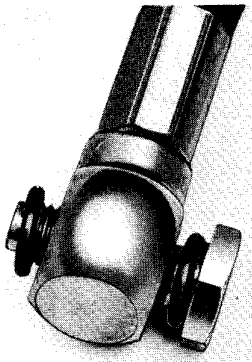
1 Fit a new 'O' ring and refit the hydraulic accumulator.

Tightening torque: 34-36 Nm (25-27 lbf ft)

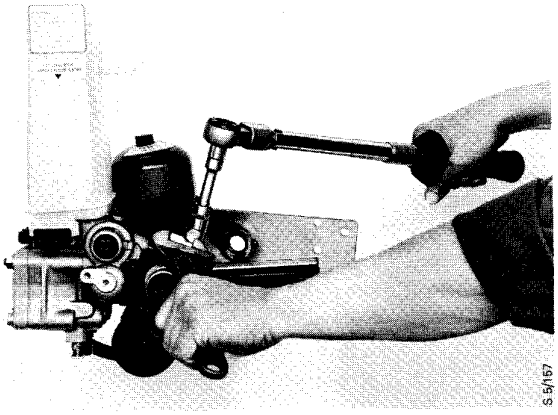

S 5/151

Pump delivery hose

When disconnecting and reconnecting the two banjo couplings, note the two 'O' rings in each coupling, one above and one below the nipple, which must be renewed before the hose is refitted.


S 5/152

Tightening torque on refitting: 16-24 Nm (12-18 lbf ft).

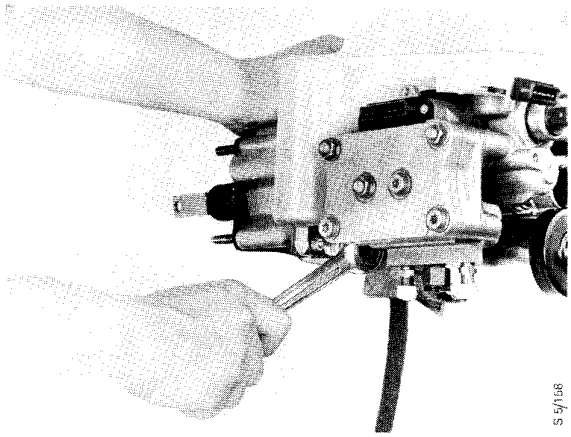

S 5/157

Brake fluid reservoir

To remove

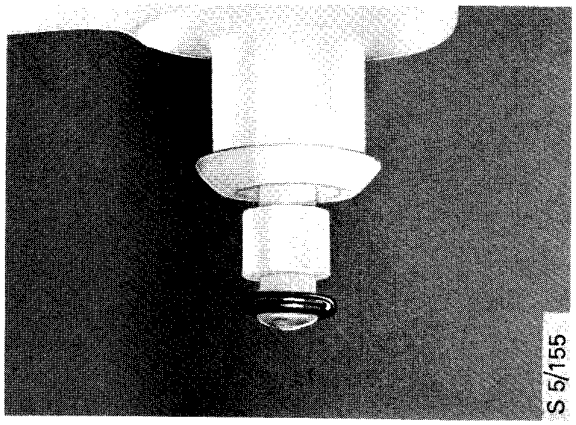
1 Start by draining all remaining brake fluid from the reservoir and disconnect from the reservoir the inlet hose to the pump.

2 Remove the reservoir securing bolt (through-bolt).



N.B.
A distance piece and an 'O' ring are fitted on the rear connection of the reservoir.

Using a screwdriver, carefully lever the reservoir spigot connectors out of the rubber grommets in the hydraulic unit.



3 Remove the rubber grommets from the hydraulic unit.

To fit

1 Fit new rubber grommets in the hydraulic unit.

2 Fit a distance piece and a new 'O' ring onto the reservoir rear spigot conector and press the reservoir onto the hydraulic unit. Make sure that the reservoir spigots are pressed fully home.

3 Fit the through-bolt and tighten to the specified torque.

Tightening torque: 4-6 Nm (3-4 lbf ft).

Pump unit

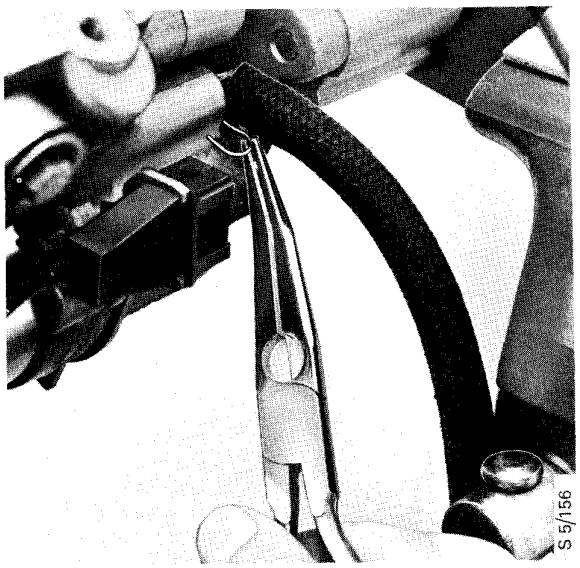
To remove

1 Remove the hydraulic accumulator (as described earlier in this section).

2 Disconnect the pump delivery hose from the pump unit (as described in the section, 'Pump delivery hose').

3 Remove the pressure switch (as described in the section, 'Pressure switch').

4 Remove the retaining clip holding the pump inlet hose spigot connector in the pump unit and disconnect the hose.

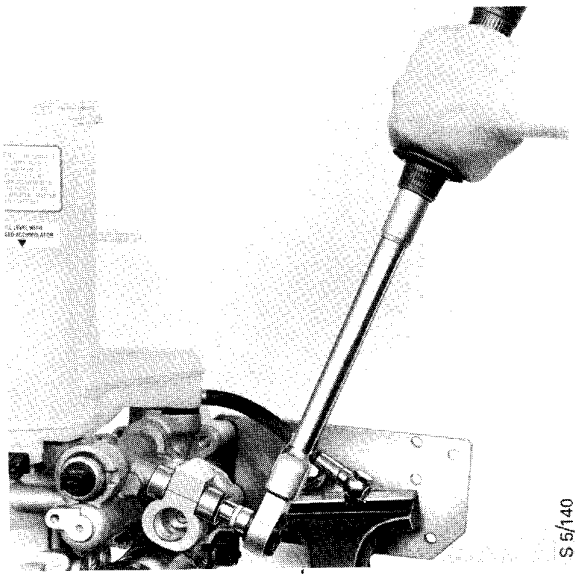


5 Undo the securing bolt and lift off the pump unit.

To refit

1 Fit the pump unit and tighten the securing bolt to the specified torque.

Tightening torque: 7-9 Nm (5-7 lbf ft).



2 Fit a new 'O' ring on the pump inlet hose spigot, insert the spigot in the pump unit and fit the retaining clip.

3 Connect the pump delivery hose.

Tightening torque: 16-24 Nm (12-18 lbf ft).

4 Refit the hydraulic accumulator.

Tightening torque: 34-46 Nm (25-34 lbf ft).

5 Refit the pressure switch.

Tightening torque: 20-26 Nm (15-19 lbf ft).

Hydraulic unit

To refit

1 Lift the hydraulic unit into position and fit the nuts securing the unit to the bulkhead.

2 Connect the pushrod to the brake pedal, fitting the clevis pin and pin retaining clip.

3 Fit the trim panel.

4 Remove the dust caps from the brake pipe ends and the ports in the valve block, and connect the brake pipes.

5 Plug in the connector on the pump motor.

6 Lower the car. Fit the steady bar and reconnect the earth lead to the master cylinder. Press the cable clip for the wiring loom into the steady bar and plug the electrical leads onto the connectors for the master valve, valve block, pressure switch and fluid level indicator.

7 Fit the rubber duct between the inlet mani fold and throttle housing.

8 Fit the battery shelf and connect the leads to the junction box on the front of the shelf.

9 Replace the battery and reconnect the battery leads.

10 Switch on the ignition and check that the pump is running. Top up the system with brake fluid (DOT 4). Check that there are no leaks in the system and that the warning lights are working.

11 Fit the wing liner sections and bleed the system as described in the section, 'Bleeding the system'.

12 Replace the wheel.

13 Check that the system is working properly and effectively.

Bleeding the system

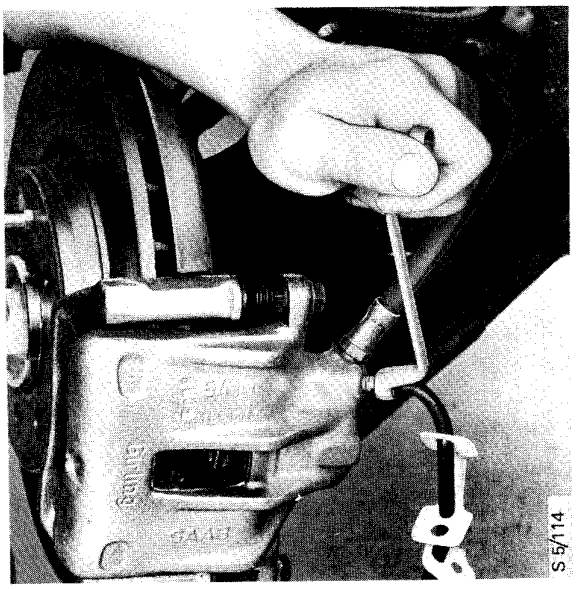
N.B.
Always handle brake fluid carefully; should any drops spill onto the paintwork, wash off immediately with cold water.

1 Top up, as necessary, with brake fluid to DOT 4.

2 Start bleeding the system at the left front wheel. Connect a hose to the bleed nipple on the brake caliper and place the other end in a suitable receptacle.

3 Have an assistant depress the brake pedal at the same time as you unscrew the bleed nipple. Close the bleed nipple and have the assistant release the pedal. Repeat this procedure until no more air bubbles are visible in the fluid pumped out.

4 Repeat steps 2 and 3 at the right front wheel.

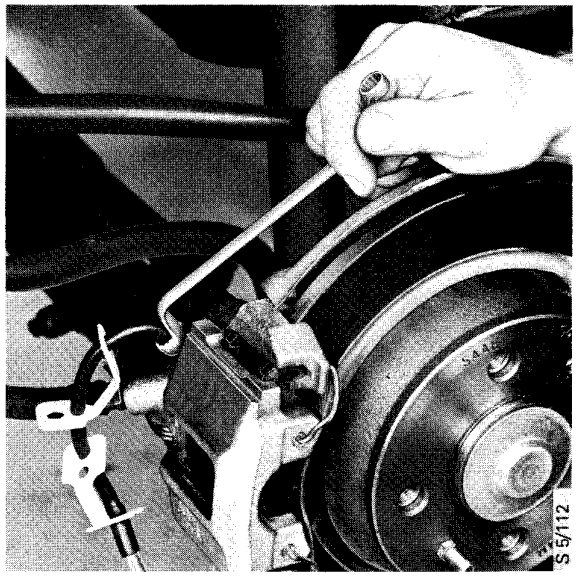


Caution

Before the rear wheel circuits can be bled, the system must be depressurized. To do this, depress the brake pedal about twenty times until positive resistance is felt in the pedal.

5 Connect a hose to the bleed nipple for the left rear wheel. Unscrew the bleed nipple and have an assistant depress the brake pedal and switch on the ignition. The pump will now start running and brake fluid will be pumped out through the bleed hose. When no more air bubbles are visible in the brake fluid, close the bleed nipple and have your assistant switch off the ignition and release the brake pedal.

6 Release the pressure in the system as before and bleed the circuit for the right rear wheel.



7 Switch on the ignition, wait until the hydraulic pump has stopped and then switch off the ignition.

8 Add brake fluid to the reservoir until the fluid is up to the level of the MAX mark.

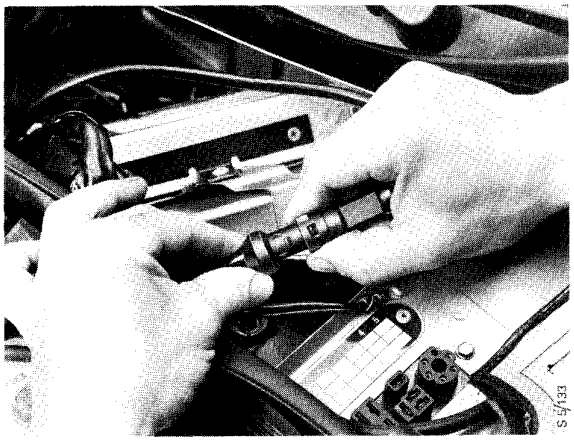
9 Check that the warning lights are working.

10 Check that there are no leaks in the system and that it is working properly and effectively.

Wheel sensors

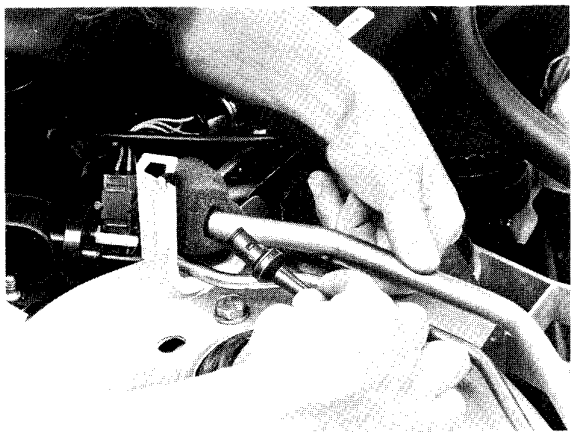
To remove

1 Unplug the connector for the sensor lead:
front-wheel sensors - inside the engine compartment;
rear-wheel sensors - underneath the rear seat cushion.

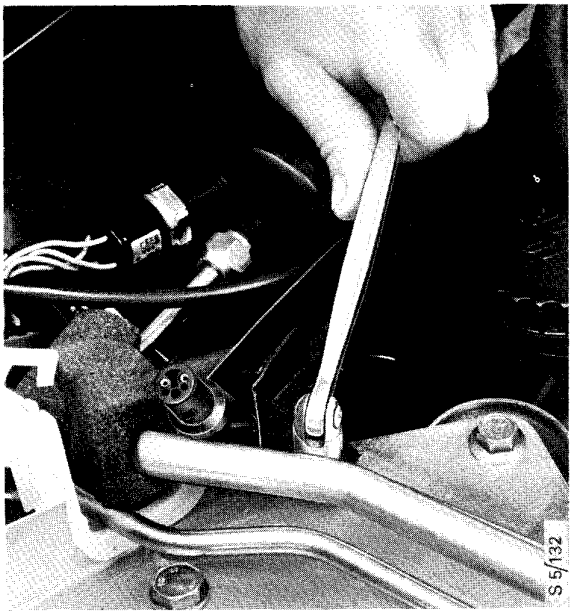


From the left-hand side:
Lift the rubber moulding on the false bulkhead panel and undo the plastic clip in the cable lead-through.

On the right-hand side:
Undo the clip for the pressure and return lines for the AC system. Lift the rubber moulding on the false bulkhead panel and open the plastic clip in the cable lead-through. Lift the AC wiring loom and withdraw the sensor lead.



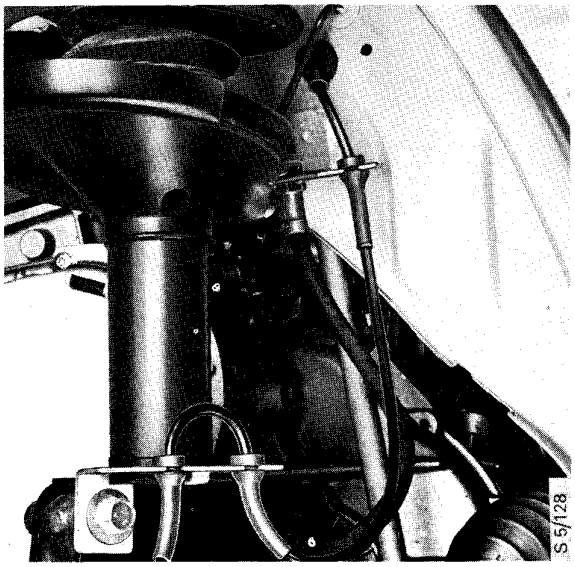
Undo the retaining screw for the false bulkhead panel fixing, raise the fixing slightly and withdraw the sensor lead.



2 Raise the car and remove the wheels.

3 Remove the rear sections of the wing liners (front wheel arches).

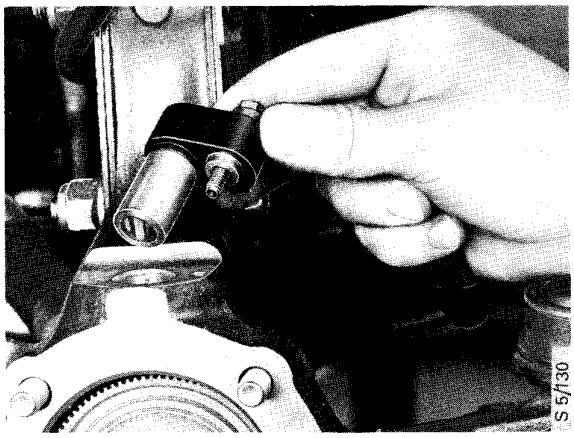
4 Free the sensor lead by withdrawing the rubber grommet from the lead-through in the car body. Undo the clips securing the sensor lead.



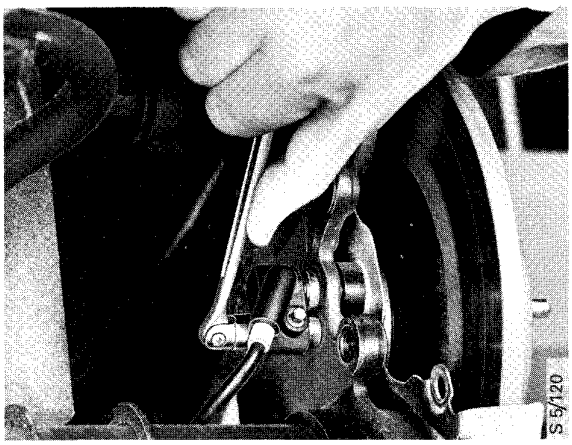
Clips for sensor lead (front wheels)

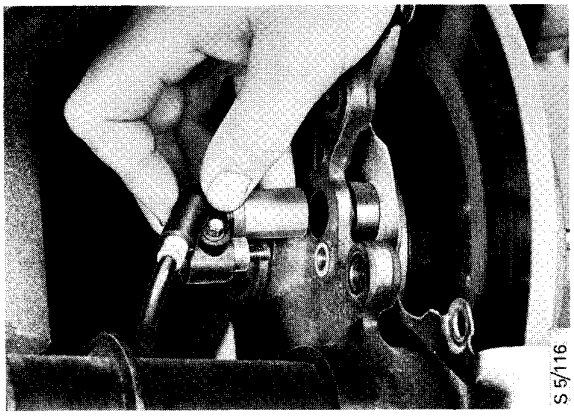
5 Thoroughly clean the surfaces around the wheel sensor.

6 Front wheels: undo the retaining screw and lift up the sensor.



Rear wheels: undo the retaining screw and lift up the sensor.




S 5/116

7 Remove the sensor complete with lead.

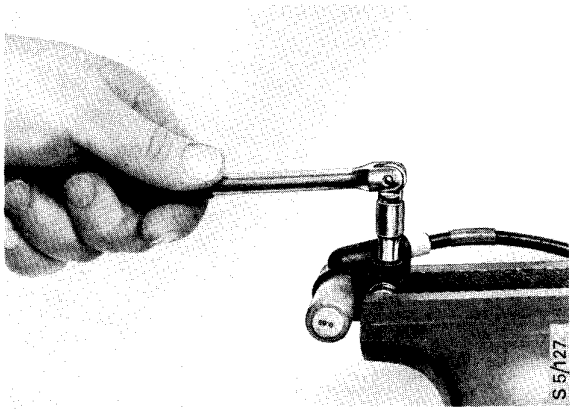
To fit

N.B.
If the setscrew is difficult to undo:
Mount the sensor in a vice, gripping it on the adjusting sleeve.
Never clamp the sensor body itself in the vice or apply pressure to it in any way as the body can become distorted.

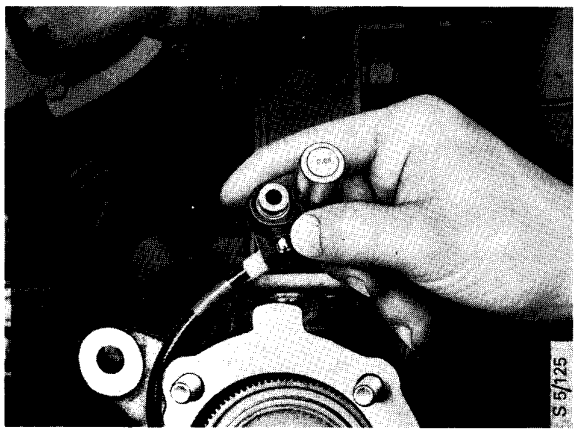
1 Undo the setscrew and transfer the adjusting sleeve to the new sensor. Check that the sleeve moves freely. If not, polish the surface with a piece of fine emery cloth and then clean and lubricate the surface thoroughly before fitting.

2 Clean the end of the sensor using a wire brush, removing all traces of the old fibre spacer. Wipe the surface clean with a dry cloth or a cloth slightly moistened with petrol.

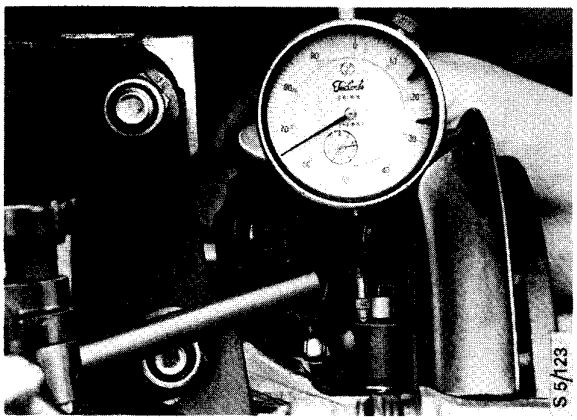
3 Through the hole for the sensor body, check to ensure that there are no traces of the old fibre spacer or other dirt above the sensor wheel. Rotate the road wheel hub slowly and inspect the sensor wheel to ensure that it is in good condition.


S 5/127

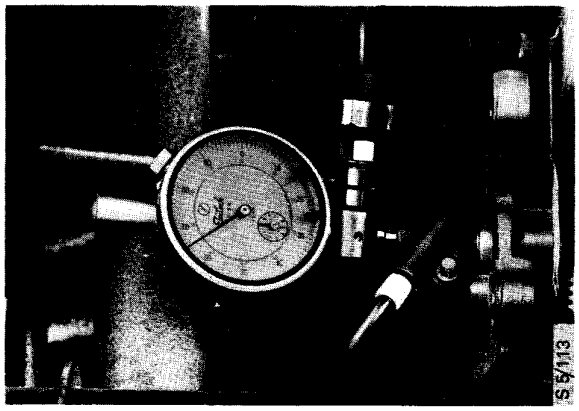
4 Glue a new spacer onto the end of the sensor.
Spacer thickness: 0.65 mm.



If special reasons exist, it is also possible to set the position of the sensor body using a dial indicator mounted on a stand.

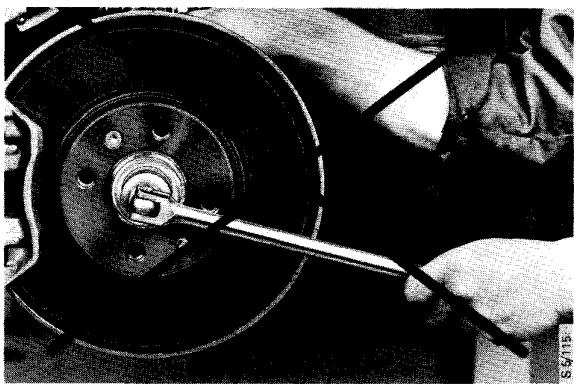


Setting the clearance between the sensor and sensor wheel (front)



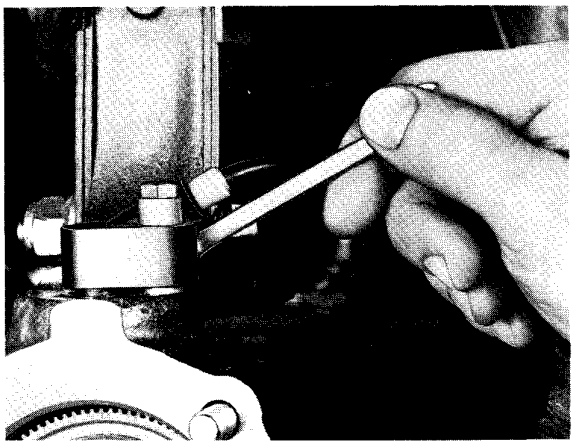
Setting the clearance between the sensor and sensor wheel (rear)

N.B.
When the sensor with a new spacer is moved into position by the sensor wheel, the road-wheel hub must not be rotated before the sensor has been secured in its correct position. Failure to observe this will result in destruction of the spacer by the toothed sensor wheel and an incorrect setting for the sensor.
Make sure that the setscrew bottoms on the adjusting sleeve at a different point to before, to avoid jeopardizing correct setting of the sensor body.

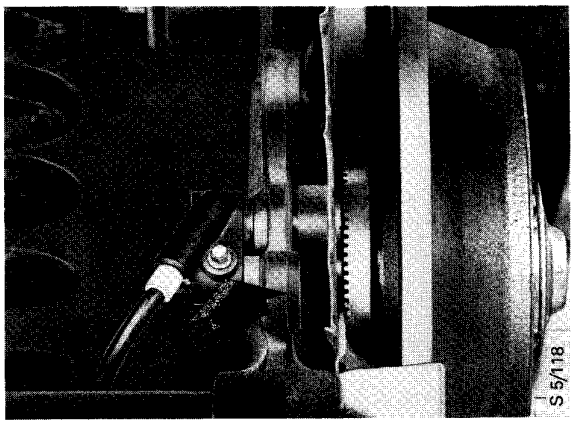


5 Position the sensor correctly and tighten the securing screw.

6 Press the sensor body gently against the sensor wheel and tighten the setscrew.



Tightening the setscrew (front)



Setscrew for rear sensor

7 Secure the sensor lead in its clips and refit the rubber grommet in the hole in the body.

8 Fit the wing liners in the front wheel arches, replace the road wheels and lower the car.

9 Plug together the connectors for the sensor leads:
Front wheel sensors - in engine compartment
Rear wheel sensors - underneath the rear seat cushion.

10 Check that the system is working properly and effectively.

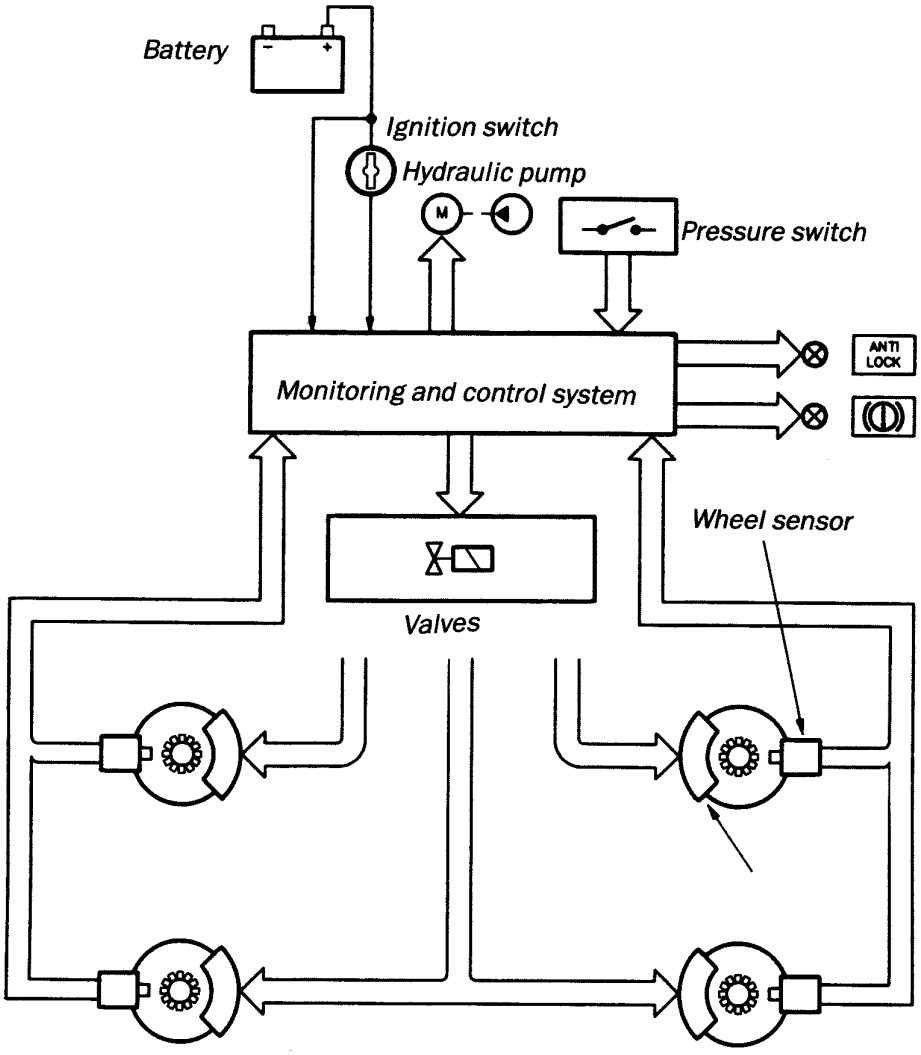
ABS system electrics

The braking system on cars with ABS braking is monitored and controlled electrically.

The monitoring and control system includes an electronic control unit incorporating two microprocessors, as well as various relays and fuses. The ECU is a readily replaceable module and not designed for repair in the workshop.

The power supply for the system comes partly direct from the battery and partly across the ignition switch, depending on the position of the key.

A sensor at each road wheel sends signals to the ECU, providing data on the speed of rotation of the wheels. If a tendency is detected for a wheel to lock, the ECU will modulate the pressure in the brake circuits (and thus the braking force) by means of a number of solenoid valves. Brake pressure modulation is effected individually for the front wheels but jointly for the rear wheels.



In contrast to the case with conventional braking systems, the depression in the inlet manifold is not used to provide the power assistance; instead, the hydraulic unit connected to the brake pedal incorporates an electrically driven hydraulic pump, one of whose tasks is to provide hydraulic pressure to the servo. The pressure is maintained at the required level by means of a pressure switch which controls the operation of the pump motor.

Two warning lights for the brake system are incorporated in the main instrument display panel: the ABS warning light (ANTI LOCK) and the brake warning light (which is also fitted to cars without ABS braking).

For fault diagnosis of the ABS system, please refer to the separate manual, 'ABS System Tester', which contains detailed instructions for fault diagnosis using the special ABS system tester. **Fault diagnosis using conventional equipment is not recommended, as this is likely to damage the terminal pins.**

A list of the electrical components of the system and their location in the car is given in the section headed, 'Component locations'.

Power supply and hydraulic pressure

Description of operation

Power for the ABS system components is supplied via the fuses in the fuse and relay holder (302) fitted behind the false bulkhead panel.

The ECU (291) is protected by a 10 A fuse, and the system relay (292) and pump relay (293) by the two 30 A fuses.

When the ignition switch is in the drive or starting position, the two warning lights (47Q and 47F) also receive 15 V power via fuse 13.

System power-up

When the ignition switch is in the drive position, current (54 V) flows to pin 2 of the ECU. The ECU then feeds current to pin 8 and the system relay (292) operates, thereby providing current (30 V) for operation of the control valves in the hydraulic unit.

Operation of warning lights on starting

Every time the engine is started, the warning lights for the braking system come on to enable the driver to check that they are working. (For details of how the warning lights operate on system malfunctions, refer to the section headed, 'Monitoring functions'.)

When the ignition key is turned to the starting position, the 54 V supply to the system relay (292) is broken and the relay is de-energized. ABS warning light (47Q) is thus earthed via the diode (303A) and the relay terminal to earthing point (300). Even if the relay were to operate directly, the light would still remain on for at least two seconds, since pin 8 on the light would instead be earthed via pin 27 on the ECU during this time. (The light can remain on for up to sixty seconds, until design hydraulic pressure has been reached.)

When the ignition key is turned to the starting position, it passes through the test position, causing brake-warning light (47F) to be earthed via the ignition switch (20) and thus be switched on.

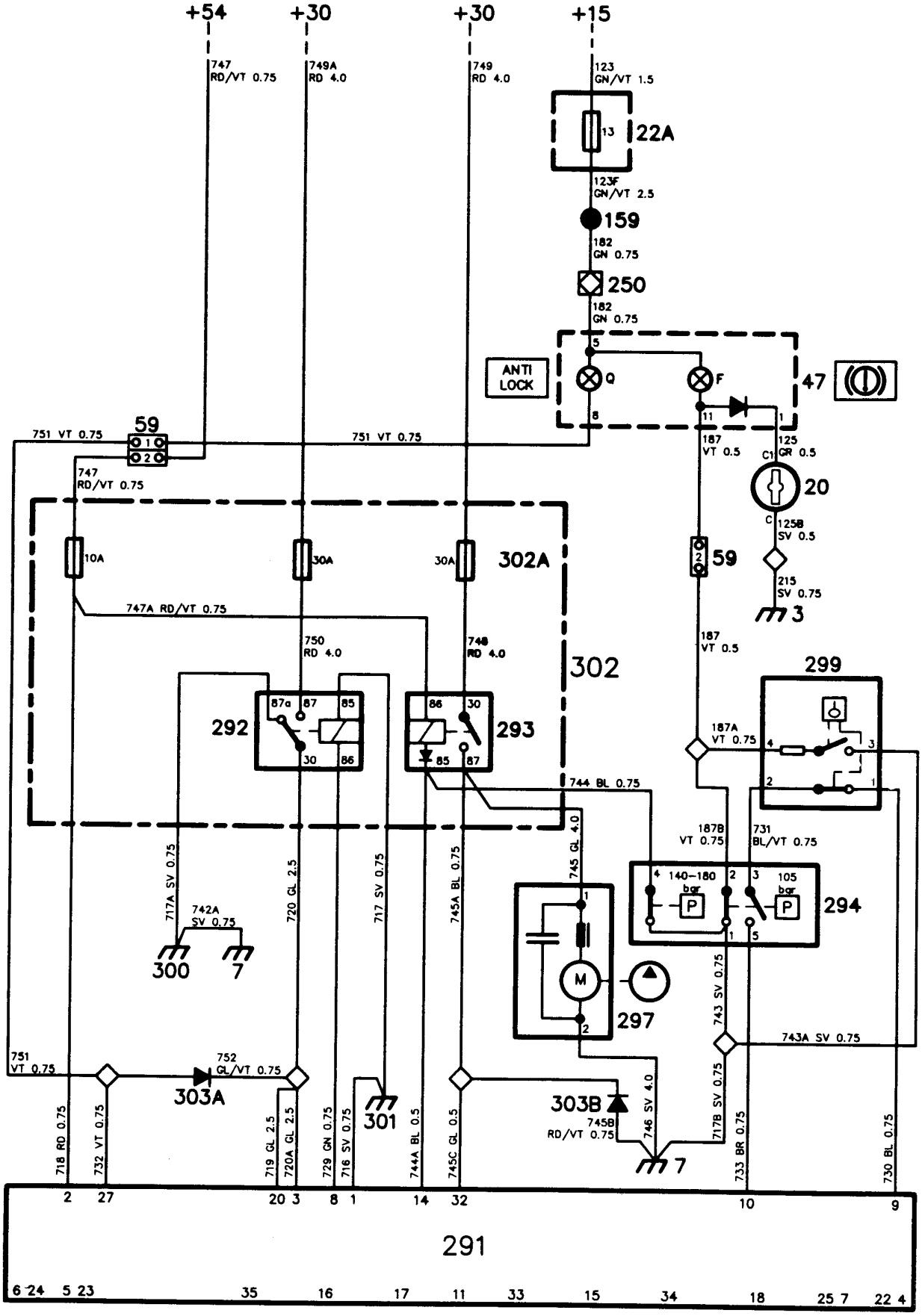
Hydraulic pressure

The pressure inside the hydraulic accumulator in the hydraulic unit is maintained at the correct value by means of an hydraulic pump driven by motor (297) and controlled by the pressure switch (294).

When the engine is switched on, the pressure is zero and the contacts (4-1) are closed. The coil in the pump relay (293) is then earthed and the current flows via the relay contacts to the motor (297).

Once the hydraulic pump has raised the pressure in the hydraulic accumulator to 180 bar (2610 psi), the contacts open and the motor is switched off. When the pressure subsequently falls to 140 bar (2030 psi) as the car is being driven, the contacts close again and the pump starts running. The pump runs for ten or fifteen seconds to raise the pressure from 140 back up to 180 bar.

Power supply and hydraulic pressure



Brake pressure modulation

Description of operation

The ECU (291) receives continuous wheel-speed data from the four wheel sensors:

298A - left front
298B - right front
298C - left rear
298D - right rear

On the basis of the data received from the wheel sensors, the ECU modulates the pressure in the brake circuits to the wheels via the six hydraulic valves (296) in the hydraulic unit. Modulation is effected individually for the front wheels and jointly for the rear wheels. Two valves are provided for each function, one inlet and one outlet valve.

Left front wheel:
IFL = Inlet valve for Front Left
OFL = Outlet valve for Front Left

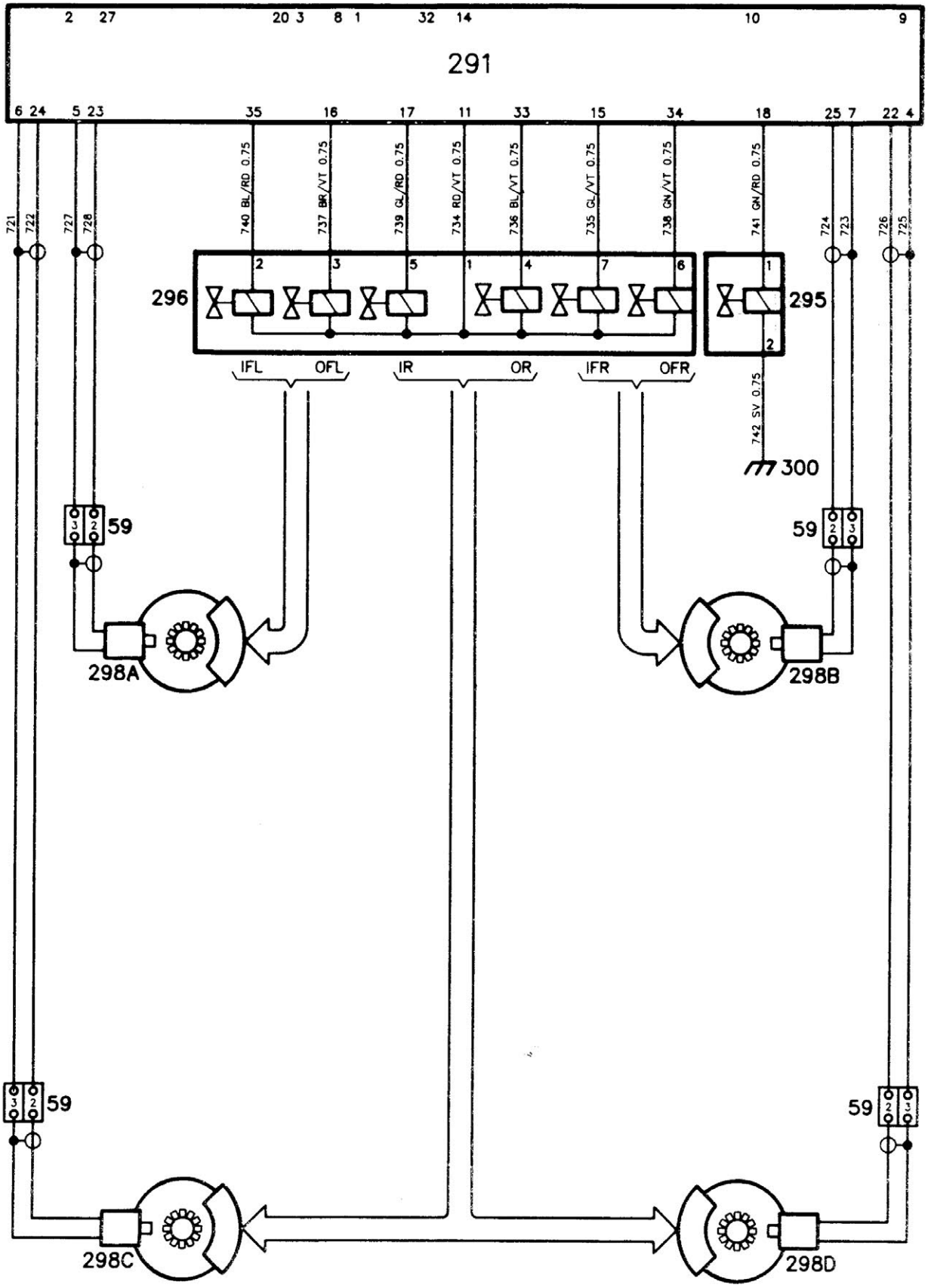
Right front wheel:
IFR = Inlet valve for Front Right
OFR = Outlet valve for Front Right

Rear wheels (common circuit):
IR = Inlet valve for Rear wheels
OR = Outlet valve for Rear wheels

In the normal (de-energized) state, the inlet valves are open and the outlet valves closed.

During braking with ABS control, the master valve (295) is energized and thus open.

Brake pressure modulation



Monitoring functions

Description of operation

As regards operation of the warning lights during starting, refer to the section headed, 'Power supply and hydraulic pressure'.

Brake-warning light

The brake-warning light (47F) will come on in any of the following conditions:

- If the level in the brake fluid reservoir falls to the MIN mark on the side of the reservoir; the light will then be earthed through earthing point 7 via contacts (4-3) in the fluid level indicator (299)
- If the pressure in the accumulator in the hydraulic unit falls below 105 bar (1523 psi); the lamp will then be earthed through earthing point 7 via contacts (2-1) in the pressure switch (294) - whereby the ABS-warning light will also come on.

(Both sets of contacts are normally open)

The brake-warning light is also fitted to cars without ABS braking, but then serves merely to alert the driver to the fact that the level of fluid in the brake fluid reservoir is low.

ABS-warning light

The ECU monitors operation of the ABS system and in the event of a malfunction switches on the ABS-warning light (ANTI LOCK - 47Q). When this light shows, the ABS system is inoperative and the braking system operates like a conventional braking system.

In any of the following conditions, the light will come on by being earthed through pin 27 of the ECU (291):

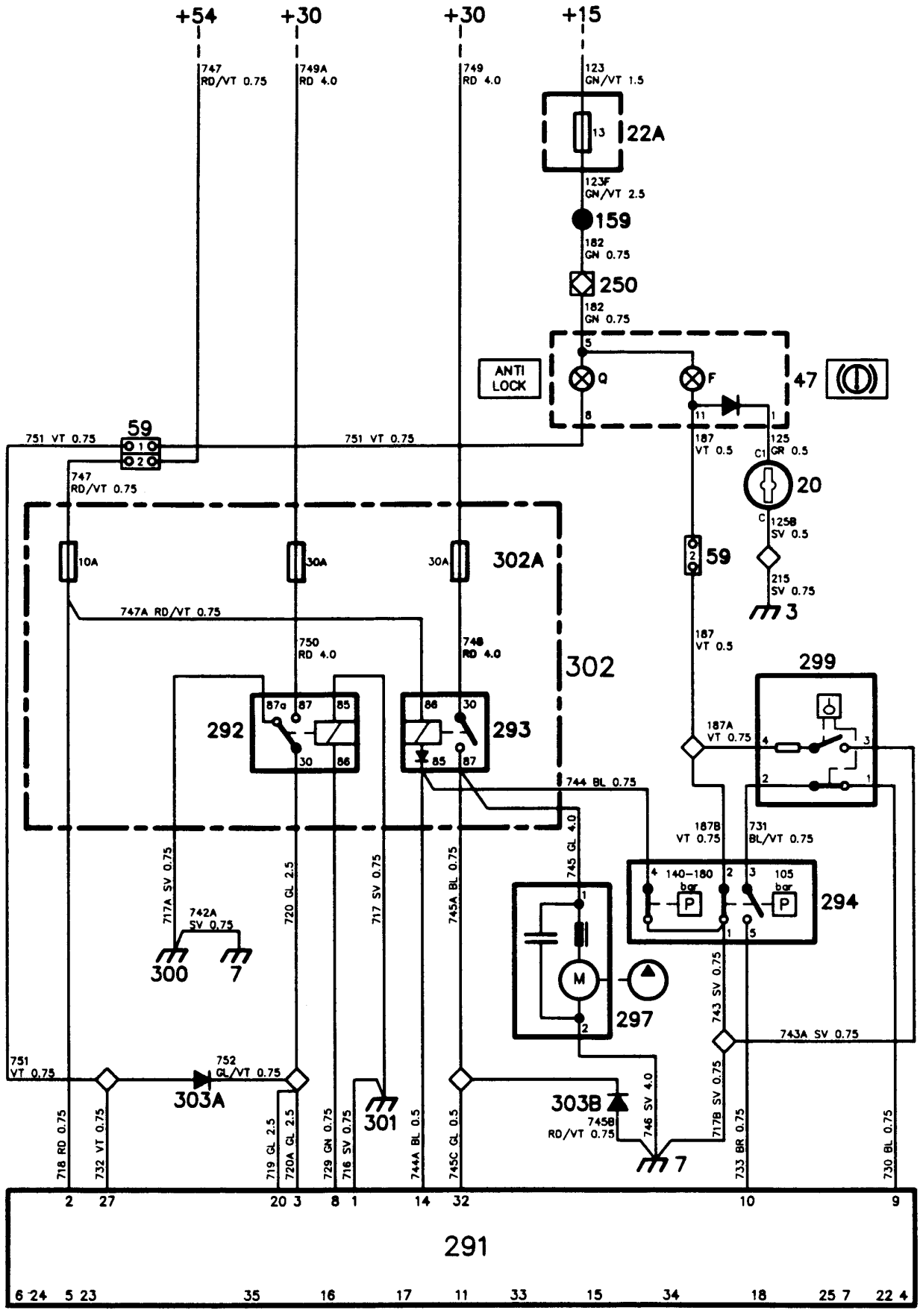
- If the level in the brake fluid reservoir falls below the MIN mark on the side of the reservoir; contacts (1 - 2) in the fluid level indicator (299) open, thereby breaking the circuit between pins 9 and 10 of the ECU. The contacts (3 - 5) in the pressure switch (294) are normally closed. (In this case, the brake-warning light will also be switched on.)
- If the pressure in the accumulator in the hydraulic unit falls below 105 bar (1523 psi), whereupon the contacts (3 - 5) in the pressure switch (294) open. Contacts (1 - 2) in the pressure switch (294) are normally closed. (In this case, the brake-warning light will also be switched on.)
- If a weak signal is received from a wheel sensor (298).

The light will also come on:

- if a break occurs in the electrical circuits (including connectors) to the valve block (296), wheel sensors (298) or master valve (295).
- or if a malfunction occurs in the ECU.

In either of these cases, the power supply to pin 8 of the ECU (291) is cut off, the system relay (292) de-energized and the 30-V supply to the ECU, for operation of the control valves in the hydraulic unit, lost; the light is thus earthed to earthing point (300) via contacts (30 - 87a) of the system relay.

Monitoring functions



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