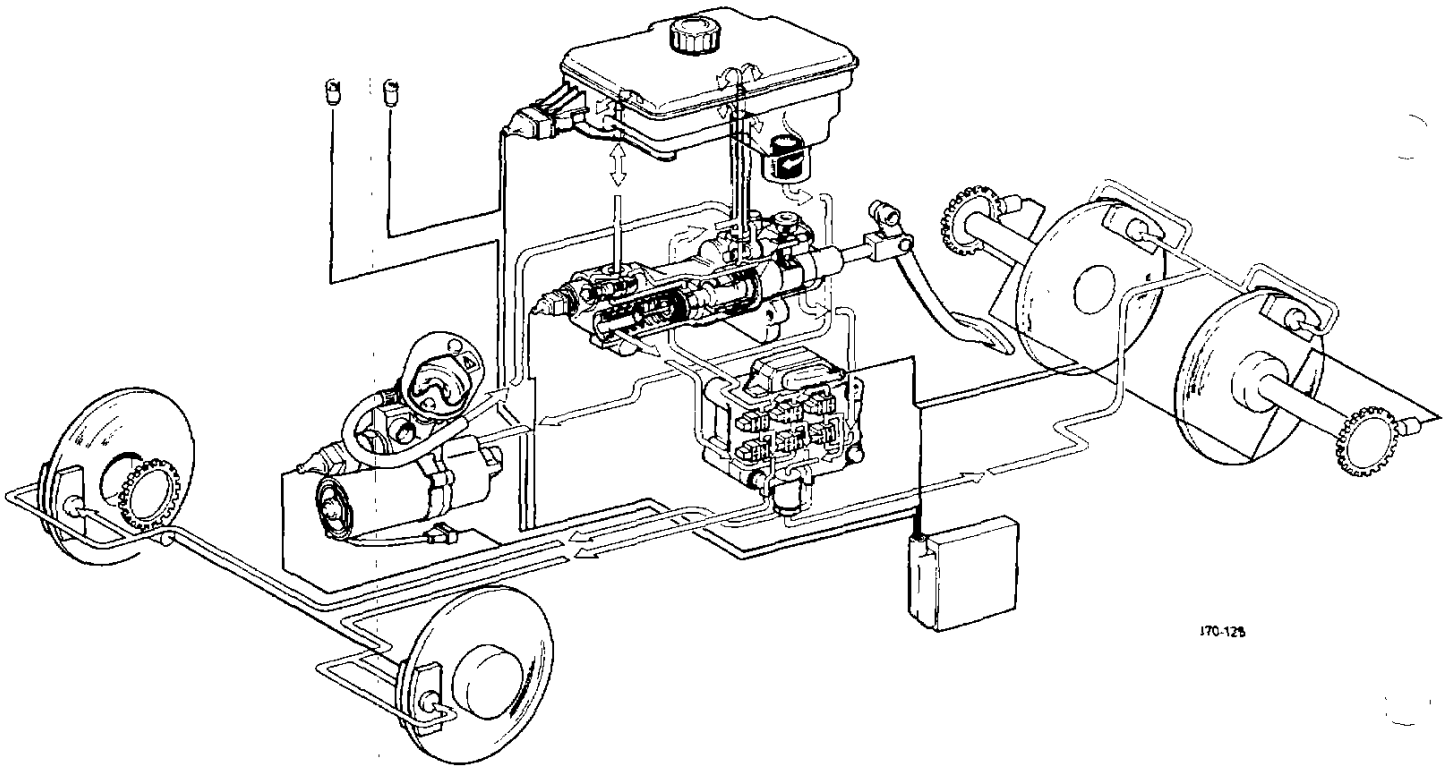
## ANTI LOCK BRAKING SYSTEM



## ANTI-LOCK BRAKING SYSTEM

### DESCRIPTION 70.00.00

The hydraulic components necessary for the anti-lock control are integrated with a servo-hydraulic booster (Fig. 1) and its operating components; brake fluid is used as the single working fluid. An energy source consisting **of** an electric motor, a pump, a pressure switch and an accumulator (Fig. 2) provides high pressure fluid to operate the booster during normal braking as well as providing a means *of* increasing brake line pressure when required during anti-lock braking **(ABS). Also** contained in this assembly are the master cylinder the solenoid valves and the reservoir.

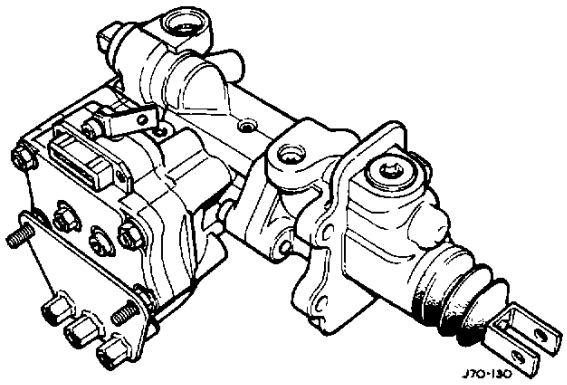



Fig. **1**

In the installation the frnnt hydraulic circuit is operated conventionally by the master cylinder, assisted by the booster. The rearcircuit is operated directly by the controlled, pressurized fluid in the booster. The front circuit is "static" and the rear circuit "dynamic".
Howeverwhentheanti-lockcontrol is required-the front also becomes "dynamic". Then inlet and outlet solenoid valves operate in each of the three circuits to control the pressure as required to prevent wheel-lock.

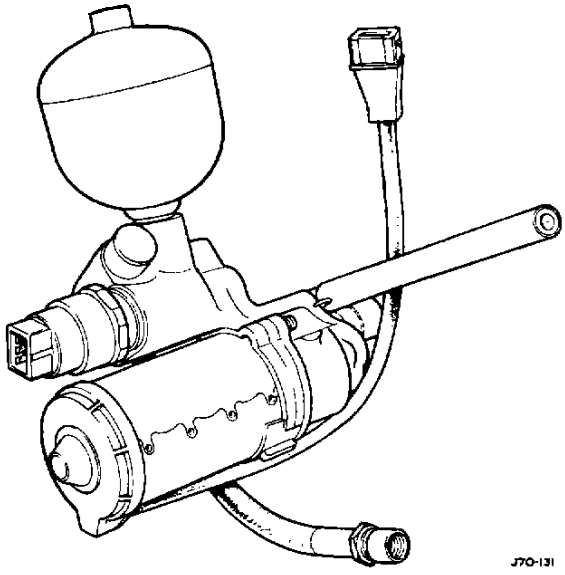



Fig. 2

Sensors are installed at each wheel. Their wheel speed related signals are processed by an electronic control module (ECM) which operates the solenoid valves in the hydraulic system. The front wheels are controlled individually and the rear wheels, which are ona single hydrauliccircuit, are controlled together on the select low principle. Therefore a tendency for one wheel to lock results in control **of** both wheels according to the need of the "locking" wheel.

The state of the anti-lock system is continuously monitored by the ECM, which automatically switches off the system if a failure is identified, illuminating a warning lamp and leaving full, boosted braking to all wheels. Warning lamps **also** indicate low accumulator pressure or low fluid level in the reservoir (Fig. 3).
Ifthefront hydrauliccircuitfails, pedal TRAVEL will increase. If the rear circuit fails, pedal EFFORT will increase.

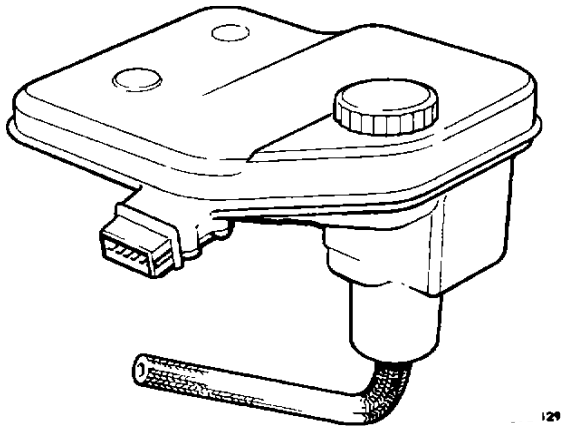



Fig. 3

Hydraulic brake booster

One important aspect of the ABS is the hydraulic booster (Fig. 1) which boosts the pedal force by means of hydraulic pressure. The dynamic circuit of the rear brakes is supplied from the hydraulic accumulator via a control valve in the booster.
The pressure in the booster and the rear brake circuit is proportional to the pedal force i.e:

Low pedal force – low pressure
High pedal force – high pressure

The booster compriges an actuating piston (1 Fig. 2) and a booster piston (2 Fig. 2). The movable, mechanical connection between the control valve (3 Fig. 2) and the two pistons is made by means of a scissqr-lever mechanism (4 Fig. 2). The control valve (3 Fig. 2) opens the unpressurized booster chamber to the reservoir (9 Fig. 2); simultaneously the channel from the hydraulic accumulatbr is closed. The accumulator is constantly maintained in an operating pressure range between 140 to 180 bar.
As force is applied to the brake pedal, the actuating piston (1 Fig. 2) with the scissor (4 Fig. 2) moves forward. The two lower articulated balls (5 & 6 Fig. 2) move towards one another while the upper balls (7 & 8 Fig. 2) move apart. Due to this movement, the control valve (3 Fig. 2) opens the intake channel from the accumulator just after it closes the return flow. In the brake booster, a pressure is built up which is transmitted to the rear brakes and which acting simultaneously on the booster piston (2 Fig. 2) boosting the actuating force on the master cylinder piston. At the same time the pressure acts between the booster piston (2 Fig. 2) and the actuating piston (1 Fig. 2) separating the two parts. The lower articulated balls (5 & 6 Fig. 2) move apart whilst the upper balls move towards one another, this movement closes the intake by means of the control valve: the return flow remains closed.,
The control valve (3 Fig.2) is closed when the pressure acting on the actuating plate (1 Fig. 2) causes a force which is equal to the preset pedal force, i.e. when there is a balance of forces. The pressure acting on the annular circle of the booster piston (2 Fig. 2) increases the pedal force. The pedal force is increased in the ratio 1:4, the booster ratio depends on the ratio of actuating piston area (1 Fig. 2) to booster piston area (2 Fig. 2).
The pressure in the booster is proportional to the pedal force.
In maximum braking, position, the control valve is open completely, the entire accumulator pressure of 180 bar acts on the booster piston. The maximum possible brake boosting is utilized. The brake pressure to the front wheel brakes can only be increased when the pedal force is increased. The brake pressure in rear wheel brakes cannot exceed 180 bar even in the case of the pedal force increase.

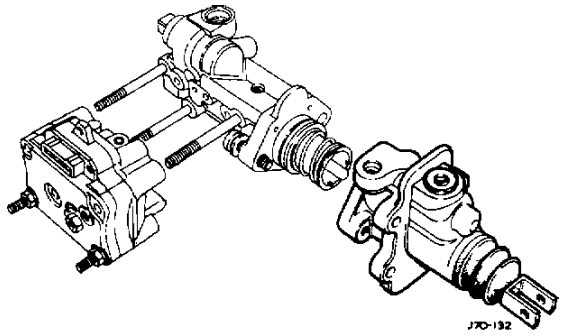



Fig. 1

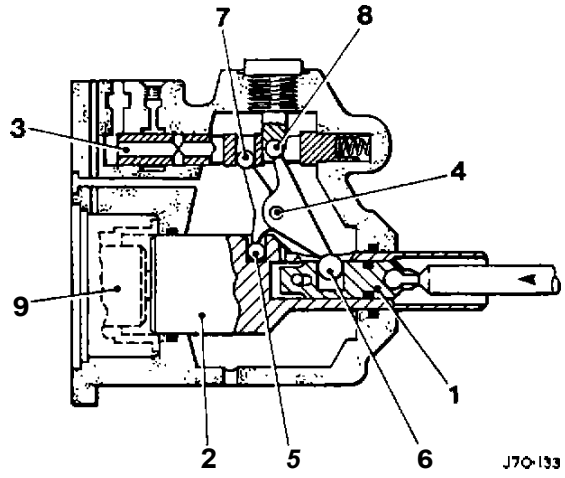



Fig. 2

Electronic control **module (ECM)**

The ECM processes the signals from the four wheel sensors, converts their frequency information into values which correspond to wheel speed and then, with the data received, controls the solenoid valves during braking under ABS control.

The ECM (Fig. 1) checks the input and output signals in order to indicate any ABS disturbances. A self-monitoring function **is** integrated in the ECM which, in the case of a system failure, illuminates the ABS warning lamp.

During ABS control the respective solenoid valves in the wheel circuit concerned are controlled. The main valve is controlled when a front wheel is under ABS control. In order to enable the wheel to transmit the optimum brake force under all road conditions, the control of the valves must be operated very rapidly. up to ***6*** times a second.

When the ignition is switched on, battery voltage is supplied to pin 2 of the ECM which is fed internally to pin 8. From pin 8, the main relay coil is activated closing the relay contacts thereby allowing Battery Voltage to be applied to pins 3 and 20. which switches on the ECM thus starting the test routines. The module is protected by a 30A fuse.

During the test routines, the ABS warning lamp is illuminated by being switched to earth via pin 1. The time the lamp is illuminated depends on the charging of the hydraulic accumulator. If the system test routines prove satisfactory the electronic control module opens the earth circuit between pins 1 and 27, the warning light is then extinguished. The warning lamp is supplied with battery voltage from the ignition switch when the ignition is switched on.

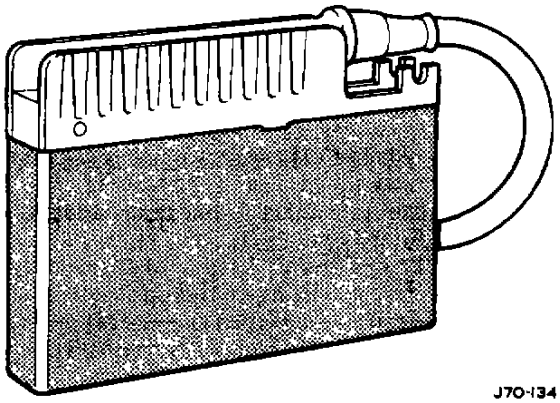



Fig. 1

**ABS** and brake warning lamp

The ABS warning lamp warns the driver in the case of a malfunction in the ABS system i.e. loss of pressure and indicates that the ECM has switched off the ABS system. The consequence is the **loss** of the anti-lock function, the conventional brake with brake boosting is, however maintained.

In the case of a failure due to faulty plug connections, broken cables or defective components, such as sensors or/and solenoid valves, the voltage supply to the main relay is switched off by the ECM via terminal 8. The relay de-energises disconnecting the supply to pins 3 and 20.

Voltage (Refer to Fig. 1) is available to the ABS warning lamp from the ignition switch. The earth circuit for the warning lamp is via the diode and contacts 30/87a of the main relay.
If the ECM is not connected the warning lamp will illuminate because it is connected to earth via the main relay.
Should the ABS and the brake warning lamp illuminate simultaneously brake pedal feels normal but the fluid is low.
The brake warning is illuminated because an earth connection for the warning lamp is made via the switch contacts located in the reservoir.
The ABS warning lamp is illuminated because fluid level switch is open and the circuit between terminals 9/10 of the ECM is broken. During the system self test, the ECM will recognize this failure and switch terminal 27 from the warning lamp to earth, at the same time, the system will be partially inhibited.
Should the pedal feel hard (after some brake applications) i.e. in the case of accumulator pressure below 85 bar there is no boost braking.
The brake warning lamp illuminates because the pressure is below 105 bar. The warning lamp switch contacts in the combined pressure switch close so a circuit is made to earth via terminals 1 and 2.
The ABS warning lamp illuminates simultaneously because the warding switch contacts open breaking the circuit between terminals 9 and 10 of the ECM. During the system self test, the ECM recognizes this failure and switches terminal 27 from the warning lamp to earth, at the same time, the system will be partially inhibited.

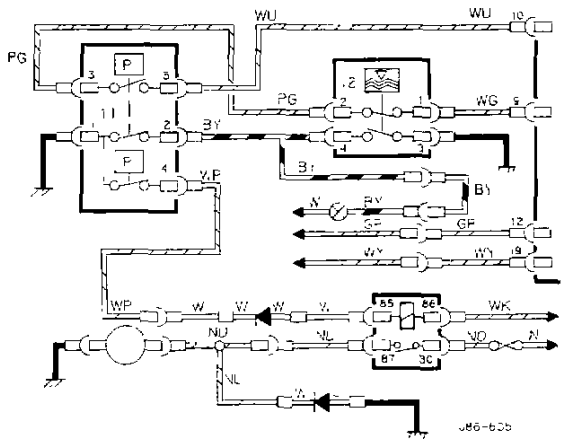



Fig. 1

Pump motor operation (Fig. 1)

With the pressure in the hydraulic accumulator below 140 bar the motor will switch on.
When the ignition is switched on battery power is supplied to the relay coil, if the pressure in the hydraulic accumulator is below 140 bar, the coil will be earthed.
Battery power is then supplied to the pump motor via the closed contacts of the relay and a 30 amp fuse.
The motor operate9 until a pressure of 180 bar is achieved. Having reached a pressure of 180 bar the pressure switch contacts open de-activating the relay thus switching off the pump motor. When the pressure drops to 140 bar the pressure switch closes, switching on the pump motor so that the system pressure is maintained at between 140 to 180 bar.

Motor **pump** unit **(Fig. 1)**

With the motor pump unit, an independent energy supply is obtained by means of a motor and a pump which generates hydraulic energy, and accumulates the pressure energy in a hydraulic accumulator. From the hydraulic accumulator the pressure supply for the dynamic circuit of the rear wheel brakes, the hydraulic brake booster and the static circuit of the front wheel brakes is provided during a braking with **ABS** control.
The motor (1 Fig. **2)** drives via a coupling (2 Fig. 2) a rotor (3 Fig.2) which includes two pistons (4 Fig. 2) and two balls (5 Fig. 2) which move in an eccentric ring (6 Fig. 2). Brake fluid is drawn via the suction channel (7 Fig. 2), a filter (8 Fig. 2), through the control shaft (9 Fig. 2) on the upper side of the lower piston. The rotation causes a reduction of space due to the eccentric ring and ball. The piston is moved towards the control shaft and a pressure is generated. The pressure opens a check valve (10 Fig. 2), is transmitted to the accumulator and to the annular chamber of the control piston in the booster. Simultaneously the pressure acts on the tappet (11 Fig. 2) of the combined pressure warning switch (**12** Fig. 2) and moves it till the system pressure of 180 bar is achieved, the pressure switch in the combined pressure switch switches the motor off.
The hydraulic system is protected against damage by the pressure control valve which releases pressure at **210** bar.

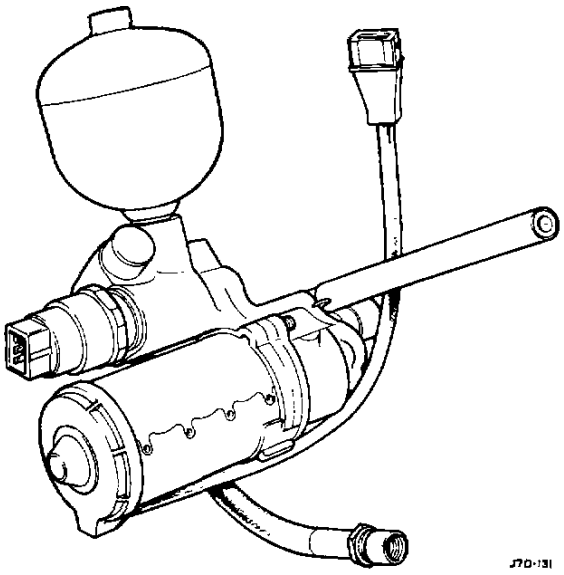



Fig. 1

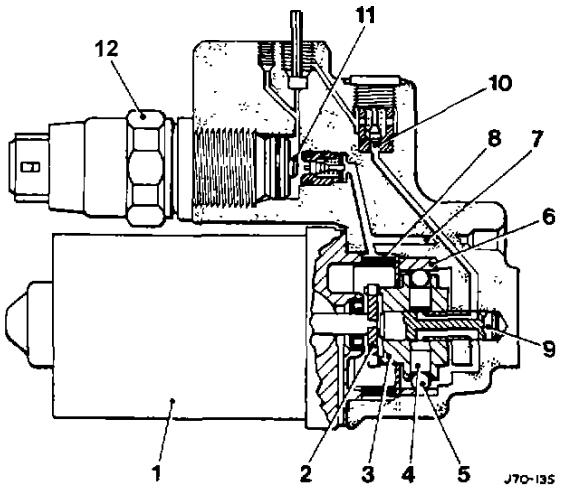



Fig. 2

Hydraulic accumulator

The hydraulic accumulator (Fig. 3) accumulates the hydraulic pressure and makes it available to the hydraulic system for the booster and rear wheel brakes.
Owing to the fact that fluids are almost incompressible they cannot be used for an accumulation of energy. The additional use of compressible nitrogen gas in the hydraulic accumulator allows an energy accumulation. The gas and fluid must be separated by means of a membrane (1 Fig. 3).
The hydraulic accumulator has a reservoir which is divided into two chambers by a membrane (1 Fig. 3). The upper chamber (2 Fig. 3) is filled with nitrogen gas to an initial pressure of **84** bar. The lower chamber (3 Fig. 3) is filled with brake fluid supplied by the pump.
With an increasing amount of brake fluid the pressure in the system also increases, the nitrogen gas is compressed and the gas pressure is increased i.e. the nitrogen volume becomes smaller. Equally the accumulator volume for the brake fluid increases up to the cut-off pressure of **180** bar. The pressure in the accumulator is maintained by means of a check valve which is integrated in the motor pump unit and is available up to the annular chamber of the control piston in the booster.

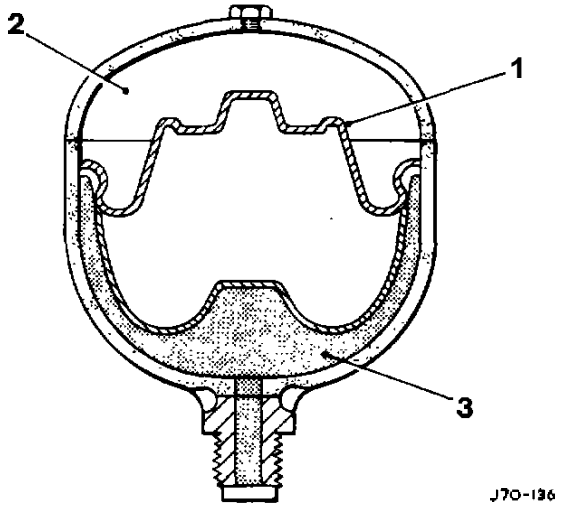



Fig. 3

Combined pressure ,warning switch (Fig. 1)

The pump generates a pressure in the system which acts on the tappet (1 Fig. 2). The tappet moves against a spring (2 Fig. 2). At a pressure of 130 bar the warningiswitch (3 Fig. 2) is actuated. First, the brake warning light will be extinguished followed a short time after by the **ABS** warning light. The tappet (1 Fig. 2) is moved further by pressure and opens the pressure switch (4 Fig. 2) at a pressure of 180 bar to open the pump relay coil circuit *so* stopping the pump motor.
If, after a number of brake applications or normal leak down, the system pressurefalls below 140 bar, the pressure switch (5 Fig. 2) closes and the pump will operate until the cut-off pressure of 180 bar is reached. In this way, the system pressure is maintained within the range of 140 to 180 bar. If due to a hydraulic failure or a electrical failure, a pressure drop below 105 bar occurs, the brake warning switch (4 Fig. 2) contacts close. The brake warning lamp lights, simultaneously the ABS warning switch (3 Fig. 2) contacts open and the circuit between terminals 9 and 10 of the ECM is broken. The ECM is partially inhibited, ABS control for the front wheel brakes is switched off and the ABS warning light is illuminated.

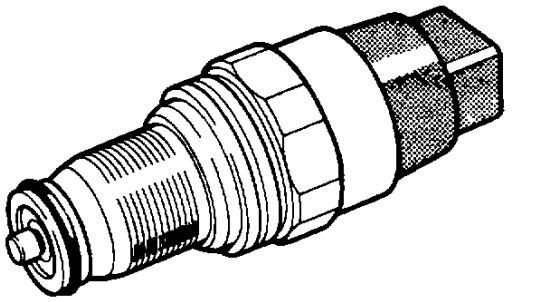


Fig. 1 J70-137

**Wheel** sensors

At each road wheel a speed sensor and a toothed rotor is fitted. By means of a magnetic core (1 Fig. 3) in a coil (2 Fig. 3) a sinusoidal alternating voltage signal is generated by a toothed rotor (3 Fig. 3) breaking the magnetic field and inducing voltage in the coil. The frequency of which is dependent on the wheel speed. The voltage is transmitted to the ECM via screened cables. The gap between the sensor and the toothed wheel is very important i.e. a large gap will generate a low voltage, and a small gap a high voltage.

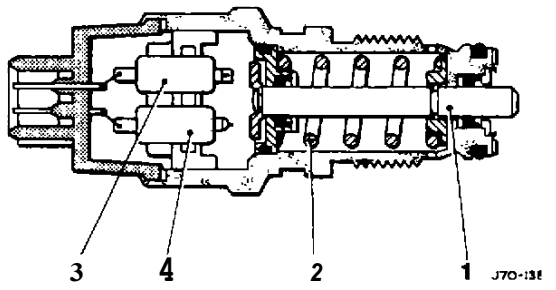



Fig. 2

Valve block

The valve block contains three pairs of solenoid valves, one pair for each of the front brakes and one pair for the rear brakes. Each paircontain an outlet and an inlet valve. The valves are electronically operated by signals from the ECM. During braking with ABS control, the ECM provides a voltage to the inlet and outlet solenoid valves, which influence the hydraulic pressure to the brakes. The control to the rear brakes is determined by the wheel which first shows a tendency to lock. The brake pressure at both rear wheels is thus determined by the wheel having the lowestfriction coefficient.

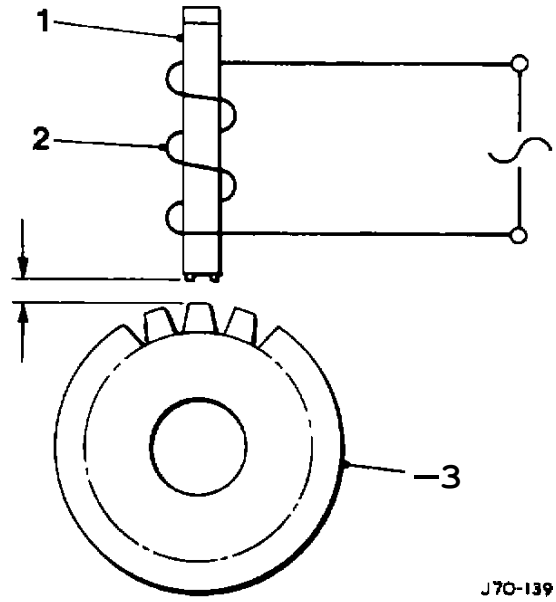



Fig. 3

This ensures that in the case of braking on a surface with low friction coefficient neither of the rear wheels will lock.
All the valves with the exemption of the main valve have a common earth point which is connected to pin 11 of the ECM.
The earth connection pin 11 is known as the reference earth, via this connection the ECM receives test pulses for the valves.

**Note:** During normal braking the anti-lock system will not **be** activated. However, if the braking force applied is sufficient to overcome tyre/road adhesion the anti-lock system will automatically be activated preventing the road wheel from locking.

With no current flowing through the inlet solenoids the valves are open so that during braking the brake pressure can be applied direct to the wheel brakes.
With no current flowing through the outlet solenoids the valves are closed and disconnect the wheel brakes from the reservoir.
To maintain pressure the outlet valve (1 Fig. 1) stays closed, and the inlet valve (2 Fig. 1) to a 'wheel with a tendency to lock' closes, ensuring the brake pressure to that wheel cannot be increased.
To decrease pressure the inlet valve closes and the outlet valve opens. The brake pressure to the wheel is decreased.
To increase the pressure to the wheel the inlet valve opens and the outlet valve closes and the brake pressure to the wheel is again increased almost up to the locking pressure limit.
These phases are repeated up to six times a second until the tendency for the wheel to lock is eliminated.

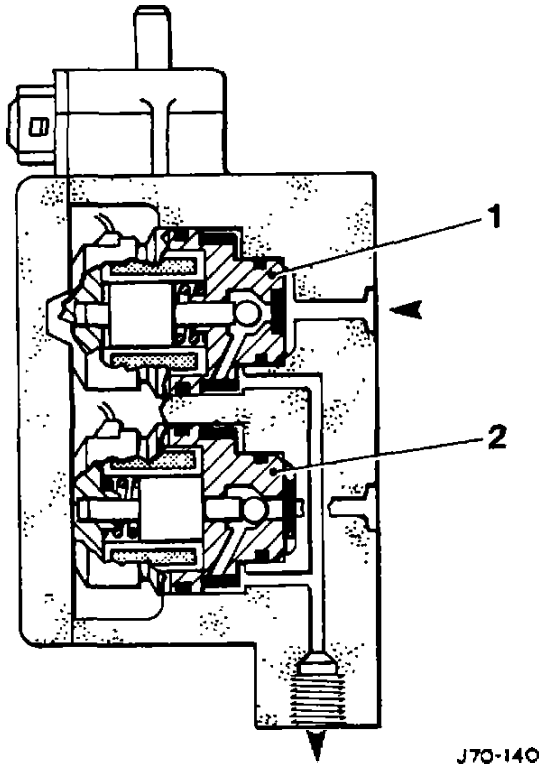



Fig. 1

### Main valve

The main valve is a solenoid operated valve which during ABS control supplies the front wheel brakes with pressure and causes a push back of the pedal by applying a pressure to the positioning sleeve.
In a braking position without ABS control the solenoid valve (1 Fig. 2) is de-energized and connects the reservoir (2 Fig. 2) with the master cylinder (3 Fig. 2).
The connection between the booster, the master cylinder and the return flow is closed.
At the beginning of ABS control the main solenoid valve is energized and connects the dynamic circuit of the booster with the static circuit of the master cylinder.
The connection between the master cylinder and the reservoir is closed.

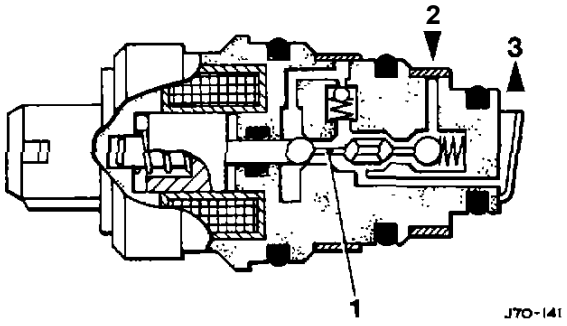



Fig. 2

**Master cylinder**

The master cylinder (Fig. 1) acts exclusively on the front wheel brakes, the static circuit. The pressure in the master cylinder is generated by means of force acting from the booster piston to static fluid column.

In addition, the posiitioning sleeve and the main valve are integrated in the master cylinder.

The brake pressure to the rear wheel brakes *is* supplied by the hydraulic accumulator through the control valve.

As pressure is applied to the brake pedal, the master cylinder piston (1 Fig. 2) is moved forward by the booster piston (5 Fig. 2). The control valve (2 Fig. 2) closes and a pressure is built up in the front wheel brakes. Siimultaneouslytothe forward movement of the baoster piston, the positioning sleeve (3 Fig. 2) is pulled to the left. The main valve (4 Fig. 2) is in an inoperative position. The connection between the master cylinder and the reservoir is open, the connection between the booster and the master cylinder is closed.

Ifthere is a wheel locking tendency during braking at one or more front wheels, the main valve (4 Fig. 2) is controlled by the ECM. The main valve closes the connection between the static circuit of the master cylinder and the reservoir.

Simultaneously. the connection between the dynamic circuit in the rear wheel brakes, the booster, and the static circuit in the front wheel brakes is made.

The dynamic pressure isapplied to the positioning sleeve (3 Fig. 2) which is moved to its stopping point. This movement causesthe push back of the booster piston and of the pedal. At the same time, thedynamic flow-in over the primary seal (6 Fig. 2) of the mastercylindqr piston (1 Fig. 2) andthusthe direct pressure supply in the wheels occurs.

The pressure on the right side of the primary seal is higher than on the left side and due to this the primary seal is pushed forward.

Due to the pressure compensation, the master cylinder piston (1 Fig. 2) is pushed to the booster piston (5 Fig. 2).

The direct flow into the front wheel brakes and the push back of the pedal, avoids a pedal pulsation during braking under **ABS** control and guarantees at the same time that sufficient reserve is available in case of rear circuit failure.

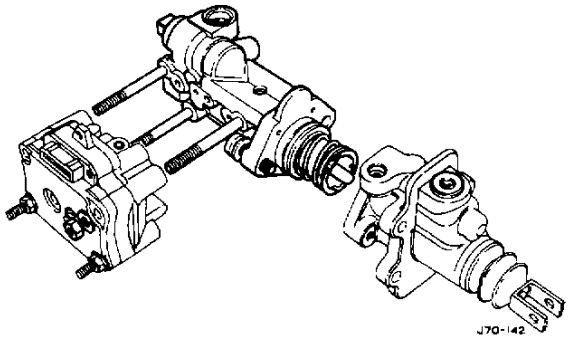



Fig. 1

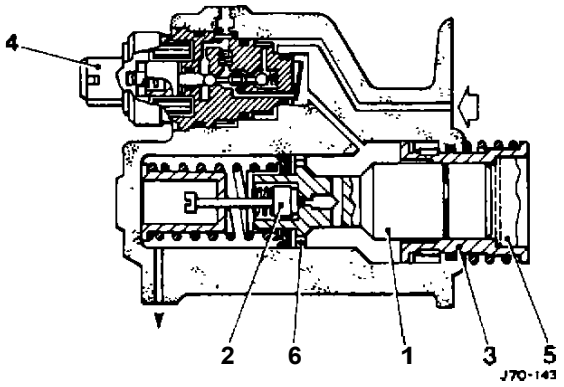



Fig. 2

Positioning **sleeve**

The positioning sleeve is a safety feature which ensures that in the case of a circuit failure in the rear wheel brakes there is sufficient master cylinder stroke left during ABS controlled braking.
In its inoperative position the sleeve (1 Fig. 1) is at itsstopping point. The chamber (2 Fig. 1) leftofthe positioning sleeve is connected with the reservoir via the main valve. The chamber right of the sleeve is connected direct with the reservoir.
Braking without ABS control, pressure is applied to the brake pedal, the booster piston (3 Fig. 1) moves to the left pushing the positioning sleeve to the left against the spring tension.
Braking on surfaces with a high friction coefficient under ABS control, pressure is applied from the dynamic circuit by opening the main valve. The positioning sleeve (1 Fig. 1) moves to the right to its stopping point and pushes back the booster piston (3 Fig. 1) as well as the brake pedal.
At the beginning of ABS control the brake pedal has a hard pedal feel'.
During braking on surfaces with a low friction coefficient the booster piston and the brake pedal moves gradually to the stopping point of the positioning sleeve. Therefore, no push back movement of the pedal can be felt.

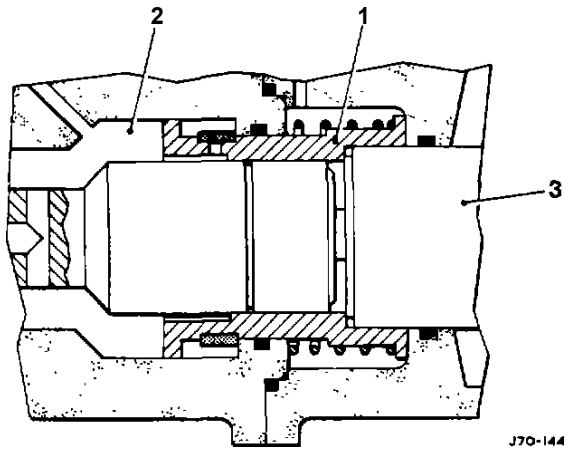



Fig. 1

Reservoir

The reservoir has chambers. The most important chambers deliver supply to:

1. The front wheel brakes, (1 Fig. 2) i.e for the master cylinder via the main valve.
2. The motor pump unit, i.e. for the boosterand rear wheel brakes (2 Fig. 2).
3. For the return flow from the booster (3 Fig. 2). the rear brakes (2 Fig. 2), the valve block and the position sleeve (4 Fig. 2).

If due to a leakage, e.g. in the front wheel brakes, brakefluidislost, the necessaryamountoffluidfor operating the rear wheel brakes is still available. The ECM is partially inhibited, the ABS for the front wheel brakes is switched off and the ABS warning light is illuminated.
In the case of a leakage in the rear wheel brakes, a residual amount of fluid is available for operating the front wheel brakes to decelerate the vehicle. The ECM is partially inhibited, the ABS for the front wheel brakes is switched off and the ABS warning light is illuminated.

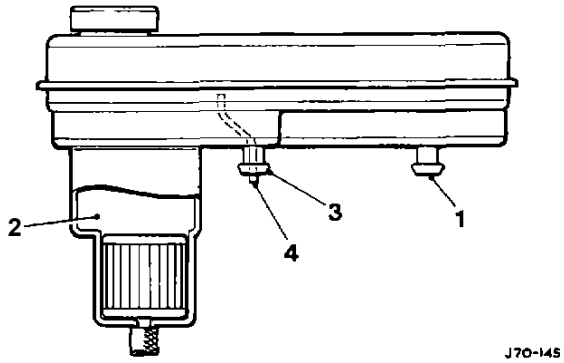



Fig. 2

The fluid level is monitored by two reed contacts on different levels; inside the reservoir. The contactsareswitched by contact plates (1 Fig. 1) on a float stem.
With fluid **loss,** the lower reed contact (2 Fig. 1) switches on the brake warning lamp, the same as a conventional brakelsystem.
With further **loss** ofl brake fluid the upper reed contact (3 Fig. 1) is opened. The circuit between terminals **9** and 10 is broken. The **ECM** senses the open circuit during its continuous tests and is partially inhibited. The **ABS** for the front wheel brakes is switched off and the ABS warning lamp is illuminated.

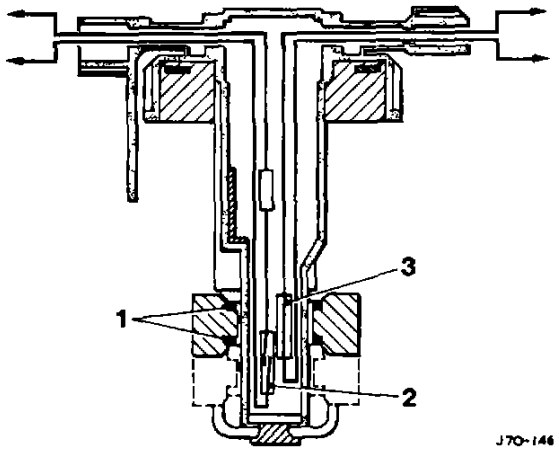



Fig. 1

## ANTI-LOCK BRAKING SYSTEM

### FAULT DIAGNOSIS 70.00.00

SYSTEM TEST

| | |
|---|---|
| TEST 1<br>Battery voltage at ECM Multi-meter connected to terminals 1 and 2 at ECM set to 'DC VOLTS'<br>Ignition 'ON' should be over 10 volts | – If incorrect check banery condition.<br>– Check wiring from terminal 2 to ignition switch<br>– Check wiring from terminal 1 to earth |
| TEST 2<br>Main relay continuitytest between Terminals 1 and 3 ECM<br>ignition 'OFF' Multimeter to OHMS<br>Should have continuity | – If incorrect remove relay and check terminal 3 to pin 30 at relav<br>– Check wiring from pin 87a of relay to earth. If OK renew relay. |
| TEST 3<br>Main relay continuity test between Terminals 1 and 20 ECM<br>Ignition 'OFF' Multi-meterto OHMS<br>Should have continuity | – If incorrect remove relay and check wiring from terminal 20 to pin 30 at relay<br>– Check wiring from pin 87a of relay to earth. If OK renew relay. |
| TEST 4<br>Main relay resistance test.<br>Terminals 8 and 1 ECM<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be 50 to 100 ohms | – If incorrect remove main relay and check wiring from terminal 8 to pin 86 at relay<br>– Check wiring from pin 85 at relay to earth. |
| TEST 5<br>Main relay operation<br>Bridge ECM terminals 2 and 8<br>Multi-meter to ECM terminals 1 and 3<br>Ignition 'ON' Multi-meter to DC VOLTS<br>Should be over 10 volts | – If incorrect Ignition OFF remove main relay Check fuse<br>– Check wiring from pin 87 of relay to fuse<br>– Remove bridge wire |
| TEST 6<br>Main relay operation<br>Bridge ABS terminals 2 and 8<br>Iti- eter to ECM termina ls 1 and 20<br>iti( 'ON' Multi-meter to DC VOLTS<br>should be over 10 volts | – If incorrect and wiring OK renew relay<br>– Remove bridge wire |
| TEST 7<br>Left-hand side rear wheel sensor resistance eck<br>C nn t Multi ete between terminals 24 and 6<br>Ignition 'OFF' l ulti-m OHMS<br>Resistance should be 4 K ohms | – If incorrect check wheel sensor connector<br>– Disconnect wheel sensor and check sens r resistance if inc orrect renew sensor.<br>– If resistance of sensor correct check wiring m sensor to ECM block connector terminals 6 and 24 |
| TEST 8<br>Right-hand side front wheel sensor resistance check<br>Connect Multi-meter between terminals 25 and 7<br>Ignition 'OFF' Multi-meter to OHMS<br>Resistance should be 0.8–1.4 K ohms | – If incorrect check wheel sensor connector<br>– Disconnect wheel sensor and check sensor resistance if incorrect renew sensor.<br>– If resistance of sensor correct check wiring from sensorto ECM blockconnectorterminals 7 and 25 |
| TEST 9<br>Right-hand side rear wheel sensor resistance check<br>Connect Multi-meter between terminals 22 and 4<br>Ignition 'OFF' Multi-meter to OHMS<br>Resistance should be 0.8–1.4 K ohms | – If incorrect check wheel sensor connector<br>– Disconnect wheel sensor and check sensor resistance if incorrect renew sensor.<br>– If resistance of sensor correct check wiring from sensorto ECM block connector terminals 4 and 22 |
| TEST 10<br>Left-hand side front wheel sensor resistance check<br>Connect ohmmeter between terminals 23 and 5<br>Ignition 'OFF' Multi-meter to OHMS<br>Resistance should be 0.8–1.4 K ohms | – If incorrect check wheel sensor connector<br>– Disconnect wheel sensor and check sensor resistance if incorrect renew sensor.<br>– If resistance of sensor correct check wiring from sensor to ECM block connector terminals 5 and 23 |

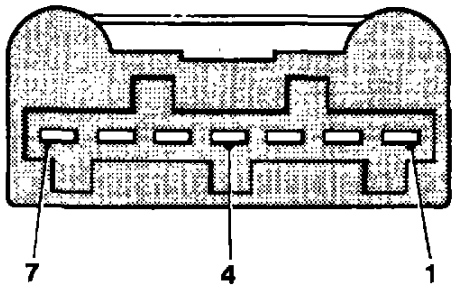
| | |
|---|---|
| TEST 11<br>Left-hand side rear sensor voltage<br>Raise car on wheel free ramp<br>Spin wheel at 1 rev per second<br>Multi-meter connected to terminals 24 and 6 of ECM<br>Ignition 'OFF' Multi-meter to AC VOLTS<br>Should be 0.04–0.1 volts | – If incorrect:<br>– Check sensor mounting<br>– Check toothed wheel<br>– Check hub carrier |
| TEST 12<br>Right-hand side front sensor voltage<br>Raise car on wheel free ramp<br>Spin wheel at 1 rev per second<br>Multi-meter connected to terminals 25 and 7 of ECM<br>Ignition 'OFF' Multi-meter to AC VOLTS<br>Should be 0.15–0.7 volts | – If incorrect:<br>– Check sensor mounting<br>– Check toothed wheel<br>– Checkvertical link |
| TEST 13<br>Right-hand side rear sensor voltage<br>Raise car on wheel free ramp<br>Spin wheel at 1 rev der second<br>Multi-meter connected to terminals 22 and 4 of ECM<br>Ignition 'OFF' Multi-meter to AC VOLTS<br>Should be 0.04–0.1 volts | – If incorrect:<br>– Check sensor mounting<br>– Check toothed wheel<br>– Check hub carrier |
| TEST 14<br>Left-hand side front sensor voltage<br>Raise car on wheel free ramp<br>Spin wheel at 1 rev per second<br>Multi-meter connected to terminals 23 and 5 of ECM<br>Ignition 'OFF' Multi-meter to AC VOLTS<br>Should be 0.15–0.7 volts | – If incorrect:<br>– Check sensor mounting<br>– Check toothed wheel<br>– Checkvertical link |
| TEST 15<br>Sensor cable screen continuity test<br>Left-hand rear<br>Multi-meter connected to terminals 6 and 1<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be zero reading | – If incorrect check that sensor is not earthed<br>– Check sensor cable from sensor to module is not earthed |
| TEST 16<br>Sensor cable screen continuity test<br>Right-hand front<br>Multi-meter connected to terminals 7 and 1<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be zero readilng | – If incorrect check that sensor is not earthed<br>– Check sensor cable from sensor to module is not earthed |
| TEST 17<br>Sensor cable screen continuity test<br>Right-hand rear<br>Multi-meter connected to terminals 4 and 1<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be zero reading | – If incorrect check that sensor is not earthed<br>– Check sensor cable from sensor to module is not earthed |
| TEST 18<br>Sensor cable screen continuity test<br>Left-hand front<br>Multi-meter connected to terminals 5 and 1<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be zero reading | – If incorrect check that sensor is not earthed<br>– Check sensor cable from sensor to module is not earthed |

| | |
|---|---|
| TEST 19<br>Check valve block earth connection<br>Connect multi-meter between terminal 11 and 1 at ECM connector<br>Multi-meter to OHMS | – If no continuity disconnect the valve block<br>– Check pin 7 of valve block is earthed to housing and valve block is housing earth to vehicle<br>– Check wiring from terminal 11 of ECM to pin 7 of valve block |
| TEST 20<br>Main valve resistance<br>Multi-meter connected to terminals 11 and 18 of ECM<br>Ignition 'OFF' Multi-meter to OHMS<br>Correct reading 2–5 ohms | – If incorrect disconnect the main valve<br>– Measure main valve resistance<br>– Checkcontinuity of wiring from pin 1 of valve to terminal 18 of ECM connector<br>– Check wiring from terminal 11 of ECM connector to earth<br>– Check pin 1 terminal of valve to earth |
| TEST 21<br>Check resistance of RH front inlet valve (RHD)<br>Multi-meter connected to terminals 15 and 11 of ECM<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be 3–5 ohms | – if incorrect disconnect valve block and measure resistance between valve pins 1 and 7<br>– Check wiring from ECM terminal 15 to pin 6 of valve block |
| TEST 22<br>Check resistance of rear inlet valve (RHD)<br>Multi-meter connected to terminals 17 and 11 of ECM<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be 3-5 ohms | – If incorrect disconnect valve block and measure resistance between valve pins 1 and 7<br>– Check wiring from ECM terminal 17 to pin 3 of valve block |
| TEST 23<br>Check resistance of LH front inlet valve (RHD)<br>Multi-meter connected to terminals 35 and 11 of ECM<br>Ignition 'OFF' Muiti-meter to OHMS<br>Should be 3–5 ohms | – If incorrect disconnect valve block and measure resistance between valve pins 5 and 7<br>– Check wiring from ECM terminal 35 to pin 1 of valve block |
| TEST 24<br>Check resistance of rear outlet valve<br>Multi-meter connected to terminals 33 and 11 of ECM<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be 5–7 ohms | – If incorrect disconnect valve block and measure resistance between valve pins 4 and 7<br>– Check wiring from ECM terminal 33 to pin 4 of valve block |
| TEST 25<br>Check resistance of RH front outlet valve (RHD)<br>Multi-meter connected to terminals 34 and 11 of ECM<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be 5–7 ohms | – If incorrect disconnect valve block and measure resistance between valve pins 5 and 7<br>– Check wiring from ECM terminal 34 to pin 5 of valve block |
| TEST 26<br>Check resistance of LH front outlet valve (RHD)<br>Multi-meter connected to terminals 16 and 11 of ECM<br>Ignition 'OFF' Multi-meter to OHMS<br>Should be 5–7 ohms | – If incorrect disconnect valve block and measure resistance between valve pins 2 and 7<br>– Check wiring from ECM terminal 16 to pin 2 of valve block |
| TEST 27 (APPLIES TO RHD)<br>Inlet and outlet valve function Bridge ABS module terminals 2, 16 and 35<br>Ignition 'OFF' – Apply foot brake LH front wheel should be locked<br>Switch ignition **'ON'** – Road wheel must now rotate – Brake pedal must not go to the floor | – If an incorrect result is obtained renew valve block<br>– Check electric/hydraulic interconnection |

| | |
|---|---|
| TEST 28 (APPLIES TO RHD)<br>Inlet and outlet valve function<br>Bridge ABS module terminals 2.15 and 34<br>Ignition 'OFF' – Apply foot brake<br>RH front wheel should be locked<br>Switch ignition 'ON' – Road wheel must now rotate – Brake pedal must not go to the floor | – If an incorrect result is obtained renew valve block<br>– Check electric/hydraulic interconnection |
| TEST 29<br>Inlet and outlet valve function<br>Bridge ABS module terminals 2.17 and 33<br>Ignition 'OFF' – Apply foot brake<br>Both rear wheels should be locked<br>Switch ignition 'ON' – Road wheels must now rotate – Brake pedal must not go to the floor | – If an incorrect result is obtained renew valve block<br>– Check electric/hydraulic interconnection |
| TEST 30<br>Fluid level warning indicator and pressure warning switch continuity<br>Switch ignition 'ON' and wait for pump to stop running.<br>Switch ianition 'OFF'<br>Connect–Multi meter to terminals 9 and 10 of ECM<br>Should have continuity | – If incorrect disconnect reservoir plug, check for continuity between reservoir pins 1 and 2<br>– Disconnect pressure warning switch, check plug for continuity between Pressure warning switch Dins 3 and 5<br>– Check fluid level<br>– Check wiring between terminals 9 and 10 |
| TEST 31<br>Pressure warning switch operation<br>With the ignition switched 'OFF' pump the brake pedal 20 times until the pedal travel becomes hard<br>Connect Multi meter set to OHMS to ECM terminals 9 and 10 – should be no continuity. | – If incorrect check for no continuity at pins 3 and 5 of pressure warning switch: if continuity exists renew pressure switch |
| TEST 32<br>Short out pressure warning switch, fluid level switch circuit.<br>Multi meter connected to ECM connector terminals 9 and 1: then 10 and 1.<br>Should be no continuity | – If incorrect check pressure warning and fluid level switches, wiring between switches and ECM connectors 9 and 10, and switches themselves for ground short. |

**PIN IDENTIFICATION**

VALVE BLOCK MULTIPLUG



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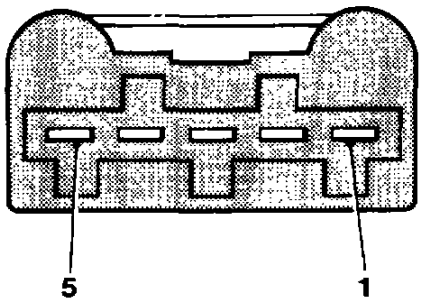
FLUID LEVEL MULTIPLUG



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Notes: System Tests, 1–32 are identical for LHD cars with the following exceptions.

On LHD cars:

1 Test 21 checks the resistance of the LH front inlet valve
2 Test 23 checks the resistance of the RH front inlet valve
3 Test 25 checks the resistance of the LH front outlet valve
4 Test 26 checks the resistance of the RH front outlet valve
5 Test 27 (inlet and outlet valve function), the RH front wheel will be locked
6 Test 28 (inlet and outlet valve function), the LH front wheel will be locked

**SINGLE FAILURE WARNINGS**

| FAILURE | EFFECT | RESULT | INDICATOR |
|---|---|---|---|
| Brake fluid low | Requires topping up | Brake fluid low at level 1 | Brake warning light on |
| Broken sensor | | No ABS | ABS warning light on |
| Partial intermittent failure on front axle | | No ABS on rears only | ABS warning light on |
| Partial intermittent failure on front axle above 40 km/hr (25 mph) | | No ABS | ABS warning light on |
| Partial intermittent failure on rear axle above 20 km/hr (12 mph) | | No ABS | ABS warning light on |
| Partial intermittent failure on rear axle below 20 km/hr (12 mph) | | No ABS | ABS warning light on |
| Pressure Switch connection broken | Accumulator will not charge | Loss of power assistance. Unboosted front brakes only No ABS | ABS warning light on |
| 30 A main fuse blown (pump motor) | Accumulator will not charge | Loss of power assistance. Unboosted front brakes only No ABS | ABS and brake warning lights on when pressure drops |
| 30 A ABS fuse blown | | NO ABS | ABS warning light on |
| Pump connection broken | Accumulator will not charge | **Loss** of power assistance. Unboosted front brakes only No ABS | ABS and brake warning lights on when pressure drops |
| Brake fluid low at level 2 | | Boosted brakes ABS on rear only | ABS and brake warning lights on |
| Failed front hydraulic circuit | **Loss** of fluid to level 2 | Boosted rears with ABS only | ABS and brake warning lights on |
| Failed rear hydraulic circuit* | **Loss** of fluid | Unboosted front brakes only No ABS | ABS and brake warning lights on |

Note: * If the front hydraulic circuit fails, pedal TRAVEL will increase.
If the rear circuit fails, pedal EFFORT will increase.

## ANTI-LOCK BRAKING SYSTEM

### ON-BOARD INTERMITTENT DIAGNOSIS 70.00.00

WARNING LAMP BLINK DISPLAY

**A** detected system failure can sometimes come from several different failure sources; for example, a failure indicating 'discontinuity of a sensor signal' can be caused by missing wheel sensorteeth. a loose sensor, interminent sensor connection or trigger failure.

To assist in on-board intermittent fault diagnosis, a warning lamp blink display system has been developed, using numerical codes cross-referenced to code identification charts to identify failures.

Carry out on-board fault diagnosis procedure as follows:

1. Ensure that the ignition is off.
2. Locate the 3-way Econoseal diagnostic connector in the rear wheel arch, close to the **ABS** ECM.
3. Insert a 'short' (JDS Referencelead) across the blacklead (ground) and the Brown/Pink lead (trigger line to pin 26 of the ECM).
4. Turn on the ignition (position 2) and observe the warning lamp.
5. After six seconds the blink sequence of the first code begins.
6. Count the blink pulses and write down the resulting two digit number. After a 6.5 seconds pause the next code begins, and *so* on, until all the failure codes are read out and the warning light remains off.
7. Remove the 'short' lead and switch the ignition OFF.

Fig. 1 shows a typical code output. The first digit (tens) is represented by two flashes (blinks), the second digit (units) by one flash (blink) giving 21.
After a 6.5 second pause, the next output is given: the first digit (tens) is represented by three blinks, the second digit (units) by one blink giving 31.

**Note**: The ECM is only capable of dealing with one type of fault at a time, eg code 21 will display but code 22 will riot – instead the blink sequence will move to the next fault type, code 31 or higher. Therefore, on completion of the required maintenance work, carry out the ECM memory erase procedure, then repeat the blink display diagnosis procedure. This will indicate any remaining or new faults in the system.

**Note**: On completiqn of all abs or associated maintenance work, carry out the ecm memory erase procedure (to erase the memory, drive the car at a speed greater than 30 km/hr (19 mph) see page 70–19). Repeat the on-board intermittent fault diagnosis procedure (see above). this will indicate any new/persistent faults still in the system.

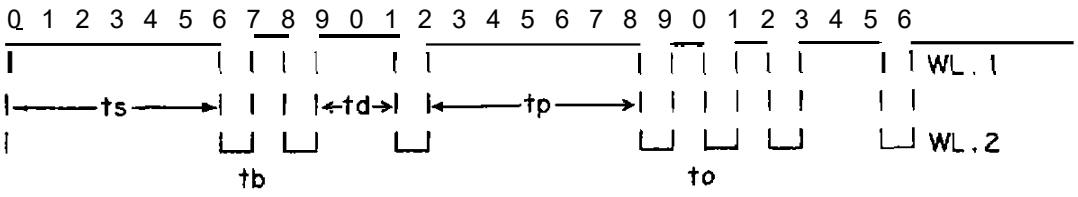


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Fig. 1

Key to Fig. 1

| | | | |
|---|---|---|---|
| WL1 | Warning1 light off | tb | Time of one blink |
| WL2 | Warning; light on | td | lime between tens and units |
| ts | Start time after ignition switched on | tp | Pause between codes |
| | | to | lime off between blinks |

**HIGH PRIORITY FAILURES**

| FAIL CODE | 1ST DIGIT | FAILURE MODE | FAILURE CAUSES | REPAIR INSTRUCTIONS (See Note 1) | 2ND DIGIT | FAILURE LOCATION |
|---|---|---|---|---|---|---|
| 11 | 1 | Redundancy failure | Disturbed/ defective redundancy channel | Check if disturbance affects **ABS** system. Check prop cable harness installation | 1 | – |
| 12 | 1 | Internal ECM failure | Defective ECM | Renew ECM | 2 | – |
| 21 | 2 | Valve failure | Defective valve/cable harness/power transistor in ECM | Check indicated solenoid valve/ terminals for short or interruption (21–27) | 1 | Main valve |
| 22 | 2 | | | | 2 | Inlet valve front left |
| 23 | 2 | | | | 3 | Outlet valve front left |
| **24** | 2 | | | | **4** | Inlet valve front right |
| 25 | 2 | | | | 5 | Outlet valve front right |
| 26 | 2 | | | | 6 | Inlet valve rear |
| 27 | 2 | | | | 7 | Outlet valve rear |

**Notes:** 1. If indicated repair instructions do not help, renew the ECM.
2. If the warning lamp stays on continuously without any failure code being displayed, the failure is probably in the ECM. Check the electric power supply FIRST, then renew the ECM.

| | | | | | | |
|---|---|---|---|---|---|---|
| 31 | 3 | Sensor failure recognised by 'Trigger Monitoring' | Interrupted/ shorted sensor coil/ sensor cable, open connector defective trigger circuit | Check indicated sensor/wire terminals for short circuit or interruption (31–34) | 1 | Sensor front left |

**HIGH PRIORITY FAILURES**

| FAIL CODE | 1ST DIGIT | FAILURE MODE' | FAILURE CAUSES | REPAIR INSTRUCTIONS (See Note 1) | 2ND DIGIT | FAILURE LOCATION |
|---|---|---|---|---|---|---|
| 32 | | | | | 2 | Sensor front right |
| 33 | 3 | | | | 3 | Sensor rear right |
| 34 | 3 | | | | 4 | Sensor rear left |
| 35 | 3 | Sensor failure recognised by 'Monitoring of **Wheel** Speed Continuity' at vehicle speed **ABOVE** 40 km/hr (25 mph) | Intermittently interrupted/ shorted sensor coil/cable. Damaged teeth on wheel too sensor large bearing clearance/ wrong air gap. | Check indicated sensor/ wire terminals for **short** circuit or interruption (35–38). Check tooth wheel regularity sensor air gap and bearing clearance See Note 3 | 5 | Sensor front left |
| 36 | 3 | | | | 6 | Sensor front right |
| 37 | 3 | | | | 7 | Sensor rear right |
| 38 | 3 | | | | 8 | Sensor rear left |
| 41 | 4 | Sensor failure recognised by 'Wheel Speed Comparison' | Missing sensor signal (sensor not inserted). too large air gap, tooth wheel not installed | Check air gap/tooth wheel | 1 | Sensor front left |
| 42 | 4 | | | | 2 | Sensor front right |
| 43 | 4 | | | | 3 | Sensor rear right |
| 44 | 4 | | | | 4 | Sensor rear left |

**Notes:** 1. If indicated repair instructions do not help, renew the ECM.

2. If the warning lamp stays on continuously without any failure code being displayed. the failure is probably in the ECM.
   Check the electric power supply FIRST, then renew the ECM.

3. If repair instructions for display codes 35–38 do not help, proceed with repair instruction 75–78, and vice versa.

**HIGH PRIORITY FAILURES**

| FAIL CODE | 1ST DIGIT | FAILURE MODE | FAILURE CAUSES | REPAIR INSTRUCTIONS (See Note 1) | 2ND DIGIT | FAILURE LOCATION |
|---|---|---|---|---|---|---|
| 51 | 5 | 'Pressure reduction and Wheel Response monitoring' at vehicle speed ABOVE 40 km/hr (25 mph) | Hydraulically non-operational outlet valve | Check indicated outlet valve hydraulically – See Note 3 | 1 | Outlet valve front left |
| 52 | 5 | | | | 2 | Outletvalve front right |
| 53 | 5 | | | | 3 | Outlet valve rear (Same as 54) |
| 54 | 5 | | | | 4 | Outlet valve rear (Same as 53) |
| 55 | 5 | 'Long Term Monitoring of Control Duration' | Long term detection of missing sensor signal (sensor loose), too large air gap | Check indicated sensor, air gap and tooth wheel (55–58) | 5 | Sensor front left |
| 56 | 5 | | | | 6 | Sensor front right |
| 57 | 5 | | | | 7 | Sensor rear right |
| 58 | 5 | | | | 8 | Sensor rear left |
| 61 | 6 | Warning switch input cannot be processed | Short circuit/ leakage current from battery to warning switch path | Check reservoir, pressure warning switches and related wires for short circuit and leakage current | 1 | – |

**Notes:** 1. If indicated repair instructions do not help, renew the ECM.

2. If the warning lamp stays on continuously without any failure code being displayed, the failure is probably in the ECM.
Check the electric power supply FIRST, then renew the ECM.

3. If repair instructions for display codes 51–54 do not help, proceed with repair instruction 71–74. and vice versa.

**LOW PRIORITY FAILURES (SEE NOTE 5)**

| FAIL CODE | 1ST DIGIT | FAILURE MODE | FAILURE CAUSES | REPAIR TRUCTIONS (See Note ) | 2ND DIGIT | ILURE OCATIO |
|---|---|---|---|---|---|---|
| 71 | 7 | 'Pressure Reduction and Wheel Response Monitoring' at vehicle speedi BELOW 40 km/hr (25 mph) | Long term detection of RFI | Check indicated ground lead a 1J ECM EMC fo1 prop( grounding (71–74) S( Note 3 | 1 | Sensor front left |
| 72 | 7 | | | | 2 | Sensor front right |
| 73 | 7 | | | | 3 | Sensor rear right |
| 74 | 7 | | | | 4 | Sensor rear left |
| 75 | 7 | Sensor failure recognised by 'Monitoring of Wheel Speed Continuity' at vehicle speed BELOW 40 km/hr (25 mph) | Disturbances caused by RFI or ignition, excessive axle vibration, too large bearing clearance/too small air gap | Check indicated sensor ground lead/ECM for proper grounding Check for axle vibration, loose sensor mounting, correct bearing clearance/air gap (75–78) See Note 4 | 5 | Sensor front left |
| 76 | 7 | | | | 6 | Sensor front right |
| 77 | 7 | | | | 7 | Sensor rear right |
| 78 | 7 | | | | 8 | Sensor rear left |

**Notes:** 1. If indicated repair instructions do not help, renew the ECM.

2. If the warning lamp stays on continuously without any failure code being displayed, the failure is probably in the ECM.
   Check the electric power supply FIRST, then renew the ECM.

3. If repair instructions for display codes 71–74 do not help, proceed with repair instruction 51-54. and vice versa.

4. If repair instructions for display codes 75–78 do not help, proceed with repair instruction 35–38. and vice versa.

5. Failures with display codes 71–78 are 'Low priority failures' which cause only temporary and partial control inhibit.
   These failures will be stored in the memory, even though they may not be noticed by the vehicle driver.

### WARNING LAMP INDICATIONS WITHOUT ERROR CODE OUTPUT

The on-board diagnosis can only monitor errors that generate electrical signals. The error code information is triggered by the diagnosis trigger input, and displayed by the warning lamp.

TEST CYCLE FOR WARNING SWITCH PATH:
After the ignition is switched 'ON' (providing the brake pressure warning light is 'OFF'). the warning lamp (WL) remains 'ON' for approximately 1.7 seconds. Then it flickers for approximately one second to test the reservoir and pressure switch path. If the warning lamp flickers continuously, this path is open or short circuited to ground potential.

IMPROPER INSTALLATION:
If the main connector is not installed in the ECM (or if the connector is loose), and the ignition is switched 'ON' (position 2), the main relay remains 'resting' and the warning lamp is switched 'ON' by the 'resting' contact of the main relay.

### FAILURES OF THE ECM

FAILURES DETECTED BY INTERNAL TIME-OUT:
Certain hardware faults cause the ECM to be switched off by internal time-out. Any hardware fault will cause the warning lamp to light continuously and, since main power is cut off, the ECM is no longer capable of storing/outputting failure codes.

SHORT CIRCUIT AT THE DIAGNOSIS TRIGGER INPUT:
If the diagnosis trigger input is shorted to ground potential, the ECM goes into the diagnosis output mode when the ignition is switched on and if a failure is stored in the continuous memory. As the car accelerates and reaches 8 km/hr (5 mph), the short to ground on the diagnosis trigger unit still exists, the ECM is switched off, and the warning lamp lights continuously.

WARNING LAMP PATH FAULTS:
Short circuiting the warning lamp wire to ground potential will activate the warning lamp, but wil! not affect the anti-lock braking facility. The ECM cannot recognise this short circuit.

DEFECTIVE WARNING LAMP DRIVER:
If there is a defect in the warning lamp driver inside the ECM, either the warning lamp will remain continuously 'OFF', or will stay continuously 'ON', depending on the internal failure cause.

MISCELLANEOUS WARNING LAMP DISPLAYS/CONDITIONS:
In the case of intermittent/defective contacts or leads in the warning lamp driving path, the warning lamp may flicker 'ON/OFF' for undefined periods.
If the warning lamp is 'blown-out' or otherwise damaged/destroyed, no information about the status of the ECM is possible.

**Note:** The driver will realise that the **ABS** warning lamp circuitry is faulty, because the lamp will not illuminate on the ignition cycle.

### MEMORY ERASE PROCEDURE

Complete the on-board fault diagnosis procedure, and repair all indicated failures.

**Note:** Ensure that all failures have been indicated and identified, i.e. that the warning lamp off at the end of the display cycle (see NOTE 5 at the end of the diagnosis procedure. page 70–26). If the display cycle has not been completed, the failure memory will not erase.

To erase the memory, drive the car at a speed greater than 30 km/h (19 mph).
The failure memory is now clear.

### BRAKE WARNING LIGHT SWITCH

During warning light switch renewal/adjustment – 86.65.51/56, the operator must ensure that the brake pedal is fully returned against its stop PRIOR TO SETTING THE SWITCH. Failure to do this may result in a no-warning lights condition.

## ANTI-LOCK BRAKING SYSTEM

**BRAKE FLUID LEVEL** **70.00.00**

**WARNING: THE ANTI-LOCK BRAKING SYSTEM OPERATES UNDER HIGH HYDRAULIC PRESSURE, AND GREAT CARE MUST BE EXERCISED WHEN SERVICING OR REPAIRING THE SYSTE[illegible] FIG. 2 [illegible]OWS [illegible]CUMULATOR WARNING LABEL AVOID [illegible] CONTA[illegible]. OR INGESTION OF BRAKE FLUID. IF SKIN OR EYES ARE ACCIDENTALLY SPLASHED WITH BRAKE FLUID, RINSE THE AFFECTED AREA IMMEDIATELY WITH PLENTY OF WATER. OBTAIN MEDICAL ATTENTION. IF BRAKE FLUID IS INGESTED, OBTAIN IMMEDIATE MEDICAL ATTENTION**

CHECKING THE FLUID LEVEL

Correct brake fluid level is essential for the efficient operation of the brake system.
There are two 'MAX' marks on the reservoir. The brake fluid level must be at the highest 'MAX' level on the reservoir (Fig. 1).

**Note:** In some cases the fluid may be above the 'MAX' mark, this is dependent upon the charged state of the hydraulic unit. Therefore the following procedure for checking or topping up the hydraulic brake fluid level must be followed.

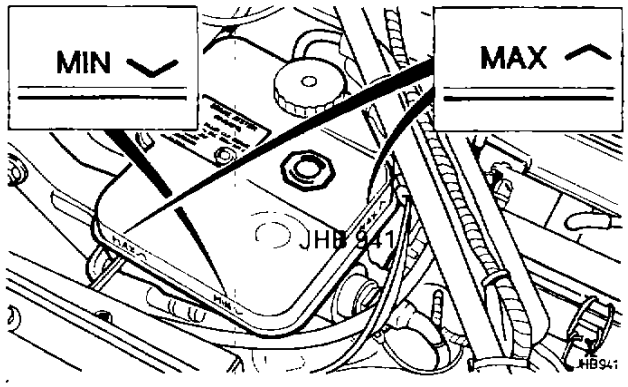


Fig. 1

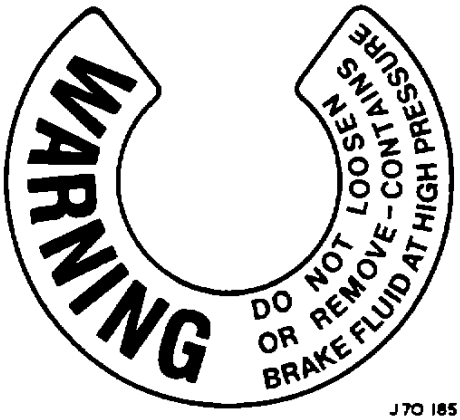


Fig. 2

**CAUTION:** Fluid must not be allowed to contact the vehicle paintwork. Remove any spilt fluid from the paintwork by rinsing away with running water.

1. Ensure the vehicle is on a level surface.
2. With the ignition switched 'OFF' pump the brake pedal at least 20 times, or until pedal travel becomes hard.
3. Switch the ignition 'ON'.
4. Wait for the pump to stop running.
5. Check brake fluid level. Fluid level must be be at the highest 'MAX level on the reservoir (Fig. 1). Top up using the recommended brake fluid.

The efficiency of the brakes may be impaired if fluid is used which does not meet JAGUAR specifications. Use ONLY Jaguar Brake and Clutch Fluid or Castrol Girling Universal to/or exceeding DOT 4 specification.
Also do not use brake fluid that has been exposed to atmosphere for any length of time. Moisture absorbed from the atmosphere dilutes the fluid and impairs its efficiency.