1 The Master Cylinder & Caliper: Figure 1

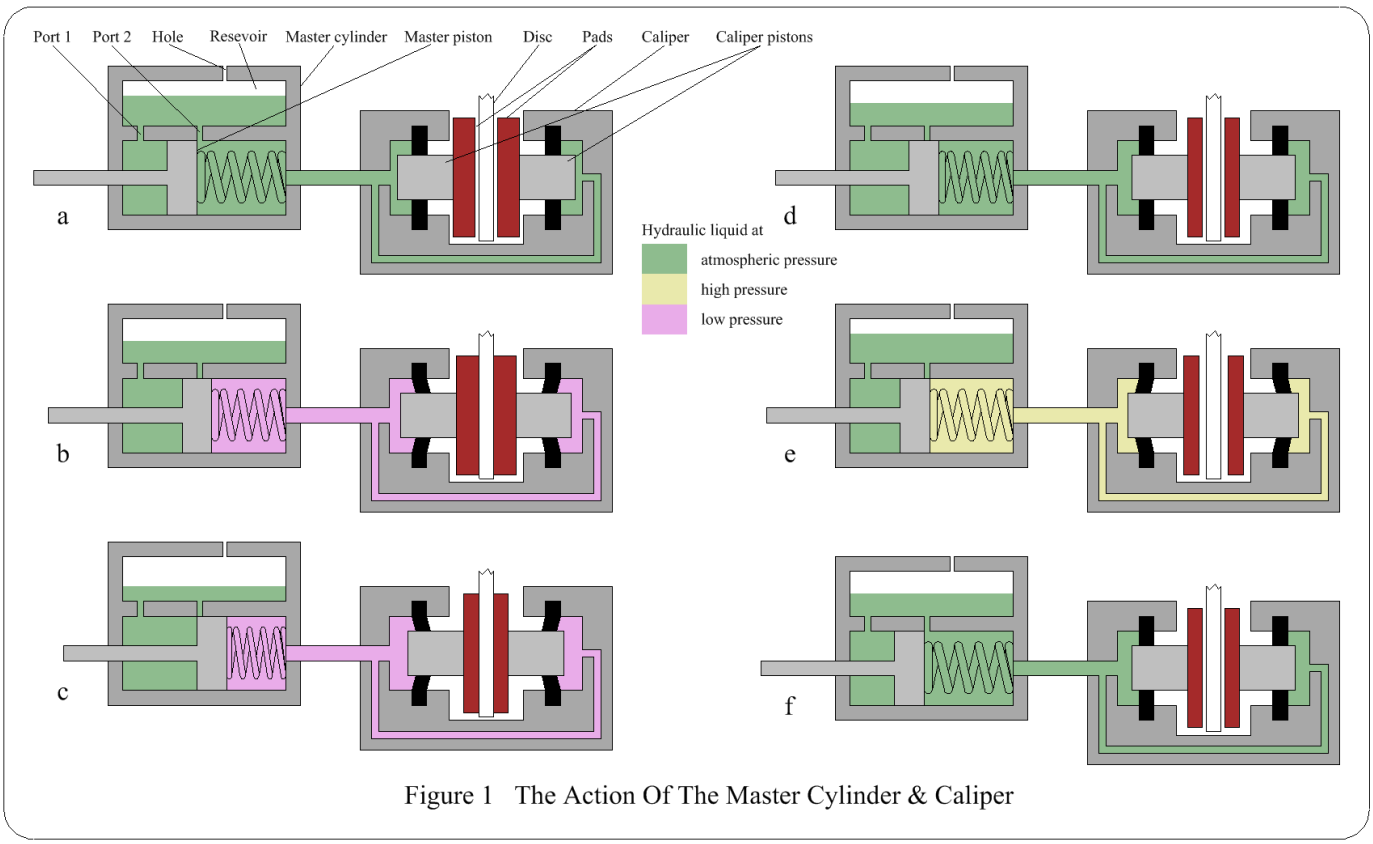

Figure 1 The Action Of The Master Cylinder & Caliper

Note: Port 1 enables liquid to fill the cylinder behind the piston, so a vacuum is not created there.

a) The brake not applied
b) Brake applied. Master piston pushed past Port 2, sealing the cylinder, & liquid pushed to caliper. Caliper pistons move. Seals deflect.
c) Pads wear. All pistons move further, the caliper pistons sliding through seals.
d) Brake released. The spring pushes the master piston back, the seals undeflect & pull the caliper pistons back.
e) The spring in the master cylinder is strong enough to always return the master piston to its starting point. The master piston moves further back, a negative pressure is created & the caliper pistons move further back, deflecting the seals.
f) The spring has pushed the master piston back to its starting point, uncovering Port 2 which enables liquid to flow from the resevoir to the cylinder, relieving the negative pressure. The seals undeflect, moving the caliper pistons forward.

The negative pressure can of course not exceed -1 atm. This is tiny in comparison with the enormous positive pressures created during brake application.

The amount of wear that can occur during any one brake application is tiny. If it is enough to cause the stiction between caliper pistons and seals to be overcome & the pistons to move through the seals, the amount of excess movement is also tiny.

After the brake operation the distance between the pad & disc is the same as it was before the operation, so the next operation does not require more movement of the brake pedal. The caliper pistons have been moved forwards, leaving some room behind them. This room is filled by liquid from the resevoir, so the level of liquid in the resevoir is now lower than it was before the operation.

As mentioned, distances are tiny. The diameter of Port 2 is < 1mm, & the seal on the master piston is next to it. This means that there must be a gap between the brake pedal & the

connecting rod of the master piston.

2 The Master Cylinder: Figure 2

Modern master cylinders have two pistons. The first drives liquid to two calipers & the second drives liquid to the other two calipers. Some manufacturers have the front brakes as a coupled pair & the rear brakes as the other coupled pair, & other manufacturers couple the brakes diagonally. The operation of the each circuit is as described above. "Primary" & "secondary" are my terminology. The primary spring is stronger than the secondary spring.

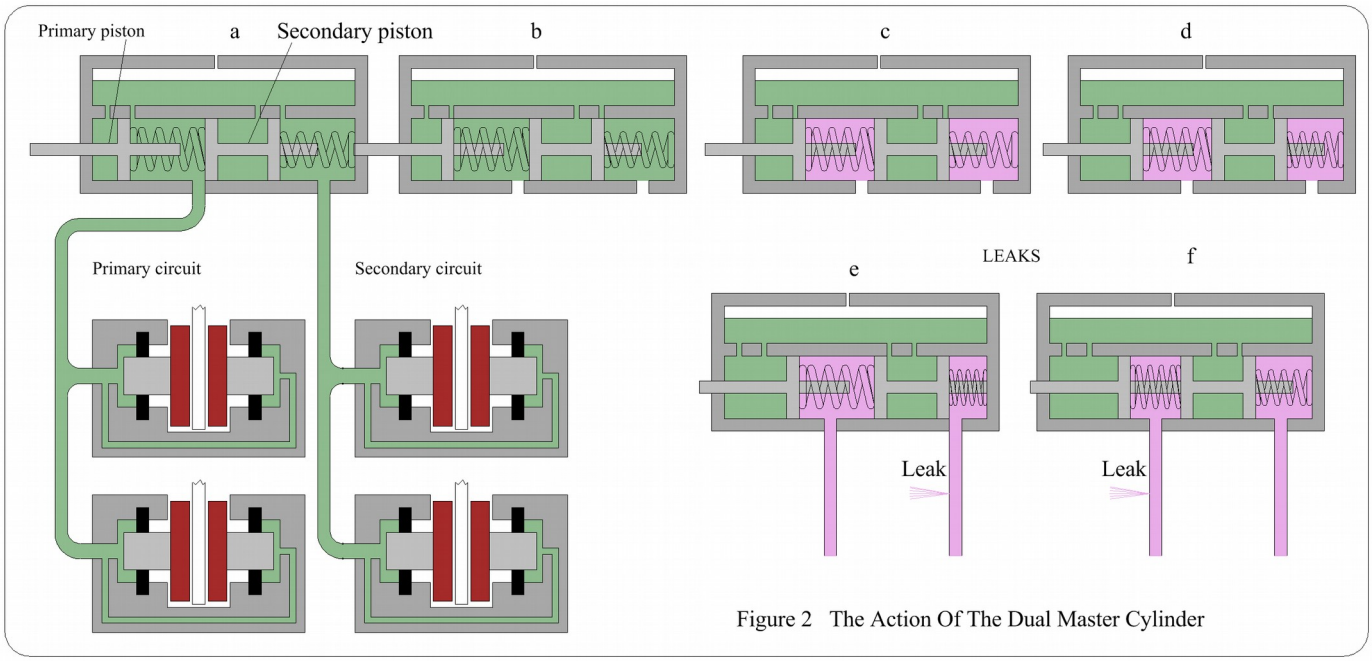

Figure 2 The Action Of The Dual Master Cylinder

a) The brake not applied
b) Brake applied. The primary piston moves forward & the primary spring pushes the second piston forward. Motion continues until the ports are closed.
c) The primary piston moves further & pressure increases in the primary circuit, reinforcing the primary spring to push to move the secondary piston further, increasing pressure in the secondary circuit.
d) Full pressure

3 Leaks, or, The Method In The Madness: Figure 2e & 2f

By using two circuits a leak in one will not affect the other. A leak in the secondary circuit will cause piston 2 to move forward until it touches the end of the master cylinder. Further travel of the brake pedal will then maintain pressure in the primary circuit. This is why the primary spring is stronger than the secondary spring.

If a leak occurs in the primary ciruit futher pedal travel will move the primary piston until it touches the secondary piston & pressure can be maintained in the secondary circuit.

A very light car can be stopped with a master cylinder & calipers. Formula 1 cars are not allowed to use anything else. But road cars are so heavy that the force required on the brake pedal would be inconveniently high. Servomechanisms are used to magnify the force applied by the pedal.

Different servos have different details but their principle of operation is the same. There are two types, direct & indirect (my terminology; indirect are often called remote), both of which are cylinders with diaphragms separating them lengthwise into two chambers. One chamber is connected to the engine inlet manifold, so a partial vacuum always exists in this chamber. That is why they are called vacuum servos.

Direct servo: Figure 3

If a direct servo is used, the pedal acts on this & the servo operates the master cylinder. Figure 3 is a diagram of such a servo.

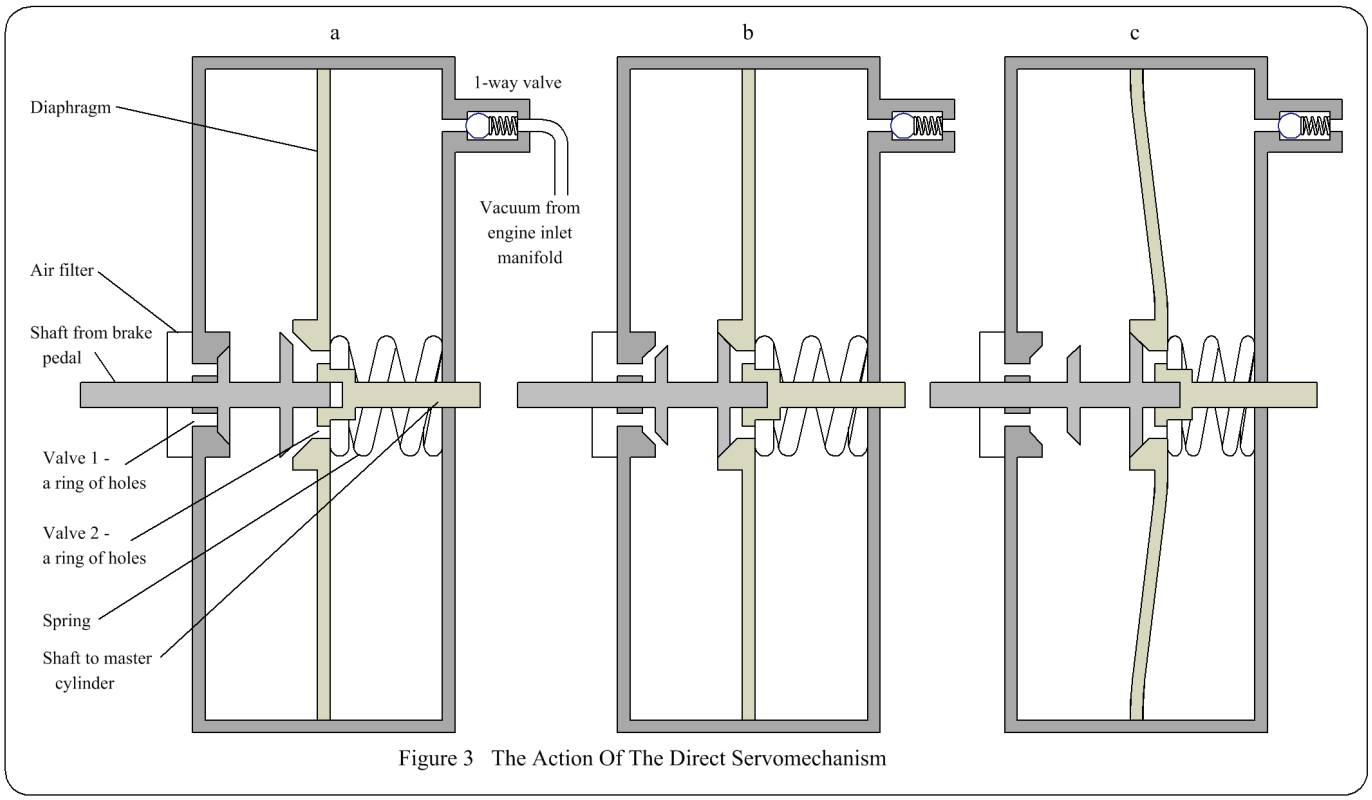

Figure 3 The Action Of The Direct Servomechanism

a) The brake not applied. Valve 1 is closed & valve 2 open. Valve 2 being open means that a vacuum exists in both chambers.
b) Brake applied. Valve 2 is closed, separating the chambers, & valve 1 is opened, enabling air to enter the left chamber through a filter, causing a differential pressure between the chambers.
c) The differential pressure pushes on the diaphragm, distorting it, & pushing the output shaft which pushes the piston in the master cylinder. Force being maintained on the pedal keeps the input shaft pushed against the diaphragm.

When the pedal is released, valve 2 opens, the vacuum sucks air out of the left chamber, differential pressure is lost & the diaphragm moves back to its relaxed state, closing valve 1.

Indirect servo: Figure 4

Although working the same way as the direct servo, this requires another cylinder. The shaft of the servo operates the cylinder which operates the brakes, & the extra cylinder, still, confusingly, called the master cylinder, operates the brake cylinder.

When the pedal is pressed hydraulic pressure moves the master cylinder piston, which operates the valves in the servo. Then the servo operates, reinforcing the force on the pedal.

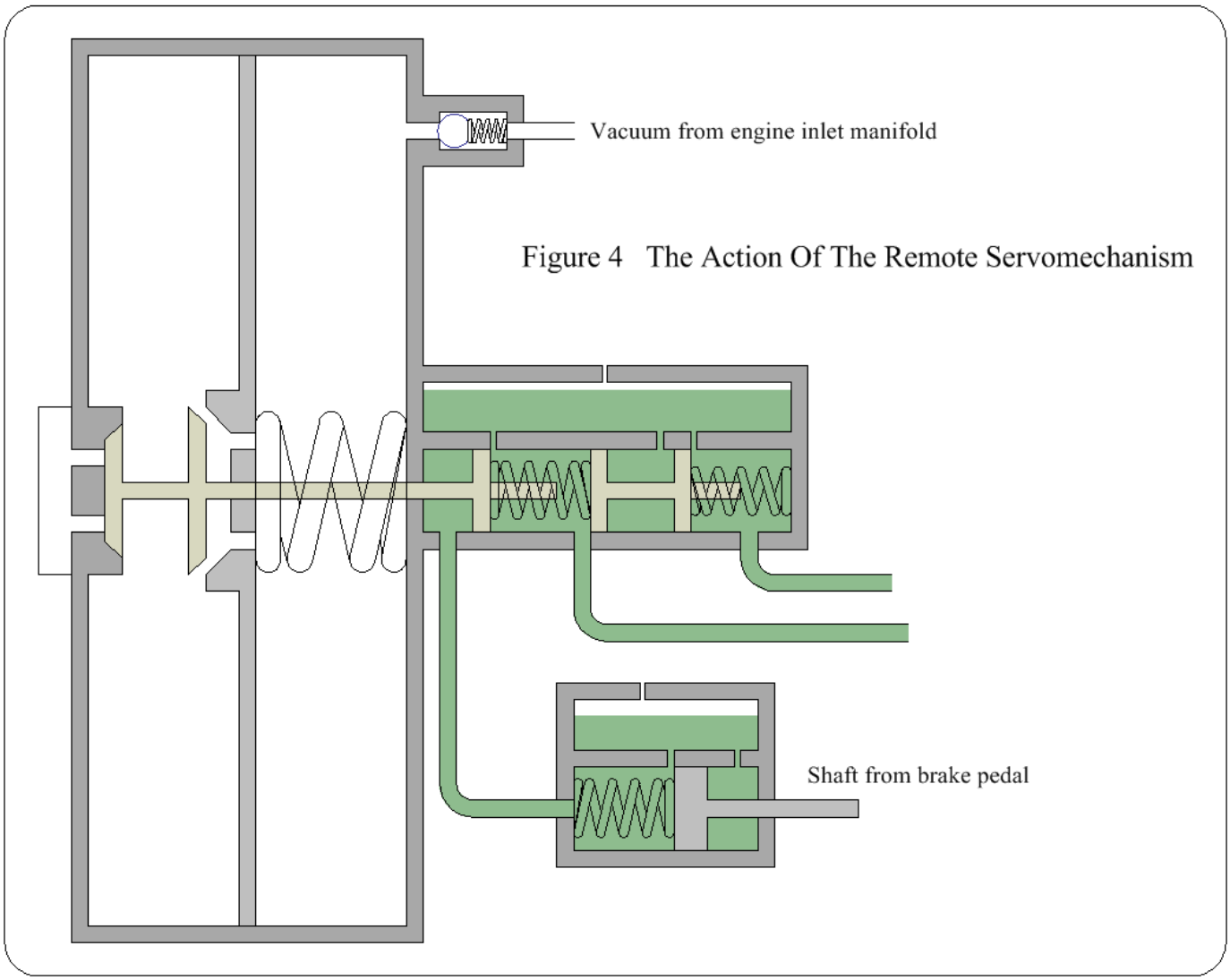

Figure 4 The Action Of The Remote Servomechanism

5 Weight transfer

When a vehicle is retarded a phenomenon called weight transfer occurs. More of the car's weight is felt on the front wheels & this extra weight is removed from the rear wheels. Whatever the car's initial front to back weight bias (which is usually more at the front anyway), weight transfer always causes the front tyres to be pressed harder onto the road than the rear tyres. This means that there is more friction between the front tyres & the road than between the rear tyres & the road. So if the maximum stopping force that could be applied to the front wheels without skidding was applied to the rear wheels, the rear wheels would skid before the front ones. It is therefore desirable to apply the maximum braking force to the front wheels & a lesser force to the rear wheels. There are many ways of achieving this but a common one is to use a proportioning valve.

Older cars using a single, as opposed to a dual, master cylinder, have front & rear brakes on one circuit, & so do newer cars with diagonally coupled brakes. A proportioning valve sense the hydraulic pressure in the front brake circuit & feeds a lesser pressure to the rear brakes. They are sealed units so their operation is not described.