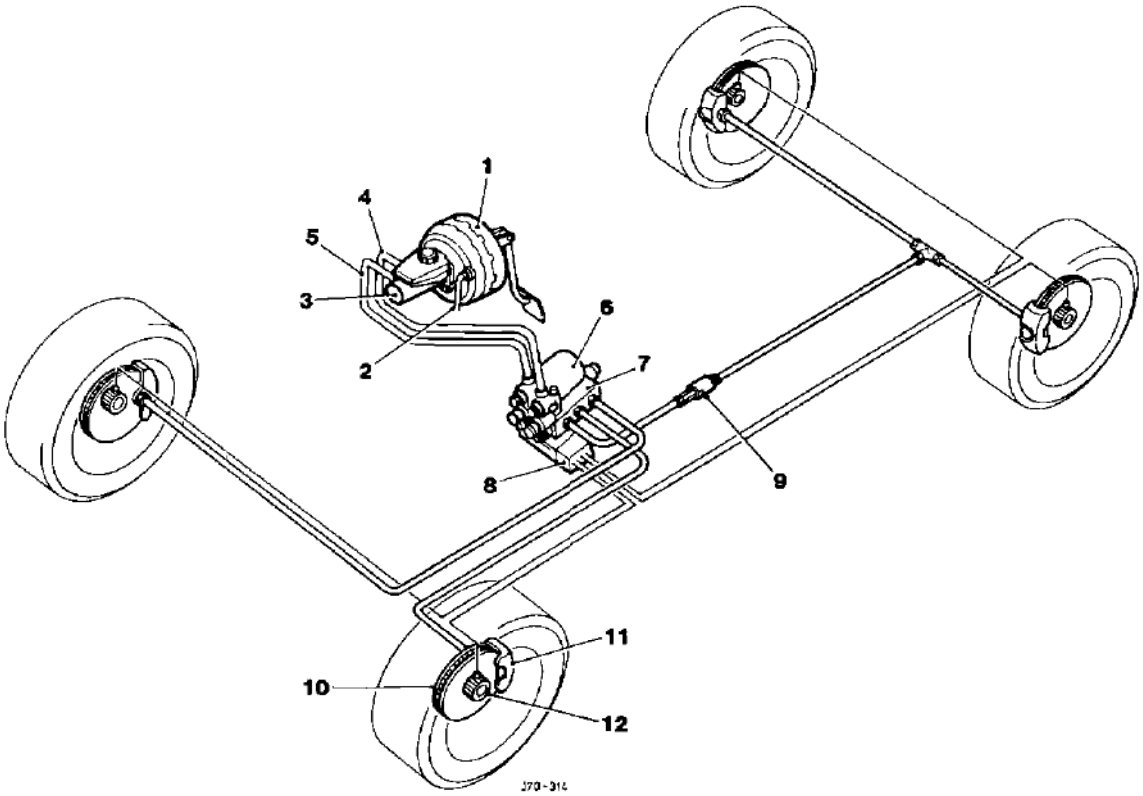
ANTI–LOCK BRAKING SYSTEM
SCHEMATIC DIAGRAM (95.25MY ON)



1. Vacuum booster
2. Vacuum hose
3. Tandem master cylinder
4. Primary brake circuit
5. Secondary brake circuit
6. Hydraulic pump / motor unit
7. Modulator valve block
8. ABS control module
9. Pressure conscious reduction valve
10. Ventilated brake disc
11. Brake caliper
12. Wheel speed sensor

ANTI–LOCK BRAKING SYSTEM

DESCRIPTION

The anti–lock braking system (ABS) components are combined with a hydraulic booster, tandem master cylinder (TMC) and ventilated disc brakes on all four wheels, to provide a two–circuit braking system. The front brakes are fitted with four–piston calipers; the rear brakes have single–piston calipers and drums for the cable operated handbrake. The anti–lock braking system comprises the following:

1. Hydraulic control module comprising electric motor driven pump, two low–pressure accumulators, modulator valve block and ABS control module (ABS CM)
2. Four inductive wheel speed sensors, hub end mounted
3. ABS warning indicator, mounted on the instrument panel
4. Auxiliary inputs providing information to the ABS CM
5. Diagnostic ISO communication BUS input / output link.

The valve block houses solenoid operated valves which are activated by voltage signals from the control module. The signals are generated using wheel speed information received from the wheel speed sensors.

The valves regulate the supply of pressure individually to the front wheels and collectively to the rear wheels, as necessary, to prevent wheel locking during braking.

When the ignition is switched on, an ABS self test is initiated. During this test, the ABS warning indicator is lit for approximately 1.7 seconds and then extinguished. After this time delay the control module is ready to process signals provided from the various input sources and, using the software defined algorithm, control the electrical and hydraulic circuits. A fault is indicated if the warning indicator remains lit or comes on whilst the vehicle is being driven. Under fault conditions the system is inhibited or disabled, although conventional braking is unaffected.

The fluid level indicator lamp, mounted on the instrument panel, is lit when the brake fluid falls below the MIN mark on the briake fluid reservoir.

Fault conditions detected by the ABS CM disable the ABS until the fault is rectified. The system will be disabled when any of the following conditions occur:

1. Valve failure
2. Sensor failure
3. Main driver failure (internal ABS CM fault)
4. Redundancy error (internal ABS CM fault)
5. Over–voltage / under–voltage
6. Pump motor failure
7. Under–voltage condition.

The input frequency from each wheel speed sensor signal is translated by the ABS CM into a comparable wheel speed. The ABS CM continually monitors the system. False wheel speed information, such as sudden speed changes or excessive speeds, is detected as a sensor malfunction. The ABS CM reacts to fault conditions in the following ways:

Inhibit – ABS is inhibited until the sensed speed returns to within an acceptable limit, whereupon ABS is restored. Conventional braking is unaffected. Depending on vehicle speed, the ABS warning indicator may come on.

Disable – ABS is disabled (switched off) and the ABS warning indicator comes on. The system will not be restored until the engine is switched off and restarted or the fault has been rectified. After the system has been disabled, the warning indicator remains on until the vehicle has reached a speed of 20 km / h (12.5 mile / h) during the first ignition cycle after fault rectification.

Vacuum booster

The vacuum booster (1 Fig.1) is mounted on the brake pedal box and secured by three bolts. The tandem master cylinder (TMC) (2 Fig. 1) locates on two studs on the vacuum booster. Two lugs locate the fluid reservoir (3 Fig. 1) on the TMC which is secured by a split pin.

The vacuum is drawn from the inlet manifold. At the vacuum booster, the vacuum hose is connected to the vacuum chamber via an elbow connector. At the inlet manifold, the vacuum hose connector is of the push–on quick–release type.

Applied pedal force is increased by the vacuum booster which actuates the intermediate piston of the TMC. The boost ratio supplied by the vacuum booster is 6.5 : 1.

Note: The vacuum booster and the TMC are supplied as a unit but are individually serviceable.

The brake fluid reservoir is fitted with a fluid level switch, which opens when fluid level is low and lights the low fluid level indicator.

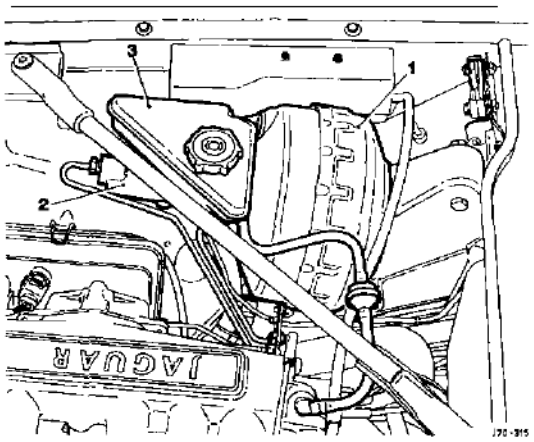


Fig. 1

Hydraulic control module

The hydraulic control module is located under the bonnet adjacent to the engine compartment bulkhead. It is secured within a steel mounting bracket at three securing points.

The hydraulic pump (1 Fig. 1) is a reciprocating two–circuit pump in which one brake circuit is assigned to each pump circuit. The pump supplies adequate pressure and volume supply to the brake circuits under anti–lock braking conditions. The pump housing incorporates a low pressure accumulator and damping chamber for each brake circuit. The pump is driven by an electric motor (2 Fig. 1) which draws 32A current at peak operation and has an internal resistance of 0.8Ω.

The modulator valve block (3 Fig. 1) houses six solenoid valves: three normally open (NO) inlet valves and three normally closed (NC) outlet valves. This provides three outlet ports, one for each front brake and one for both rear brakes.

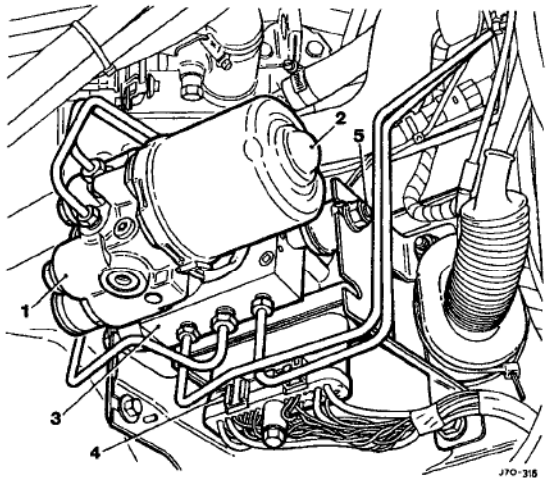


Fig. 1

All electronic and power connections are made through one cable loom connector to the ABS control module (4 Fig. 1) located below the valve block.

The pump, motor and valve block are non–serviceable. If a fault occurs in any of these components, the whole hydraulic control module must be replaced. The ABS CM control module can be replaced separately.

ABS control module

The control module (CM) (4 Fig. 1), located beneath the modulator valve block (3 Fig. 1), is the system controller and processes all the information supplied from the external sensors and probes. Refer to the Control Module Connection Diagram. The signals from the four wheel speed sensors are independently processed by the CM, calculating numerical values which correspond directly to the wheel speed. These values are converted into control signals for pressure modulation during ABS control.

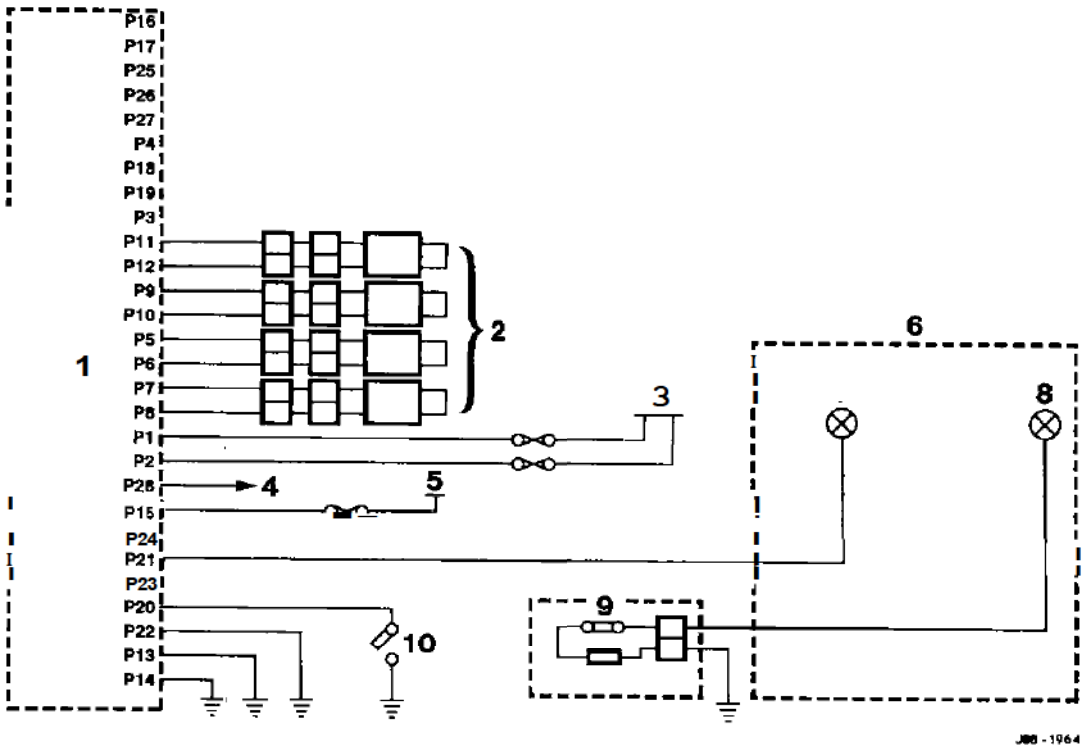
The CM continuously monitors ABS operation, lighting the ABS warning indicator and inhibiting or disabling the system when faults are detected. In a fault condition, conventional braking is unaffected. The CM is self testing and cannot be fault diagnosed beyond 'black box' level, i.e. a faulty module. The CM houses the solenoids which operate the inlet and outlet valves of the modulator valve block. There is no electrical connection between the CM and the modulator valve block, but there is an electrical connection from the CM to the pump motor.

The CM functions include the following:

1. Providing control signals for the operation of ABS solenoid valves
2. Calculating wheel speed from voltage signals transmitted by the wheel speed sensors
3. Monitoring of all electrical components
4. On Board Diagnostics (OBD): storage of fault codes in a non–volatile memory.

The fault codes generated by the CM are stored in a non–volatile memory which can be read via the OBD link. The ABS warning indicator is lit if the CM connector is loose or not fitted.

CONTROL MODULE CONNECTION DIAGRAM



1. ABS control module
2. Wheel speed sensors
3. Battery voltage inputs
4. Diagnostic communication bus
5. Ignition voltage input
6. Instrument pack
7. ABS warning indicator
8. Low fluid level indicator
9. Fluid level switch
10. Brake pedal switch

Control module connections

Control module connections, numbered 1 to 28, provide the necessary input/ output signals to enable the module to control and monitor ABS operation.

Connections are as follows:

1	Battery positive feed (via fuse F22)
2	Battery positive feed (via fuse F11)
3	Not used
4	Not used
5/6	Wheel sensor, left-hand front
7/8	Wheel sensor, right-hand front
9/10	Wheel sensor, left-hand rear
11/12	Wheel sensor, right-hand rear
13	Ground
14	Ground
15	Ignition feed (via fuse F10)
16	Not used
17	Not used
18	Not used
19	Not used
20	Brake pedal switch
21	ABS warning indicator
22	ABS ground
23	Not used
24	Not used
25	Not used
26	Not used
27	Not used
28	Diagnostic ISO communication bus

Brake calipers

The front brakes are fitted with four–piston calipers acting upon 24 mm ($^{15}/_{16}$ in) thick ventilated brake discs (Fig. 1). The caliper carrier is secured by two bolts to the suspension vertical link.

The rear brakes are fitted with single–piston calipers acting upon 20 mm ($^{25}/_{32}$ in) thick ventilated brake discs (Fig. 2). The caliper carrier is secured by two bolts (wire locked) to the hub carrier.

The brake discs must be renewed when the minimum thicknesses specified below are reached:

1. Front brake disc – 22.9 mm ($^{29}/_{32}$ in)
2. Rear brake disc – 18.5 mm ($^{47}/_{64}$ in).

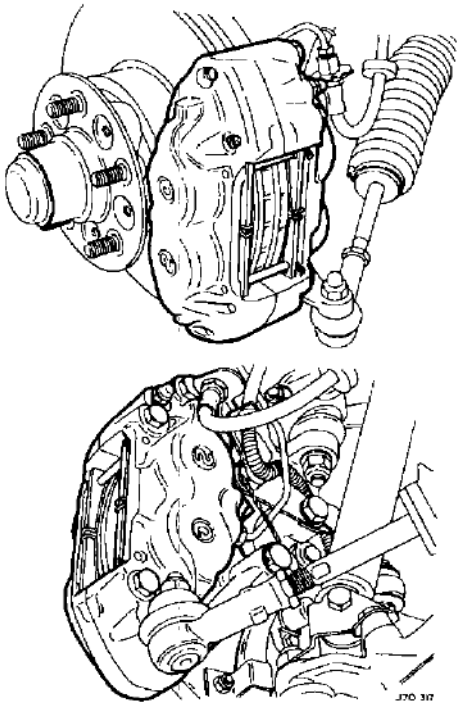


Fig. 1

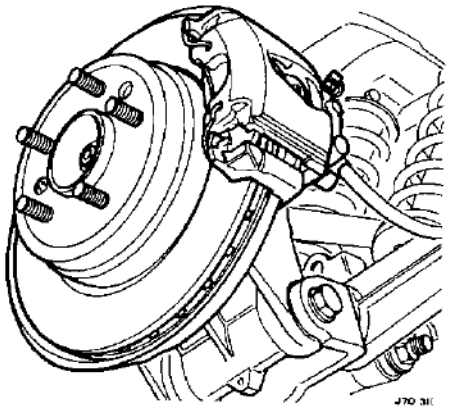


Fig. 2

The rear brake caliper (1 Fig. 1) is mounted on the carrier (2 Fig.1) by means of two guiding pins (3 Fig. 1) and a caliper retaining clip (5 Fig. 1). The guiding pins slide in bushes (4 Fig. 1) fitted to the caliper.

Note: The guiding pins are fitted with dust caps which must be fitted when reassembling the caliper.

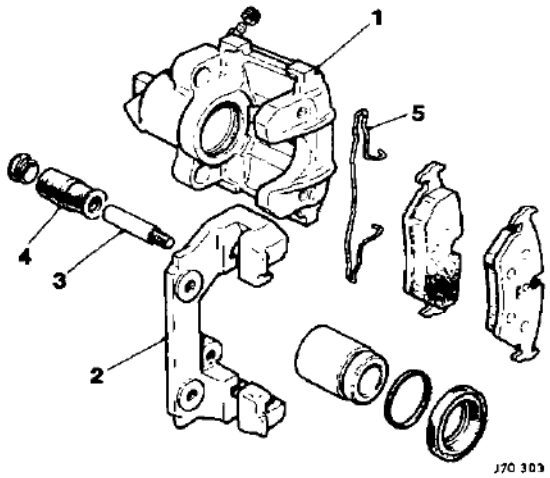


Fig. 1

Wheel speed sensors

Speedsensors are provided for each road wheel. The front sensors (1 Fig. 2) are mounted on the vertical link, while the rear sensors (1 Fig.3) are mounted on the hubcarrier. A toothed wheel, which turns with the road wheel, induces an a.c. voltage signal in the sensor. The frequency and amplitude of the a.c. voltage varies directly in relation to wheel speed, providing the control module with wheel speed information to give a comparison between the speed of each individual wheel, controlling braking as necessary.

Each sensor is monitored for open and short circuit failure, causing ABS control to be disabled on detection of a fault condition. ABS is also disabled should any sensed speed in excess of 330 km / h (205 mile / h) be detected. Similarly, ABS control is inhibited (switched off until fault condition is cleared) at speeds up to 40 km / h (25 mile / h) when frequency fluctuations are detected that are inconsistent with wheel rotation. At speeds above 40 krn / h (25 mile / h), ABS control is disabled when inconsistencies are detected.

The sensor coil has a resistance value of 1100Ω and has a voltage of 2.5V present on each connecting pin when the vehicle is stationary.

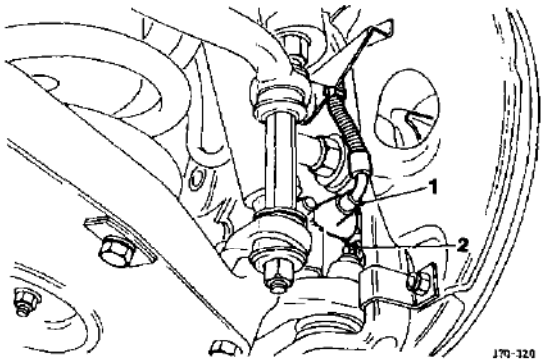


Fig. 2

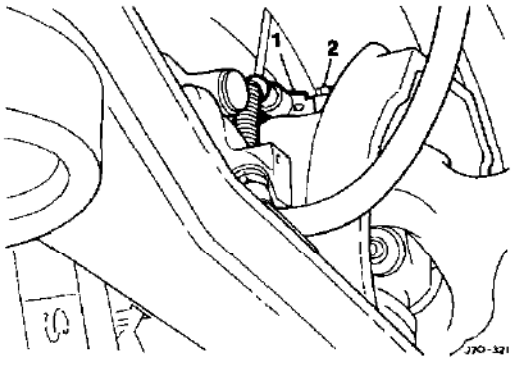


Fig. 3

Handbrake

The handbrake comprises drum brakes on each rearwheel, cable operated by the handbrake lever which is located betweenthe driver's seat and the inner sill.

When the handbrake lever is operated, the cable system applies equal force to both RH and LH brake shoe expander assemblies. The brake shoes expand and press against the hub assembly, locking the rear wheels.

The handbrakeswitch latcheswhenthe lever is operated and lights the handbrake warning indicator mounted on the instnument panel.

The drum brakes are of the duo–servo type. The expander assembly 16 Fig. 1) is mounted on the backplate mounting lug. The brake shoes locate on the expander assembly and the adjuster (1 Fig. 1). These are held in position by the upper and lower return springs (4 and 5 Fig. 1) and the hold–down springs (2 Fig. 1). The adjuster allows manual adjustment of the brake shoes.

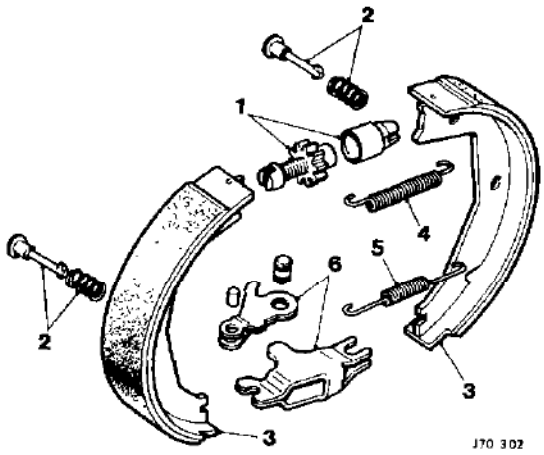


Fig. 1

ANTI–LOCK BRAKING SYSTEM

OPERATION

The wheel speed sensors, fitted to all four road wheels, transmit wheel speed information to the control module. The module uses this information to modulate brake pressure during anti–lock braking.

Brake pedal force is increased by the vacuum booster which activates the Tandem Master Cylinder (TMC) intermediate piston. Brake fluid is supplied to the pump inlet ports on two separate circuits. The primary circuit supplies the front brakes whilst the secondary circuit supplies the rear brakes.

The rear wheels are controlled collectively on a 'select–low' principle during ABS operation. This means that if locking in either rear wheel is detected, controlled brake pressure is applied to both wheels.

A pressure conscious reduction valve (PCRV) is fitted between the outlet of the valve block and the rear brake circuit. The valve is fitted to prevent over–braking at the rear wheels. Up to a threshold of 25 bar (363 lbf / in^2), brake pressure to the front and rear brakes is equal. Above this threshold, the PCRV reduces pressure to the rear brakes to provide a closer balance between front and rear brakes and optimize road adhesion.

Hydraulic operation

Referring to the Hydraulic System Schematic Diagram, the TMC primary circuit (item 1) applies brake pressure to the front brakes. Individual control of the front wheels is provided by solenoid valves. One pair of valves (items 15 and 18) controls the front left brake circuit (item 21) and another pair of valves (items 16 and 19) controls the front right brake circuit (item 22). The TMC secondary circuit (item 2) applies brake pressure to the rear brake circuit (item 20) via valves (items 14 and 17), on a 'select low' principle.

Should the ABS be initiated by a locking tendency of any wheel during braking, the pump unit (item 8) is started and the appropriate NO inlet valve (item 14, 15 or 16) closes in response to signals from the control module. This action prevents further increase of brake pressure by blocking the supply of brake fluid from the TMC (item 3). If excessive deceleration continues, the appropriate NC outlet valve (item 17, 18 or 19) opens, releasing brake pressure to the low pressure accumulators (item 9) until the wheel accelerates again.

From the low pressure accumulators, volume is pumped back into the TMC, forcing the brake pedal back. To optimize the friction coefficient between tyre and road surface, brake pressure is increased in small steps by closing the outlet valve and opening the inlet valve and recharging brake pressure.

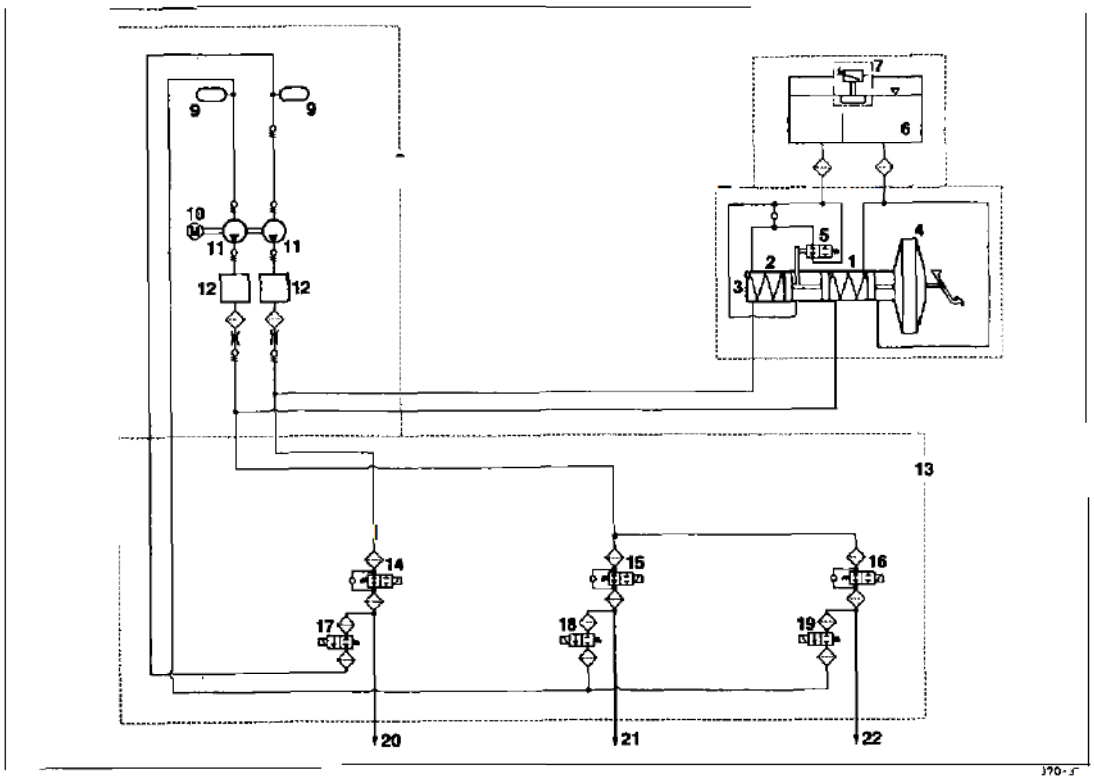
During the pressure build–up phase, the volume required for replenishment is supplied by the TMC and additionally by the pump from the low pressure accumulators. Since the delivered flow is generally greater than volume flow drained from the brake circuits, the low pressure accumulators serve as intermediate accumulators to compensate for temporary volume flow peaks.

The TMC piston positibns, and therefore the brake pedal, vary with the fluid displacement in the brake caliper. As controlled pressure in the brake caliper decreases and increases during ABS, the brake pedal 'cycles', informing the driver that controlled braking is in progress.

Actuation of the brake pedal, causes the central valve (item 5) in the TMC to close. This action prevents damage to the TMC piston seals.

At the end of a brake application, volume is restored to the TMC, at low pressure from the fluid reservoir (item 6).

HYDRAULIC SYSTEM SCHEMATIC DIAGRAM



1. TMC 1 (primary circuit)
2. TMC 2 (secondary circuit)
3. Tandem master cylinder
4. Vacuum booster;
5. Central valve
6. Fluid reservoir
7. Fluid level indicator
8. Pump motor unit
9. Low pressure accumulator
10. Electric pump motor
11. Two circuit hydraulic pump
12. Damping chamber
13. Valve block
14. Inlet valve NO
15. Inlet valve NO
16. Inlet valve NO
17. Outlet valve NC
18. Outlet valve NC
19. Outlet valve NC
20. Rear brake circuit
21. Front brake circuit (left)
22. Front brake circuit (right)

ANTI–LOCK BRAKING SYSTEM

FAULT DIAGNOSIS

rouble	Cause	Remedy
ong brake pedal	Brake caliper piston(s) or caliper guide pins (rear only) sticking	Service or renew caliper or caliper guide pins (rear only)
	Norn/damaged brake pads	Renew brake pads
'ibration during braking		
	Loose caliper mounting bolts	Tighten caliper mounting bolts
	Insufficient grease on sliding parts	Apply grease where necessary
	Foreign material or scratches on brake disc contact surface	Clean brake disc contact surface
	Damaged brake disc contact surface	Renew brake disc
'oor braking performance	Leak in hydraulic system	Repair leak. Check all pipework connections. Refill and bleed the system
	Air in hydraulic system	Check for leaks and bleed the system
	Worn / damaged brake pads	Renew brake pads
	Foreign material on brake pads	Examine brake pads and clean or renew as necessary
	Brake caliper piston malfunction	Renew faulty brake caliper piston
	Tandem master cylinder malfunction	Service or renew tandem master cylinder
	Vacuum booster fault	Renew vacuum booster
	Disconnected or damaged vacuum hose	Renew vacuum hose
	Low brake fluid level	Check for leaks, refill and bleed the system
Irakes pull to one side	Worn / damaged brake pads	Renew brake pads
	Foreign material on brake pad	Examine brake pads and clean or renew as necessary
	Failing valves in ABS valve block	Renew hydraulic control module
	Abnormal wear or distortion on front brake disc	Examine front brake disc and service or renew as necessary
	Incorrect wheel alignment	Carry out wheel alignment
	Incorrect tyre pressure	Inflate tyre to correct pressure
3rakes do not release	No brake pedal free play	Adjust brake pedal free play
	Vacuum booster binding	Renew vacuum booster
	Tandem master cylinder return port faulty	Clean return port on tandem master cylinder
	Faulty valve in ABS valve block	Renew hydraulic control module

rouble	Cause	Remedy
xcessive pedal travel	Leak in hydraulic system	Repair leak. Check all pipework connections. Refill and bleed he system
	Air in hydraulic system	:heck for leaks and bleed the system
	Worn tandem master cylinder piston seals or scored cylinder bore	Renew tandem master cylinder
	'Knock back'. Excessive brake disc run-out or loose wheel bearings	:heck brake disc run–out and 'enew as necessary. Adjust wheel bearing
rakes grab	Brake pads contaminated by grease or brake fluid	Renew brake pads. Check pipework for leaks
	Brake pads distorted, cracked or loose	Renew brake pads
	Loose caliper mounting bolts or guide pins (rear only)	Check caliper and repair / renew as necessary
rakes drag	Seized or incorrectly adjusted handbrake or cable	ixamine handbrake and repair/ 'enew as necessary
	Broken or weak handbrake return springs	Renew handbrake return springs
	Caliper piston(s) seized	Examine calipers and repair / renew as necessary
	Brake pedal binding at pivot points	Examine brake pedal bushings and repair / renew as necessary
	Vacuum booster binding	Renew vacuum booster
	Tandem master cylinder faulty	Examine tandem master cylinder and repair / renew as necessary
lard brake pedal when pressed	Lack of vacuum at the vacuum booster	Check vacuum hose. Repair or renew as necessary
	Tandem master cylinder push–rod binding	Renew tandem master cylinder
	Frozen tandem master cylinder piston	Renew tandem master cylinder
	Brake caliper piston or caliper guide pins (rear only) seized	Examine caliper and renew / repair as necessary
:xcessive brake noise	Worn brake pads	Renew brake pads
	Bent or cracked handbrake shoes	Renew handbrake shoes
	Foreign objects in brake pads or handbrake shoes	Examine brake pads and handbrake shoes. Clean or renew as necessary
	Broken / loose handbrake hold–down springs or return springs	Examine handbrake assembly. Repair or renew as necessary
	Loose caliper mounting bolts	Torque–tighten caliper mounting bolts

SYSTEM FAULT INDICATIONS

Fault indication:

ABS warning indicator still illuminated after ignition switch on and ABS CM self test.

Possible causes

1. Fuses blown
2. Faulty wheel speed sensor or harness
3. Faulty wiring
4. Faulty ABS CM.

Fault diagnosis

Note: After a fault has been successfully diagnosed and corrected, the ABS warning indicator will remain lit until the fault codes have been cleared from the non–volatile memory. This can be done by using Jaguar Diagnostic Equipment or, alternatively, by driving the vehicle to a speed above 20 km / h (12.5 mile / h). If the indicator remains on after this procedure, repeat fault diagnosis.

1. Check the fuses (F11 & F22) in the battery feed lines and fuse (F10) in the ignition line. The fuses are located in the left and right–hand scuttle fuse boxes
2. Unbolt the 28–way multi–plug connector from the ABS CM
3. Measure the resistance across each wheel speed sensor. The value should be 1100 Ω, ± 50%. If not, unplug the sensor lflying lead and measure again. If the value is now within range, inspect the harness between ABS CM and sensor, otherwise renew the sensor
4. Check continuity to ground from ABS CM harness connections 13 and 14. If the value is much greater than 0.1 Ω, renew the harness
5. Measure the voltage between ABS CM harness connection 14 and connections 1 and 2 respectively. If the value is not approximately equal to battery voltage, renew the harness
6. With the ignition switch ON, measure the voltage between ABS CM harness connections 14 and 15. If the value is not approximately equal to battery voltage, renew the harness.

Renew the ABS CM if the fault has not been located after carrying out the above procedures.

Fault indication:

ABS warning indicator illuminates at 20 km / h (12.5 mile / h).

Possible causes

1. Fuses blown
2. Faulty hydraulic control module pump / motor unit or circuitry
3. Faulty ABS CM.

Fault diagnosis

1. Check fuses
2. Disconnect the pump / motor unit and measure the resistance across the two pin connector. The measured value should be in the region of 0.8 Ω. Renew the complete hvdraulic control module if the measured value indicates excessive resistance or a short circuit
3. Unbolt the 28–way connector from the ABS CM and measure the voltage between harness connections 1 and 14. If the value is not approximately equal to battery voltage, renew the harness.

Renew the ABS CM if the fault has not been located after carrying out the above procedures.

Fault indication:

ABS warning indicator illuminates on 'pull–away' or during driving.

Possible causes

1. Faulty sensor or wiring
2. Faulty brake disc or wheel bearing installation giving inconsistent signals to the ABS CM.

Fault diagnosis

Check sensor installation for:

1. Security of sensor lead fixing bolt
2. Damage to sensor lead
3. Possible damage to brake disc
4. Excessive play in wheel bearing
5. Intermittent faults caused by poor harness connection or damage.

Pin–point tests

Wheel sensor

Testing between pins of the 28–way multi–plug connector, check that the resistance of each sensor coil is 1100 Ω, ± 50%.

Note: See Control Module Connections for the ABS CM wheel sensor connector references.

Hydraulic pomp motor

Disconnect the pump motor bi–pin connector and checkthat the resistance of the motorwinding is approximately 0.8 Ω.

Stored fault codes

The following fault codes are stored automatically within the ABS CM and may be accessed, as an aid to fault diagnosis, using Jaguar Diagnostic Equipment.

Code	Fault	*Comment*
5242h	Outlet valve, rear	
5250h	Inlet valve, rear	
5120h	Outlet valve, front right	
5214h	Inlet valve, front right	
5194h	Outlet valve, front left	
5198h	Inlet valve, front left	
5168h	Sensor, rear right	Sensor failure recognized by monitoring of d.c. voltage with vehicle stationary
5178h	Sensor, rear left	
5148h	Sensor front right	
5158h	Sensor, front left	
5165h	Sensor, rear right	Sensor failure recognized by monitoring of wheel speed continuity
5175h	Sensor, rear left	
5145h	Sensor, front right	
5155h	Sensor, front left	
5260h	Sensor, rear right	Sensor failure recognized by wheel **speed** comparison
5261h	Sensor, rear left	
5259h	Sensor, front right	
5258h	Sensor, front left	
5235h	Sensor, rear right	Sensor failure recognized by long term detection of missing sensor signal
5236h	Sensor, rear left	
5234h	Sensor, front right	
5233h	Sensor, front left	
9317h	Over-voltage	
9342h	CPU failure	
5095h	Pump motor	
5267h	Disturbance detection	