The hydraulic system of the Citroën DS explained.

Adapted & edited by Charles Vyse

from the original brief: "Citroën D Models - Hydraulic Course Notes" .

'Snoopy' on tour in the Scottish Highlands, May 2002.

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'Snoopy', the author's 1966 DS 21, coming back together after a lengthy restoration.

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Overview

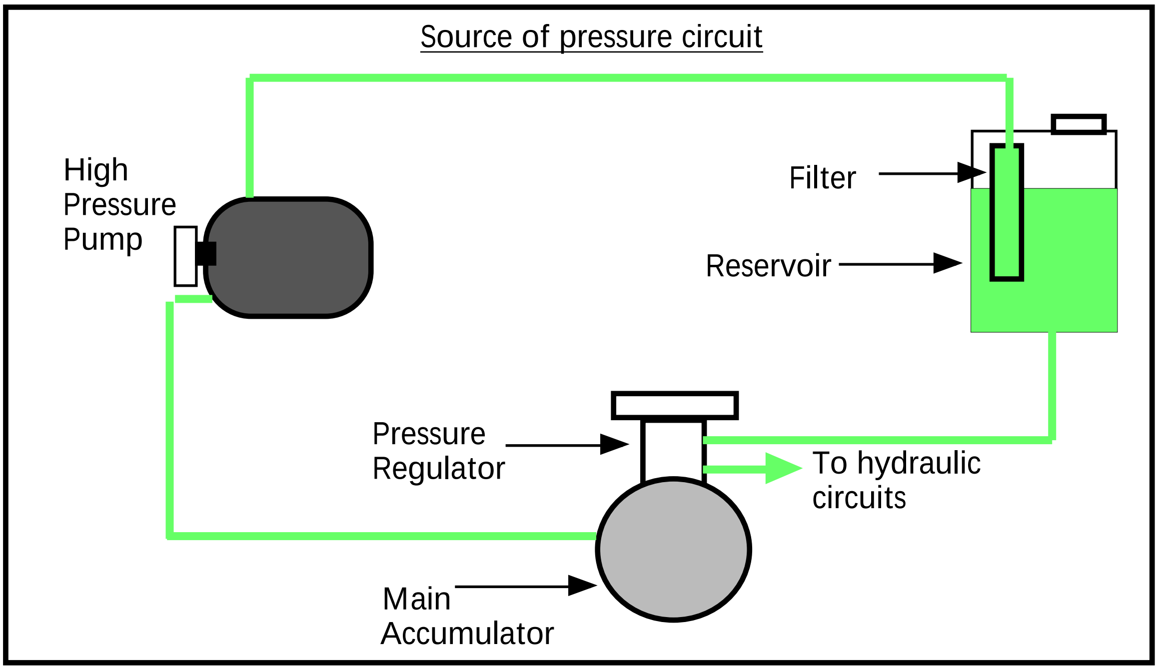
The DS hydraulic system by 1967 had been developed and refined into an extremely efficient and reliable system. In service, the main problems that will be encountered are likely to be fluid leaks and low pressure spheres. The 6 spheres to be found on this model (4 suspension, 1 accumulator, 1 brake) should be removed and repressurised with Nitrogen every 3 years irrespective of mileage covered. It is also a good idea to check the synthetic rubber diaphragms within the spheres. At the same time as sphere repressurising, the fine filter within the hydraulic reservoir should be removed and cleaned in petrol and the LHM fluid changed.

Fluid leaks, other than the obvious; such as a rusted or burst pipe, will almost always be caused by a perished or split rubber gaiter on the low pressure return side. Pipe connections on the high pressure side are designed to be self sealing as pressure builds. Whenever a high pressure pipe connection is remade, *always* replace the rubber seal and tighten the gland nut with moderate force only. The fluid used in the system is LHM, which is essentially a light green mineral oil of SAE 20 viscosity. Throughout the whole hydraulic system, all the rams and valves are designed to leak under pressure. This leakage is collected in rubber gaiters and plastic pipes and returned to the main hydraulic reservoir; if you look underneath the reservoir you will see the cluster of return pipes plumbed into the bottom of the container. This controlled leakage continuously lubricates the whole system under pressure, in exactly the same way as the hydraulic systems used on aircraft, tractors, earth movers etc. and it is just as inherently reliable.

Source of hydraulic pressure

The units comprising the source of pressure are as follows :

* *The LHM hydraulic reservoir.*
* *The high pressure pump.*
* *The high pressure regulator.*
* *The main pressure accumulator.*

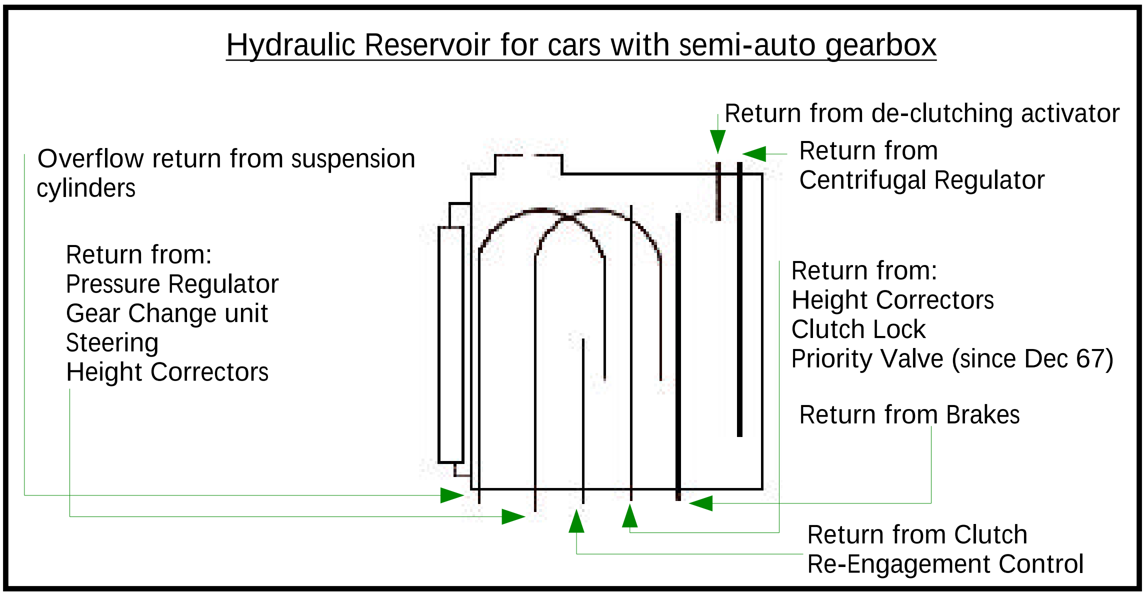


To ensure the correct operation of all hydraulic units, a minimum pressure must be maintained in the supply circuits. To avoid making the pump stop and start for each demand of hydraulic pressure, a certain amount of LHM is stored at a higher pressure than the minimum operating pressure. As long as pressure exists above the minimum operating pressure in the main accumulator, then the pump draws LHM from the reservoir and returns it without generating any pressure; the pump is operating in rest mode. The reserve of pressure is maintained in the main accumulator. The maximum and minimum pressures are controlled by the pressure-regulator which causes the flow of LHM from the pump, to be directed to : either the main accumulator (pumping under pressure) - or the reservoir, (pumping without pressure).

The hydraulic reservoir

This is a drum container mounted on the front nearside of the engine bay and has an external sight tube showing “Max” and “Min” LHM levels.

The reservoir has an internal anti-surge baffle to allow LHM returning to the tank to settle and deaerate before being delivered back to the pump. It is vented to atmosphere by a small hole in the filler cap, which must be kept clear. A rubber pipe is connected to the base of the reservoir and is brought back to the top and held by a clip. This pipe is for draining the reservoir. The feed to the hydraulic pump, is via an internal fine nylon mesh filter, accessible for cleaning by unclipping the delivery pipe from the top of the LHM reservoir.



Reading the hydraulic LHM level

It is essential that this is checked with the engine running, the manual height control lever set in the high position and wait for the car to reach maximum height before checking the level.

Repair practice

Cleanliness

To function properly, the hydraulic circuits on these cars require absolute cleanliness of the LHM hydraulic fluid and units. Before any work is carried out, protectors must be put in place. Before dismantling**,** clean the unions and pipe ends to be disconnected using petrol. After dismantling, plug all metal pipe ends and apertures in units with plastic plugs. Protect the flange unions of pipe assemblies and any open pipes with self adhesive tape.

Hydraulic Fluid

Since September 1966 all DS models use LHM. This fluid is green in colour and is of mineral origin. The ‘DS’ hydraulic reservoir contains 6 litres or 10.5 imperial pints of LHM and the ‘ID’ 5 litres or 8.8 imperial pints. The difference between the Max and Min mark on the reservoir sight tube is one litre or 1.75 imperial pints. The system should be drained and refilled with fresh fluid every 18,000 miles or every three years; whichever occurs first. Drain the reservoir after causing the greatest possible amount of fluid to return to the reservoir, by putting the suspension in low and pumping the brakes to empty the main and brake accumulators. The filter in the main reservoir must be thoroughly cleaned every 6,000 miles; a clogged filter leads to inefficiency of the hydraulic system. The filter should be cleaned in white spirit or petrol on LHM cars, and then blown through with compressed air. In an emergency situation, SAE 20 engine oil may be used in the hydraulic system. The system should be flushed and refilled with LHM at the earliest opportunity.

Cleanliness of the fluid

Never re use LHM that has been in service. Clean the filter and flush and change the LHM in the main reservoir every three years, irrespective of mileage.

Metal piping

There are two sizes of metal pipe, that carries pressurised LHM - 4.5 mm external diameter and 6.35 mm external diameter. Factory made pipes which have been pressure tested are marked with a coloured sleeve, Red for LHS 2 systems, and Green for LHM.

Plastic piping

Plastic Piping is used for seepage returns - suspension cylinder returns, height corrector returns etc. It is permissible to repair these pipes by sleeving, providing that a pipe does not have more than two sleeves which must be at least 800mm apart. The sleeve must be glued and when the glue has hardened the joint so made, must withstand 5 kg/cm2 (72 psi) pressure from a compressed air line.

Rubber piping

Rubber piping is used for the operational returns from hydraulic units, the supply from the reservoir to the High Pressure Pump, and some seepage returns. All these pipes are marked Red or Green in accordance with the fluid which they are to be used, LHS 2 or LHM respectively. Any replacement pipe for the LHM system must be mineral oil resistant.

Storage of hydraulic units

Units should be stored full of fluid, firmly plugged and protected from dust. Rubber seals and pipes must be stored away from dust, sunlight, and heat.

Sealing methods

Sealing by metal clip. This method of sealing is used to secure rubber pipes onto steel and plastic pipes and unions. When fitting; place a rubber protective ring under the clip and take care not to cut the end of the pipe.

Rubber Sleeve Seals

These seals ensure the sealing of steel pipes fitted to hydraulic units. Sealing is achieved by the deformation of the sleeve under the action of tightening the gland nut. The seals must be replaced every time a pipe is disconnected. Remove the old seal by screwing a Philips screw into the rubber and pulling on it with pliers. Clean the bore before rebuilding. Always fit the new seal to the pipe dry, so that about 2 mm of the pipe projects through the seal. Centralise the pipe in the bore of the unit and ensure that the pipe goes fully home. The swelling near the end of the pipe holds the seal in place. Start the union nut by hand and tighten moderately (1 mkg) (15 ft lbs).

Ring seals

Sealing is ensured by the deformation of the seal under the influence of the fluid under pressure. In order that the pressure may achieve this, the diameter of the ring is less than the width of the groove and greater than its depth. Three types of ring seals are employed:

- *Marked Red for LHS 2*
- *Marked Green for LHM*
- *Marked White for either.*

Seals with White markings should only be used between static components. Any marking on a seal must always face in the direction from which the pressure is coming. Additionally, the seals must be soaked in the appropriate fluid before fitting.

Sealing Plates

These are found at flange joints between pipes and units. When fitting, ensure that the holes in the plate correspond with those in the flange. The seals are marked with White and are fitted to vehicles using either type of fluid. They must be replaced at each dismantling.

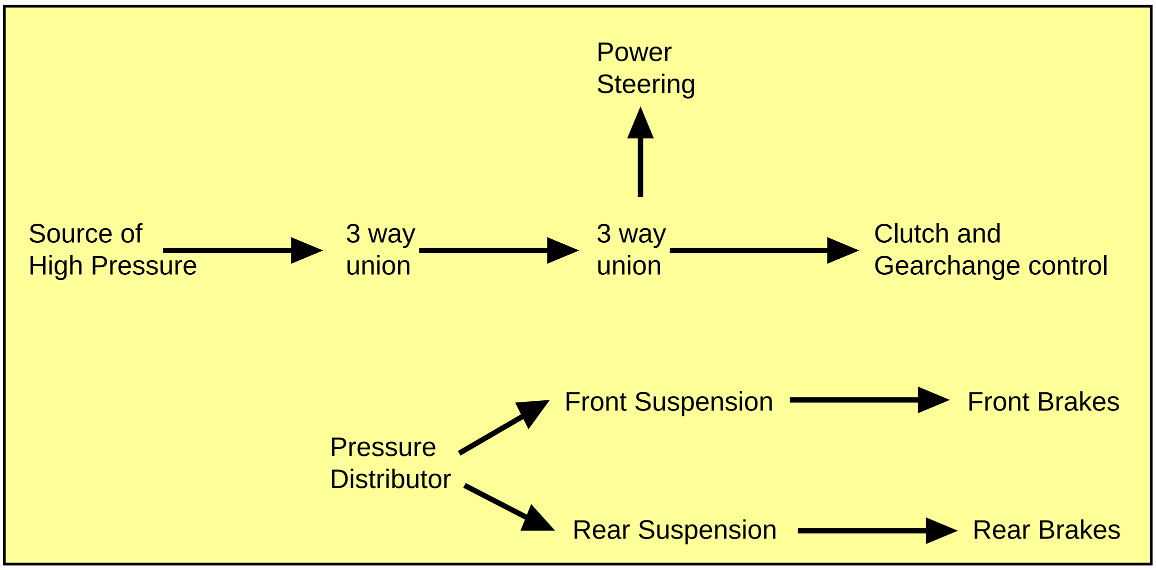
Teflon Seals

These ensure sealing of items subject to large or frequent movements, such as the hydraulic steering-rack piston and the suspension cylinders. Teflon seals may be used with either type of fluid.

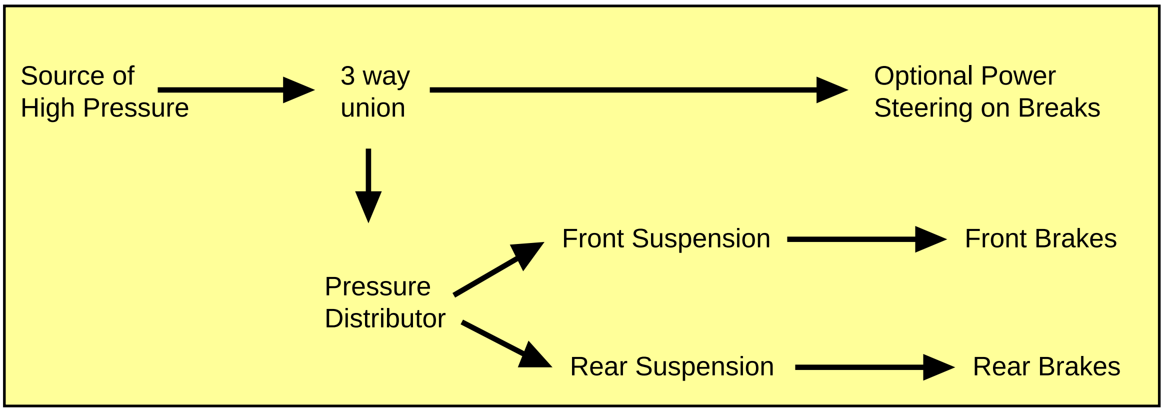
General layout of hydraulic systems

All of these vehicles have a circuit defined as 'Source of Pressure', comprising a high pressure hydraulic pump, a Pressure Regulator and an hydraulic accumulator (sphere).

DS 19 A (DY) AND *DS 21 (DX) Both until December 1967*

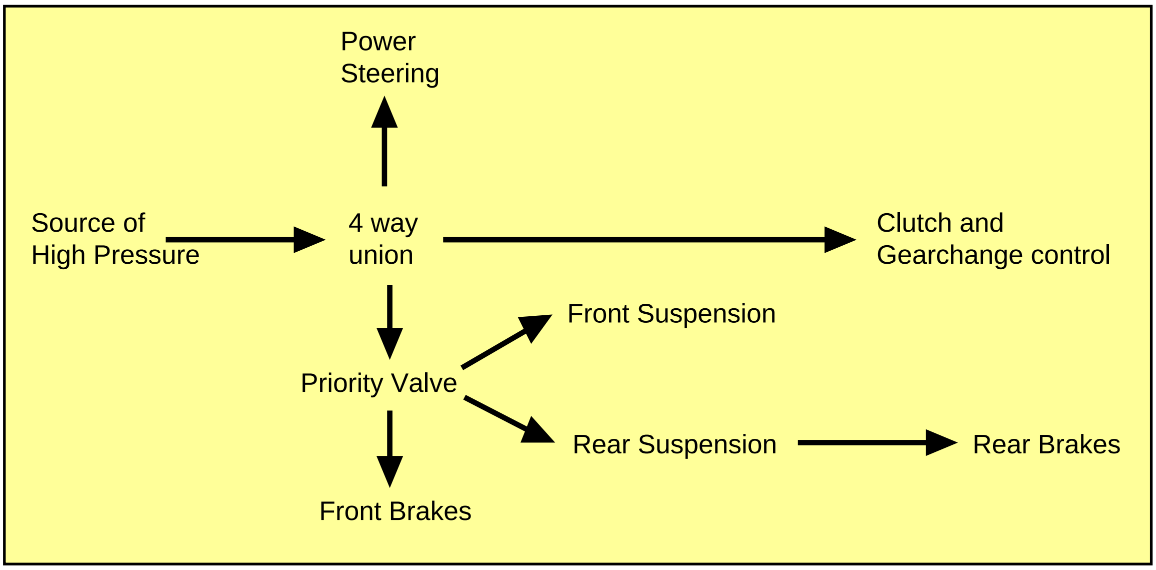


DS 19 MA (DL) & 19/21 Breaks (DJF) (DLF) AND *DS 21 M (DJ)*



DS 19A (DY) & DS 21 (DX) & (DY) Both since December 1967

19A/20/21 Breaks (DYF) (DYF) (DXF)



DS 19MA (DL) & DS 21M (DJ) & (DY) Both since December 1967 AND *DS 20 M (DL)*

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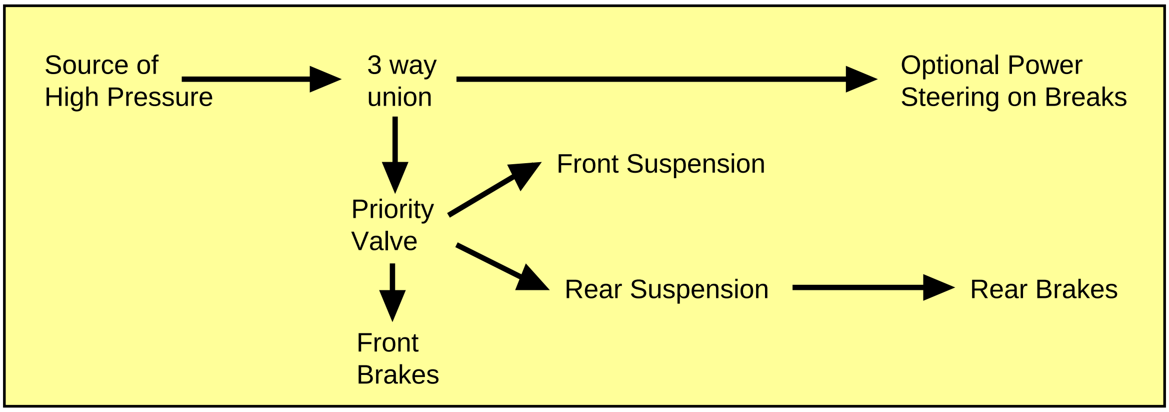
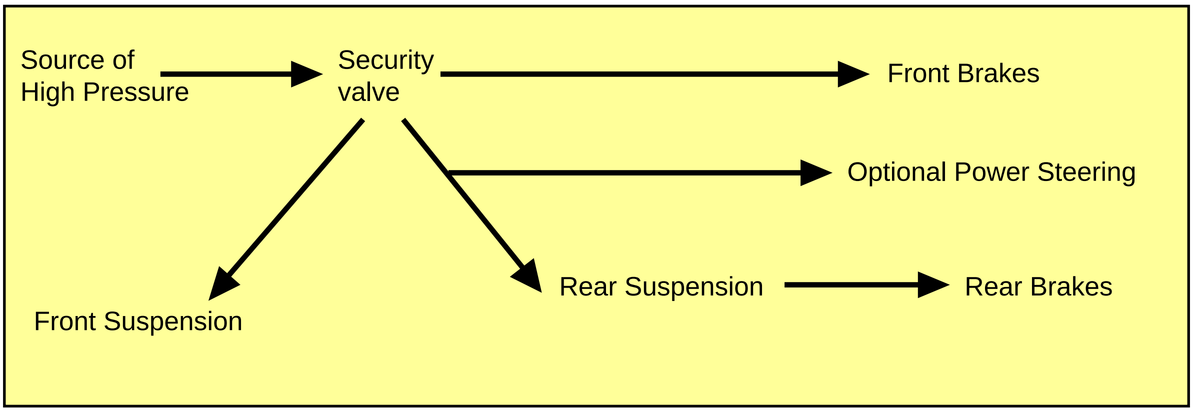
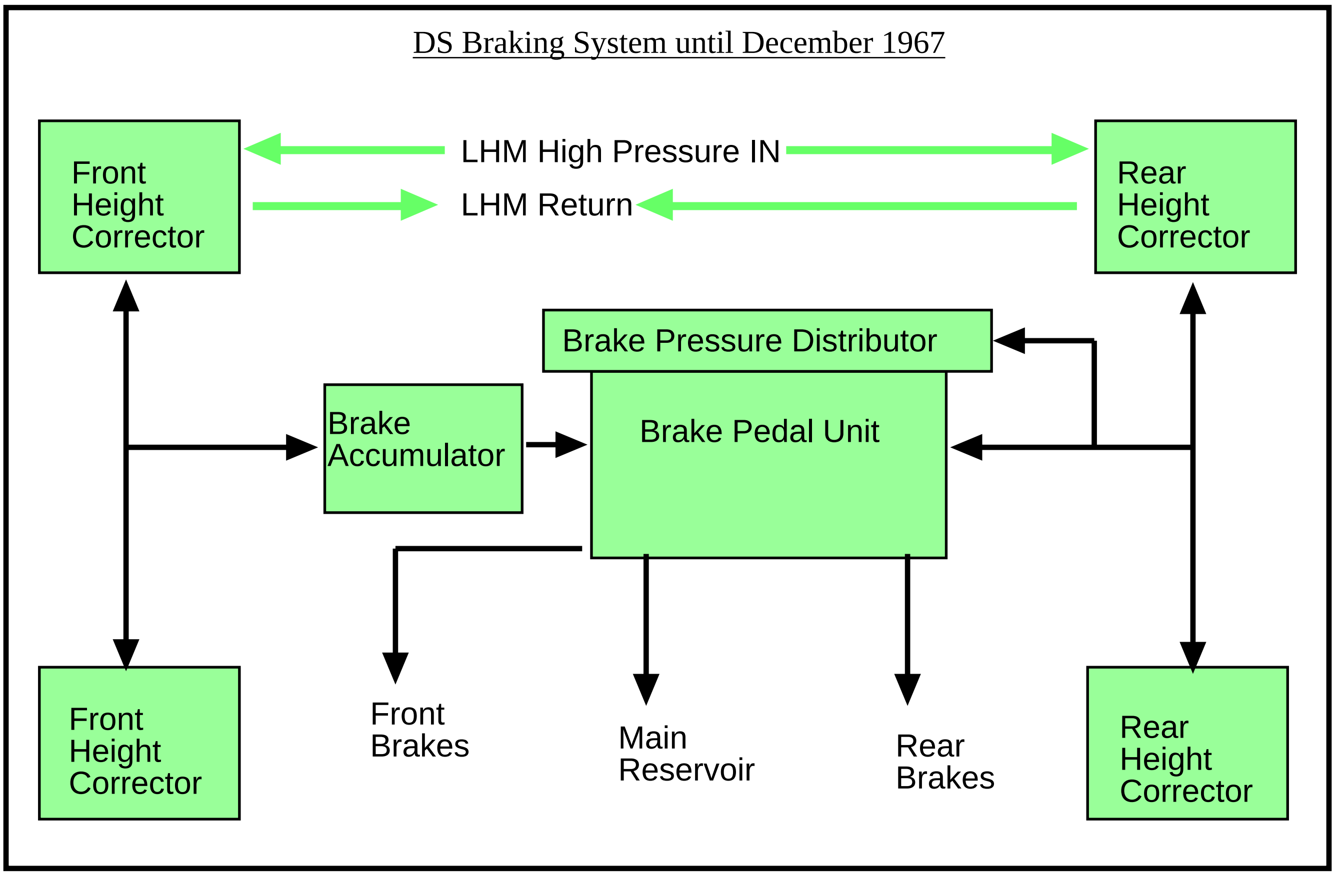


ID 19B (DV) & ID 20 (DT)



Braking Systems

All 'D' models are fitted with disc brakes at the front and drums at the rear, both of which operate off of the High Pressure hydraulic system. The braking systems for the ID model and the DS model are similar, but different. The front and rear brake circuits are separate and brake failure in one circuit, will not affect the other. The rear brakes are fed from the rear suspension; this design feature allows the maximum pressure in the rear brake circuit to be limited, to suit the load the car is carrying. There is a reserve of pressure available on demand for the front brake circuit; a separate brake pressure accumulator in the case of the DS system, the main accumulator in the case of the ID system.



DS Braking System until December 1967

The DS braking system

Circuit Layout until December 1967

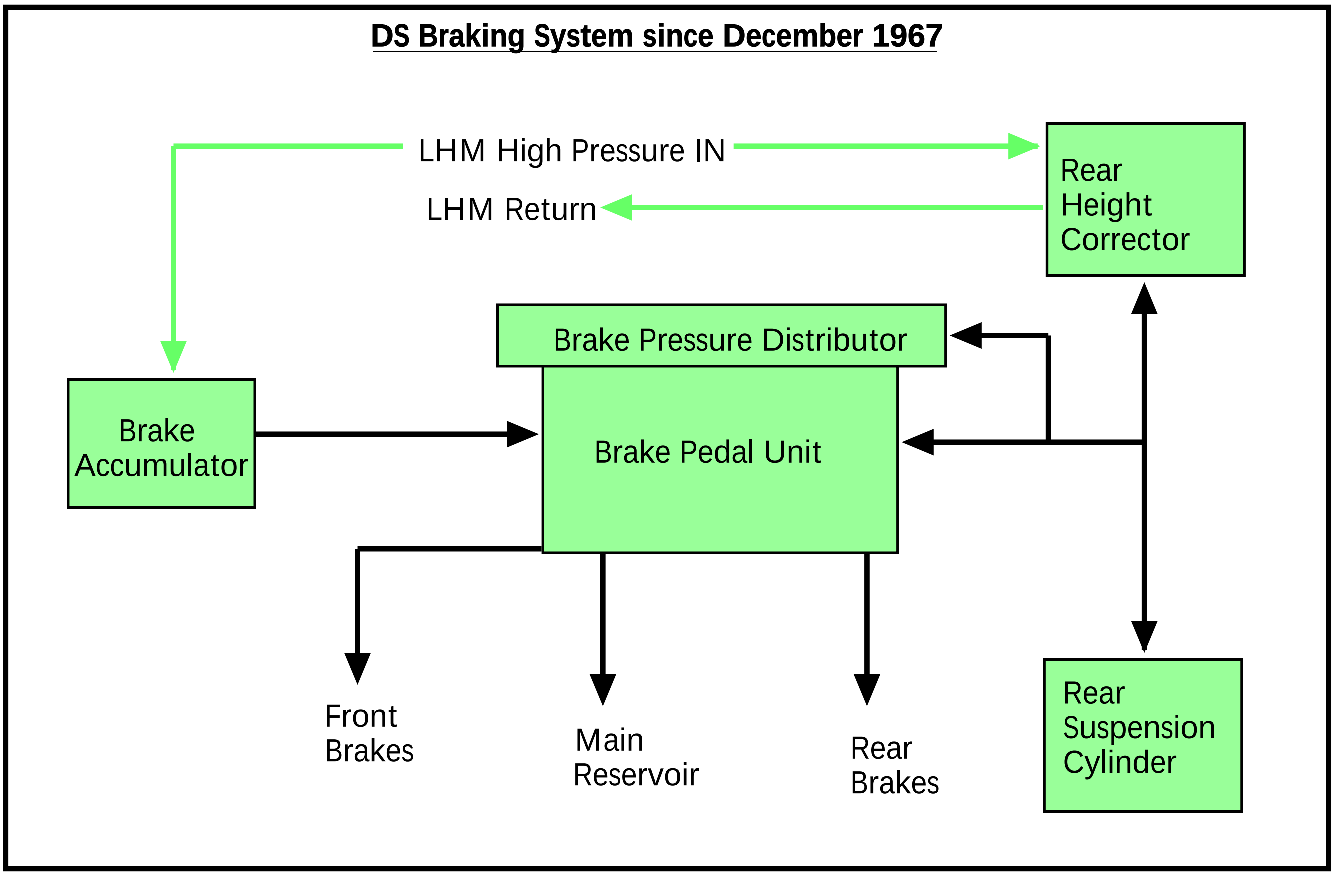
The front brake circuit and the front brake accumulator is fed from the front suspension. The rear brake circuit and the brake pressure distributor piston is fed by the rear suspension. The pressures in the two brake circuits will vary with the load the car is carrying. The available pressure range is:

*   front: 85 - 110 bars 1200-1565 psi

*   rear: 50 - 90 bars 720-1280 psi

Circuit Layout since December 1967

The front brake circuit and the front brake accumulator are fed directly from the source of pressure. The rear brake circuit and the brake pressure distributor piston are fed from the rear suspension.



The Brake Accumulator

The design and operation of the brake accumulator is identical to that of the main accumulator and suspension spheres and is a machined steel forging. It is fed either by fluid from the front suspension or from the main source of pressure. A ball type non-return valve stops fluid escaping back through the feed line. With the engine at rest, or in the event of a failure of the source of pressure, this accumulator provides a reserve of fluid under pressure to enable the vehicle to be stopped. The initial inflation pressure is 40 bars - 570 psi.

The brake pedal gear

This comprises the brake pedal assembly, the hydraulic control valves, the pressure warning light switch and the brake pressure distributor. The brake pedal assembly carries the actual pedal plate which is covered by a rubber moulding and allows a progressive braking action. The hydraulic valve assembly comprises two identical pressure control slide-valves. The slide-valves are connected by a pressure distributor plate. The force on the brake pedal is transmitted to the pressure distributor plate by means of adjustable rollers (A).

The pressure control slide-valves.

When at rest with no residual pressure in the brake circuits, the supply line to the brakes is open to the return to the reservoir. A return spring moves each slide-valve back to the 'at rest' position.

The pressure warning light

This switch senses the pressure in the front brake accumulator and illuminates a large red warning light on the dash, when the pressure falls into the range of 60 to 80 bars (870 to 1160 psi.).

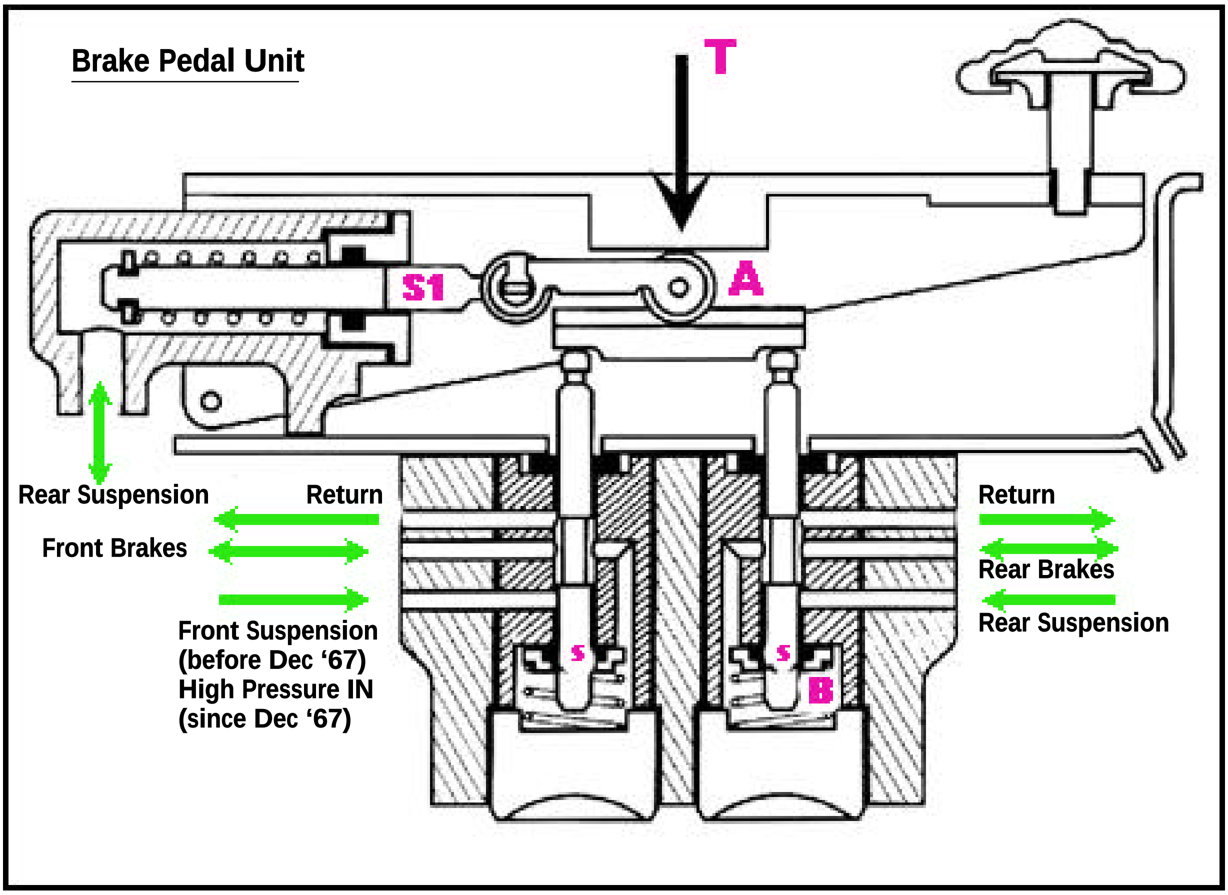
The brake pressure distributor

The cylinder of the brake pressure distributor is fed by fluid from the rear suspension; it is at the rear that the variations of pressure in relation to load are at their greatest. The pressure acts on the surface (S1) of the piston. The piston is connected to the rollers at (A). A spring returns the piston to its rest position.

Operation of the hydraulic control valves

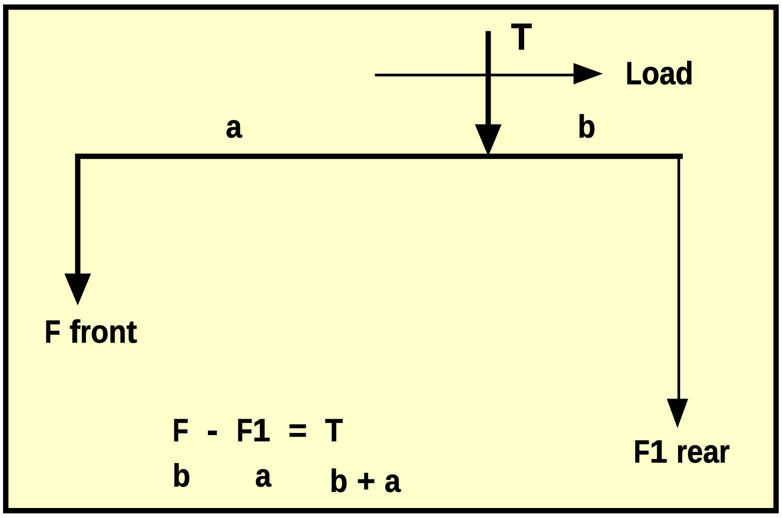
The driver applies the brake. The pressure distributor plate receives the effort (T). The slide valves are moved down, closing the return ports and then opening the inlet ports. This establishes pressure in the front and rear circuits, - p & p1. These pressures act on the undersides of the slide valves (chamber B) providing progressive 'feel' at the pedal. This reaction balances the force (T) - $T = (p + p1)S$

The sum of the two pressures is thus proportional to the force generated by the driver pressing the pedal and is *independent* of the supply pressures. By controlling the force on the pedal, the driver controls the power of the braking.



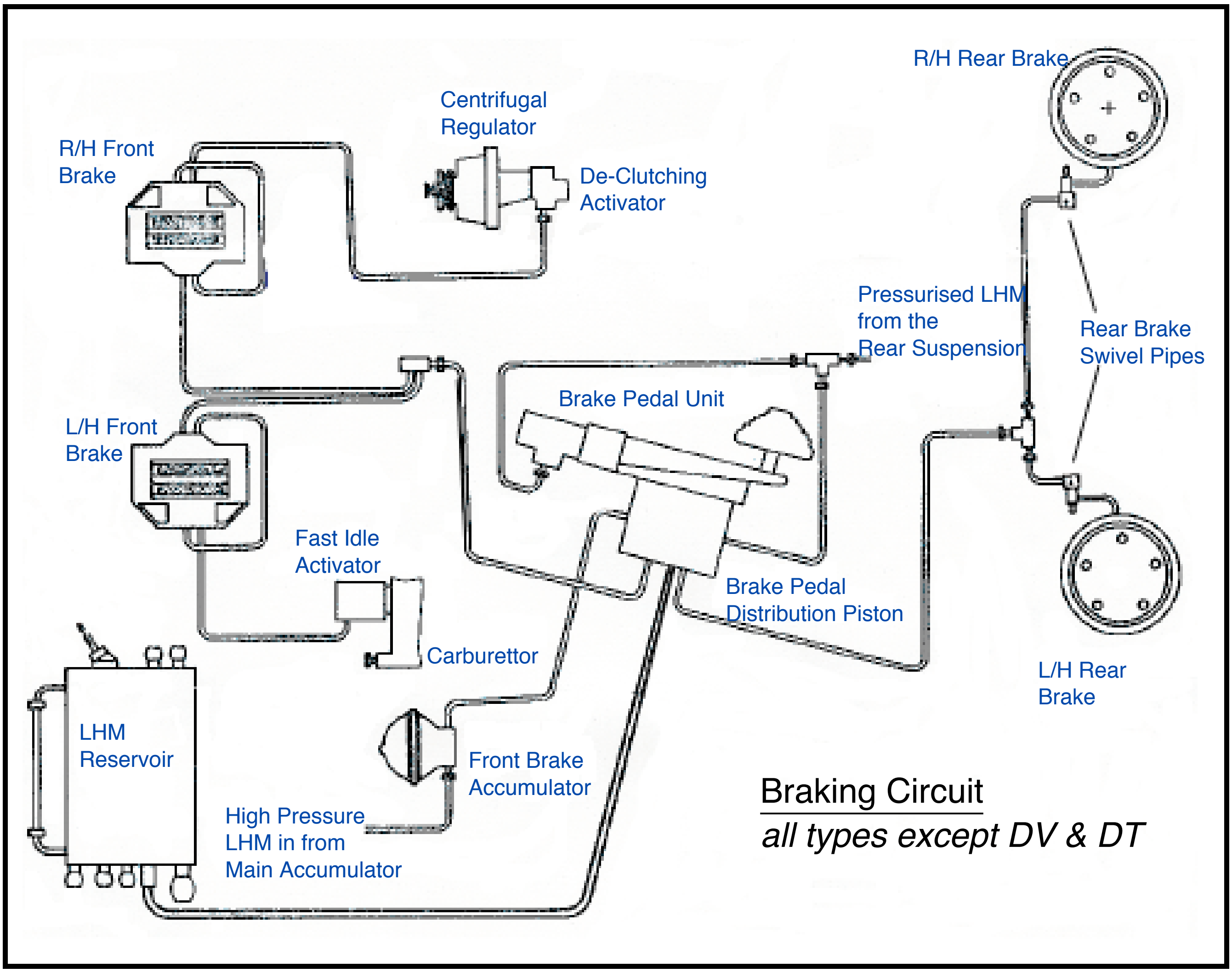
The Brake Pressure Distributor Piston

With a pressure of 60 bars (870 psi), in the Distributor Cylinder, the force (T) is applied to the middle of the Pressure Distributor Plate. The pressures in the front and rear circuits are therefore equal (p — p1). But because of the design of the piston, the braking effort is greater at the front than at the rear.



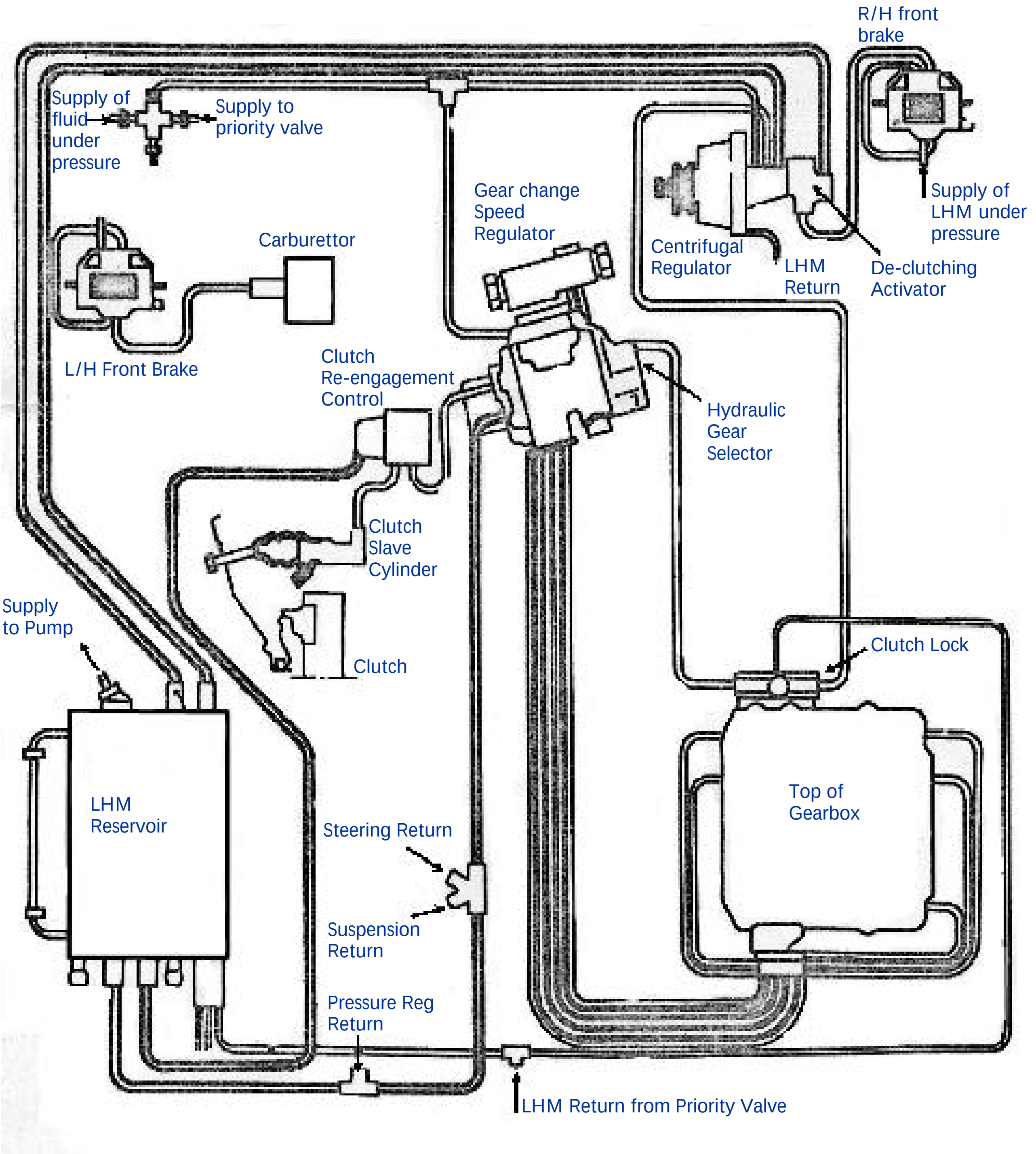
At the front, the diameter of the two pistons in each calliper is 60 mm. At the rear, the diameter of the pistons in the wheel cylinders are 18 mm (saloons) and 20 mm (estates).

If the pressure in the rear suspension increases, the piston in the Pressure Distributor moves the rollers. The pressure point of the rollers and thus of the force (T), moves towards the rear valve. The force F1 being greater than F, the pressure in the rear brake circuit rises (p1 greater than p) and the preponderance of braking effort at the front diminishes.



Braking Circuit
all types except DV & DT

Hydraulic control of Clutch and Gear Change



Overview

The DS has a conventional four speed gearbox and clutch. However there is no clutch pedal and merely a slim wand for changing gear. All clutch and gear changing functions are carried out hydraulically, but under the control of the driver. Citroën called this system BVH (Boite de Vitesses Hydraulique).

Gear selector wand

The hydraulic gear selector ensures de-clutching in neutral, and from neutral allows the engagement of any gear. During the gear change cycle, it controls in the following order

* *de-clutching*
* *disengagement of the gear in mesh*
* *engagement: of the next gear selected*
* *re-engagement of the clutch*

The hydraulic gear selector is mounted on the bulkhead, from which a cluster of 5 pipes (4 forward gears plus reverse) lead to the gear selector rams on top of the gearbox. A further pipe leads to the clutch re-engagement control, which is situated on the inlet manifold. There is also a pipe to the clutch lock on the gearbox and to the centrifugal regulator.

The selector slide valve:

This is hollow and has one inlet port for high pressure LHM and five outlet ports (one for each gear). Longitudinal and circumferential grooves are machined in the slide valve to allow the return of LHM to the reservoir, by way of the front face of the gear selector. (From a gear, for example). In neutral, the outlet ports in the slide valve are opposite a plain part of the sleeve in which it operates. Sealing is maintained by the fine accuracy of the machining of the slide valve and its sleeve; a tolerance of a few microns.

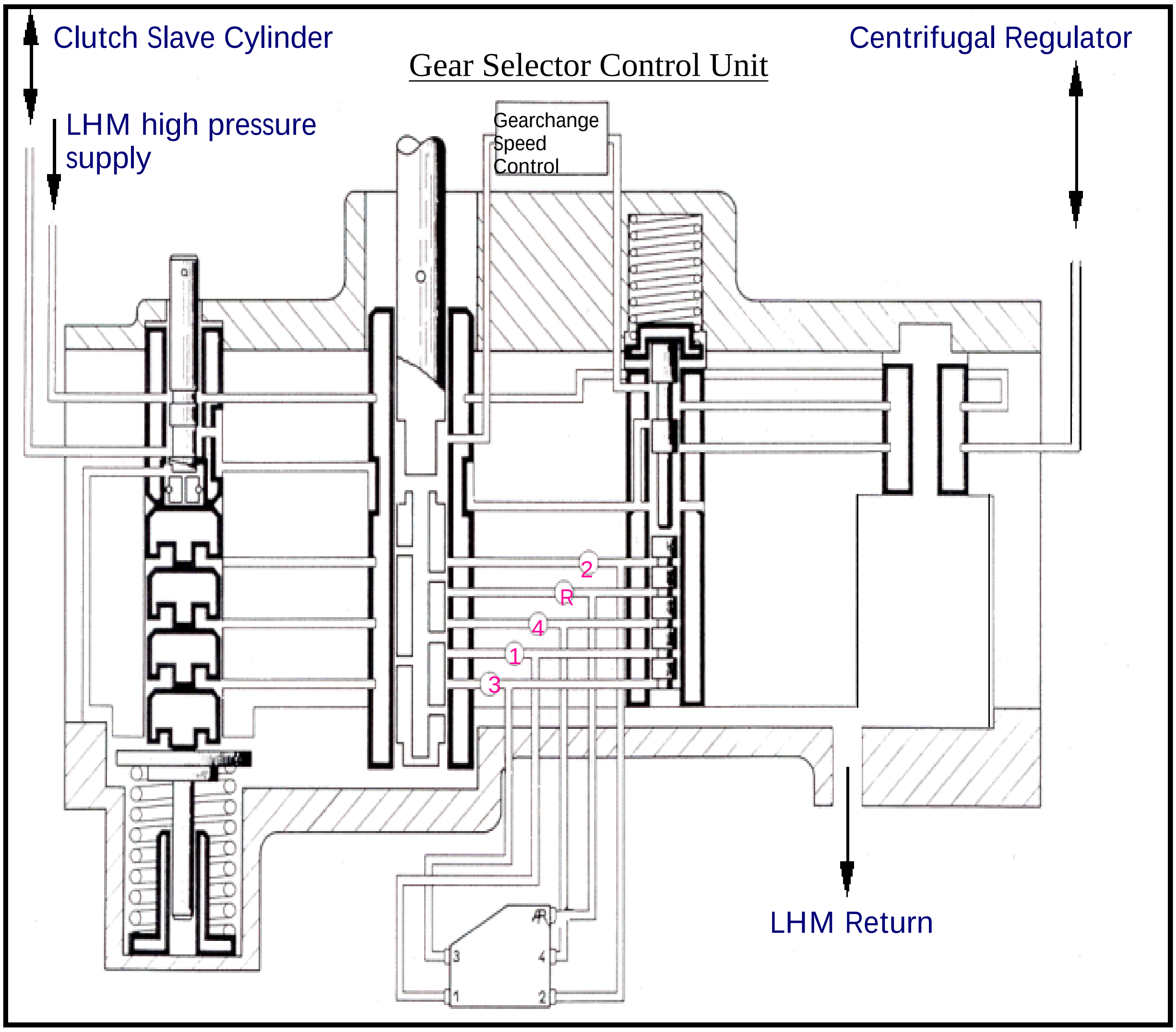
The positioning of the slide valve in its sleeve is very important, and is the object of a very precise setting which corresponds to a given position of the gear lever.

The automatic clutch control pistons:

Five pistons (one for each gear), are able to move upwards in the gear selector when they are pressurised. They return to their initial position by means of the return spring on the automatic clutch control slide valve.

The automatic clutch control slide valve.

There are four synchro-delay pistons; only three of which can move, the fourth being a plug. They are returned to their initial position by two return springs. There is no synchro-delay piston for first gear, although it is synchronised.



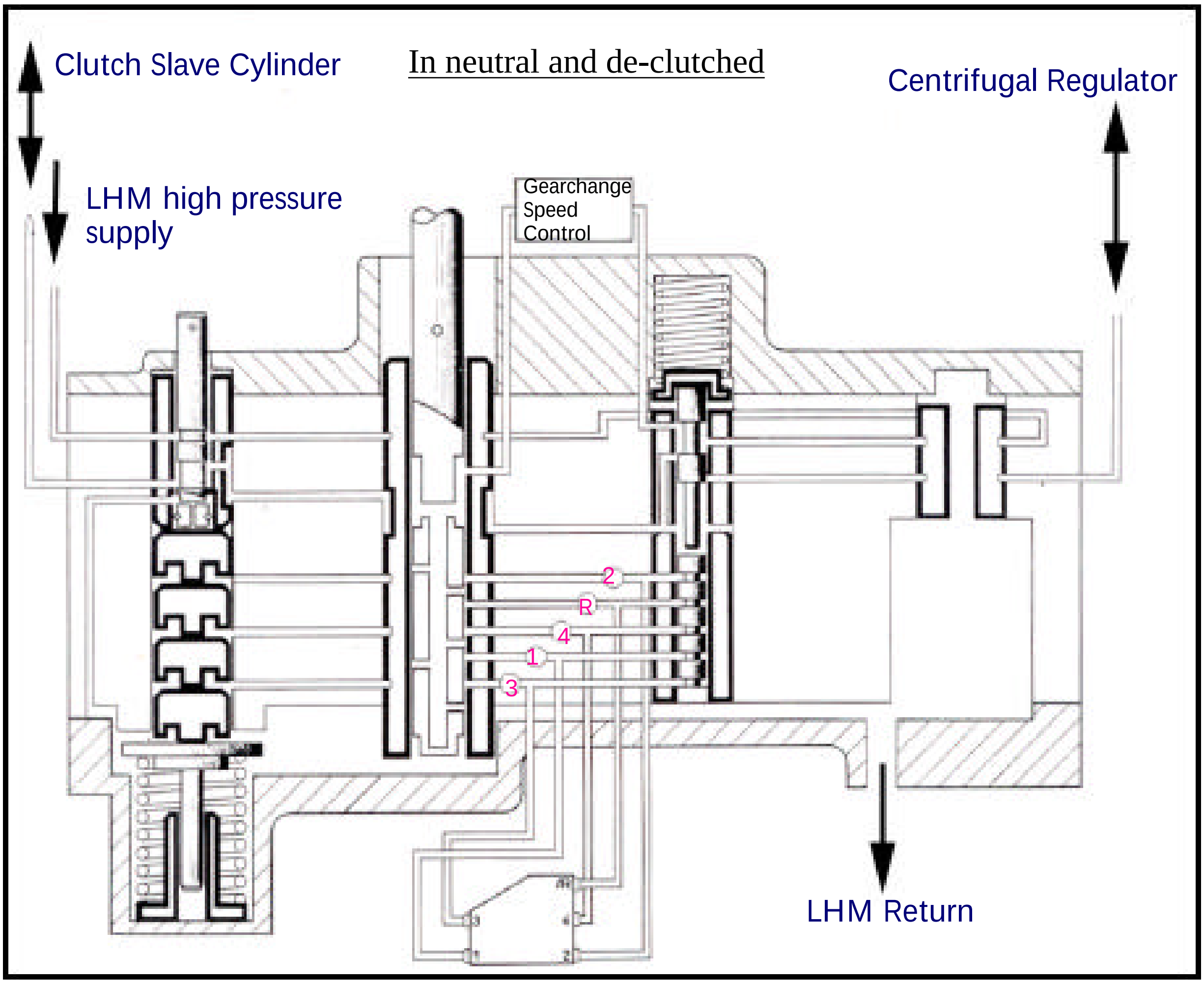
The manual clutch control slide valve:

The manual clutch control is by way of a lever situated under the dash, connected to a rod, and has only two positions; normal driving position. (slide valve in), de-clutched position. (slide valve out). At its lower end are two drillings at right-angles to each other.

With the slide valve in its normal position, LHM under high pressure is supplied to the hydraulic gear selector. However, when the slide valve is in its withdrawn position, it cuts off the supply of high pressure LHM to the clutch and gear change circuit. This allows the LHM in the clutch slave cylinder to escape to the reservoir and therefore the vehicle's clutch is engaged. For service purposes, this allows the engine to be started, or turned over, using the handle.

Rise of pressure - de-clutching: manual clutch control slide valve in its normal position

Before the hydraulic selector slide valve is supplied with LHM under pressure, the position of the automatic clutch control slide valve is such that the supply to the selector slide valve is cut off and the port to the clutch slave cylinder is open. When high pressure arrives the slide valve operates as a pressure control valve and de-clutching occurs at a pressure of 50-70 bars (725 to 1000 psi). This pressure is the result of the calibration of the spring above the slide valve. In its regulating position the slide valve allows LHM to pass to the selector slide valve, via the gear change speed control. Therefore, with the engine idling, in neutral,the clutch is disengaged.

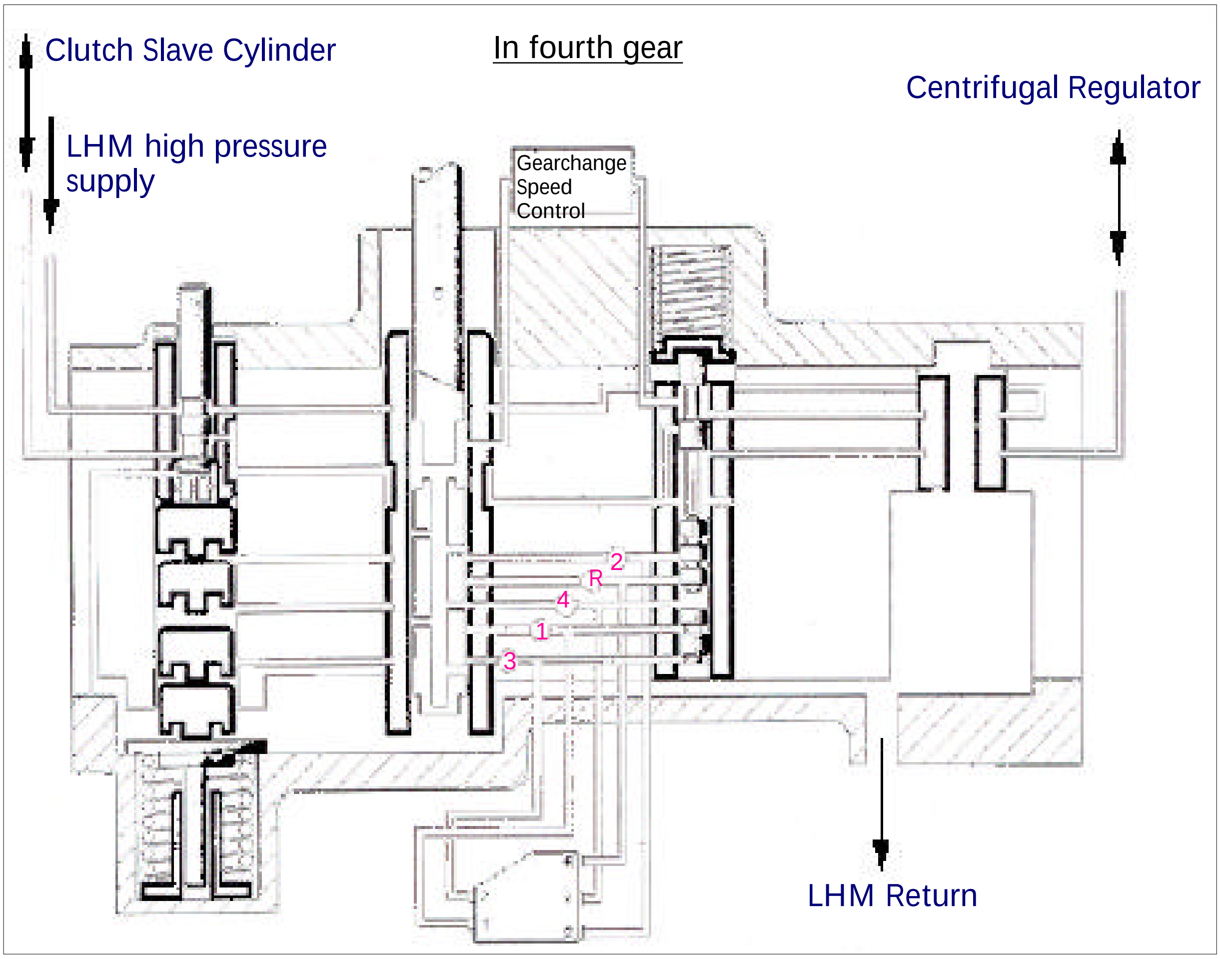


Engagement of first or reverse gear:

By moving the gear change wand, the selector slide valve is aligned in such a way, that the line to the chosen gear is pressurised. The pressure rises simultaneously in the gear circuit, (gear selector fork shaft pistons) and in the automatic clutch control pistons. The surface area of the pistons and the strength of the springs are such that the pressure causes immediate movement of the gear selector fork shaft until the gear is engaged. Then, as the pressure continues to rise, the automatic clutch control piston moves. The pressure going to the gear selector pistons within the gearbox, is in the 500 psi range, controlled by the flow control unit.

Engagement of 2nd, 3rd, or 4th gears:

When the chosen gear circuit is connected to the supply of pressure by the selector slide valve, the pressure rises simultaneously in the gear circuit (gear selector fork shaft pistons), in the automatic clutch control piston circuit and in the synchro-delay piston circuit. The different phases of operation occur in the following order:



* *Movement of the selector fork shaft until synchro cones begin to contact.*

* *Movement of the synchro delay piston: which allows the volume of LHM to increase and the pressure to stabilise, while synchronisation continues at a constant pressure.*

* *Rapid movement of the selector fork shaft, allowing full engagement of the gear once the synchro piston has bottomed.*

* *Movement of the appropriate automatic clutch control piston.*

Re-engagement of the clutch:

Whatever gear is selected, the final operation of the gear selector is the movement of the automatic clutch control piston. As it moves, the piston causes the automatic clutch control slide valve to rise. The equilibrium of the pressure balance is upset, and in its new position the slide valve allows LHM to pass to the selector slide valve (This pressure holds the gear in engagement). It also connects the clutch slave cylinder to the centrifugal regulator; clutch disengagement and re-engagement can take place when the centrifugal regulator allows the LHM in the slave cylinder to escape back to the reservoir.

Return to neutral:

Between each gear the selector slide valve connects all the circuits under pressure to return to the reservoir via the grooves it carries. All the valves return to their initial positions under the action of their return springs.

Clutch re-engagement control (CRC)

The clutch re-engagement control is a two stage flow regulator. Its purpose is to ensure rapid and progressive re-engagement of the clutch when changing gear. In use it mimics the actions of a driver using a conventional clutch. It varies the speed of clutch re-engagement according to the position of the throttle and it allows rapid disengagement of the clutch.

In the hydraulic circuit, the CRC is situated between the gear selector and the clutch slave cylinder. Physically, the unit is bolted to the inlet manifold adjacent to the carburettor. The pressure that goes to the CRC, and the clutch slave cylinder, is between 750 and 1000 psi, which is set by the slide valve that operates the manual clutch re-engagement control within the gear selector unit.

A cam (2) connected to the primary throttle butterfly spindle by a "Flector". acts via a roller, on a lever (3) which tensions a spring (4) which in turn permanently applies pressure to a slide valve. Another by-pass slide valve (8) is pushed towards the first by a weaker spring. In the centre of this slide valve, the diameter is smaller than the bore in which it operates.

Declutching:

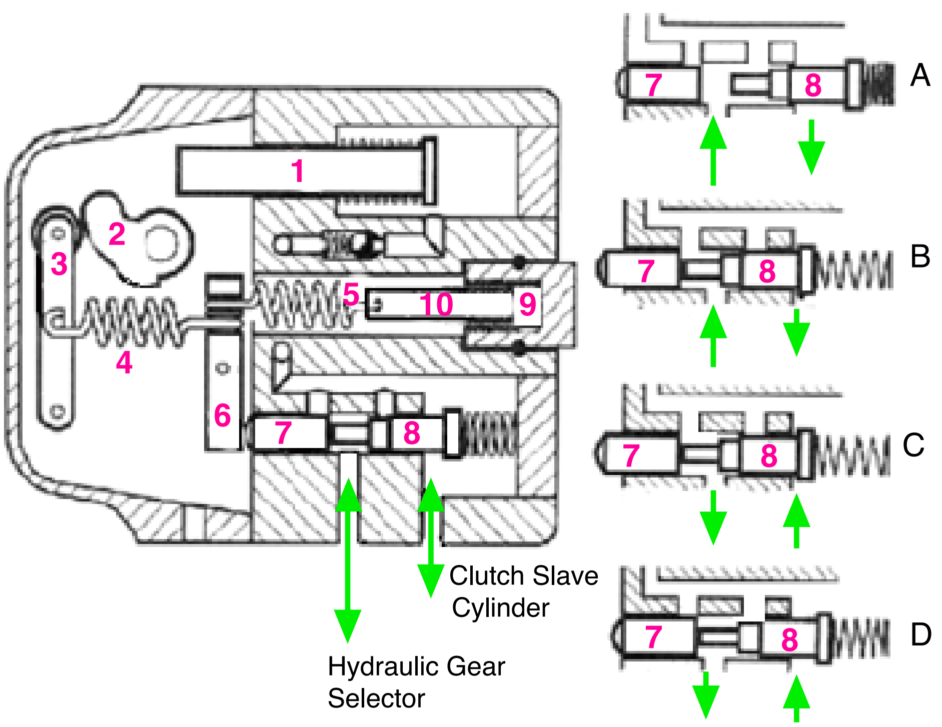
This operation needs to be as fast as possible. Therefore the CRC must not obstruct the flow of LHM from the gear selector to the clutch slave cylinder at all. In operation, with the clutch fully engaged, pressure from the gear selector when de-clutching, first moves the by-pass slide valve back because its return spring is weaker than the hydraulic pressure. The by-pass valve opens a port which allows free passage for the LHM going towards the clutch slave-cylinder.

As the pressure rises, the second slide valve (7) is moved in turn, opening a second port and stretching the spring (4) in the CRC. The movement of this slide valve stops, when its return lever bottoms. When the pressure reaches its maximum, it becomes equal on both sides of the by-pass valve, which returns to its original position under the influence of its spring. De-clutching is rapid, as the flow of LHM is virtually unobstructed.

Re-engagement:

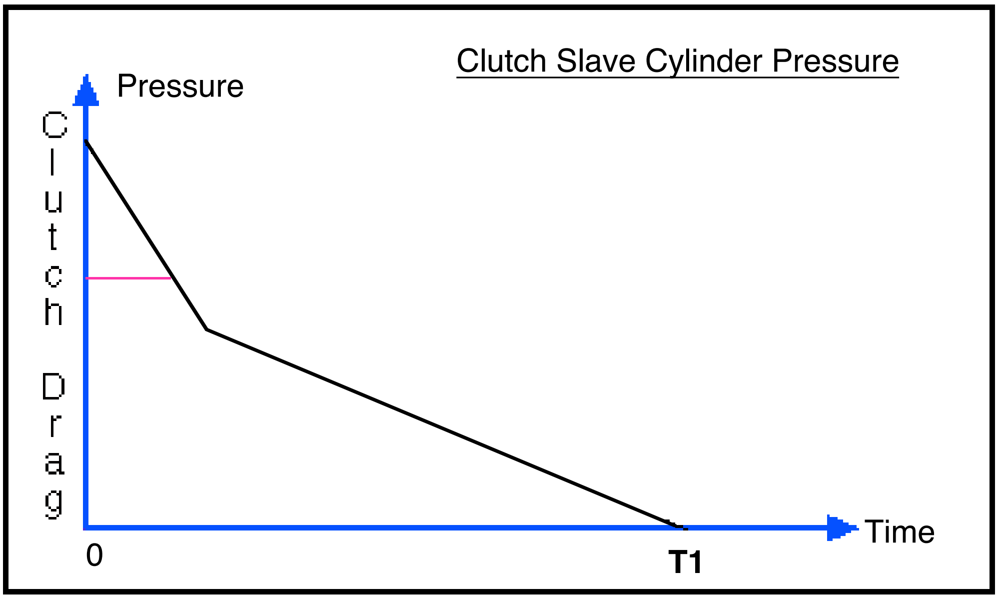
It is necessary to have a rapid first stage of engagement, to the point where the clutch begins to bite and a slower second stage to avoid sudden engagement. To manage this, the return of LHM must be free at first and slowed down thereafter. This is achieved by connecting the pipe coming from the hydraulic gear selector, to return to the reservoir by the gear selector.

Clutch Re-Engagement Control (CRC)



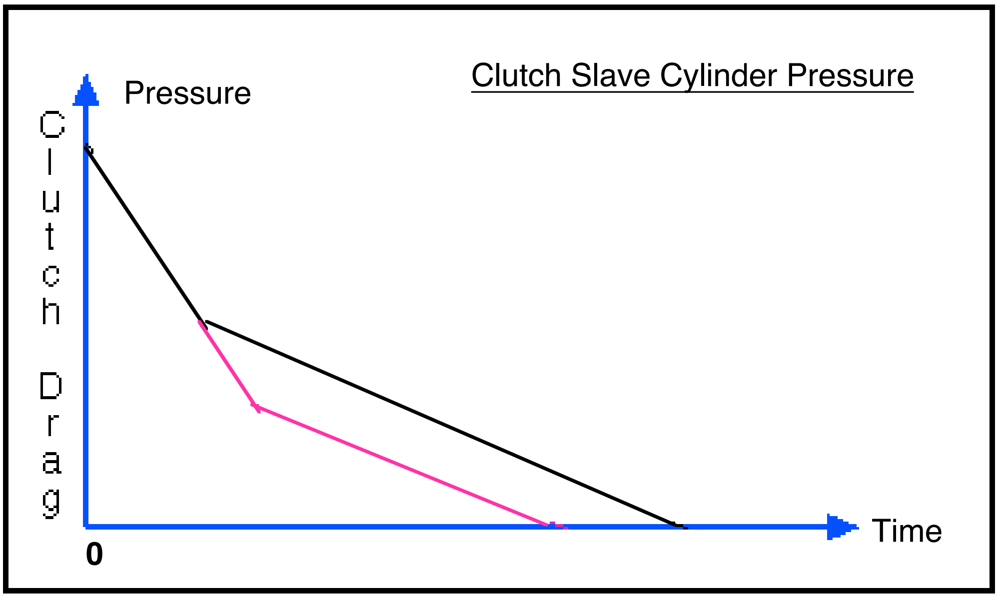
There is a rapid drop of pressure, until the slide valve obstructs the return port ; this occurs when the LHM pressure on one side of the slide valve becomes less than the effect of the spring on the return lever on the other side. This is the first phase, or rapid phase of re-engagement. In the centre portion of the bypass valve is the reduced diameter already described; this is between the outlet port and the return to gear selector. The pressure continues to drop by way of the outlet, but is slowed, due to the restriction caused by the bypass valve.

The adjusting screw on the unit will alter the speed of clutch re-engagement when gears are changed, from very slow with detectable clutch slip, to very fast when the car will lurch. To achieve this wide range of adjustment, the phase-change pressure is altered. By reducing this pressure, the rapid-drop phase is lengthened which results in the overall time of engagement being reduced. Under hard acceleration, the pressure on the slide valve decreases, so the overall time of re-engagement also decreases.



Throttle closing Piston:

So that the engine speed is not excessive at the point of clutch re-engagement, it is limited automatically by the system during declutching. This permits the driver when in a hurry, to keep his foot hard on the throttle when changing down, without affecting the smoothness of clutch engagement.



While the pressure is rising in the slave cylinder, the LHM pushes on the throttle-closing piston. The entry of LHM to the piston is slowed by making it pass a ball with 3 grooves on its seating, the LHM passing by the grooves. The restriction of the LHM is necessary to avoid ‘hammering’ in the hydraulic circuit, but it is mainly to prevent the throttle from being closed too quickly. The piston (1) moves out and limits the movement of the cam connected to the throttle spindle; therefore the engine speed is limited while the clutch is out. Upon re-engagement, the pressure drops at the same speed as in the clutch slave cylinder, and the piston returns under the influence of its return spring, giving full throttle control back to the driver.

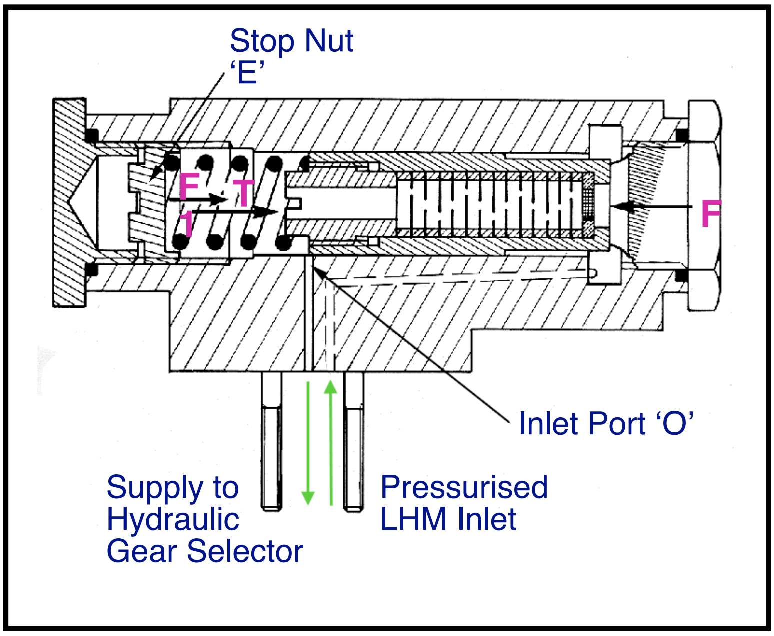
Regulating the speed of the gear change

The LHM fluid which operates the gear-change circuits is not always at the same temperature or pressure when it reaches the hydraulic gear selector. For instance, in winter the LHM circulating in the clutch circuits and warmed by engine heat is likely to be hotter and of a thinner viscosity, than the LHM at the bulkhead in the gear selector unit, giving rise to possible pressure variations. If not corrected, these variations, would cause errors in the timing of gear operations. To overcome this, the LHM operating the gears passes through a gear change speed regulator, which is mounted on top of the hydraulic gear selector.

The regulator consists of a cylinder closed at each end by a plug, and in which a hollow piston slides. A ‘stack’ of disk washers, alternately drilled with a small central hole and a small hole on the disk periphery and held apart by hollow spacers, form a zig-zag restricted LHM passage and form the piston. A factory calibrated spring positions this piston and normally should not be adjusted. However, if all other settings are correct, but the car exhibits a graunching noise when changing gear, try adjusting this nut. *Do not* adjust more than 4 turns in either direction; usually under conditions of 'graunching' the adjusting nut needs slackening slightly. If you do adjust this nut, then the centrifugal regulator and the clutch re-engagement control will also need to be re-adjusted. Upon entering the regulator, the LHM under pressure creates a force F which tends to move the hollow piston across so that its end partially closes the outlet port 'O'. The return spring exerts a force T on the piston in opposition to F. The LHM under pressure passes through the filter and the disk washer stack, to supply the gear circuits. The piston is acted upon from one side by the force F from the LHM, and from the other by the force T from the spring to which is added therefore F1 from the back pressure in the circuits in the gear selector. Depending on the values of F and F1, the position of the piston varies, covering the outlet port 'O' to a greater or lesser extent. By the regulation of this outlet, the pressure is regulated.

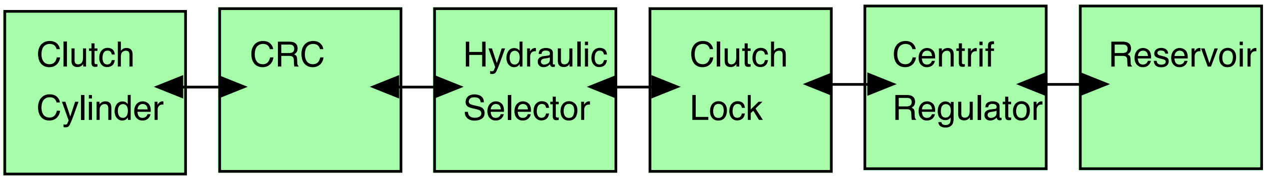
The force F1 is variable, its value depends upon the resistance to flow through the gear selector. If this resistance is high the difference between F and F1 decreases and the piston opens the port more; the pressure remains constant. Conversely, if this resistance is low, F1 decreases and the piston obscures more of the port; the pressure stays the same. The force F is variable and depends on the source of pressure and depending on this value, the outlet port 'O' will be more or less obstructed. It should be noted that the flow of LHM through the hollow piston itself, is not affected by the viscosity or temperature of the LHM.

Gear Change
Speed Regulator

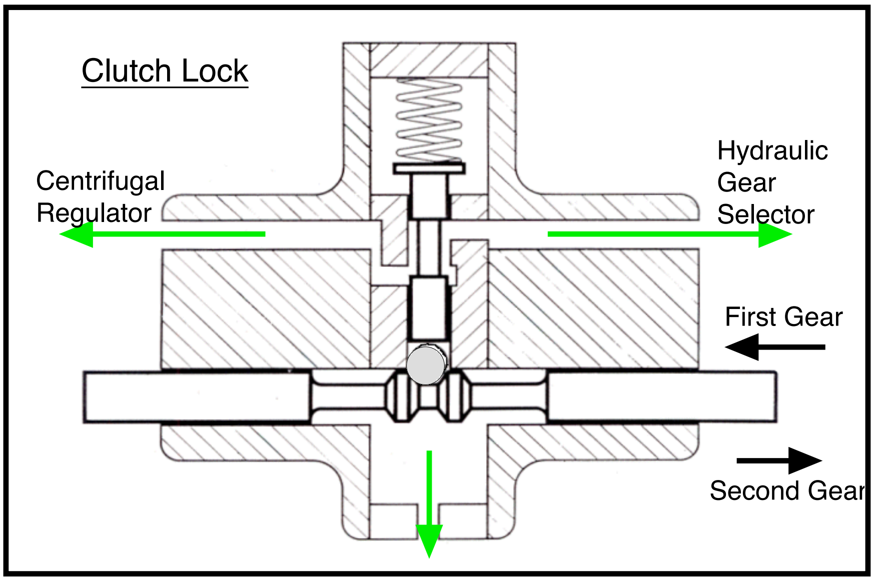


Clutch lock

The purpose of the clutch lock, is to stop the clutch re-engaging during a gear change between first and second gear, if one or other of the gears is not fully meshed. Because of the absence of a first gear synchro delay piston in the hydraulic selector, it is possible for the system to allow re-engagement before the synchro and locking dogs have had time to operate.



The clutch lock is fitted to the right hand front side of the gearbox, in the hydraulic circuit between the gear selector and the centrifugal regulator. In this position it cannot hinder de-clutching during other gear changes even if it is closed. The unit comprises 1 body, 1 slide valve sleeve, 1 slide valve with a central groove, 1 return spring for the slide valve and 1 ball control rod and ball.

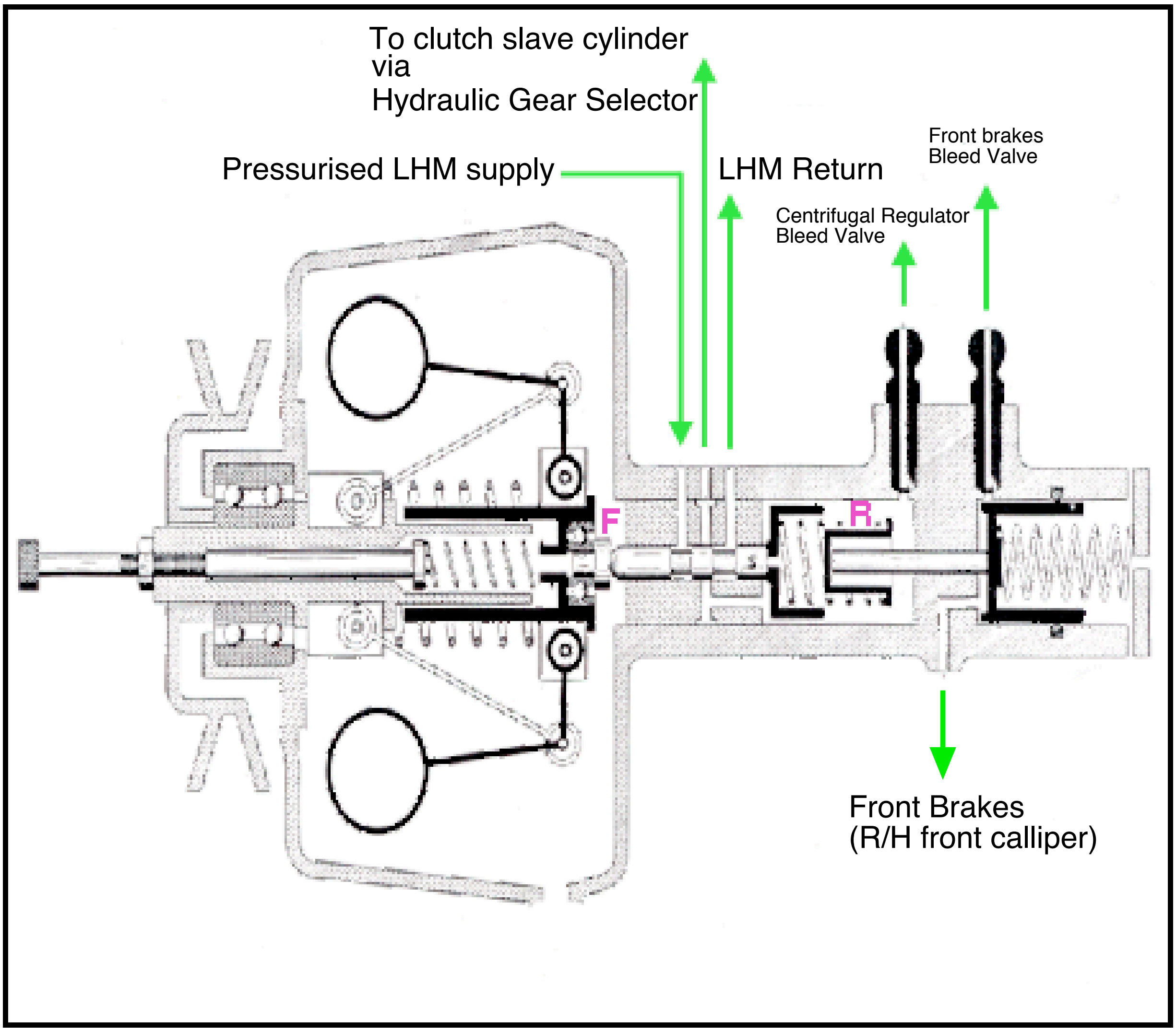


This ball control rod is connected to the selector fork shaft for first and second gears by a lever and spring. It is designed to block the pressure-release circuits if either first or second gears are not fully engaged; or the gearbox is in neutral.

When first and second gears are being engaged, the ball is lifted by a shoulder on the ball control rod, pushing the slide valve which blocks the LHM passage. If synchronisation and engagement do not take place, the selector fork shaft for first and second gears and the ball control rod, remain in this intermediate position and stop the escape of LHM from the clutch slave cylinder.

When the locking dogs are fully engaged, the selector fork shaft and the ball control rod move and the shoulder no longer holds up the ball, which returns down with the slide valve, under the influence of the return spring. LHM may now pass the groove in the slide valve and clutch re-engagement takes place. When third or fourth gears are engaged, the selector fork shaft for first and second remains in neutral and the clutch lock remains inoperative.

The Centrifugal Regulator



The centrifugal regulator controls the clutch engagement when moving off and its disengagement when the vehicle stops with a gear still engaged. Its operation is in relation to engine rpm. It comprises three major parts; a mechanical centrifugal governor, a pressure control slide valve/sleeve assembly and a de-clutching activator fed by pressure from the front brakes.

As engine rpm rises, two bob weights mounted on sprung levers throw outwards under centrifugal force. This motion is transmitted via the levers to the end of the control slide valve. This part of the centrifugal regulator is contained within the large canister that holds the drive pulley for the unit and is separated from the hydraulic end of the unit. The levers, springs, bob weights etc are greased 'for life' as no LHM circulates here.

With the engine stopped, the springs pull the bob weights in and zero force is applied to the slide valve. As increasing engine rpm throw the weights outwards, the springs compress until there is a state of balance between the centrifugal force and the spring pressure.

Pressure-control slide valve assembly:

The slide valve and its sleeve act as a pressure-control device. Equilibrium of the slide valve is achieved when the forces acting on its end (pressure and spring) are equal to the force exerted by the bob weight pressure pad: $p \times s + R = F$

The operating pressure (regulated pressure) is thus solely a function of the force F, namely the engine speed: $p = (F-R) / s$

Thus the regulated pressure diminishes when the engine speed is increased and vice-versa.

It should be noted that when the clutch is engaged, the slide valve's position connects the clutch circuit to the return system. Therefore during gear changes, only the automatic clutch control slide valve controls de-clutching and engagement. A dash-pot is provided to damp sudden pressure rises and the movement of the control slide valve.

De-clutching activator:

The purpose of the activator is to quickly de-clutch during a rapid stop with the brakes applied and a gear engaged. Fast de-clutching is obtained by increasing the pressure in the clutch circuit by about 10 bars (145 psi). When the car is losing speed under brakes, the pressure in the brakes also acts on the de-clutching activator piston, compressing its return spring. As it is moved back, the piston effectively reduces the strength of the spring R at the end of the slide valve. For a given engine speed, the slide valve's equilibrium is obtained with a higher pressure: previously $p = (F - R) / s$

R becomes less, F remains constant, so p increases (by 10 bars, approx 145 psi).

Adjustment of the clutch engagement speed:

Let p be the pressure corresponding to clutch drag at a given engine speed. By screwing in the adjuster screw, both F and p increase. The pressure corresponding to the clutch drag will be obtained at higher engine revolutions. By unscrewing the adjuster, the reverse occurs.

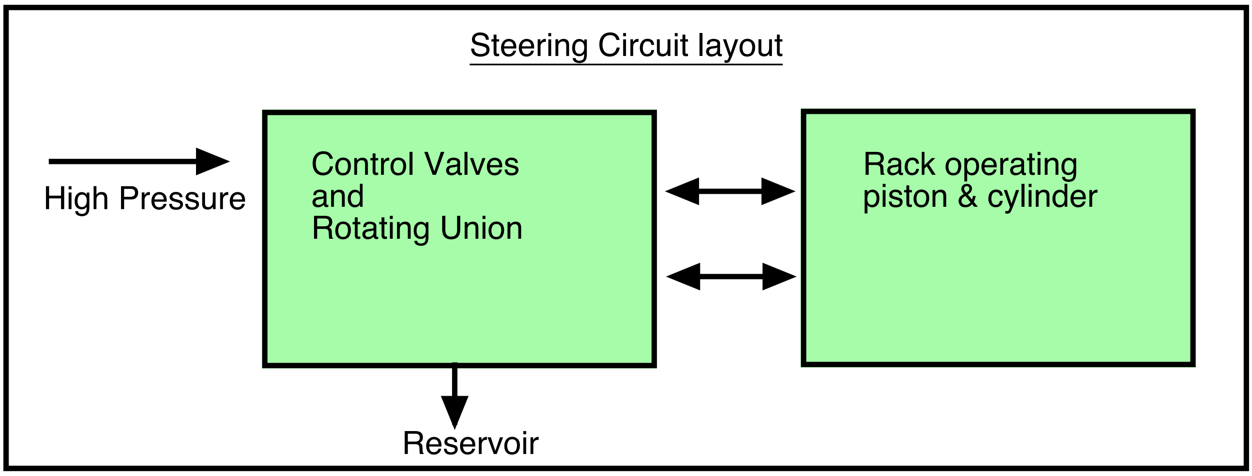
Power assisted steering

The steering system used on the DS, is a hydraulically powered rack and pinion system. There are two main units; a double-acting piston connected to the rack, and the control valves with rotating union.

Two pressure-control slide-valves (one for each side of the piston) are connected to the steering by way of a coupling fork. As the slide-valves move due to the action of the steering wheel, the hydraulic connections between the fixed (supply of pressure and return) and moving (valve block) parts are maintained by the rotating union. A dash-pot is situated under each slide valve.

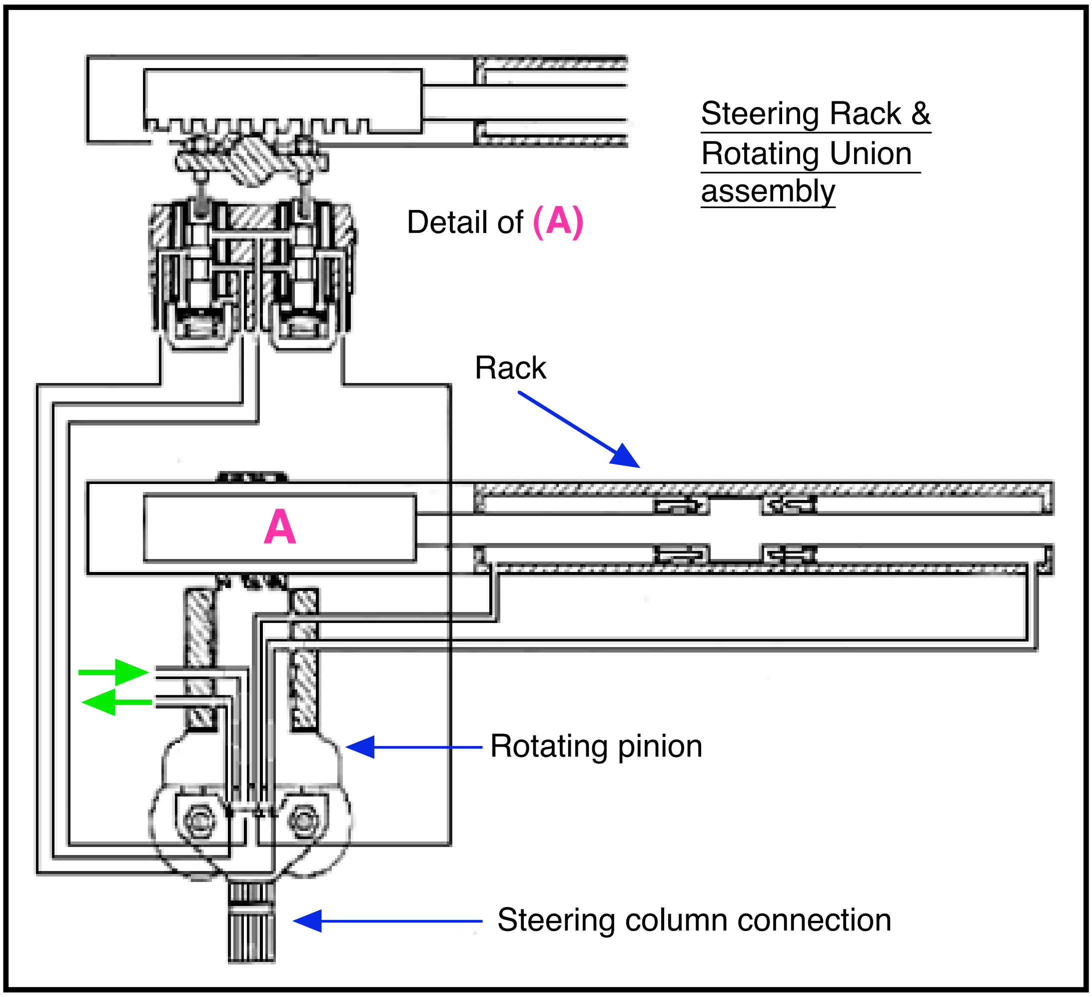
No movement of the steering wheel:

Under this condition, the fork is at rest and the pressure-control slide-valves are also in equilibrium, closing the inlet ports in the valve block.



Movement of the steering wheel:

When the steering wheel is turned, this leads to a movement of the slide-valves in relation to the sleeves in the valve block. One slide valve moves down, the other rises. The valve which moves down connects high-pressure to one side of the piston. The second slide valve which rises, allows LHM on the other side of the piston to return to the reservoir.

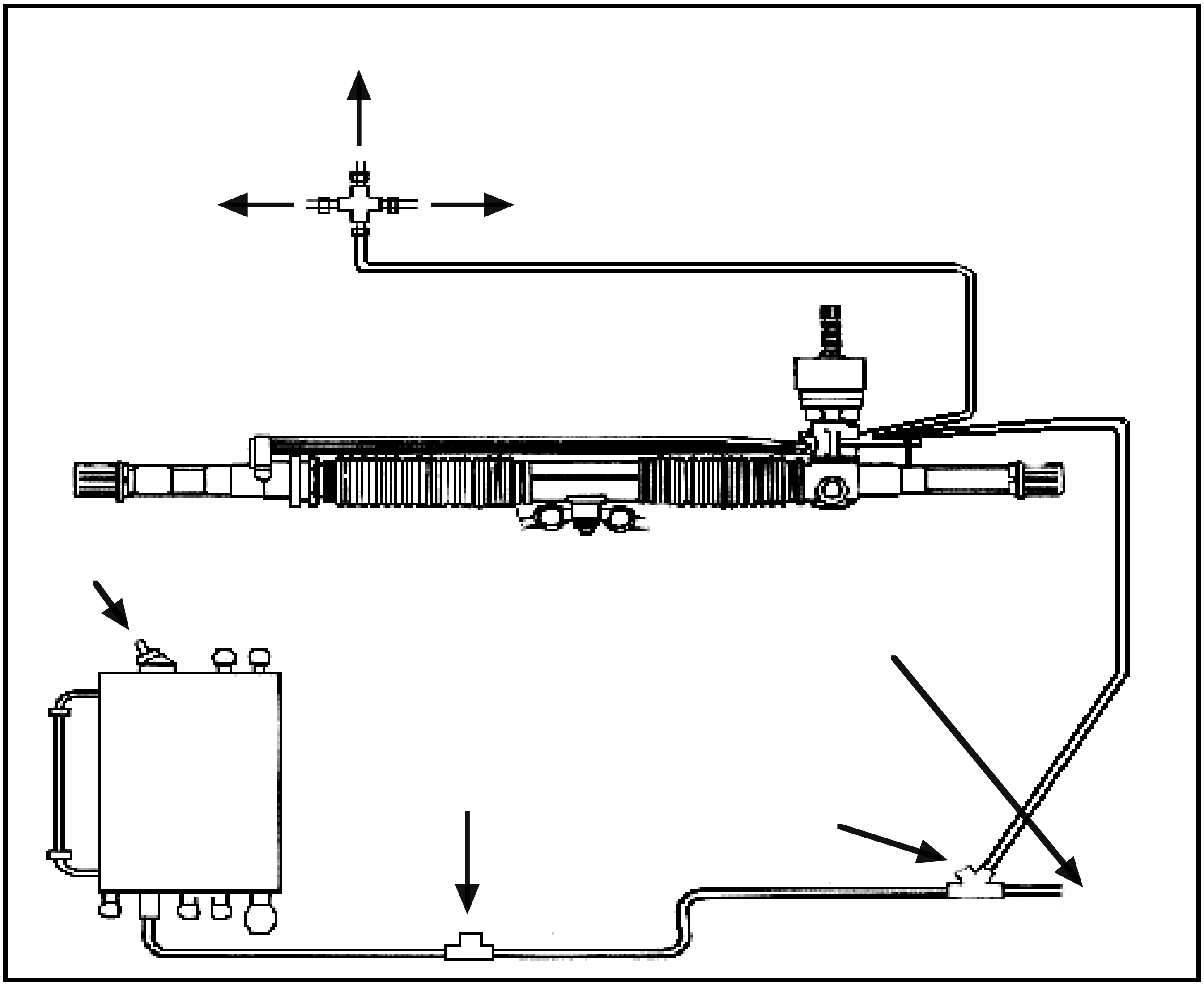


Stopping movement of the steering wheel:

When the rack moves it turns the pinion, which moves the sleeves, in which the control slide-valves are situated, in the direction which would tend to make the valves return to the cut off position. As long as the driver turns the steering wheel he holds the slide-valves in the open position, but when he ceases to turn, the sleeves return to their cut off position in relation to the slide-valves and the rack stops moving.

Residual pressure:

A residual pressure is maintained on either side of the piston when the steering is at rest. This pressure is maintained by the pressure-distributor valve assembly and its value is a function of the position of the pressure-control slide-valves in their sleeves. This is known as the crossover pressures. Because of this, any movement of the steering wheel causes an immediate response by the rack, by virtue of rising pressure on one side of the piston and falling pressure on the other side. The movement of the rack is thus immediate.

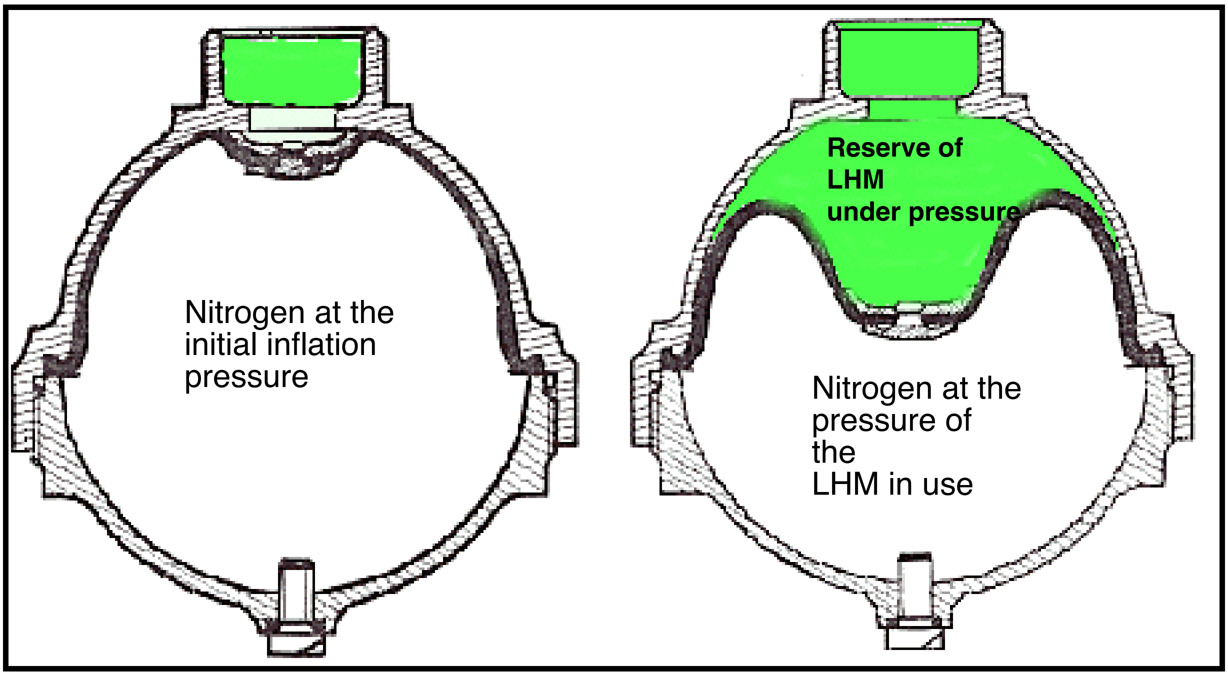


Suspension

Suspension is independent all round, by means of oleo-pneumatic spheres, connected to suspension cylinders and which are in turn mechanically connected to the wheels of the car. The design of the forged steel spheres, is similar to the spheres fitted to the pressure regulator and the brake pressure reservoir.

Each sphere is given an initial charge of nitrogen gas. The initial pressure of the front spheres is different from that of the rears and is a function of the unladen weight of the car. If the initial pressure is too high, this will lead to hammering of the metal cup in the flexible diaphragm on its seat in the sphere. This will happen if a front sphere is accidentally fitted on the rear.

Two states of a Suspension Sphere



In the absence of road wheel movements, the gas and the LHM are at identical pressures on either side of the rubber diaphragm. This pressure is determined by the weight supported and is the same on both sides of the same axle. This pressure is different between the front and rear axles, due to the difference in the unladen weight of the two axles.

When the road wheel meets an obstacle and is bumped upwards, the piston is moved in the suspension cylinder and forces the fluid in the cylinder into the sphere, compressing the gas and thereby providing controlled suspension movement. As the bump in the road recedes, the force on the road wheel is reduced, allowing the compressed gas in the sphere to release its energy. The gas expands, the fluid in the sphere exerts a force on the piston in the suspension cylinder and the road wheel is pushed firmly onto the road.

The compression or expansion of the nitrogen gas, prevents the force of the suspension shock from reaching the chassis. After passing the obstacle, the pressure re-establishes its equilibrium and the piston returns to its original position. By pumping more LHM into the suspension cylinders, it also enables the driver to control the static height of the car, for traversing rough terrain. By pumping the car to its maximum height and holding it there via a steel strut placed between the chassis and the ground and then releasing all the LHM out of the suspension cylinders, the suspension system also acts as a jacking system. Under this condition, the nitrogen gas forces all the LHM out of the sphere, the suspension piston is fully extended and the road wheel is lifted up off of the ground.

As suspension travel compresses the Nitrogen in the sphere at a steadily rising rate, the suspension gets progressively stiffer with wheel travel and/or roll. Yet the DS suspension system is approximately 20 times more compliant than a conventionally sprung suspension system and provides a fairly constant patch pressure on the tyres over the entire range of suspension travel. The only event that will unsettle the suspension, is when the road wheel leaves the ground entirely, such as cresting a hump backed bridge at speed. The car will maintain a constant level in any of the three intermediate height control positions. Within the design limits of the accumulator it will respond to changes in load and maintain a constant height.

Shock absorbers

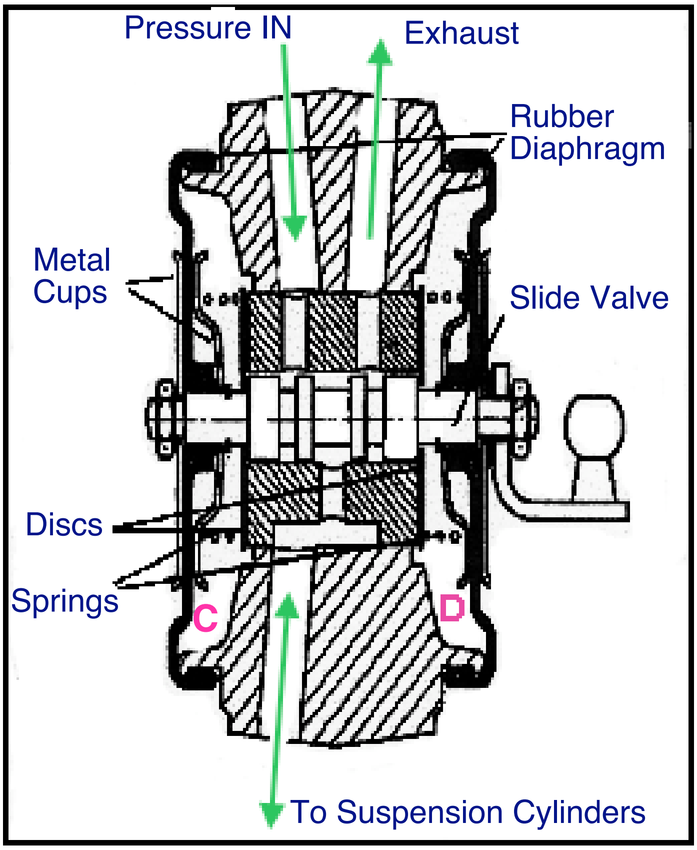
Fluid dampers are incorporated in the neck of the spheres and serve as double-acting shock absorbers. The damping action is achieved by careful flow restriction of the LHM. The damper is a precision machined metal part with a series of precisely drilled passages. The upper and lower surfaces of the facing nuts are domed to allow the flexible discs to lift off the LHM passages. Suspension resistance can be varied by changing the thickness of these flexible discs. There is also a calibrated hole drilled in the damper body allowing a direct flow of LHM from the suspension cylinder to the sphere and back again. Its purpose is to minimise damping under conditions of small road wheel movement, when adequate damping is supplied by the tyres themselves.

In older cars this by-pass hole does not exist. The same basic effect is achieved by using a 0.001 thou shim, placed between the damper and the flexible disc on one side. This provided a slight gap for free movement of LHM under the conditions described above.

Chassis height correction

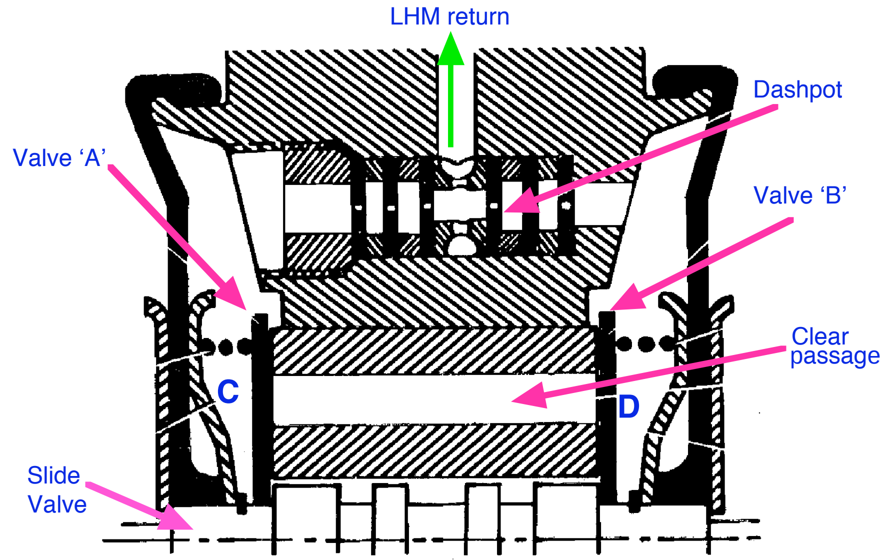
The design of the system allows for a simple yet effective automatic ride height correction of the suspension, relative to the load carried. This is accomplished by two identical mechanical correctors using pressure from the main hydraulic system. The correctors are controlled by a mechanical linkage bolted to the anti-roll bars, which are themselves connected to the front and rear suspension arms. The system also has a manual override control under the command of the driver, which is situated on the inner offside sill. This control works simultaneously on both the front and rear height correction units and allows changes to the ride height to be made, for traversing water or rough terrain.

Height Corrector



Both height correctors are a three way distributor block that depending on the position of the main internal slide valve, can connect the suspension cylinders to the high pressure LHM source. Or connect the suspension cylinders to the outlet which returns LHM to the main reservoir, or isolate both the inlet and outlet ports in the central or cut-off position.

The chambers C and D are sealed by rubber diaphragms which are themselves reinforced by metal cups. These chambers are full of LHM which arises from controlled seepage past the slide valve. A plastic return pipe takes this LHM back to the reservoir. Both chambers are interconnected by a clear passage drilled in the sleeve of the slide valve and which is closed at each end by disc valves, controlled by the movement of the slide valve. In the central position, each disc is held against a face on the sleeve by a weak spring. A restricted dash-pot passage inserted in the body of the corrector, limits the flow of LHM from C to D and back. This passage is connected to the return to the Reservoir.



Slide Valve in central cut-off position

As the slide-valve is moved from its central or cut-off position, the disc valve in chamber C is held on its seating by its return spring, closing off the passage. The disc-valve in chamber D is lifted off its seating in turn, by the shoulder on the slide-valve which now allows free LHM movement. LHM in chamber C is now free to pass through the dash-pot, which slows down the fluid movement. This in turn, slows down the movement of the slide-valve.

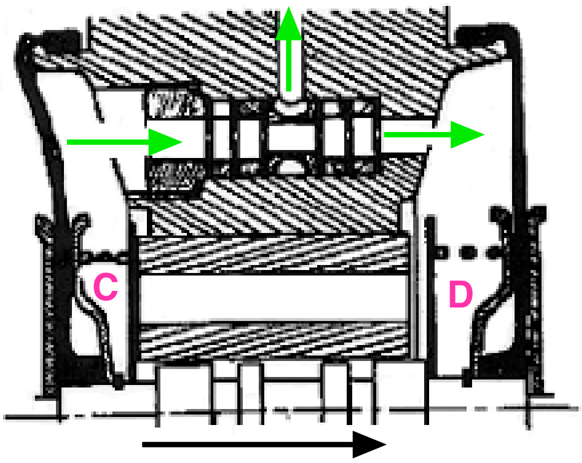
The net effect is that there must be positive effort on the slide valve for a certain period of time, before it can move to the exhaust position. This prevents movement of the slide valve under conditions of small rapid movements of the road wheel, which would give rise to excessive suspension travel.

When the slide-valve is returned to the cut-off position, LHM in chamber D returns to chamber C by way of the now clear passage, lifting the disc-valve against its return spring as it does so. As the movement of the disc valve is not restricted, the return is rapid. As soon as the slide valve returns to the cut-off position again, the disc valve in chamber D closes the passage, stopping the slide-valve from over running the cut-off position. This helps to avoid secondary corrections that would be caused by the valve overshooting the central position.

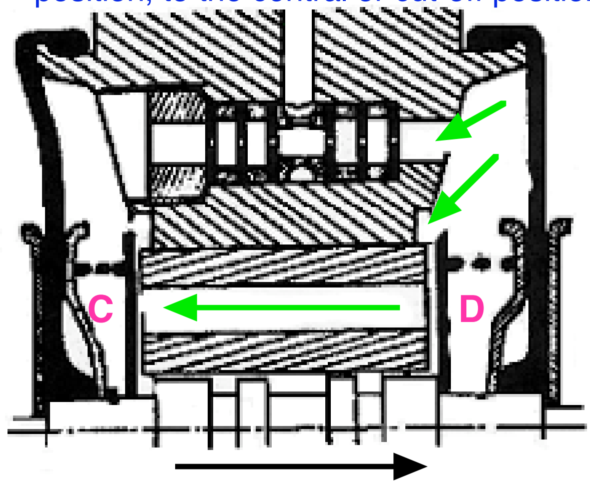
When the slide-valve moves, the disc valve in chamber D is now held againby its spring, closing the clear passage. At the same time the disc valve in chamber C is lifted off its seating by the shoulder on the slide-valve, thus opening the clear passage. LHM in chamber D will now pass through the dash-pot which restricts the flow, slowing down the movement of the slide-valve. As with the exhaust sequence, the slide valve must be held in this position for a period of time, before the inlet passage is opened.

Going from the inlet position back to the central or cut-off position, follows the same sequence of events as going from the exhaust to cut-off, but in the reverse direction.

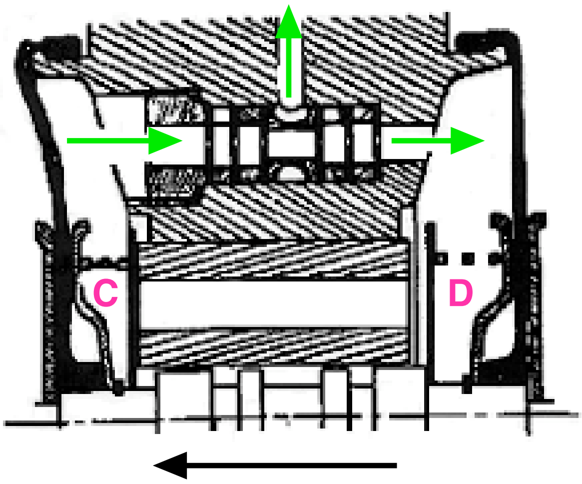
Slide valve moves from the cut-off (central) position, to the exhaust position.



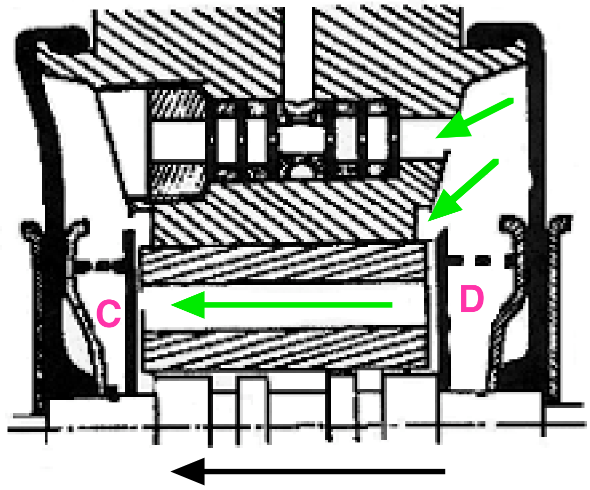
Slide valve moves from the exhaust position, to the central or cut-off position.



Slide valve moves from the cut-off (central) position, to the inlet position.



Slide valve moves back to the central or cut-off position.

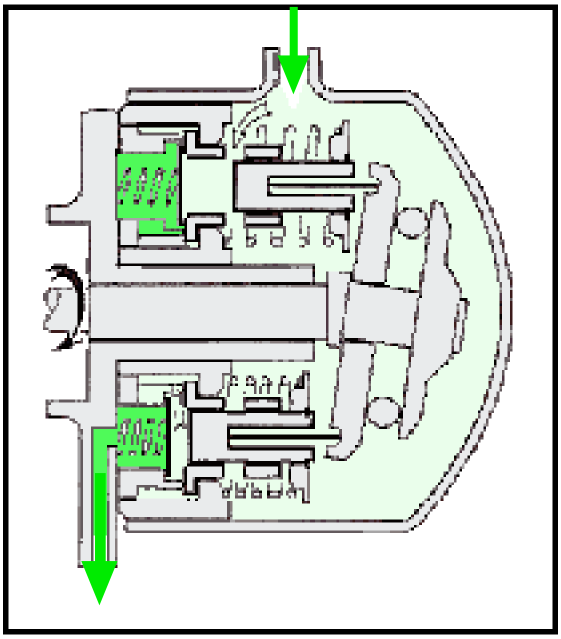


It should be noted that there is a wire restrictor fitted within the return line to the reservoir, from the exhaust port of the rear height corrector. This restrictor prevents all the LHM in the suspension cylinders returning to the reservoir at an uncontrolled rate, when the height control is moved to maximum low and which would cause the car to drop very suddenly. If the car is new to you and/or there is any suspicion that the hydraulic lines that run through the sills have been replaced, it is good practice to observe the car's suspension drop speed, before fitting the jacking strut. It is also good practice when jacking the car, to check that the jacking strut is located properly on the sill mounted stud and to move the height control lever to its next notch and recheck the strut location again, before moving the lever all the way to max low.

The high pressure pump

A single cylinder pump was fitted to ID's without power steering; the more common 7 cylinder pump is fitted to all other models. There are two outer case variants on the 7 cylinder pump; the semi-auto car has an extra fitting lug on the pump, to take the drive belt adjusting strut of the centrifugal regulator. The seven cylinder pump is fitted above the bell housing on the offside and driven at half engine speed by a pair of belts off the crankshaft. This is a volumetric pump; in other words, the swept volume remains the same, whatever the pressure.

The pump comprises seven pistons arranged in such a way as to provide a continuous flow of LHM and at the same time supply the necessary pressure to the LHM. The pistons pump within cylinders and all are arranged in a circle. An oscillating swashplate powers the movement of the pistons via push-rods. In the cylinder wall of each of the 7 bores are 4 inlet ports, each with a non-return valve held on its seat by a spring. All the ports are inter-connected and are in turn connected to the high pressure outlet of the pump.



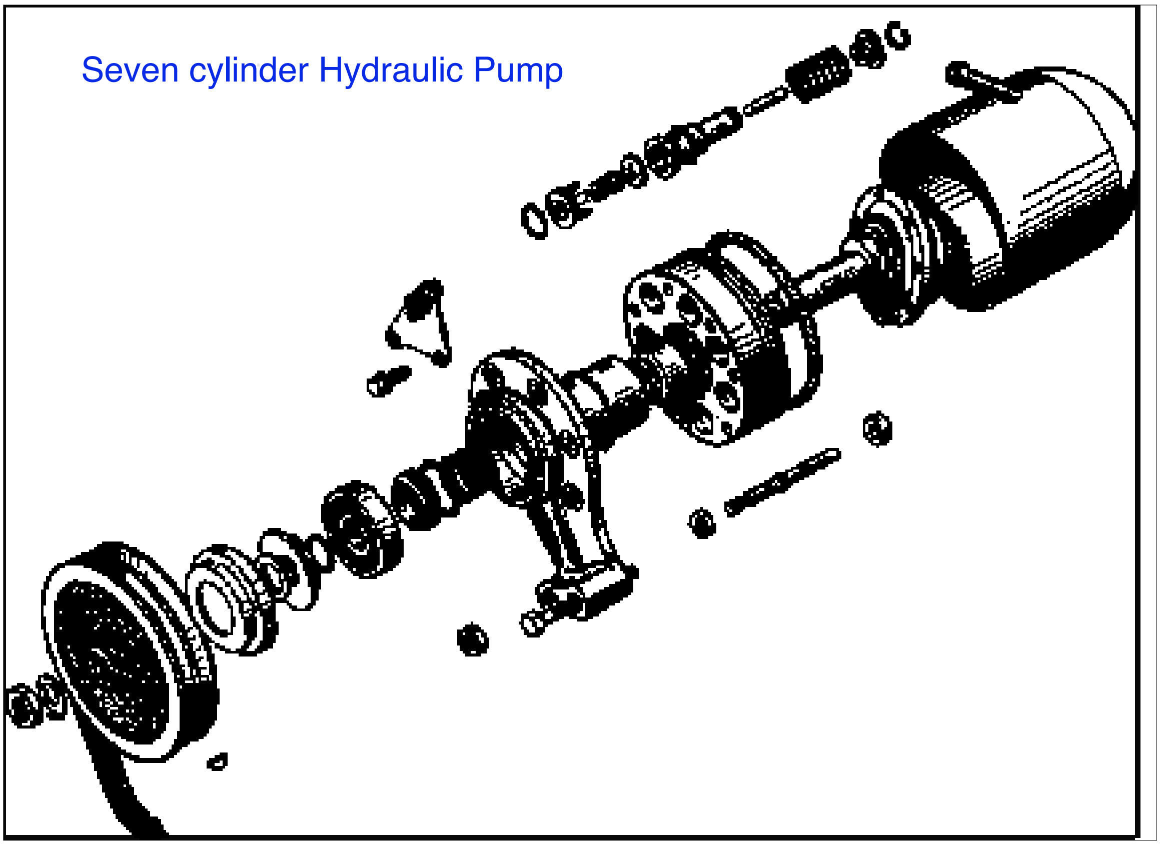
Seven cylinder hydraulic pump

Operation:

Each piston on its downward stroke which is powered by a return spring, produces a depression within the bore. When the inlet ports are uncovered, this depression draws LHM into the bore. As the piston continues to move, the inlet ports are covered and the piston starts to compress the LHM. When the LHM within the bore reaches a pressure greater than that already present in the system, the non-return valve opens and pressurised LHM is delivered to the pressure accumulator. The non-return valve then closes by the action of its spring and the pressure existing in the system holds the valve shut on its seating.

The pump delivery is 2.80 cc per revolution or 840 cc per minute at an engine speed of 600 rpm with a new pump. While the pump is idling, the pressure is only enough to return the LHM to the reservoir through the pressure-regulator. The maximum pressure is controlled by the pressure-regulator.

Seven cylinder Hydraulic Pump



Main accumulator

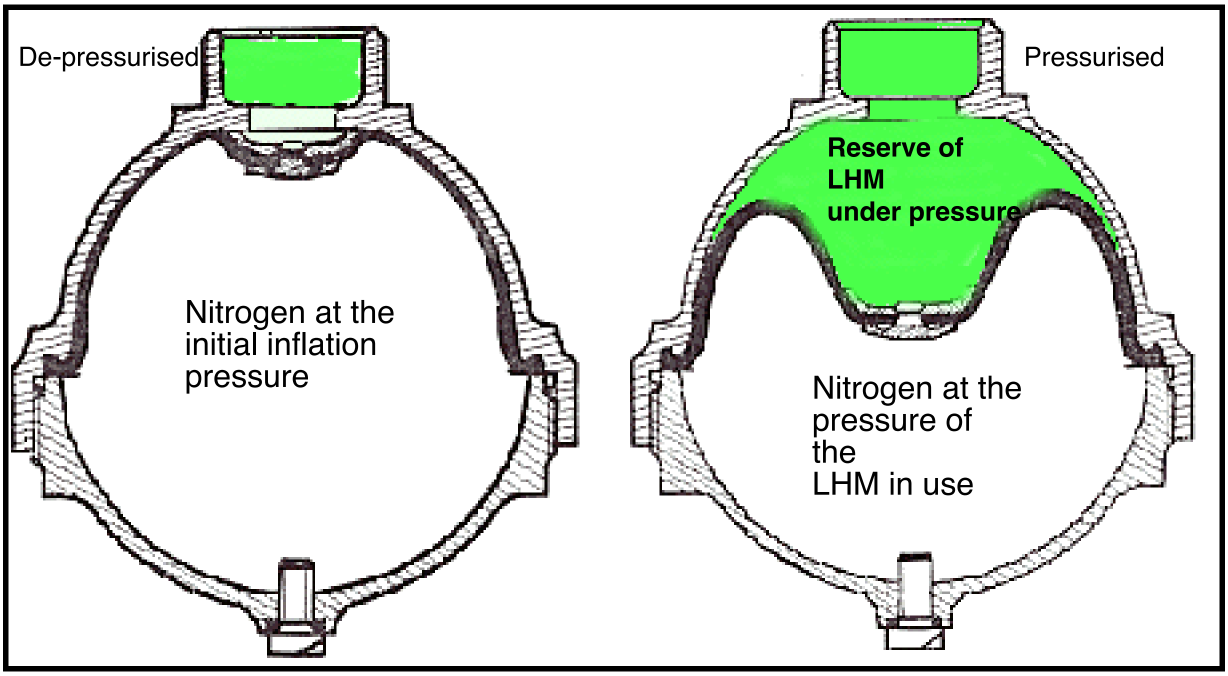
Their are two types of accumulator, differentiated by a number punched on the head of the nitrogen gas filler screw:-

40 - *for vehicles with the ID type brake system ID 19B (DV) & ID 20 (DT)*

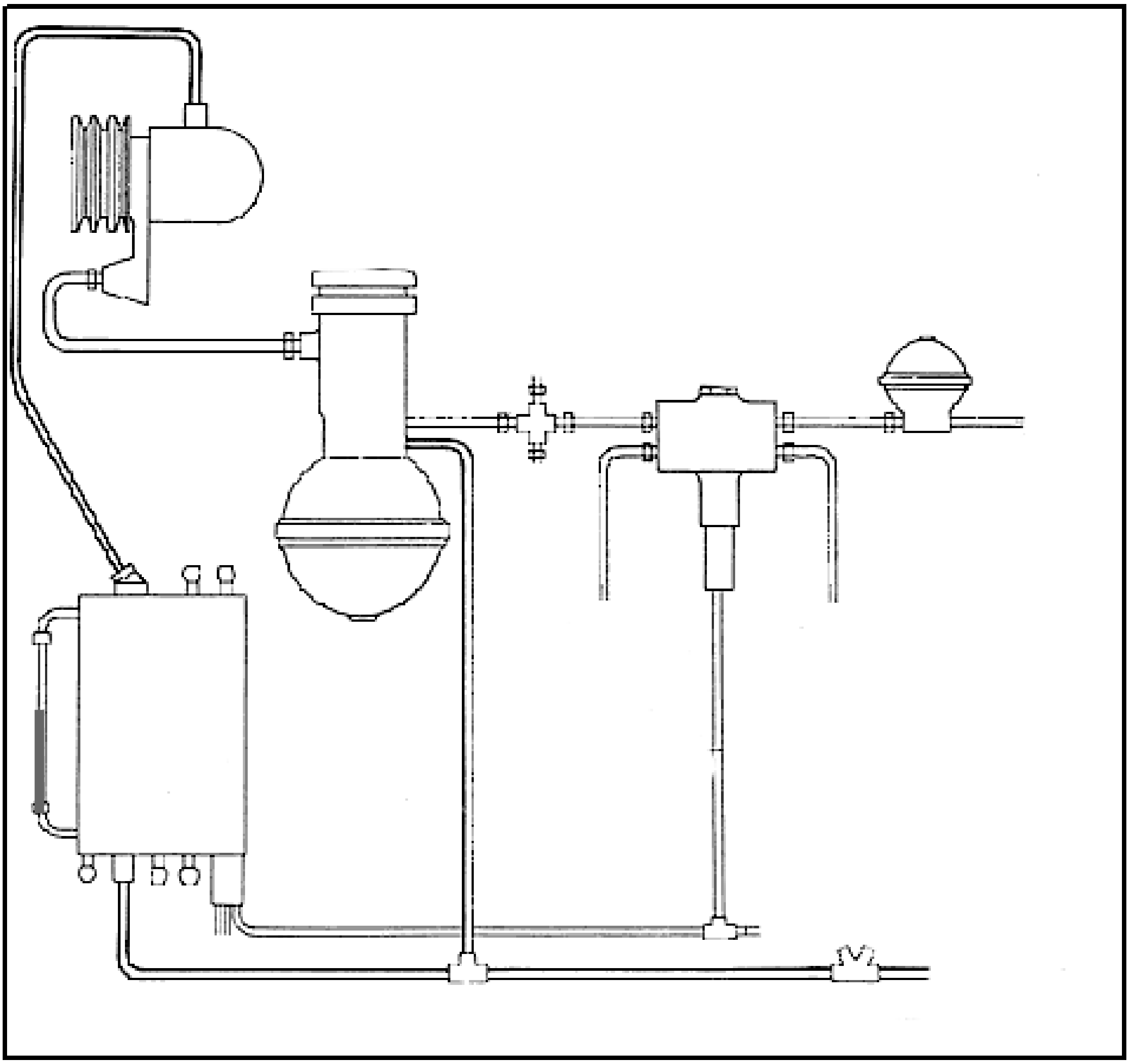
65 - *for all other D models.*

The accumulator consists of a forged steel pressure sphere which unscrews into two halves. It is attached to the pressure regulator and both are fitted low down on the nearside of the engine block. The purpose of the accumulator is to improve the flexibility of the hydraulic system, by immediately supplying pressurised LHM in the event of heavy demand. It also allows the pump to idle and eliminates repeated cutting-in and out. Finally, it smooths demand in the system and acts as a damper.

Stretched across the inside of the two halves of the sphere is a flexible diaphragm made from synthetic rubber. The top half of the sphere is filled with nitrogen under pressure, the bottom half is connected to the pressure regulator and holds the pressurised LHM.



A basic law of physics is utilised in the innovative DS hydraulic sphere concept. This law (Boyles Law) states that gas (nitrogen) can be compressed. Fluid (LHM) cannot be compressed. It should be noted that the rubber diaphragm within the sphere is not load bearing. The pressure of the nitrogen above and the pressure of the LHM below, directly act on one another through the diaphragm, which flexes according to the differing pressures present. With the system de-pressurised, the diaphragm balloons out under the pressure of the ever present nitrogen and is blown hard against the wall of the bottom half of the sphere. Conversely, when the sphere is fully pressurised by the pump, the LHM which is now at a greater pressure than the nitrogen, causes the diaphragm to balloon upwards, compressing the nitrogen still further, until the LHM and nitrogen pressures equalise leaving the rubber diaphragm in a state of equilibrium. When pressure is used by the system, causing a drop in both LHM volume and pressure, the compressed nitrogen expands to compensate for these changes and the flexible diaphragm takes up a different position of equilibrium. The nitrogen and LHM are still at identical pressures, but of a lower value. The flexible diaphragm therefore, plays a passive role in the work of the accumulator, simply that of separating the gas and LHM.



Pressure Regulator

Pressure regulators fitted to cars with a single piston hydraulic pump and cars with the 7 piston pump, operate under different pressures.

Single-cylinder pumps up to mid-February 1969:

Marking: No groove on the lower part of the end cap.

Pressures: Cut-out 130 - 140 bars (1850 - 1990 psi)

Cut-in 100 - 110 bars (1420 - 1560 psi)

Seven cylinder pumps, and single cylinder types from mid-February 1969:

Marking: A circular groove on the lower part of the end cap.

Pressures: Cut-out 150 - 175 bars (2130 - 2490 psi)

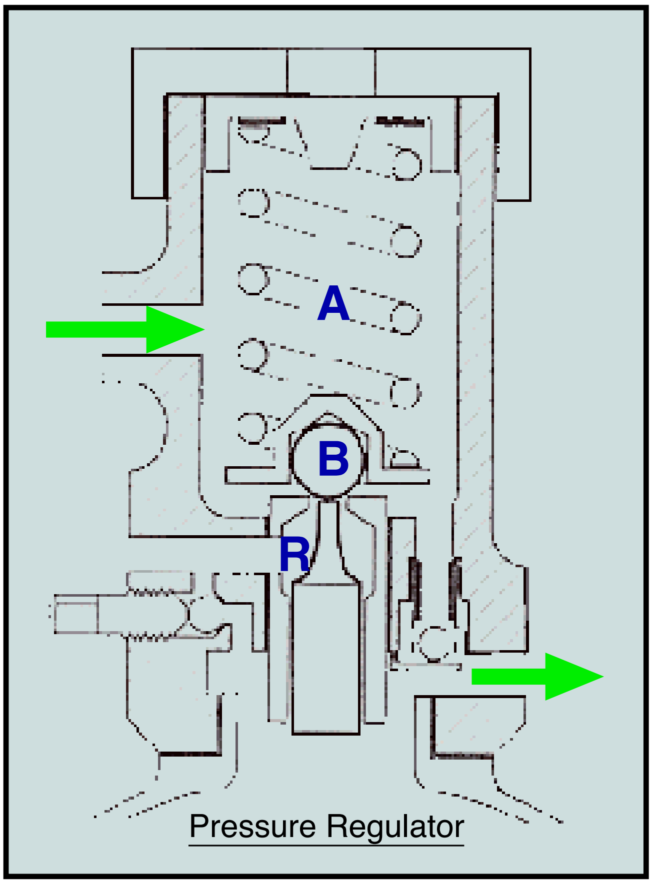
Cut-in 125 - 140 bars (1775 - 1990 psi)

The Pressure Regulator consists of three chambers interconnected via two valves.

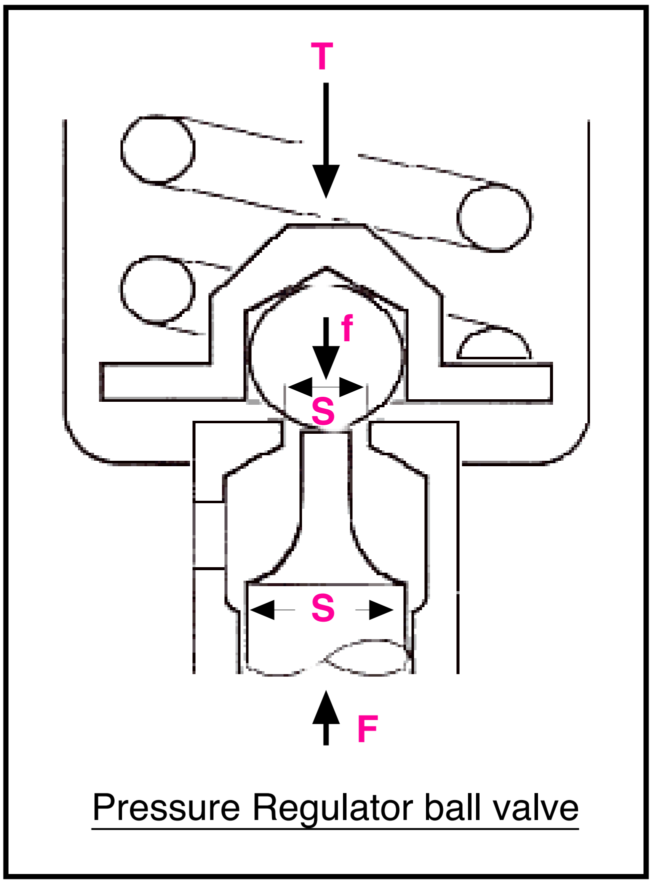
* *Chamber A is connected to the feed from the pump.*

* *Chamber U is connected to the accumulator and the high pressure feed out.*

* *Chamber R is connected to the LHM reservoir.*



Pressure Regulator



Pressure Regulator ball valve

The non-return valve allows LHM to pass only from A to U. The valve between chambers A and R is controlled by the pressure in chamber U, by way of a piston in contact with the ball B of the valve. The pressure-release screw when unscrewed, allows the LHM in the accumulator and supply circuits to be released back to the reservoir. This act depressurises **all** the hydraulic units on the car.

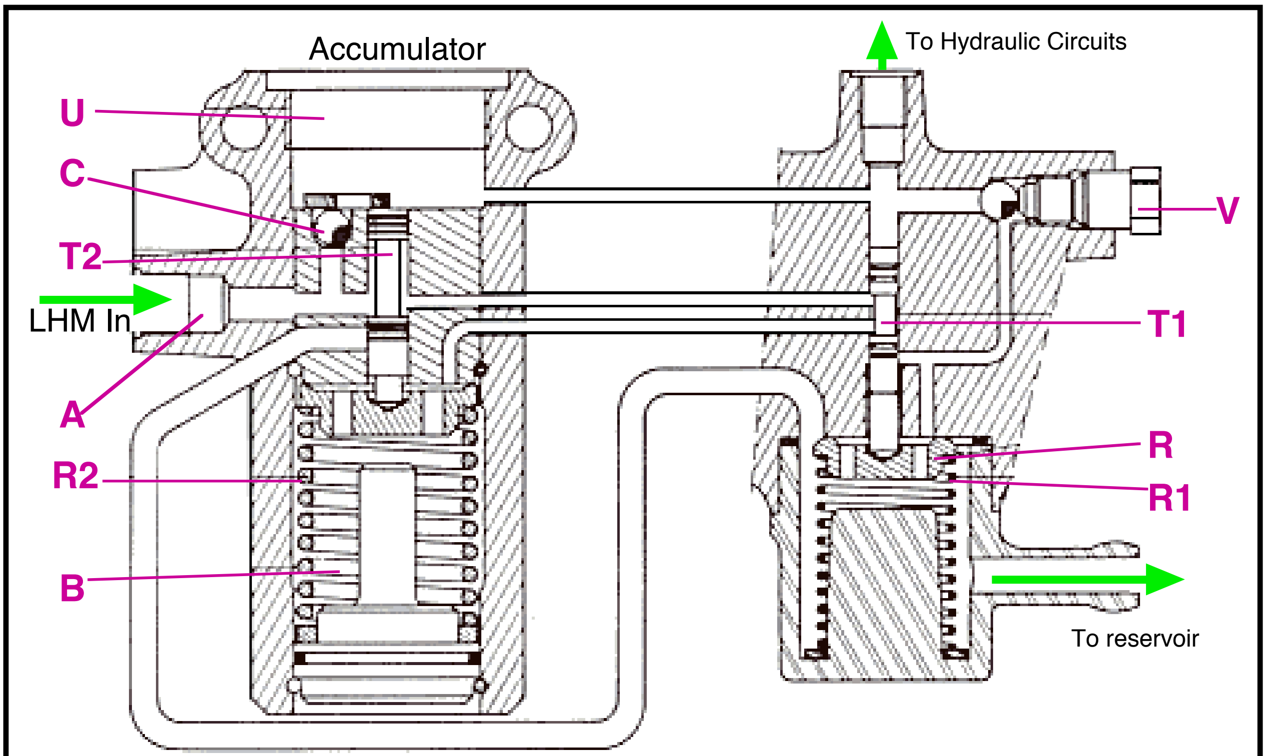
In operation, with the engine running the pump supplies pressurised LHM to the sphere. Pressure then rises in chamber A, lifting the ball of the non-return valve and allowing pressurised

LHM to enter the accumulator U. There is no pressure in chamber R.

Pressure acting on the surface of the ball creates a force F = p x s which tends to force the ball onto its seat. This same pressure acting on the piston head (in chamber U) creates a force F= P x S which tends to lift the ball off its seating. The surface S being larger than s, the result of F and f: (F - f) would lift the ball off its seat as soon as pressure arrives. To hold the ball on its seat until the cut-out pressure is achieved, a spring A is situated under the ball. When the product of (F - f) exceeds force T, the ball B is lifted off its seat. Pressure drops in chamber A and the ball of the non-return valve seats again. Since the pressure in chamber A drops to nil, the force F also becomes nil, thus increasing the strength of F over T which helps to maintain the cut-out condition.

The use of pressurised LHM by the various hydraulic units, leads to a drop in pressure in the accumulator and the force F weakens. When T becomes the stronger it forces the ball B back onto its seat. Pressure rises in chamber A, creating again a force F which helps the spring T. The pump then circulates LHM under pressure to the chambers A and U.

From May 1969 a Pilot-Valve type Regulator was introduced.



Pilot-Valve Regulator at cut-in phase

The Pilot-Valve Regulator consists of 4 chambers interconnected via a non-return valve and two slide valves.

Chamber A is connected to the feed from the pump.

Chamber U is connected to chamber A, the accumulator and supply to units.

Chamber B is connected to chamber A or chamber R depending on the position of the pilot valve T1.

Chamber R is connected to the LHM reservoir.

Pilot Valve T; this allows LHM to flow into chamber B or from chamber B to chamber R. It is controlled by the pressure of the LHM in chamber U

Slide Valve T2; this allows LHM to flow from chamber A to chamber R depending upon its position. It is controlled by the pressure of LHM in chambers U and B.

Non-return Valve C; this allows LHM to pass only from chamber A to chamber U.

Pressure-release screw V; this allows LHM in chamber U to escape back to the reservoir via chamber R, if required.

Operation of Regulator cut-in

LHM from the HP pump (in chamber A) rises in pressure in chamber U and the supply circuits by lifting the non-return valve C. This pressure rises simultaneously in chamber B via pilot valve T1. Eventually the cut-out will operate, as the rising pressure in chamber U creates an increasing force F on the upper face of the pilot valve T1, which tends to force the slide valve downwards. As soon as this force F becomes stronger than the force of spring R1, the pilot valve T1 moves downwards slightly, cutting off the supply of high pressure LHM to chamber B. Meanwhile the pressure continues to rise in chamber U and the pilot valve T1 is forced further down and connects chamber B to the reservoir via chamber R. When the pressure in chamber B drops to zero, the slide valve T2, now subjected to the pressure in chamber U, moves down and compresses the spring R2. This slide valve connects the feed from the HP pump (chamber A) to the chamber R and to the return to the reservoir. Therefore the pressure existing in chamber U closes the non-return valve C and the pump circulates LHM back to the reservoir without pressure.

Operation of Regulator cut-out

As LHM pressure is used by the hydraulic systems, this leads to a drop in pressure in the accumulator and chamber U. The pilot valve T1 then moves up under the influence of the spring Rl. First it closes the port leading to chamber R, then connects the LHM feed from the pump to chamber B. At this point, slide valve T2 under the influence of spring R2 moves up and closes the return to the reservoir via chamber R. The pump circulates LHM under pressure to chamber U.

Operating Pressures

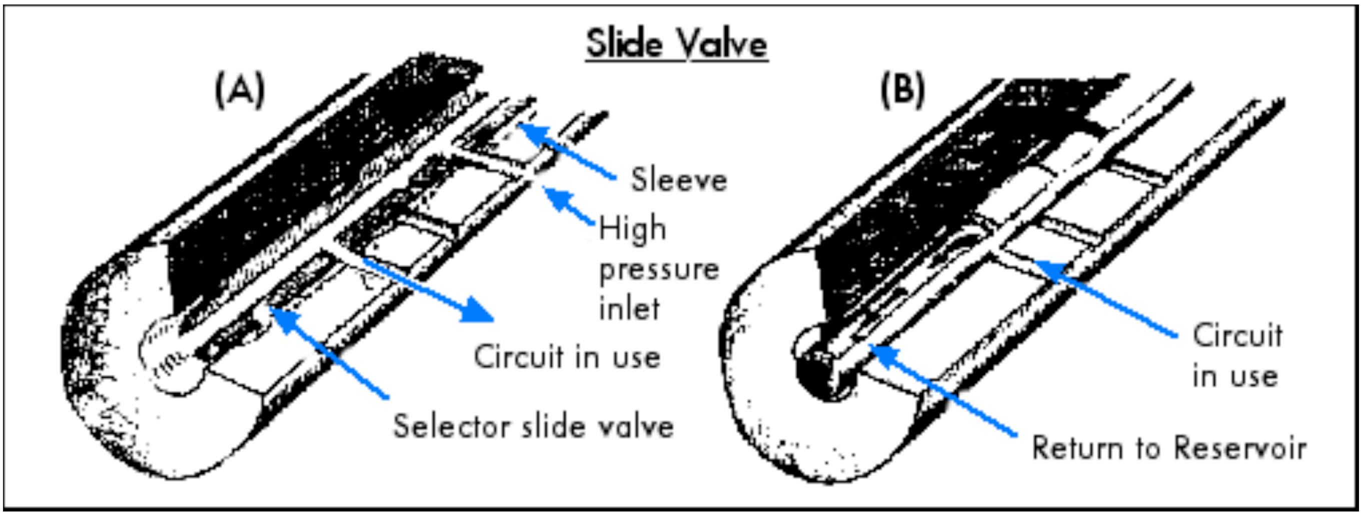
Cut-out pressure 162 - 175 bars (2305 - 2490 psi)

Cut-in pressure 140 - 147 bars (1990 - 2090 psi)

Distribution and regulation of pressure within the hydraulic system

Pressure distributors and regulators are integral parts of many of the hydraulic units on the DS. It is therefore essential to know their principles of operation to understand the working of the units.

A pressure distributor is a valve which will admit or exhaust LHM under pressure to or from one or more circuits. A distributor may also isolate this unit or units from both the inlet and exhaust lines. The Pressure Distributor generally takes the form of a slide valve operating within a sleeve. It is the position of the slide valve which is the controlling factor in the operation of the circuit.



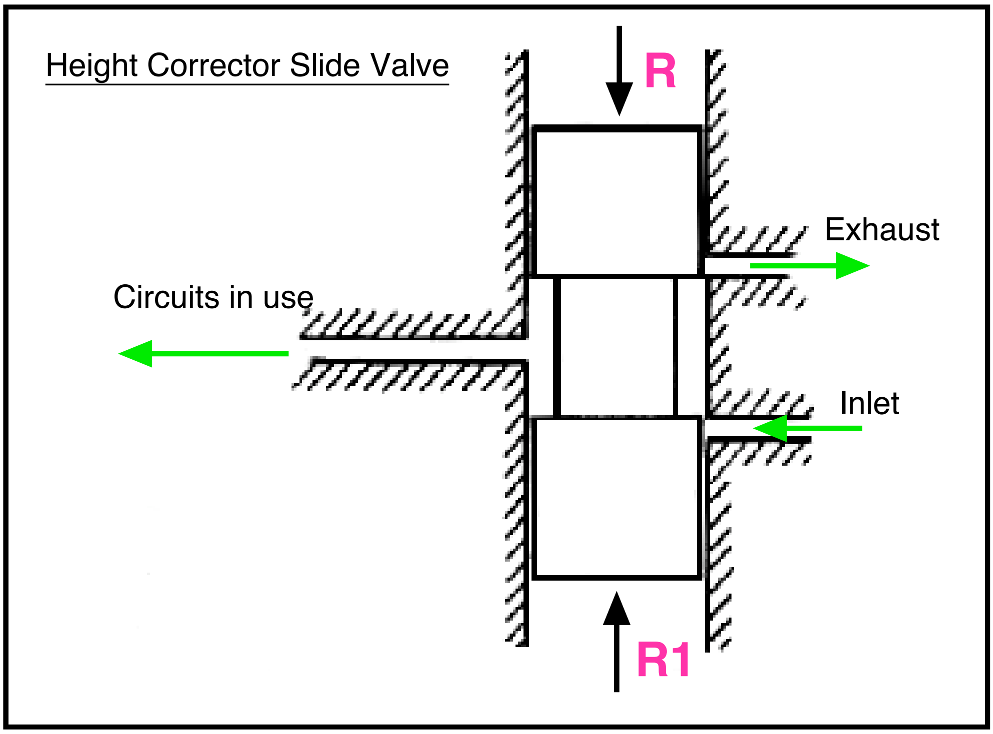
Gear Selector Slide Valve

An example of this type of pressure distributor, as used on the DS, is the gear selector slide valve, which operates within a sleeve. This slide valve is hollow and has one inlet for the supply of pressurised LHM and five outlets; one to engage each of the four forward gears plus reverse. Longitudinal and circumferential grooves machined in the slide valve allow the LHM to return to the reservoir from the various circuits. The sleeve has 5 ports, one to supply each gear.

With the gearbox in neutral, the valve is at rest and the various outlets from the slide valve align with a plain part of the sleeve. The various ports on the sleeve communicate with the reservoir via the grooves in the slide valve.

Pressurisation (Diagram A): When the slide valve is moved, a port is aligned with a corresponding port in the sleeve and the circuit is pressurised.

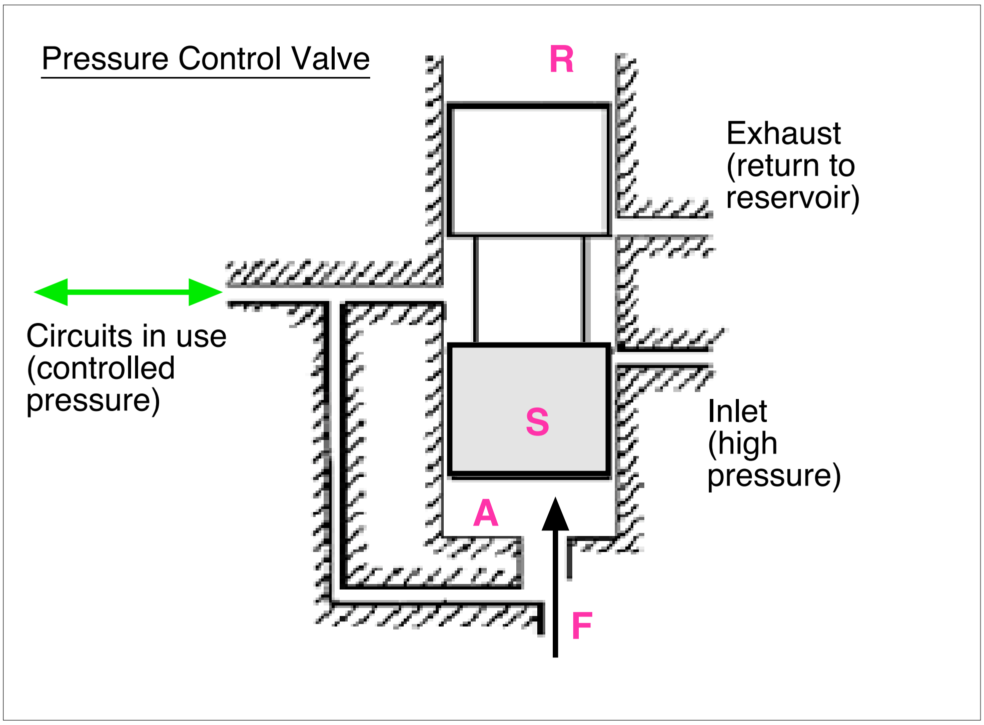
De-Pressurisation (Diagram B): With the slide valve in any position which allows alignment of an outlet to a circuit, to connect with the return to the reservoir, the LHM under pressure in that circuit will flow out and return to the reservoir. It should be noted that the operation of this distributor is independent of the amount of effort applied to the slide valve when it is being moved. Only the movements and positioning of the slide-valve itself, permits the distribution of LHM.



Another type of pressure distributor, are the height correctors. This is a slide valve with two shoulders that slide in a sleeve in which there are three ports. In the neutral position the slide valve closes the inlet and exhaust ports. The supply port to the circuit is always open. The slightest effort "R" on the slide valve, will introduce pressure and move it so that the inlet port is opened. The circuit is then connected to the source of pressure. Thus the pressure in the source of pressure circuit will enter the circuit in use and the pressure values in the two circuits will be equal, regardless of the effort on the slide valve.

Conversely, a force R 1 (opposed to R) applied to the slide valve will move it so that the exhaust port is opened and it will depressurise. The LHM under pressure in the circuit in use will flow out and return to the reservoir. It should be noted that the forces R and R 1 are connected with the operation of the slide valve only by the presence of a dash-pot in the height corrector.

It is the case that some hydraulic units can only be made to operate correctly by using a pressure lower than that held in the Source of Pressure circuit. In some cases it is necessary to use a variable but controllable pressure, such as for the steering and braking circuits. Or a constant but relatively low pressure, such as the clutch circuit. However, a simple pressure distributor cannot satisfy all these conditions; in these cases the DS uses a pressure control-valve.



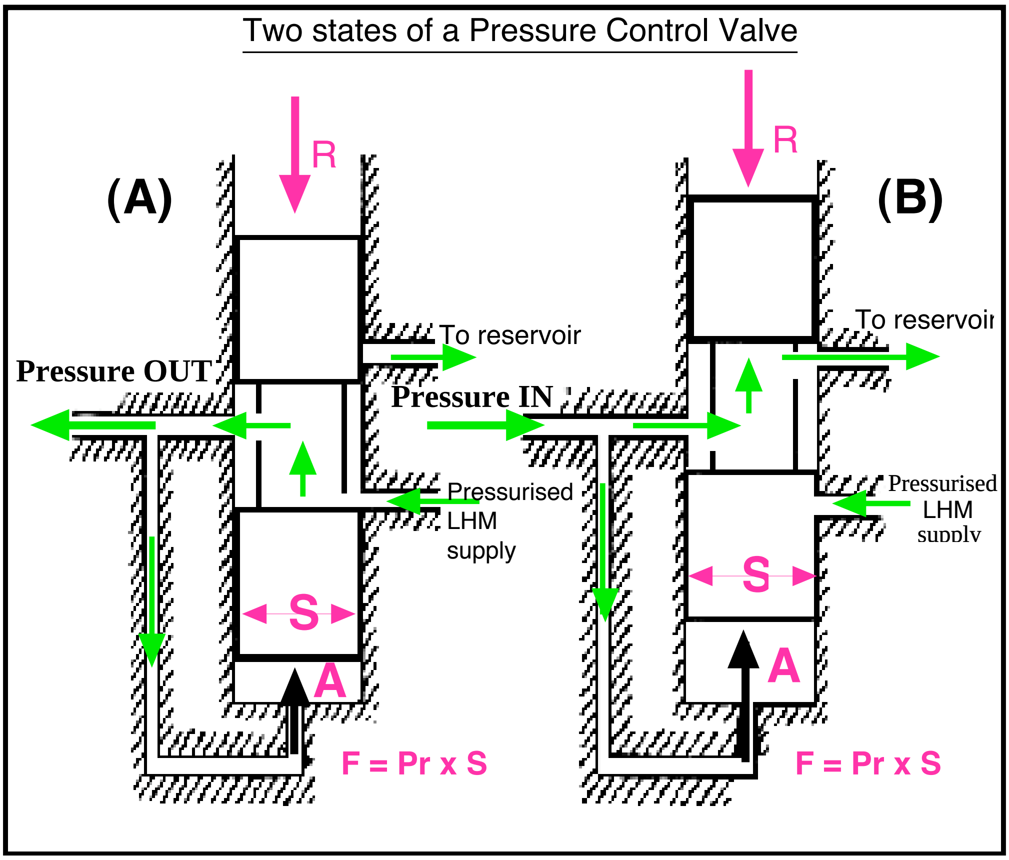
Pressure control valve

The diagram shows the various parts which comprise the pressure control-valve. The force R applied to the end of the slide valve may be the strength of a spring, the effect of the different calibrations of several springs, or a physical input from the driver.

To make the control-valve operate, it is necessary to connect the source of pressure with the circuits to be used. This connection can be made automatically; at rest the source of pressure is connected to the circuit. Or it can be operated manually; at rest the position of the slide valve is not important.

When pressure rises in the circuit in use, pressure P also rises in chamber A under the slide valve. A force F = P x S opposes the force R (S = The surface area of the slide valve).

When F becomes equal to R the slide valve takes up a position of equilibrium in which both the inlet and exhaust ports are closed. The pressure in the circuit is therefore limited to a value P = R / S. This pressure is independent of that existing in the source of pressure circuit. If force R is increased, the controlled pressure rises, and vice versa.



For a fixed value of R: If the pressure drops in the circuit being used, F decreases, R prevails, the slide valve moves to the inlet position, and the regulated pressure Pr increases. (Figure A). If the pressure rises in the circuit being used, F increases, the slide valve moves to the exhaust position and the pressure decreases (Figure B).

These two states, resulting from seepage and friction between the slide valve and its sleeve, result in the regulated pressure oscillating between two values very close to the theoretical pressure.

Applications:

If R is the calibrated strength of a spring T, a regulated pressure is obtained: Pr = T / S. An example of this, is the automatic gear change slide valve in the gear selector.

If R is a variable manual force, or the variable calibration of a spring (the calibration varying with the movement of the spring's abutment) a pressure is obtained which is proportional to the force R. This is therefore an adjustable regulator. An example of this, is the hydraulic Brake Control and Centrifugal Regulator.

Dash-Pots:

To avoid a rise of pressure which is too rapid in the circuit in use, the movement of the slide valve may be slowed down by the use of a dash-pot. This method also avoids oscillation of the slide valve. A piston with a calibrated amount of clearance slides within chamber A, the diameter of which is greater than the slide valve. When the slide valve moves down, the LHM is restricted in its movement between the piston and the walls of the chamber A, which slows down the movement of the valve. A weak spring and a hole drilled in the head of the piston allow a rapid return of the slide valve.