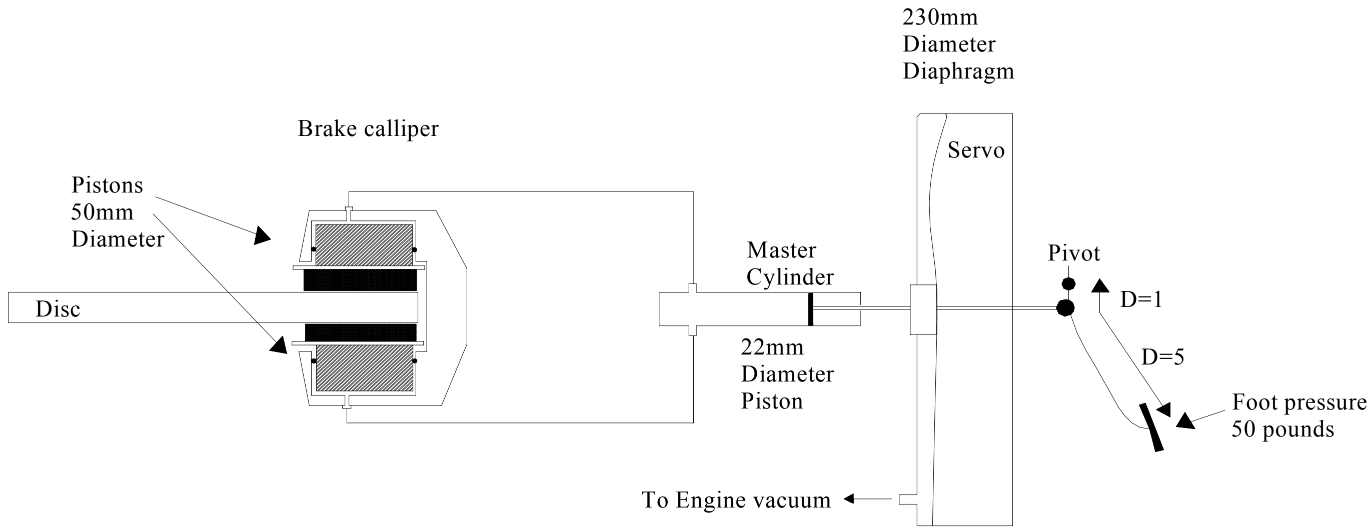
TECHNICAL DATA SHEETS



Introduction – Pressing the brake peddle and stopping the car seems such a straight forward thing to do, but have you ever thought what is actually happening under the bonnet to bring this simple action about?

Pictured above is a simplified pictorial representation of a braking system consisting of a peddle, servo, master cylinder and brake calliper. I will use this as a method to describe the physics of force multiplication to achieve an effective braking system.

Peddle – The brake peddle is mounted on a block together with the accelerator and clutch (if fitted), the point at which it mounts is the pivot point. The take off point for the push rod going to the servo and master cylinder is a little distance (D=1) from the pivot; not too far so this will restrict the arc that it must travel through when the peddle is pressed. The point where your foot presses the peddle is another distance (D=5) from the pivot point and it is the ratio of these two distances that provide the mechanical advantage.

Your foot travels; for instance 5 inches but the take off point for the push rood will only travel 1 inch, therefore there is a mechanical advantage of 5 to 1. So the 50 pounds of force you exert with you foot is now multiplied up to 250 pounds of force.

Servo – The servo is basically a pressure multiplier that makes use of the engine generated vacuum, this vacuum, if it were a perfect vacuum like that of outer space would be minus 14.5 pounds per square inch (PSI), but considering this vacuum is being generated by the crudest of vacuum generators; the engine, I shall consider this vacuum to be minus 10 PSI although in the real world this would be a little better than that.

This minus 10 PSI is applied to both sides of a diaphragm so with the same (negative) pressure both sides the net result is nothing during normal driving. When the peddle is pressed this allows the vacuum from the right hand side to escape, not all of it just a bit so in this example I will allow half of it to escape because of the moderate 50 pounds of force applied by the foot. This means that there is now minus 10 PSI on the left of the diaphragm and only minus 5 on the right, this effectively means that there is 5 PSI pressing away from the peddle towards the master cylinder. The more you press the peddle, the more vacuum escapes so the more force is applied.

This 5 PSI (remember that this is 5 pounds per square inch) acts on the diaphragm inside the servo, I allowed a 230mm diaphragm which is 9 inches diameter. The next bit is important because it is used further along. To work out how much mechanical advantage 5 PSI gives on a 9 inch diaphragm we need to work out the surface area of the diaphragm (remember – pounds per square inch). To do this we need the radius which is half the diameter so half of 9 inches is 4.5 inches, now this radius needs to be squared (multiplied by itself), so 4.5 times 4.5 is 20.25 square inches. This 20.25 in^2 now needs to be multiplied by pie ($\pi = 3.142$ which is the ratio of a circle's circumference to it's diameter), so we now get 20.25 times 3.142 which equals 63.6 square inches of diaphragm, so with our 5 PSI (pounds per square inch) we get 5 pounds times 63.6 square inches giving 318 pounds of force.

Quick summary to date – The driver presses with 50 pounds of force, the peddle multiplies this by 5 from it's mechanical advantage to get 250 pounds of force plus the extra 318 pounds from the servo we how have 568 pounds of force available to us.

Brake master cylinder – This where our purely mechanical force gets transformed into hydraulic pressure where the real work gets done. This hydraulic system relies on the system being completely leak proof and free of trapped air.

The master cylinder is simply a tube, called the bore with a piston and seal running up and down it connected to the output of the servo. When the piston is pressed towards the closed end of the bore it builds up pressure in front of it and it is this pressure that is sent to the brake calliper that actually starts stopping the car.

The bore of our master cylinder is 22mm in diameter, converted into inches is 0.866 inches. To work out the area as we did with the servo we must square the radius and multiply by π. So 0.866 divided by 2 is 0.433, 0.433 squared is 0.2, 0.2 multiplied by π (3.142) is 0.59.

With our 568 pounds of force to date and a bore area of 0.59 we are now generating a hydraulic pressure of 335 PSI. I know this seems like a reduction in force but bear with me.

Brake calliper – A brake calliper consists of a heavy chunk of metal with two pistons facing each other that push on two brake pads that in turn squeeze the brake disc that is connected to the road wheel.

The diameter of the pistons in the calliper is 50mm, which is 2 inches. So with 335 pounds per square inch pushing the pistons we again need to know the surface area of the pistons to work out the actual force applied through the pads to the disc; and road wheel.

2 inches diameter is 1 inch radius, 1 squared is 1, multiplied by π (3.142) is 3.142 square inches of calliper piston area. With our pressure of 335 PSI from the master cylinder we now have a force of 335 times 3.142 square inches of piston giving 1052 pounds of force.

With the surface area of the master cylinder 0.59 and the combined surface area of the calliper pistons being (2 times 3.142) 6.284 we have achieved a mechanical advantage of 6.284 divided by 0.59 giving an advantage of 10 to 1.

Summary - OK, so there are two pistons gripping the disc through the pads which gives 2104 pounds of force and because we have two front wheels this is now 4208 pounds of stopping force; not bad for an initial 50 pounds of foot pressure and of course there are the rear wheels probably giving about an extra 1000 pounds of force.

Components working against us. – With 4000 pounds of stopping power for a very moderate application of 50 pounds seems very good, but there are two things working against us reducing the stopping power.

1. It is the tyres that are in contact with the road driving the wheel round, the wheel is connected to the brake disc at the same point; the bearing/stub axle. This means that the wheel and disc are effectively one item, but the disc and where the brake pads grip this disc are smaller than the wheel/tyre combination so this means that our levers are now working against us just as at the brake peddle it was working for us. So if you consider the brake disc being half the diameter of the wheel and tyre we have now halved our effective stopping power from 2104 pounds per wheel down to 1052 pounds.

2. The other part working against us is the coefficient of friction of the brake disc against the brake pad friction material. Sliding steel over steel and rubber over rubber give different coefficient of frictions even thought they are the same material sliding over each other. For this exercise we shall assume that the manufacturers have done their homework and got a coefficient of friction of one, meaning we get no loss of stopping power through the brake pads.

Problems with braking systems. –

1. With all this hydraulic pressure you must assure that the system has no leaks because the pressure will drop off very quickly given the limited volume of brake fluid the master cylinder can move in one peddle operation. Air in a system entering through a leak will cause the brake master cylinder to compress the air in the system rather than brake fluid, if this happens you cannon exert as much pressure on the discs.

2. Contamination of the disc and brake pad surface, this will lower the coefficient of friction and reduce the efficiency dramatically, think of going through deep water and how poor the brakes are after that!

3. Old brake fluid, this DOT4 brake fluid id hydroscopic, this means it absorbs water over time, if this happens to get to the fluid behind the pads; which it will, and you start using the brakes heavily you will transmit enough heat to the fluid to boil the water content, this produces steam which is compressible and reacts the same as air; you get crap brakes! Brake fluid should be changed every 2 years irrespective of mileage. DOT5 brake fluid is silicone based and does not absorb water so eradicated this, however the DOT5 fluid is slightly compressible so gives a slightly poorer peddle feel; more spongy.

The only way to improve braking is. – to do any of the following;-

1. Increase the diameter of the discs AND mound the calliper further away from the stub axle toward the outside of the tyre. This will make the levers principle work less against you.

2. Increase the diameter of the pistons inside brake calliper, or increase the number of pistons in the calliper whose total surface area is larger than the original single piston.

3. REDUCE the diameter of the bore/piston of the master cylinder and keep the same callipers. This method is risky because although it increases the mechanical advantage (master cylinder to brake calliper) the total volume of fluid moving will be the same and will require the peddle to move further to achieve this and will give a poor peddle feel.

4. Change the composition of the brake pads to a material with a greater coefficient of friction compared to the standard material. The drawback with this is this type of pad will only be efficient over a certain temperature so will not wok well from cold, also you don't get something for nothing so don't expect the discs to last long because if the pads aren't wearing you can sure bet you discs will! To overcome this a different material disc will have to be used like carbon fibre or ceramic so expect big bills!

Common errors while trying to improve braking efficiency. – Do not do any of the following;-

1. Don't increase the pad size to get better braking; this will do absolutely nothing. It will help with brake cooling and make the pads last forever but that is all.

2. Don't increase the size of the master cylinder by fitting one with a larger bore. This will make thing much worse by reducing the mechanical advantage you will have to put twice as much foot pressure on the peddle to recover to the original braking effort.