



TR250 & TR6 Brakes

Part I - Overview & Theory

I have a pile of parts in a rented storage garage that someday will be a '70 TR6. It's winter now, too cold and snowy to get the TRs out and thus a good time to do some bench work on the brake system. I also volunteered to host a Buckeye Triumphs "Brake Tech Session" using parts from the '70 as well as parts members bring with them. This is photo opportunity too good to miss. It is also an opportunity to write a description of the TR250 & TR6 Brake System and how one amateur mechanic overhauled his system.

Before jumping in, a word or two about organization. The brake system has many components and at first glance might seem overwhelming since it's distributed all over the car. I've found that projects such as this are best dealt with on a top down basis. With this in mind, I've organized this into eleven separate notes, this theory & overview followed by ten notes dealing with the nitty gritty of overhauling and troubleshooting the system components:

- **Theory & Overview**
- **Master Cylinder & PDWA**
- **Servo**
- **Pedals**
- **Front Brakes**
- **Rear Brakes**
- **Handbrake**
- **Brake Pipes**
- **Brake Fluids**
- **Bleeding & Adjusting**
- **Troubleshooting**

Past experience has shown that as soon as one of these set of notes are put on the club website I get a flurry of emails with suggestions & corrections. Breaking into smaller sections as done here permits quicker and easier revisions to incorporate all the corrections and usually some really neat suggestions. Also, in this case, the parts of several notes are being deferred awaiting completion of the frame overhaul for the '70 s that the brake pipes and cables can be installed.

One last point before digging in: these notes describe what I did on my car for my personal use and are provided here for entertainment; they are not meant to be instructions for others to do maintenance on their vehicles.

Overview: The same brake system with only a few minor changes was used from the first TR250 manufactured in 1968 through the last TR6 manufactured in 1976. The system is hydraulically operated using disk brakes in the front and drum brakes in the rear. Separate hydraulic systems are used for the front and rear so that a failure of either the front or rear hydraulic system should allow a measure of braking through the other half the system. The system employs a single master cylinder with separate chambers and reservoirs for the front and rear. The master cylinder is designed such that under normal operation the front and rear have equal hydraulic pressure. The system is equipped with a Pressure Differential Warning Alarm (PDWA) device that senses a difference in pressure between the two parts that indicates a failure in half the system. The PDWA is equipped with an electrical switch that turns on the red **BRAKE** warning light on the dash when a failure is sensed. The system is equipped with a servo that amplifiers the force applied to the pedal resulting in a reduced pedal force required to operate the brakes. The system also has a cable mechanical arrangement to operate the rear brakes for the hand brake function.

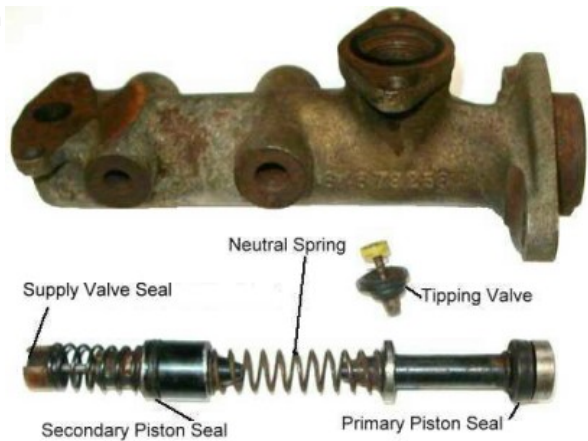
The variations to the system are:

- **Front calipers:** The front caliper pistons were changed at CC29928 to accommodate a different style piston boot. The calipers were changed to use metric threads at CC81078 in 1972. The metric threads include the caliper end of the short pipe between the caliper and the front hoses and the bleed screws. The two bolts attaching the calipers to the caliper mounting plate were also changed to accommodate different size holes in the calipers. The pad retaining pins were changed from 1/4" to 3/16" (3/16" metric?).
- **Rear wheel cylinders:** The rear wheel cylinders were changed from 0.70" diameter to 0.75" diameter either late in the '75 model year or early in the '76 model year.
- **Handbrake:** The handbrake handle was changed at commission number CF50,000 (~'76) with the addition of a switch to operate the Brake warning lamp when the park Brake is engaged and extenders on the rear wheel cylinder levers to apply greater force to the rear shoes.
- **Servo:** Apparently there were minor variations in the seals & non-return valves. Repair of the servo is normally beyond the scope of the amateur mechanic. However, after I finally got one apart (without using saw, cutting torch or explosives), I decided to examine it too.

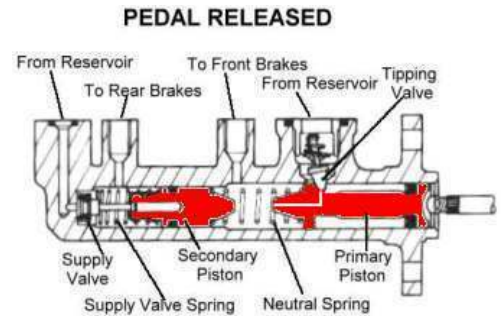
Master Cylinder: A plastic reservoir is attached to the top of the master cylinder casting as shown on the right. The reservoir has two sections, a small section at the front for the rear brakes and a larger section to the rear for the front brakes. The ports to the front and rear brake pipes are also shown. These ports use different size fittings to prevent connecting the system incorrectly. However, the ability of an amateur mechanic in this regard should not be underestimated.



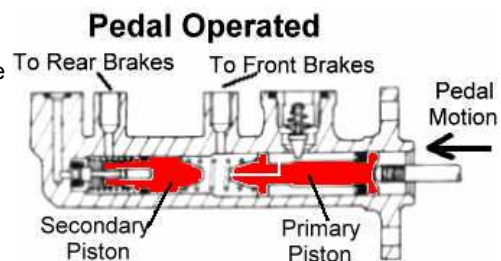
The master cylinder internal components are shown on the right. The system uses tandem pistons. Although it's not obvious from the picture, the primary piston is a little larger diameter than the secondary piston. The primary piston pushes the fluid to the front brakes as well as pushing fluid to drive the secondary piston that supplies the rear brakes; hence the primary piston does double duty. Aren't these parts filthy? They really clean up nice as seen later.



The sketch at the right shows the situation when the pedal is released. The supply valve spring pushes the secondary piston to the right, which also opens the supply valve allowing fluid from the rear brake reservoir to flow into the cylinder and on to the pipes to the rear brakes. The neutral spring pushes the primary piston to the right against the tipping valve. The tipping valve tips and opens letting fluid flow from the front brake reservoir into the cylinder and via the holes in the side and end of the primary piston into the area between the pistons and on to the pipes to the front brakes. The tipping valve prevents further movement of the primary piston to the right.



This sketch shows the situation after pedal motion forces the primary piston to the left. The side force on the tipping valve is removed allowing it to straighten and close off the front brake reservoir from the cylinder. The primary piston pushes the fluid into the front brake calipers where the pistons move out and push the pads against the rotors. This same fluid pushes the secondary piston to the left which first closes the supply valve and then forces fluid into the rear brake cylinders where the pistons move out and push the shoes against the drums.



There is a subtle but interesting point relating to the two different piston sizes. A little further on we see that the front brakes have no springs to push the pistons back into the calipers whereas the rear brakes have springs that push the pistons back into the wheel cylinders. Also, the front caliper pistons are much larger than the rear wheel cylinder pistons. The net effect is that as the master cylinder primary piston is pushed by the pedal a small pressure develops in the front system that pushes the pistons against the pads and in turn, the pads against the rotors removing all slack from the front system. This pressure is probably too small to overcome the force of the rear shoe springs with the small rear cylinder pistons. Once the slack is out of the front brakes, pressure will build as required. It is at this point the secondary piston starts to move. The interesting point is that since the master cylinder secondary piston is slightly smaller than the primary piston, the secondary piston will move further than the primary piston once the all slack is removed from the front brakes.

Nearly all the piston movement in the master cylinder and the calipers as well as the rear cylinders occurs under fairly low pressure. If there is no air in the system, additional force will cause little motion but instead cause the force of the pads against the rotors and the shoes against the drums to increase resulting in increased braking force.

Several things about the system are really neat. The secondary piston has the pressure of the front system on one side and the rear system on the other. This means that the front and rear systems operate at the same pressure; otherwise the secondary piston would move in the direction of the lower pressure until the pressures equalize. (This neglects the effect of the springs pushing on the secondary piston. However, the spring forces are small, nearly equal and oppose, so they essentially cancel.) This same feature allows the system to self adjust to differences in the fluid required to the two halves. For example, if the rear brakes are out of adjustment, the secondary piston will have to move further to provide sufficient fluid to move the shoes against the drums. The primary piston will also move further (more pedal to apply brakes), but the pressure in the two halves will still be the same.

Now what happens if part of the system fails? Lets first assume a rear brake line ruptures. When the pedal is pushed the same operation as described above will happen except that the secondary piston and hence the primary piston and the pedal will not encounter much resistance until the secondary piston runs into the back of the cylinder. After that point the secondary piston can't move any more and the pressure can then build between the two pistons and in the front system. On the other hand, if the front system ruptures, the pedal and primary piston will not encounter resistance until the primary piston physically runs into the secondary piston and then moves it to the point that the rear shoes are against the drums.

The failure of either half the system will significantly increase the brake pedal motion and will at best provide barely adequate emergency braking. The car should not be driven until all brake problems are repaired.

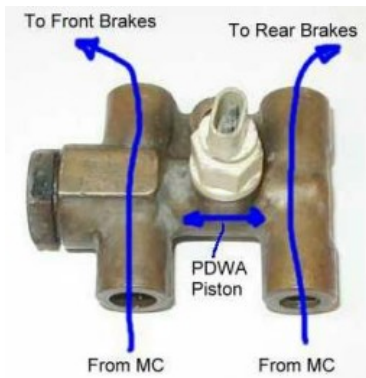
Pressure Differential Warning Actuator (PDWA): The PDWA is connected to the two master cylinder outputs by the short pipes shown on the right. The master cylinder is installed at an angle with the front pointing up. Recall that the front output of the master cylinder is for the rear brakes. These pipes cross so that the fluid for the front brakes gets to the front part of the PDWA and the fluid for the rear brakes gets to the back part of the PDWA.

The PDWA is **not a brake-proportioning valve**. If it were, it'd be called a **brake-proportioning valve**. (A brake-proportioning valve is used to reduce the pressure in part of the brake hydraulic system.)

The PDWA is a device that senses a **Pressure Difference** between the front and rear hydraulic lines and causes a **Warning** to be **Actuated** if a pressure difference exists. We noted earlier that the floating secondary piston in the master cylinder would normally keep the pressure in both sides the system equal. A difference in pressure between the two sides indicates that one side will generate less than normal and possibly no braking forces, a serious fault. This can be caused by a rupture in one side of the system or an air pocket in one side of the system. The PDWA will not sense the failure where both halves of the system loose pressure.

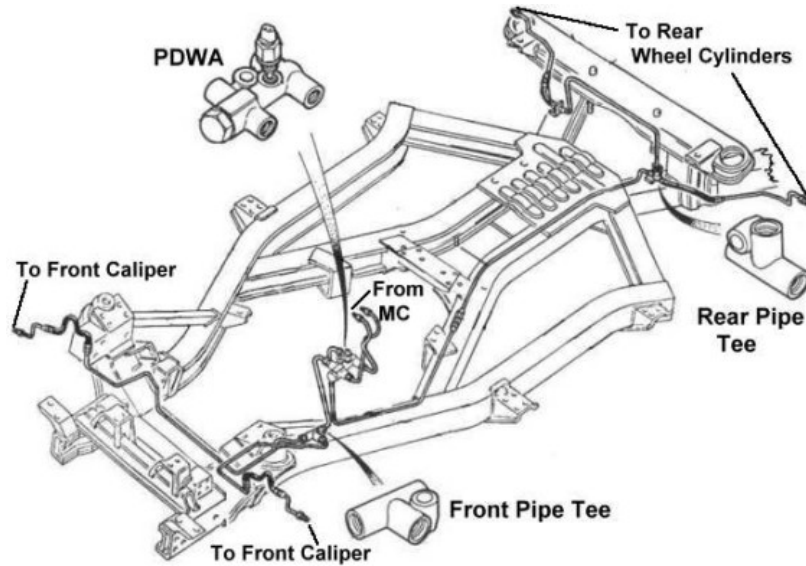


The PDWA is an H shaped pipefitting made of brass. The front leg of the H provides the hydraulic path for the front brakes and the rear leg of the H provides the hydraulic path for the rear brakes. A small piston rides in the cross piece of the H and prevents fluid from flowing between the two sides. If the pressure is the same on each side of the H, the piston will not move. If the pressure is different between the two sides, the piston will move toward the lower pressure side. The PDWA is equipped with an electrical switch that operates if the piston moves off center. The switch and piston are shown in the right photo below. The switch plunger normally rides on the narrow part in the center of the piston. If the piston moves off center, a larger diameter part of the piston comes under the switch and pushes the plunger into the switch, operating the switch in the process. The operated switch will then turn on the **BRAKE** warning lamp on the dash.

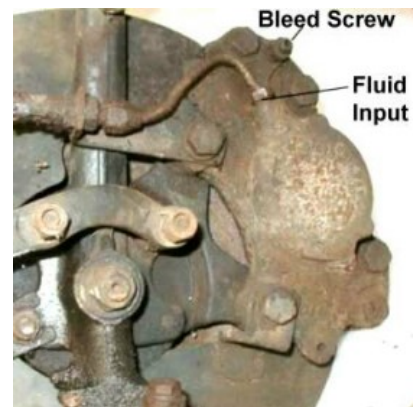
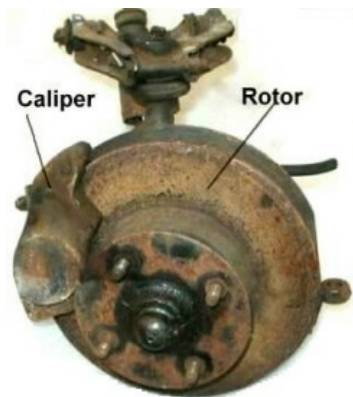


The pipes (plumbing): The sketch below the shows the brake pipes. (This sketch was copied from the TRF TR250 catalogue and then "processed".) The master cylinder and PDWA are both mounted to the body. The fluid for the front brakes goes through a short pipe from the PDWA to a tee mounted on the frame and then through separate pipes along the frame to each front suspension tower. A short hose connects the pipe on each tower to a pipe on each front caliper assembly and then via that short pipe to the caliper. The drawing is a little misleading in that the routing of the pipe between the suspension towers is actually on the back side of the frame cross member rather on the top as implied from the drawing. The fluid for the rear brakes goes through a pipe from the PDWA along

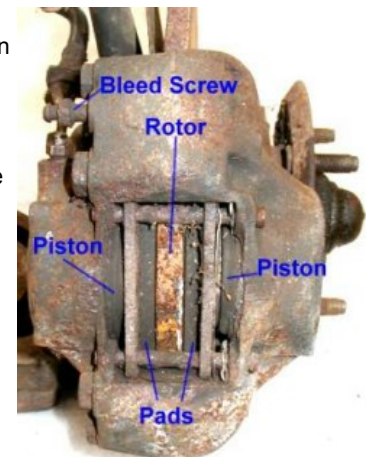
the inside of the frame member under the top cruciform plate to a tee mounted on the top of the left frame member. A hose connects from the tee to a pipe on the left suspension arm that runs to the left wheel cylinder. A pipe runs from the tee across the front of the rear suspension cross member to a fixture on the top of the right main frame member and then to the hose that connects to the pipe on the right suspension arm that connects to the right wheel cylinder.



Front Brakes: The right front suspension from my '70 TR6 is shown below. These have been off the car since the late '80s. The rotor surface would normally be smooth from usage. (Hopefully they'll look a little better after we've overhauled them.) The caliper is to the rear upper side of the axel. The fluid input pipe and bleed screw are on the upper back side of the caliper.

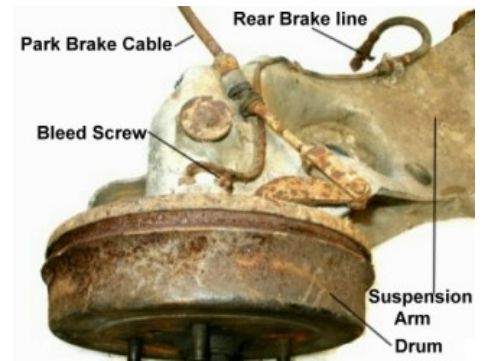


The photo on right shows an edge view of the caliper. When the brakes are applied the pistons squeeze the pads against the rotor. There are no springs to pull the pads away from the rotor when the hydraulic pressure is removed. The pistons ride against the pads that are adjacent to the rotor when the brakes are released. This system is self-adjusting in that as the pads wear, the quiescent position of the pistons moves closer to the rotor. It is also self-adjusting with respect to the position of the rotor; when pressure is applied to the pedal each piston moves to push its pad against the rotor. The braking force is then applied between the two pistons. Afterwards, when the pressure is released, the pistons remain in essentially the same position.

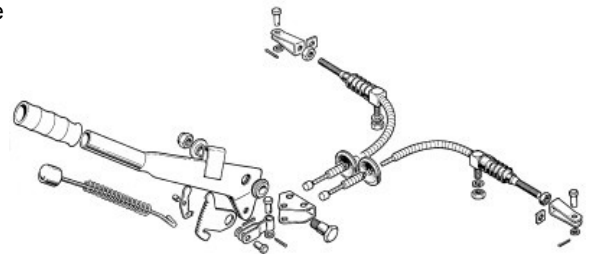


Rear Brakes: The photo on right shows the top of the right rear suspension arm with various brake components identified. The photo below shows the side view with the drum removed. (Things are pretty dirty which is usually the case after a couple a weeks or months of use.) The adjuster at the bottom is set to hold the lower part of the shoes just short of rubbing the drum. When the brakes are applied, the fluid forces the piston out of the cylinder in turn forcing the shoes apart at the top and against the drum. The cylinder is free to slide to front and rear as required to adjust to the position of the drum. This floating design insures that all the force generated in the cylinder is applied to forcing

the shoes against the drum. There is a mechanical lever beside the rear cylinder that also forces the top of the shoes apart and against the drum when the handbrake is applied.



Handbrake: The sketch on the right shows the components of the handbrake system. The sketch was taken from the TRF TR250 catalogue and then processed. The system consists of a ratcheting handle that is connected via cables to a lever in each rear wheel that forces the brake shoes against the drums.



Servo: The photo taken from the right side of my '76 TR6 shows the brake master cylinder and the servo, the big black canister to which the master cylinder is mounted. The black hose connects the servo to the intake manifold. I looked up servo at Merriam-Webster OnLine and was referred to **ser·vo·mech·a·nism** 🗣️

Pronunciation: 's&r-v0-"me-k&-"ni-z&m

Function: *noun*

Etymology: *servo-* (as in *servomotor*) + *mechanism*

Date: 1926: "an automatic device for controlling large amounts of power by means of very small amounts of power and automatically correcting the performance of a mechanism." The little speaker symbol can be clicked (on the Merriam-Webster site, not here) to hear the word pronounced properly.

For this system, the controlled is the force applied to the master cylinder piston. The controlling is the force applied to the brake pedal. If everything is working right, a small force on the brake pedal can produce a large force on the master cylinder piston. Where does the extra force come from ---- as some of the younger generation are fond of saying --- "it sucks" -- the suction coming from that black hose to the intake manifold. Us more mature folks might say "the depression in the intake manifold is transferred via the black hose to the servo creating a situation where atmospheric pressure can be used to push on the brakes".



The middle and lower photos on the right are of an old servo I had laying around. Note that the orientation is the opposite from the photo of my '76; the pedal is on the right and the master cylinder is on the left. The big black plastic thing in the middle is called the diaphragm plate and the rubber thing around it is called the diaphragm. The diaphragm is pulled back from part of the plate in the center photo. The push rod from the pedal is held separated about a 1/4" from the push rod on the master cylinder by the spring visible on the pedal side push rod. If the system fails, this spring merely compresses the ~1/4" and the pedal

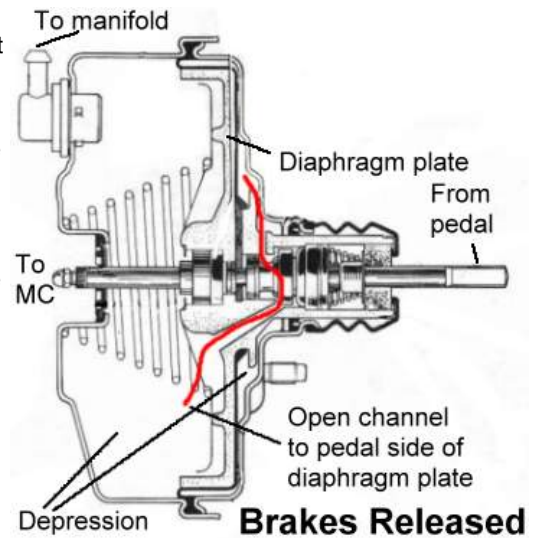
force is transferred to the master cylinder. The big bedspring forces the diaphragm to the pedal side of the canister in the relaxed state.

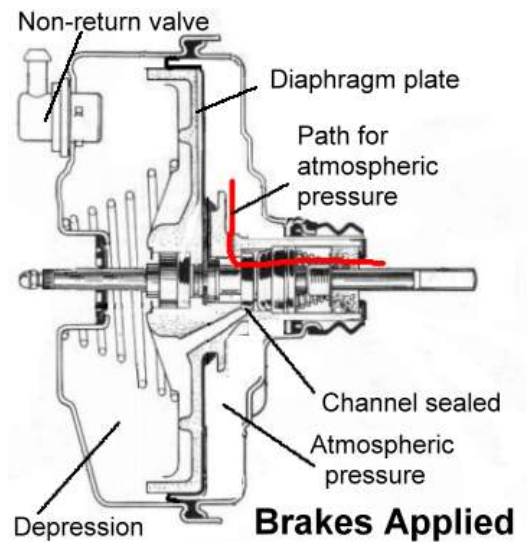


The sketches below show a little more detail of the servo. I started with a sketch from an old Haynes manual and then "processed it" to get the two views. The left sketch shows the relaxed position. The chamber inside the canister is sealed. If you hook up a vacuum gage to the hose from the intake manifold to the servo you should read 15 to 20 inches of mercury (engine at idle). Recall that atmospheric pressure is ~30 inches of mercury or ~ 14.7 psi (at sea level). This means that the atmosphere is pushing on the manifold with a relative pressure of 15 to 20 inches of mercury or about 7 to 10 psi. So, the suction from the intake manifold reduces the pressure inside the canister creating a depression such that the atmosphere is pushing on the outside with a pressure 7 to 10 psi greater than the pressure on the inside is pushing back. The little plastic fitting on the upper left where the hose connects contains a non-return valve oriented such that air can't flow back from the manifold side to canister should the engine stall losing manifold depression. (An alternate description that could have been generated by one of my former students: "Now I understand it ----- the canister is filled up with a vacuum and the non-return valve keeps it from leaking out". You can speculate as to her hair color.)

The rubber diaphragm together with the diaphragm plate divides the canister into two airtight chambers. The key to the operation is a pair of valves located on the left end of the pedal push rod that controls the pressure on the pedal side of the diaphragm plate. In the relaxed state, there is an open channel shown in red on the upper sketch that equalizes the pressure on both sides to the 7 to 10 psi depression of the manifold. The big spring forces the diaphragm to the pedal side of the canister.

When the pedal is depressed slightly, a valve seals the channel between the two sides of the diaphragm plate. As the pedal is depressed slightly further, a path is opened along side of the pedal push rod and into the pedal side of the diaphragm plate to allow air into the pedal side chamber where it quickly reaches atmospheric pressure (see lower sketch). This means that the pressure on the pedal side of the diaphragm is 7 to 10 psi greater than on the master cylinder side. The diaphragm is 6" diameter or ~ 28 square inches. At 7 to 10 psi that gives 200 to 280 pounds force ---- yes that helps push the master cylinder piston.





Now what happens if one pushes the pedal part way and the master cylinder piston has moved part way but hasn't reached the point where the pads and shoes are firmly against the rotors and drums --- the master cylinder piston is still easy to push because the pressure in the hydraulic system hasn't started to build? Will the diaphragm plate continue to move to the left forcing the left push rod further into the master cylinder? The answer is (fortunately) no.

But first --- what kind of forces are exerted by the springs? With the vacuum not connect I measured a force of ~ 25 pounds to get the output to start moving and ~ 40 pounds to get movement when the spring was fully extended. With the vacuum connected, the output moved over it's entire range with an input force of ~ 15 pounds. The pedal is really a big lever as shown on the right where the servo connects 2.56" from the fulcrum and the center of the pedal is 9.85" from the fulcrum. That means the pedal force is $2.56/9.85 = .256 \sim 1/4$ the force on the servo. (Conversely, the pedal moves $9.85/2.56 = 3.85$ times the distance as the master cylinder primary piston.) So, the ~ 15 pounds required to move the output with the vacuum connected requires less than 4 pounds pedal force.



Now, back to the case where you're holding the pedal part way down and have not yet encountered significant back force from the master cylinder piston. The pressure on the pedal side chamber will continue to push the diaphragm plate a very short distance till the valve to the atmosphere closes and then slightly further till the valve between the two chambers opens just long enough to allow the pressure on the two sides to adjust to exactly match the back force from the master cylinder; it then stops moving. This is the **"automatically correcting the performance of a mechanism"** from the definition. Slick!

Now what if:

- the engine stalls? The non-return valve stops air entering from the manifold. However, each time the brakes are applied, air enters the pedal side chamber and then goes to the master cylinder side chamber when the pedal is released. Rough guess -- you loose half the remaining assistance each pedal pump.
- the servo system fails completely? The brakes can be applied without the servo assistance with the additional 25 to 40 pounds servo input force (6 to 10 pounds at the pedal) to overcome the force of the bedspring. However, much greater pedal pressure is required to stop a moving vehicle.

The forces: Guess we've beat the servo to death. But, before we leave the theory, let's try to get a handle on the hydraulic pressure in the brake lines and the forces on the shoes and pads. Lets assume you slam on the brakes with the engine decelerating. We should get 250 pounds net force from the servo (high depression in the manifold due to deceleration). Let's assume you can put 80 pounds pedal pressure, which translates to 308 pound force (amplified by the 3.85 pedal mechanical ratio). Hence, we get 308 pounds force on the primary piston without the servo and 558 pounds with both pedal and servo.

The master cylinder primary piston diameter is 0.81" so the cross sectional area is ~0.52 square inches. Therefore, the 308 pounds pedal force on the piston will produce an hydraulic pressure of ~590 psi, and the combined pedal plus servo force of 558 pounds will produce ~1070 psi.

The pistons in the front calipers are 2 1/8 inch diameter so the cross-sectional is ~3.5 square inches so the ~590/1070 psi hydraulic pressure produces a force of ~2065/3745 pounds on each of the four pistons and also on the associated pads against the rotors.

The rear cylinder pistons are 0.7 inches diameter giving ~0.38 squares inches cross section and a force of ~225/405 pounds on each of the four rear brake shoes due to the ~590/1070 psi hydraulic pressure. The brake shoes are really levers that pivot around the around the adjustor at the one end and are pushed by the wheel cylinder piston on the other end. The lever has the effect of increasing the force of the shoes on the drum somewhat --- maybe by a factor of two if the brakes are adjusted snug to the drums.

Measurements: Calculations are fine, but what if I slipped a few digits on the

calculator and the pressure is really 100,000 psi? This is easily solved with a few measurements. The test setup I used is shown on the right. I took a 14" by 24" scrap board and attached a 12" square shelf to the upper right corner. The pedal assembly is attached to the underside of the shelf. The servo and master cylinder are mounted to the board. The hose at the top goes to the vacuum pump that is setting behind the board. (I blocked out the trash on the bench and shelves behind the board to make the photo look better.) I made a 7/16" to 3/8" reducer for the front brake port and screwed a bleed nipple into the reducer. A 0 to 1000 psi gauge is attached to the rear brake port using an old rear brake hose.

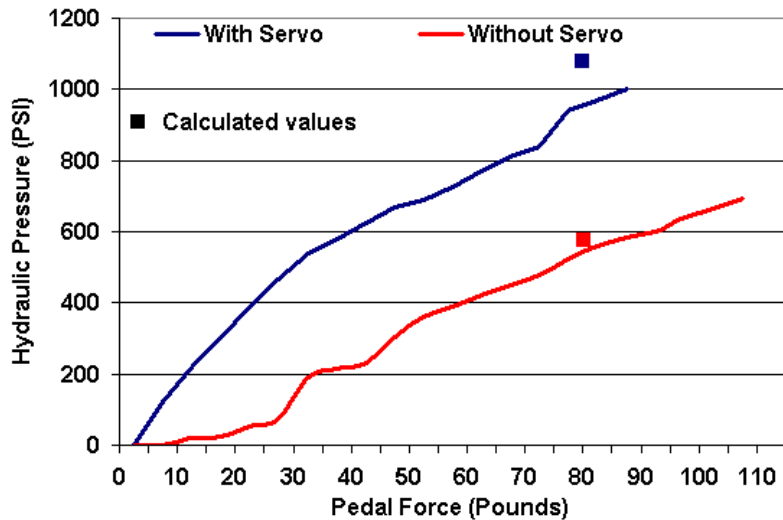


I used a bathroom scale with a stick attached to measure the input force. The setup is shown on the right. The stick is positioned against the pedal and the scale is then pressed with the desired force as indicated by the scale reading. Every project needs the universal fastener as seen on the bottom of the scale.



The measurements are plotted below. The curves are a little erratic; the system operation is probably more linear than indicated. The problem was that I had a difficult time holding the scale steady. The gauge topped out at 1000 psi, which is why the "With Servo" curve stopped at 1000 psi. The "Without Servo" stopped at about 110 pounds pedal pressure where I topped out. The computed values from above are plotted and are well within a reasonable error for all the assumptions and the "Rube Goldberg" test setup. I was a bit surprised with the servo operation. I expected the curve to kick in at a little higher pedal force and I expected the curve to be steeper initially. One thing is clear, using the brake pedal for a footrest is probably bad for the fuel efficiency.

Brake Hydraulic Pressure vs Pedal Force



I'm now ready to move from talking about the brakes to actually working on them.