Silver Spirit and Bentley Mulsanne 1987-1989 Model Years
20,000-Series Supplement

ABS Braking System

Workbook

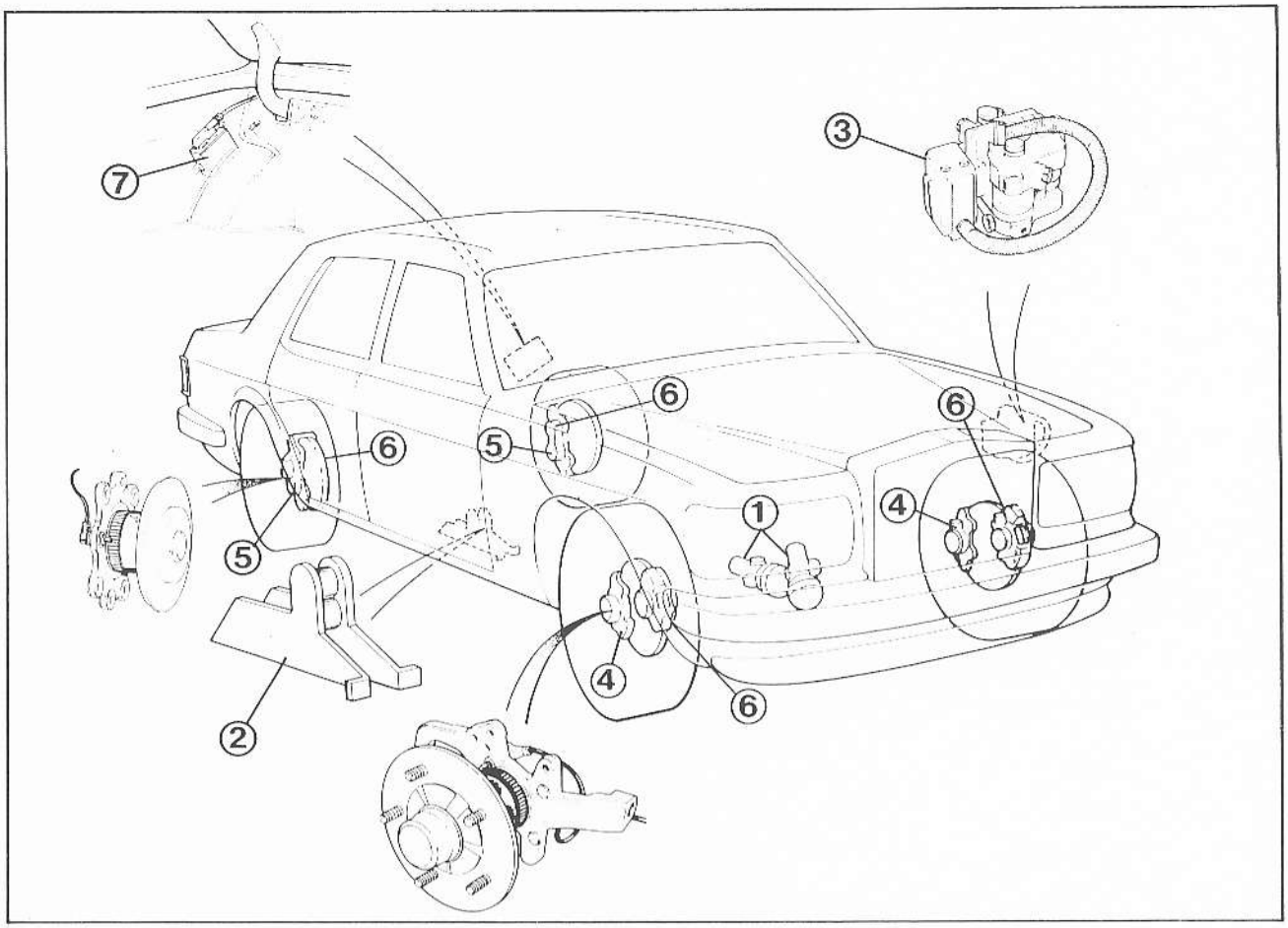
rht 22 September 2008

FOREWORD

This workbook is for use with the Rolls-Royce Mastertech Video Programme **'Anti-lock Brakes and Hydraulic System Changes from VIN 20001'**

It contains additional information about the design and working principles of the Anti-lock Braking System and Hydraulics Systems fitted to Rolls-Royce Motor Cars from VIN 20001

CONTENTS



Introduction

Components

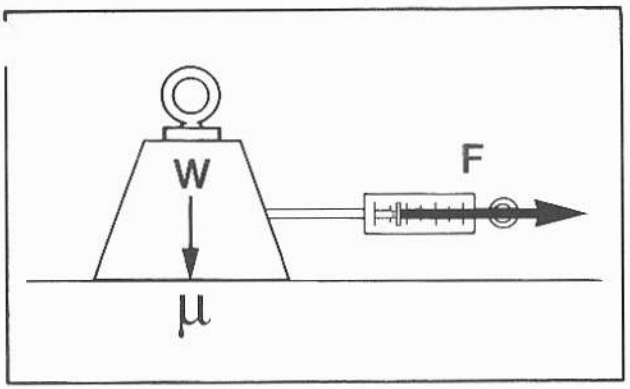
1 Accumulators
2 Brake distribution valve
3 Hydraulic modulator
4 Front wheel calipers
5 Rear wheel calipers
6 Wheel sensors
7 Electronic control unit

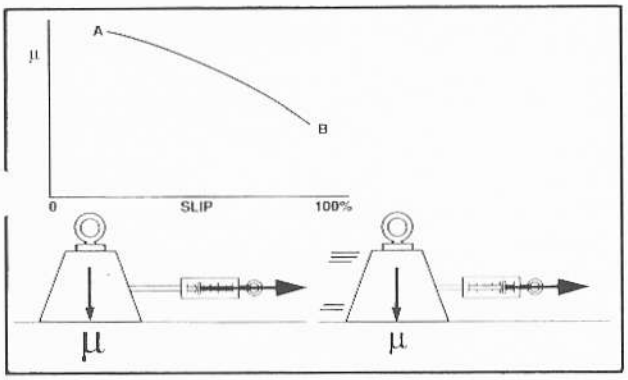
Operation

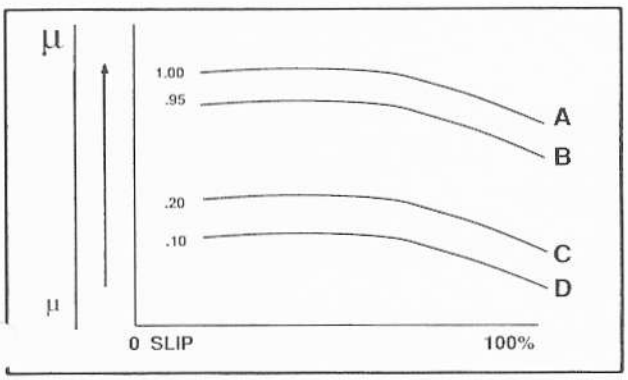
An Anti-lock Braking System is a braking system which incorporates a control function to prevent the wheels locking during braking with resultant loss of braking efficiency and directional stability.

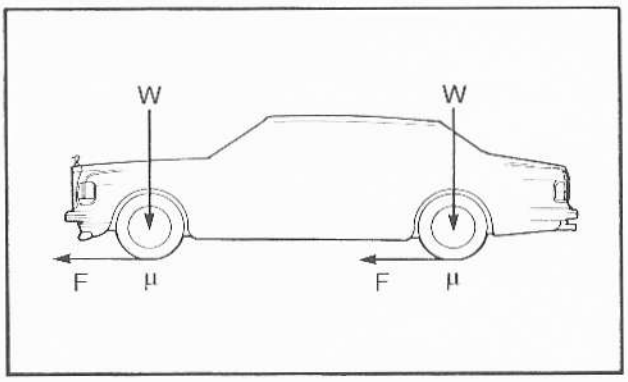
The Anti-lock Braking System fitted to Rolls-Royce and Bentley Motor Cars incorporates a wheel sensor system, an electronic control unit and electrically operated valves in the braking circuits.

The wheel sensor system continually monitors the status of each individual wheel during braking. When a wheel is about to lock, the electronic control unit operates valves in the braking circuits to control the brake caliper pressure to obtain optimum braking.









Braking Theory

Friction

Friction is the resistance to movement which occurs when one object slides over another.

The friction force (**F**) is equal to the weight of the object (**W**) times the coefficient of friction (μ). Frictional force does not depend on the contact area.

Coefficient of friction

The coefficient of friction changes with the speed at which one object slides over another.

The highest value of coefficient occurs when the object is just about to move and is referred to as the static coefficient of friction (**A**).

The lowest value of coefficient occurs when the object is moving and is referred to as the dynamic coefficient of friction (**B**).

The static coefficient of friction is higher than the dynamic coefficient of friction.

The value of the coefficient of friction changes according to the sliding surface between the objects. For example, the static coefficients of friction between a road tyre and the road surface vary from 1.00 for dry concrete, (**A**), to 0.95 for wet concrete, (**B**).

If the road is covered in snow, the coefficient of friction falls to 0.20, (**C**), while the coefficient of friction for a tyre on ice is 0.10, (**D**).

Tyre/road braking force

The maximum braking force between the road and wheel is limited by two factors, the vehicle weight and the coefficient of friction between the road and wheel.

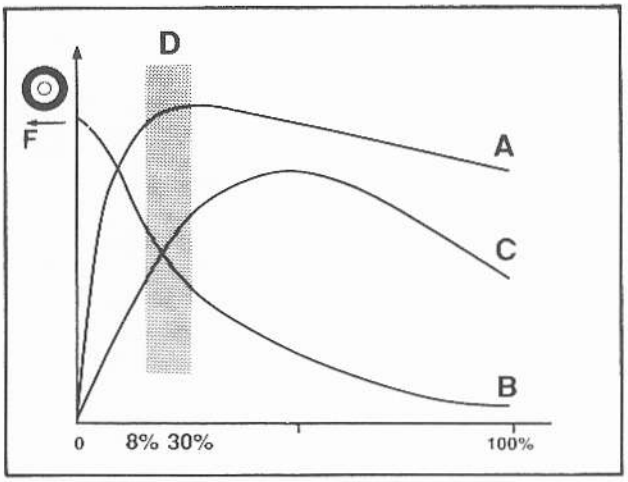
A rolling wheel is static friction. A locked or sliding wheel is a dynamic friction situation.

Therefore, during braking it is most important that the wheel does not lock. If it does, the coefficient of friction will be reduced, increasing the wheel locking effect and reducing the maximum braking force.

Wheel slip

A Straight line braking
B Cornering force
C Combined braking and cornering force
D Anti-lock brake operating range

A certain amount of slip between the tyre and road is necessary for a roadwheel to roll and steer efficiently. Anti-lock brakes operate efficiently in a 8% - 30% range of wheel slip.

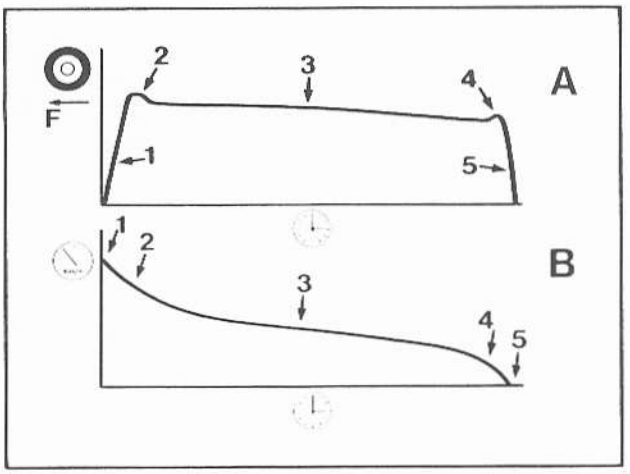


Comparison between 'Normal' and 'Anti-lock' braking in a skid situation

Graph A - Brake Force Vs Time
Graph B - Road Speed Vs Time

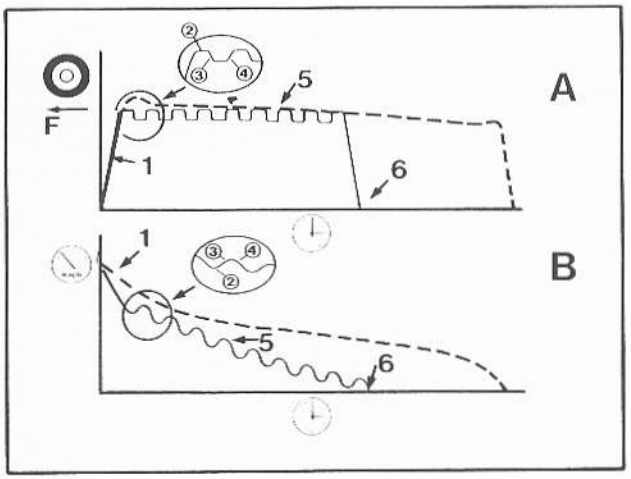
1. Normal Braking System

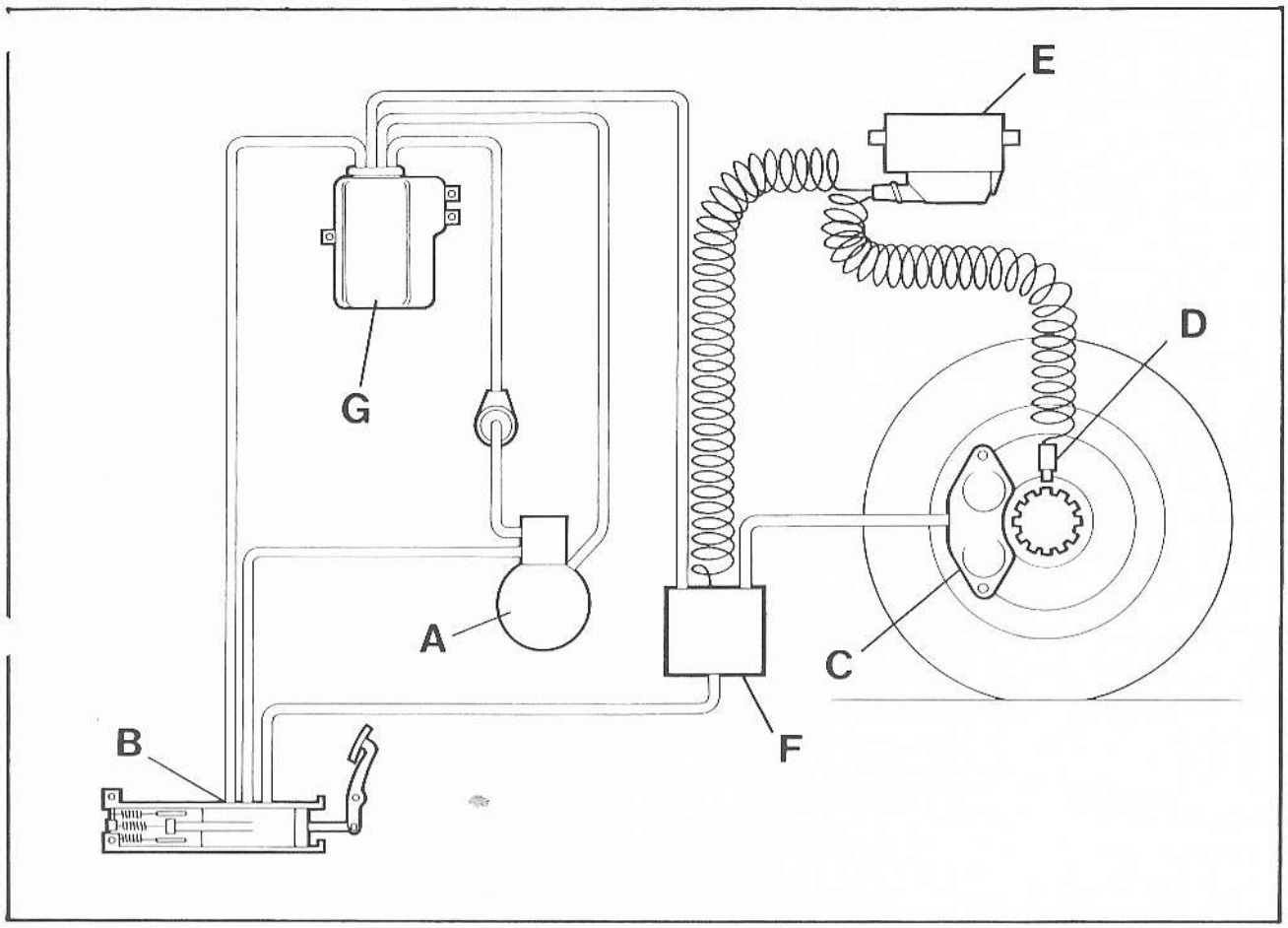
When the brakes are applied, the brake force between the road and wheel increases rapidly (**1**) up to the point at which the wheel locks. As this occurs, the maximum braking force available at the tyre - road interface for braking is reduced by the transition from static to dynamic friction (**2**). As long as the same braking conditions prevail, the wheel will continue to skid (**3**) until it finally stops. Just before the car stops, the speed reduces to the point where the friction returns to a static condition and the brake force increases momentarily (**4**). As soon as the car stops, the brakes are released (**5**).



2. Anti-lock Braking System

When the brakes are applied, the brake force between the road and wheel increases rapidly (**1**) up to the point at which the ABS system senses that the wheel is about to lock. As this occurs, the anti-lock braking system first holds the braking force constant (**2**) while monitoring the change in wheel deceleration. If the ABS system judges that the wheel will still lock, it reduces the brake force momentarily (**3**) until the wheel is rolling again. The ABS system then restores maximum braking force (**4**) until it senses that wheel lock will happen again when it holds the brake pressure. The 'Hold - Release - Restore' cycle (**5**) is repeated throughout the brake application ensuring that optimum braking is achieved until the car stops and the brakes are released (**6**).





Modulator Valve Controlled Anti-lock Braking Circuit - Principles of Operation

Components

A Accumulator
B Brake distribution valve
C Brake caliper
D Wheel speed sensor
E Electronic control unit
F Modulator valve
G Reservoir

Each individual Anti-lock Braking Circuit comprises a normal power braking system of an accumulator, A, brake distribution valve, B, and brake caliper, C, which incorporates an additional electrically controlled modulator valve, F.

The modulator valve also has an hydraulic connection to the reservoir, G. It contains a valve system which can control the flow of mineral oil to the brake caliper.

The operation of the modulator valve is controlled by an electronic control unit, E, which is supplied with wheel speed information signals by the wheel speed sensor, D.

Whenever braking occurs, the electronic control unit monitors the wheel speed signals for each wheel and determines the car speed, individual wheel speed, individual wheel deceleration and individual wheel slip.

If the electronic control unit receives signals indicating heavy wheel deceleration likely to cause wheel lock, it sends electrical signals to the modulator valve to control the braking pressure to the appropriate wheel.

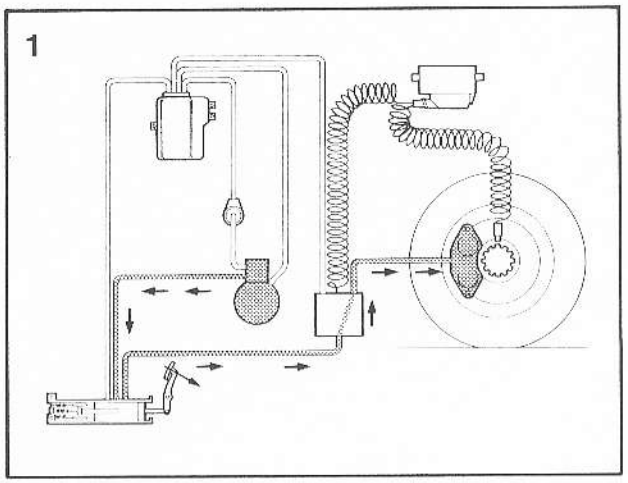
This braking control is achieved using three modes, Normal, Hold and Release operating at a high frequency between 4 to 10 times per second dependant on road conditions.

Operation

1. Normal mode

In the normal mode, the modulator valve is in an open position in which it has no effect on the brake hydraulic pressure between the brake distribution valve and wheel caliper.

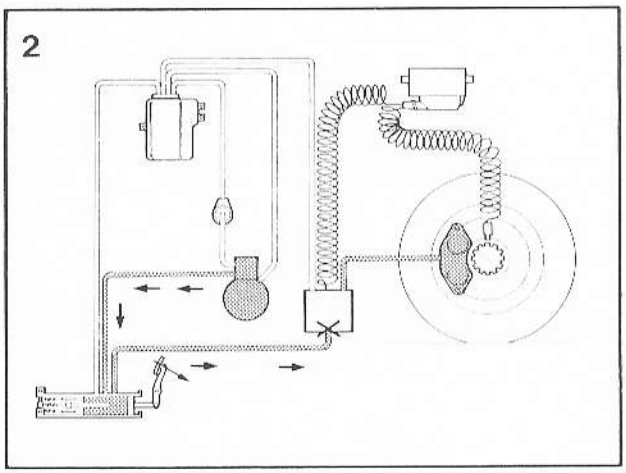
When the modulator valve is in this position, the brakes operate in the normal way.



2. Hold mode

In the hold mode, the electronic control unit causes the modulator valve to close the hydraulic circuit between the brake distribution valve and the wheel caliper.

This action effectively seals the brake circuit between the modulator valve and wheel caliper preventing any further increase in brake caliper pressure.

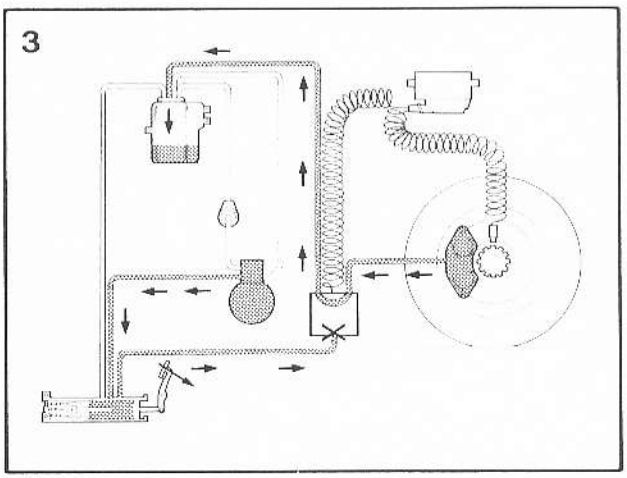


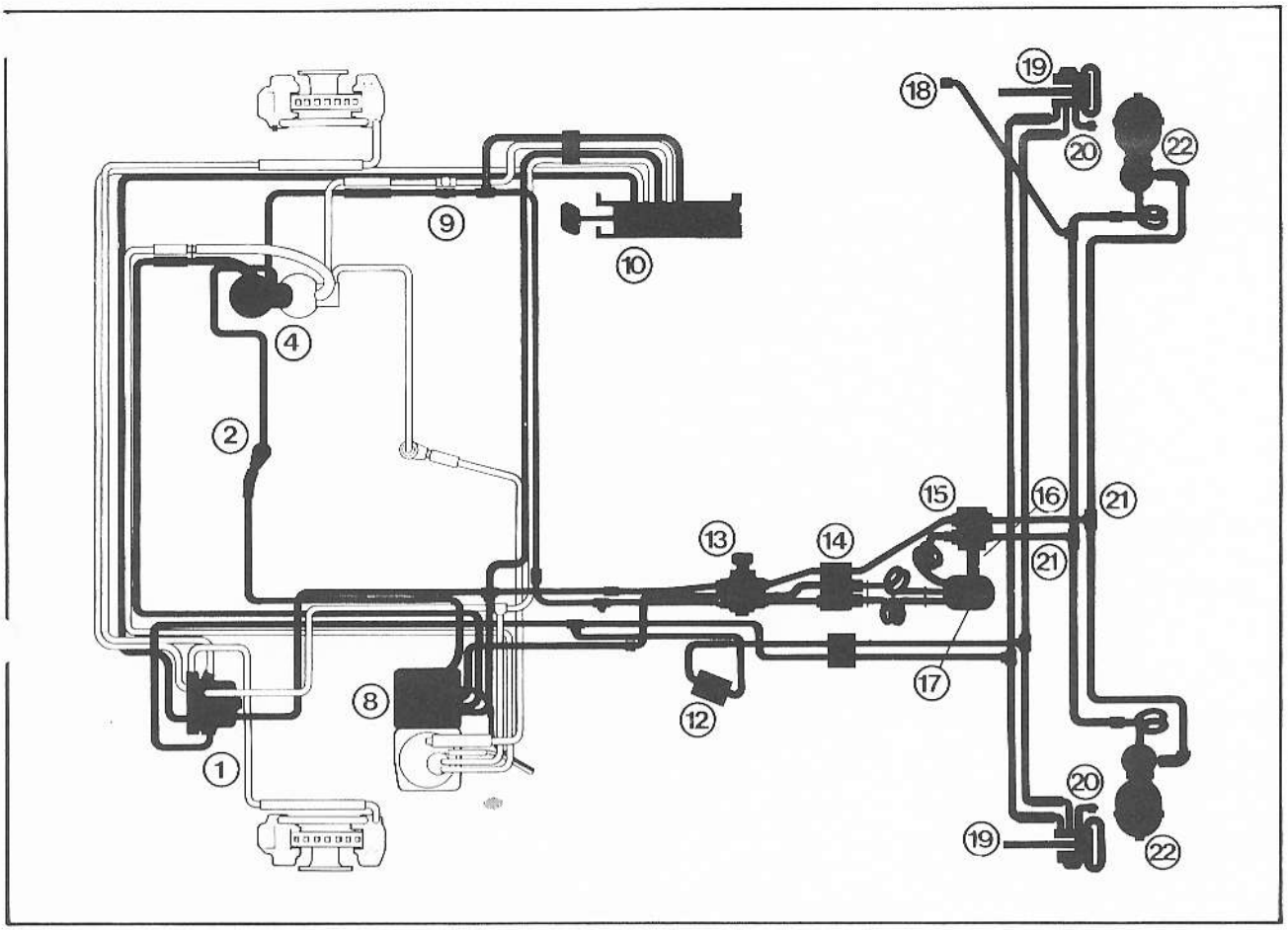
3. Release mode

In the release mode, the electronic control unit causes the modulator valve to open a return circuit between the brake caliper and reservoir.

This allows some of the mineral oil in the wheel caliper to return to the reservoir, effectively reducing the caliper pressure.

At the same time, the modulator keeps the hydraulic supply from the brake distribution valve closed, preventing any increase in the caliper pressure until the normal mode is selected.

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Number 1 Hydraulic System

Components

1 Modulator (anti-locking brakes)
2 Front hydraulic pump
4 Front hydraulic accumulator
8 Hydraulic mineral oil reservoir
9 Hydraulic pressure warning switch
10 Upper distribution valve
12 Deceleration conscious pressure limiting valve ('G' valve)
13 Priority valve
14 Filter block assembly
15 Minimum pressure valve
16 Seepage return hose
17 Levelling valve
18 Bleed point - Suspension struts
19 Rear brake caliper (four cylinder)
20 Rear brake caliper bleed point
21 Restrictor
22 Gas spring and Suspension strut

Description

Number One Hydraulic System comprises two circuits fed by the front pump and front accumulator:

The Rear Braking Circuit

The Height Control Circuit

Rear braking circuit

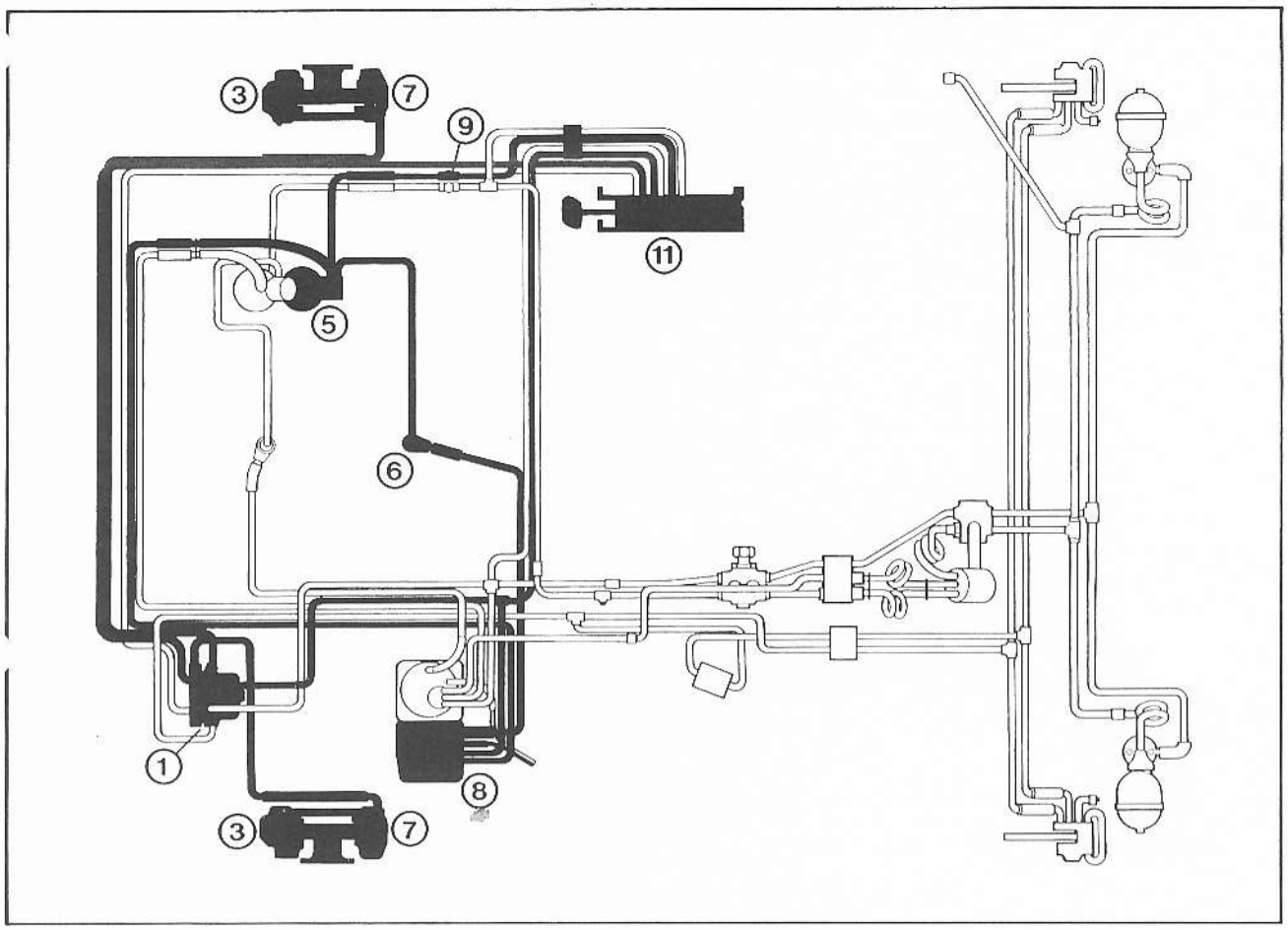
Rear braking is achieved using two parallel circuits supplied by the same brake distribution valve and modulator valve which operate the conventional four cylinder rear wheel calipers.

One of the circuits incorporates the repositioned 'G' valve to maintain optimum performance of the rear brakes.

Height control circuit

The height control circuit features a priority valve, minimum pressure valve and a single height control valve to operate the conventional mineral oil gas spring and suspension strut.

Relocation of the height control valve and a new actuation system (see page 17) ensure that the height control system reacts only to addition or subtraction of vehicle weight.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Number 2 Hydraulic System

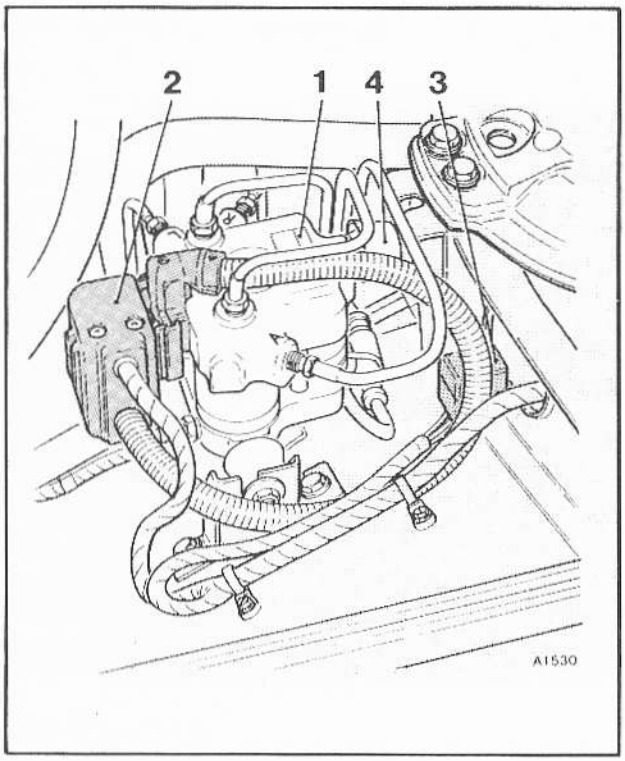
Components

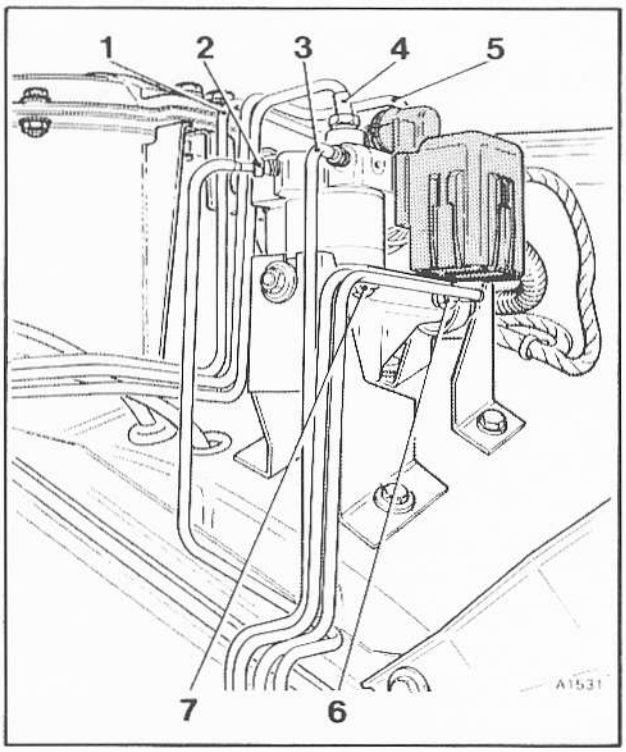
1 Modulator (anti-locking brakes)
3 Front leading brake caliper (twin cylinder)
5 Rear hydraulic accumulator
6 Rear hydraulic pump
7 Front trailing brake caliper (twin cylinder)
8 Hydraulic mineral oil reservoir
9 Hydraulic pressure warning switch
11 Lower distribution valve

Description

Number Two Hydraulic System which is fed by the rear pump and rear accumulator, provides front wheel braking only through conventional twin cylinder leading and trailing brake calipers.

The brake system is divided into two circuits at the modulator valve where individual modulators control the operation of the front left wheel brakes and front right wheel brakes.





Hydraulic Modulator Assembly

Components

1 Modulator assembly
2 Electrical plug
3 Modulator relay
4 Flexible mountings

The hydraulic modulator valve assembly is located in the engine compartment, immediately in front of the left-hand front spring pot.

The assembly contains three electrically operated solenoid valves which provide separate anti-lock brake control for the left hand front brake circuit, the right hand front brake circuit and a common rear brake circuit.

The modulator assembly is located by three flexible mounts, one on the inboard side of the modulator, one on the outboard side and one at the rear of the modulator.

The modulator relay is specially built to much higher tolerances and must not be substituted by a standard relay.

Hydraulic connections

1 To rear brake calipers,
Blue pipe, Port A.

2 To right-hand front calipers,
Mauve pipe, Port R.

3 To left-hand front calipers,
Mauve pipe, Port L.

4 To outboard reservoir (System 2),
White pipe, Port T.

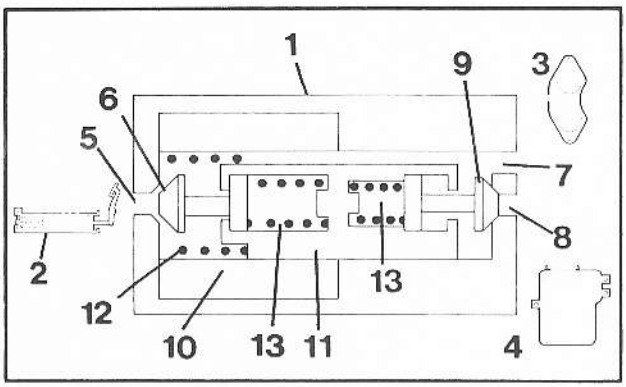
5 To inboard reservoir (System 1),
Black pipe, Port TT.

6 From upper brake distribution valve,
Blue pipe.

7 From lower brake distribution valve.
Mauve pipe.

Components

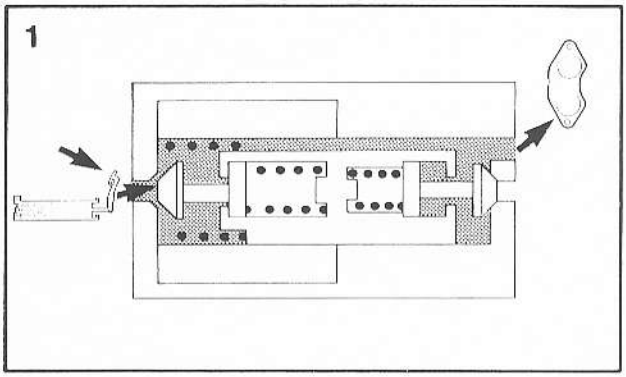
1 Modulator valve
2 Brake distribution valve
3 Brake caliper
4 Reservoir
5 Inlet port from brake distribution valve
6 Inlet valve (normally open)
7 Outlet port to brake caliper
8 Outlet port to reservoir
9 Outlet valve (normally closed)
10 Electrical solenoid
11 Solenoid plunger
12 Return spring
13 Valve springs



Operation

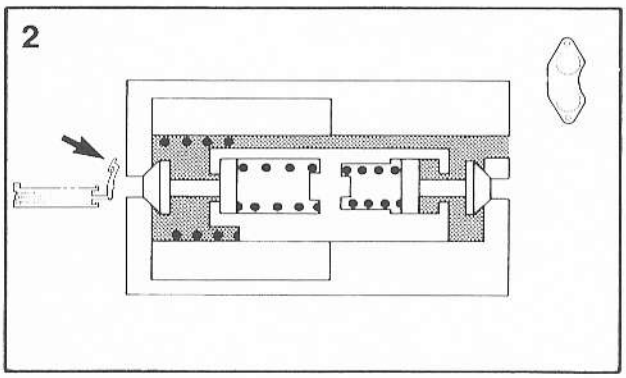
1 Normal mode

In the normal position, no current flows through the solenoid. The return spring pushes the plunger to the right. The outlet valve is held closed and the inlet valve is held open. Mineral oil from the brake distribution valve can flow to and from the brake caliper without any effect.



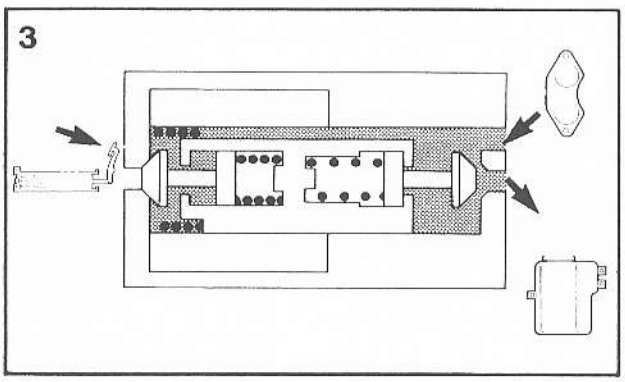
2 Hold mode

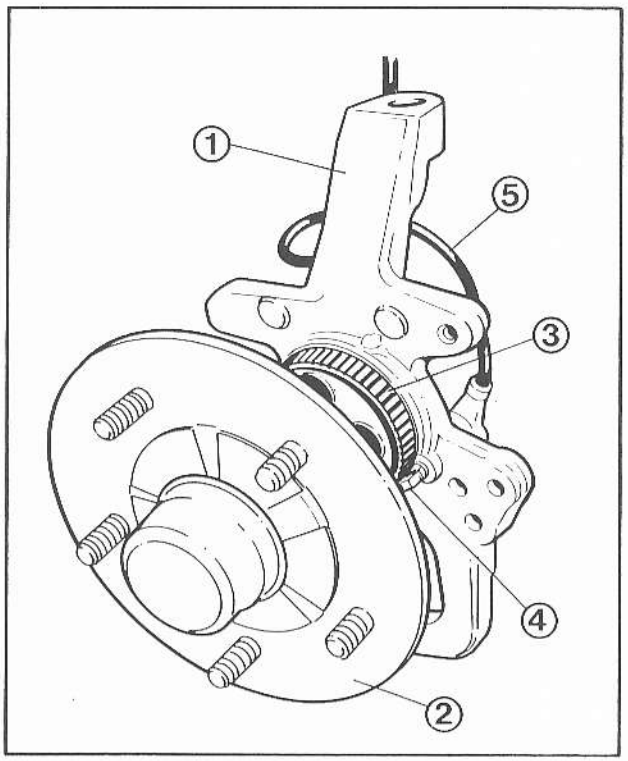
In the hold position, electrical current passing through the solenoid causes the plunger to move to the left. This action closes the inlet valve. The outlet valve remains closed. Brake pressure between the modulator and caliper is held constant.



3 Release mode

In the release position, increased electrical current passing through the solenoid causes the plunger to move further to the left. This action opens the outlet valve. The inlet valve remains closed. Brake pressure between the modulator and caliper is reduced by mineral oil returning to the reservoir.





Wheel Sensors and Phonic Wheels

Front hub components

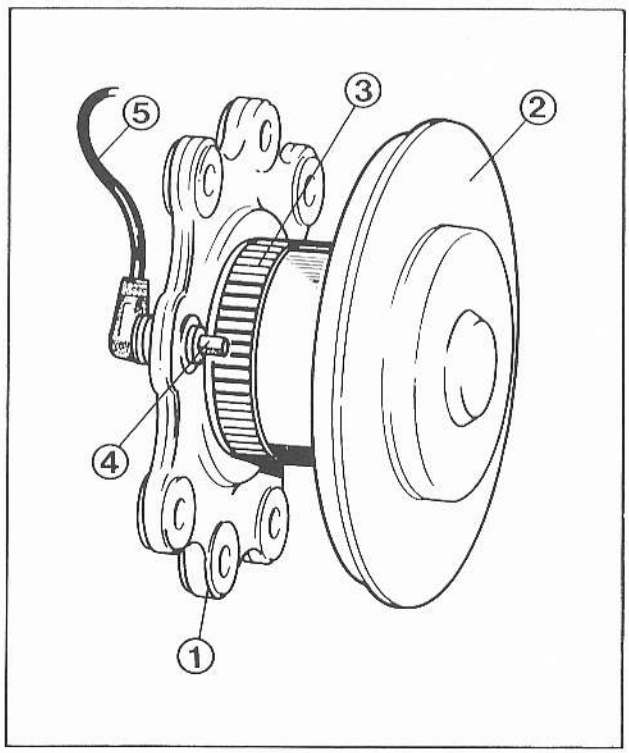
1 Front hub carrier
2 Front hub
3 Front hub phonic wheel
4 Front wheel sensor
5 Sensor signal cable

The ABS phonic wheel is a separate component which is pressed onto the front hub.

The ABS system senses individual wheel speed using an inductive sensor and a rotating toothed phonic wheel.

The phonic wheel forms part of the wheel hub. The sensor is securely located in the hub carrier in a position where the teeth on the phonic wheel pass the sensor face.

The distance between the sensor face and the teeth of the phonic wheel is 0.25 - 1.52 mm (0.010 - 0.060 in.). This gap is not adjustable.



The output signal cable from the sensor is integral with the sensor at the sensor end and is electrically shielded. A plug is attached to the other end of the cable to facilitate sensor replacement.

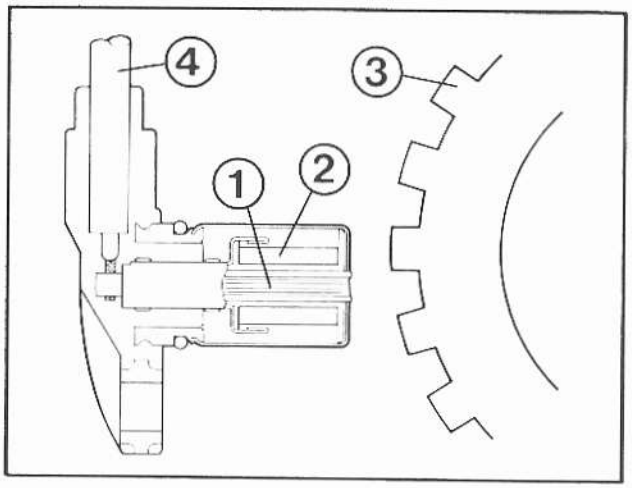
Rear hub components

1 Rear hub carrier
2 Rear hub
3 Rear hub phonic wheel
4 Rear wheel sensor
5 Sensor signal cable

The ABS phonic wheel is machined into the rear hub.

Components

1 Permanent magnet
2 Inductive coil
3 Phonic (toothed) wheel
4 Shielded signal cable to the electronic control unit.



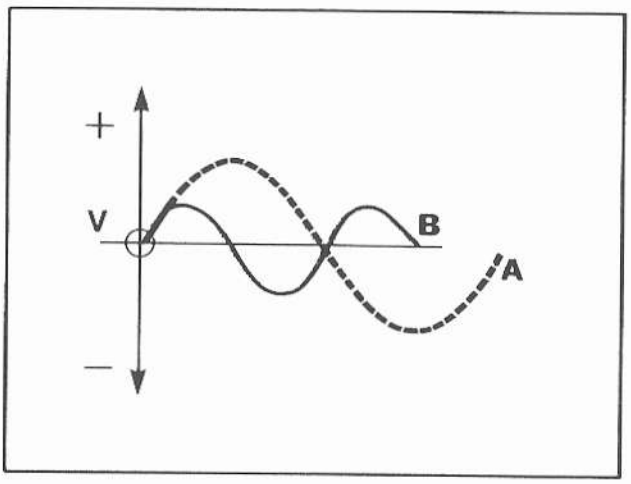
Operation

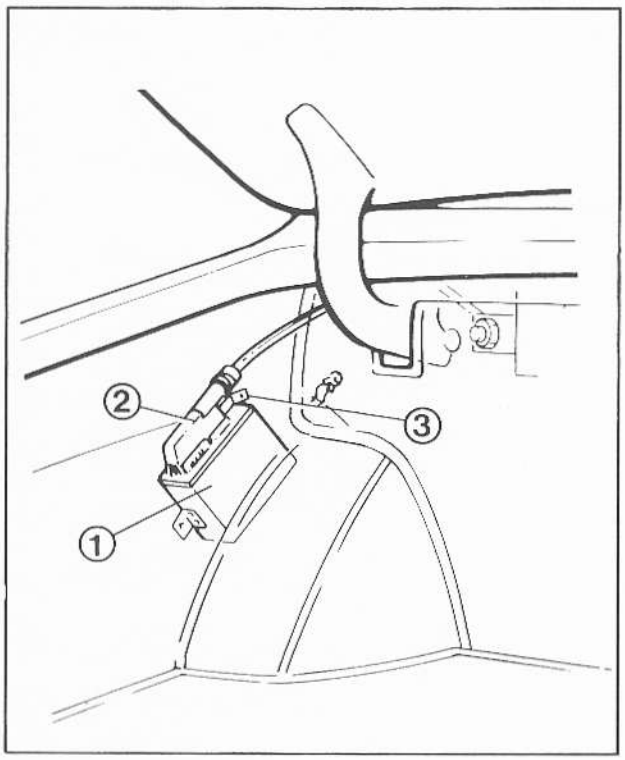
As each tooth on the the phonic wheel passes the face of the sensor, it changes the magnetic field surrounding the permanent magnet. The change in magnetic field induces electrical current in the inductive coil which is connected to the electronic control unit.

Output signal

The output signal from the sensor is sinusoidal. The frequency of the signal changes with and is proportional to wheel speed.

Wheel speed **'B'** is twice wheel speed **'A'**.





Electronic Control Unit

Components

1 Electronic control unit
2 Wiring harness 35 pin plug
3 35 pin plug locating latch

The electronic control unit is located in the luggage compartment. It is mounted on the left-hand side rear wheel arch behind the trim panel. Connections are made through a 35 pin plug connector which is latched to the control unit for security.

Operation

Whenever braking occurs, the electronic control unit continually monitors the wheel speed signals from all four wheel sensors. From these signals, it computes the road speed, individual wheel speed, and the acceleration, deceleration and wheel slip of each individual wheel.

From the signals it receives, the electronic control unit can determine whether or not the deceleration of a wheel or wheels is likely to result in wheel lock.

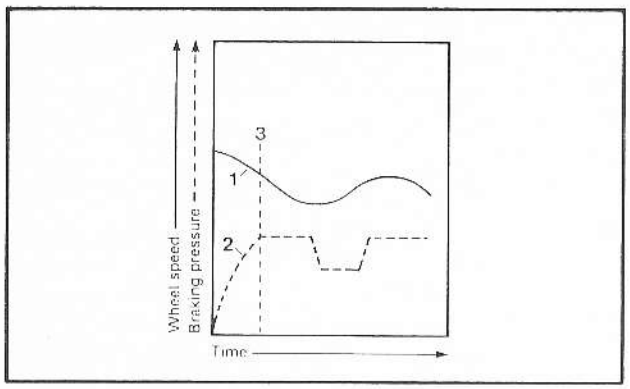
In the event of heavy deceleration occurring likely to cause wheel lock, the electronic control unit sends signals to the appropriate modulating valve to adjust the braking pressure to the wheel, by holding, reducing or increasing the brake pressure as appropriate to the wheel deceleration status. The effect of each control action is monitored by the electronic control unit from the change in the signals emitted by the wheel sensors.

The electronic control unit is programmed with a self-test sequence which checks the integrity of the ABS electrical system each time the engine is started. If it detects a fault during this test, it will automatically switch itself off and cause the 'ANTILOCK' warning light to illuminate.

When this occurs the modulators remain fail-safe in the normal position allowing the braking system to function normally.

Operating phases

The action of the electronic control unit (ECU) can be considered as three phases, normal, hold and release, corresponding to the three modulator valve positions.

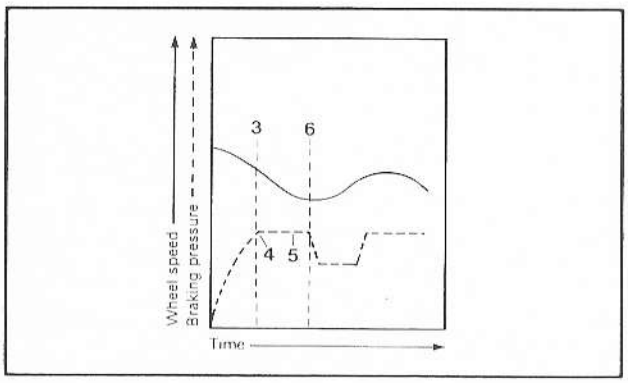


Normal phase

1 The wheel is decelerating.
2 Brake pressure is increasing.
3 The ECU determines that wheel lock is likely to occur.

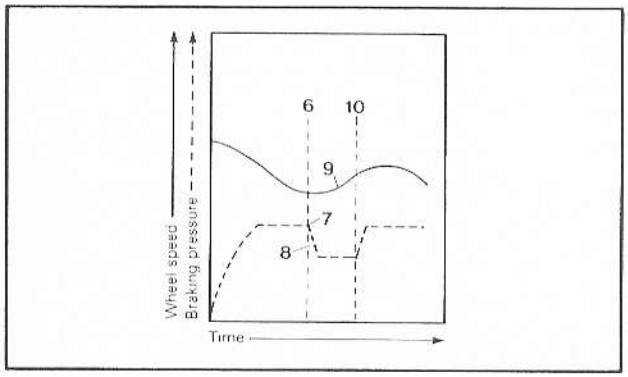
Hold phase

3 The ECU determines that wheel lock is likely to occur.
4 The ECU switches the modulator valve to 'Hold' position.
5 Brake pressure is held constant.
6 The ECU determines that the wheel deceleration is still likely to cause wheel lock.



Release phase

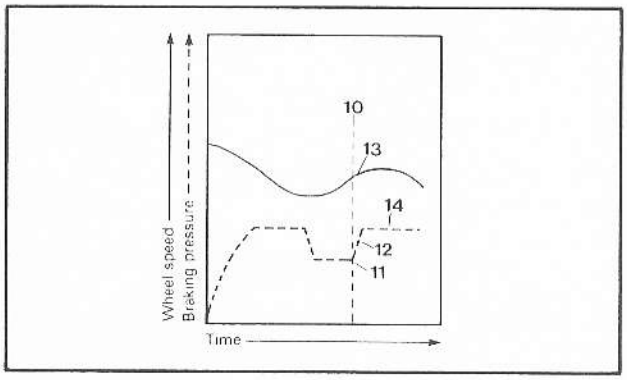
6 The ECU determines that the wheel deceleration is still likely to cause wheel lock.
7 The ECU switches the modulator valve to 'Release' position.
8 Brake pressure is reduced.
9 The wheel accelerates again.
10 The ECU determines that the wheel is not being braked efficiently.

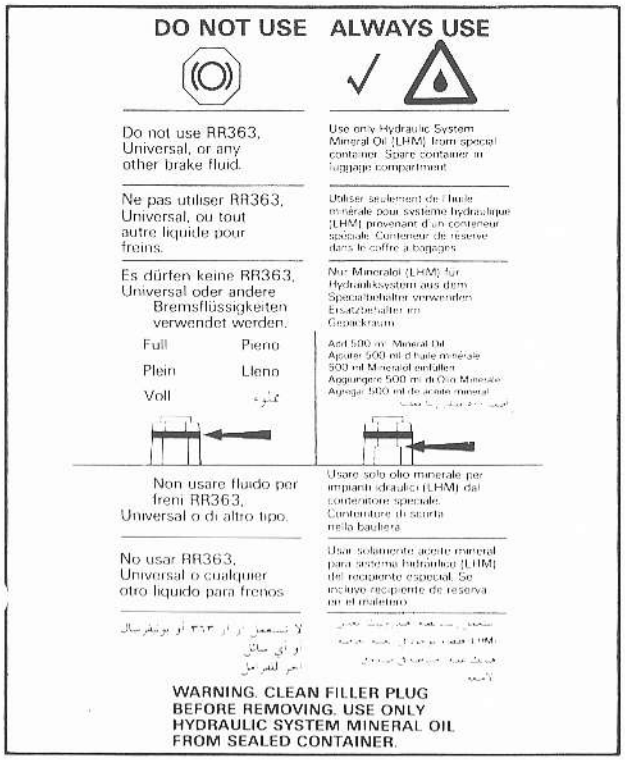


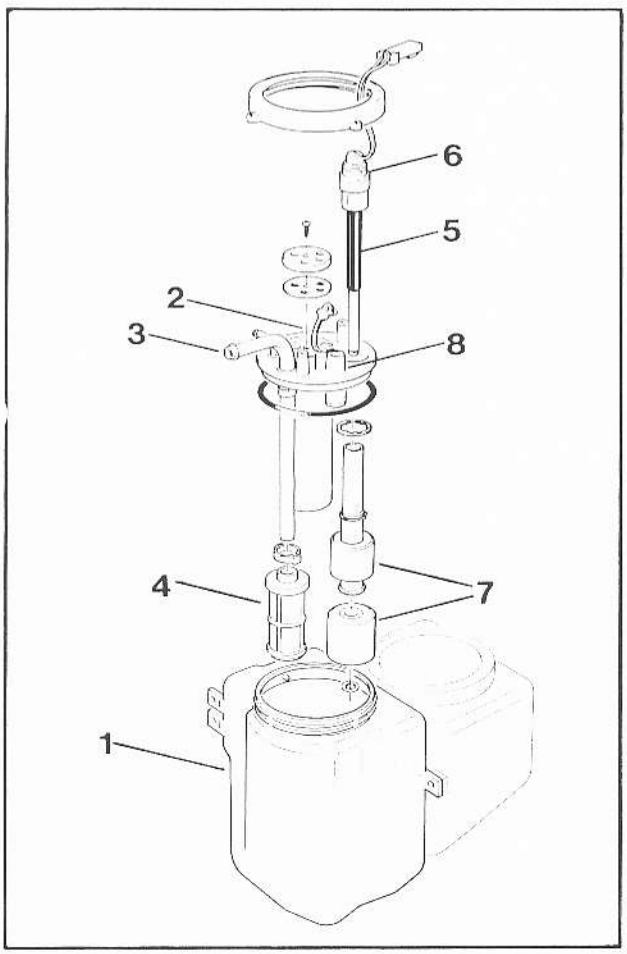
Normal phase

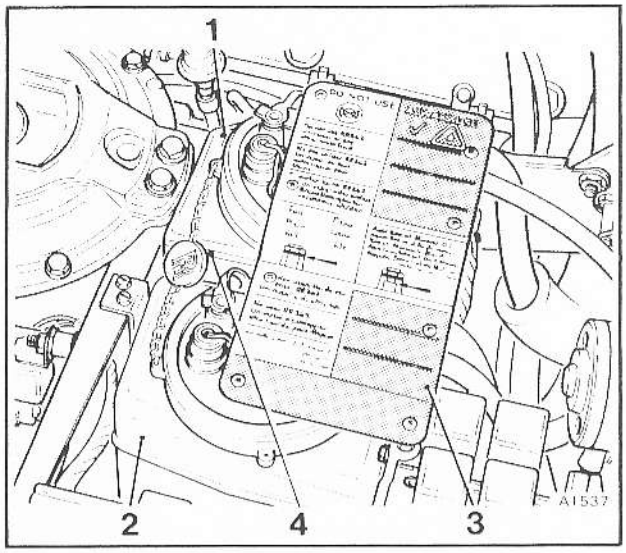
10 The ECU determines that the wheel is not being braked efficiently.
11 The ECU switches the modulator valve to 'Normal' position.
12 Brake pressure increases again.
13 The wheel decelerates again
14 The 'Hold' cycle repeats.

The control sequence can be repeated 4 to 10 times per second to provide maximum braking effect for the prevailing conditions.









Hydraulic Mineral Oil Reservoirs

Components

1 Number one system reservoir
2 Number two system reservoir
3 Multi-lingual warning panel
4 Wire and seal

Number one reservoir supplies mineral oil for the rear brakes and height control.

Number two reservoir supplies mineral oil for the front brakes only.

Reservoir components

1 Reservoir
2 Reservoir top
3 Outlet to hydraulic pump
4 Filter
5 Combined reservoir level indicator and level switch
6 Level sight glass
7 Level indicator float mechanism
8 Filling point

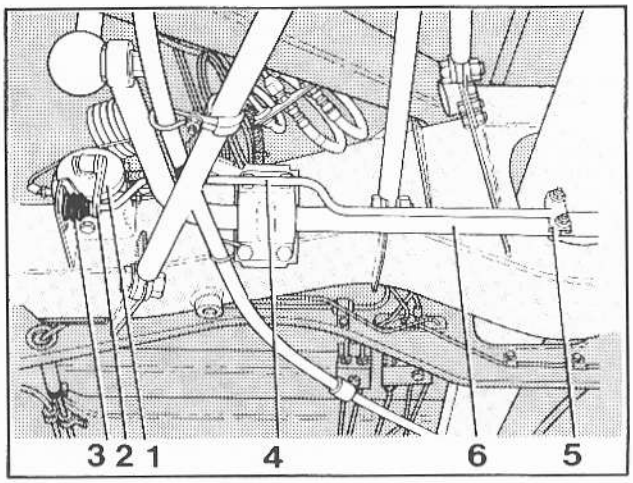
Features

The new hydraulic reservoirs are manufactured from an opaque material. All connections are made through the top of the reservoir to minimise leakage. Level indication is achieved by a double float system which operates a visual level indicator. The level indication system incorporates a reed switch which controls the operation of the low mineral oil warning light. One of the floats in the system allows for natural changes in the reservoir levels caused by the charging and discharging of the height control struts, thereby avoiding inaccurate level indications caused by vehicle load conditions.

Height Control Valve

Components

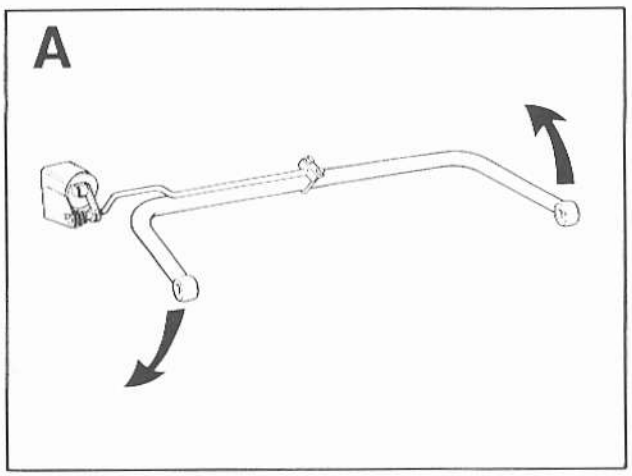
1 Height control valve
2 Operating lever
3 Pivot
4 Torsion bar
5 Clamping point
6 Rear anti-roll bar



Operation

The height control system is operated by a single height control valve mounted on the left-hand side of the rear cross member. Actuation is achieved by a torsion bar which is clamped to the centre of the rear anti-roll bar.

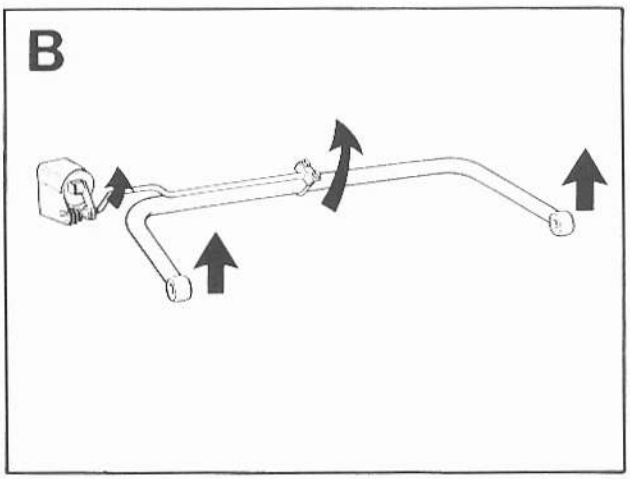
The new configuration of the height control valve and its operating mechanism negates the effect of body roll on the height control system, ensuring that the system is affected by changes in vehicle weight only.



A - Cornering

When the car corners, body roll causes an upward deflection of one end of the anti-roll bar and a corresponding equal downward deflection of the other end.

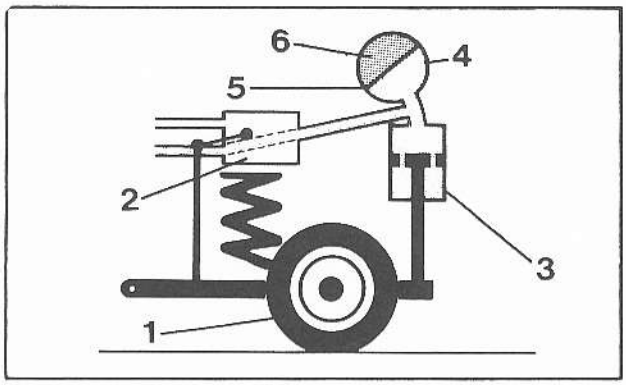
At the centre of the anti-roll bar, no movement takes place as the deflection of the ends of the anti-roll bar is taken up by twist in the centre portion of the bar. As a result, this twisting action of the anti-roll bar caused by body roll during cornering has no effect on the height control system.



B - Height control

When weight is added to or removed from the car, both ends of the anti-roll bar deflect in the same direction, upwards when weight is added, downwards when weight is removed.

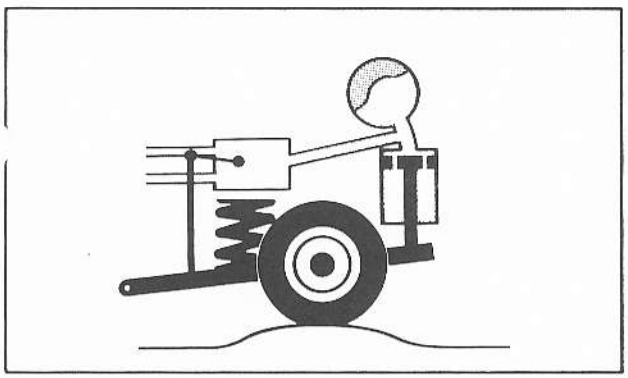
In this case, the centre of the anti-roll bar rotates causing movement in the torsion bar connected to the height control valve. This action is transmitted to a lever which compresses or expands the height control valve accordingly.



Height Control System - Principles of Operation

Components

1 Rear wheel
2 Height control valve
3 Rear suspension strut
4 Gas spring
5 Diaphragm
6 Compressed gas

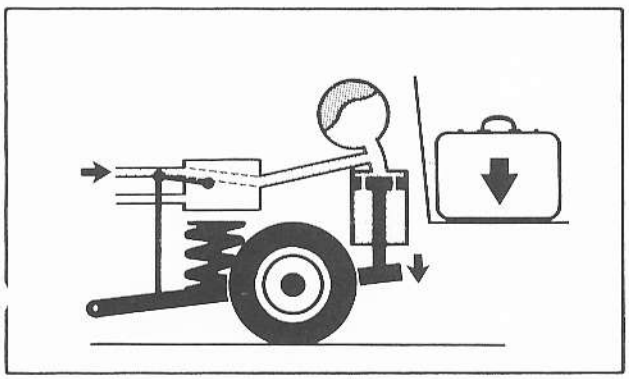


Operation

Normal suspension movement

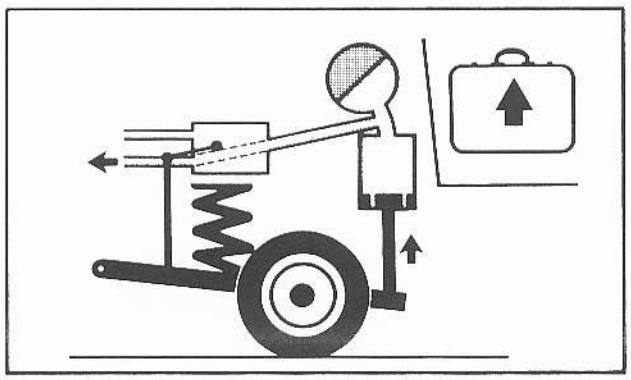
When the wheel hits a bump in the road, the piston is forced upwards into the strut. Mineral oil in the strut is forced into the gas spring, compressing the gas behind the diaphragm.

Conversely, when the wheel hits a pot - hole, the piston is forced downwards by the expansion of the gas.



Height control

As weight is added to the car, it causes compression of the suspension. This reaction is transmitted to the height control valve which restores the car to its correct height by increasing the volume of mineral oil in the strut. The increased volume forces the piston rod out of the strut.



Conversely, as weight is removed from the car, the resultant expansion of the suspension causes the height control valve to allow mineral oil to return from the strut to the reservoir. The piston moves upwards reducing the car height until the valve closes.