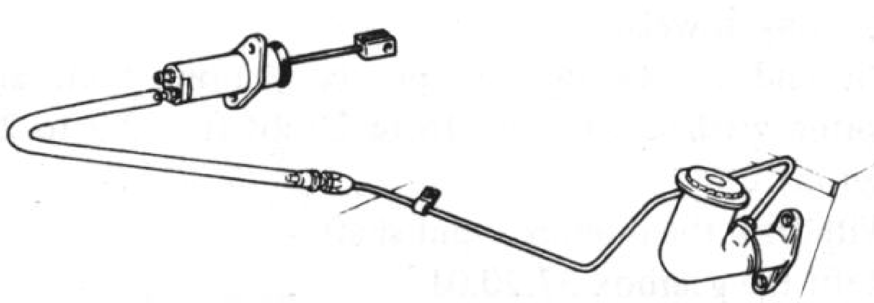
TR250/TR6 Clutch Release Calculations

TR250s and TR6s use hydraulics to transfer the clutch pedal motion to the clutch-operating shaft in the front of the gearbox. The system is nice in that it is self-adjusting and requires little maintenance except for occasionally checking the fluid level in the master cylinder reservoir. The sketch below from a TR6 Maintenance Manual shows the basic system. The clutch pedal connects to a piston in the master cylinder (on the right). When the pedal is pressed, the piston in the master cylinder is pushed in forcing hydraulic fluid from the master cylinder through the tube and hose to the slave cylinder (on the left). The fluid pushes the slave cylinder piston toward the open end of the cylinder pushing the push rod that connects to the lever on the clutch-operating shaft that in turn releases the clutch.



While under the car bleeding the system you might notice that the clutch arm doesn't move very far while the pedal moves a large distance from full out to full in. What is going on? To answer that we examine the pedal and hydraulic systems and apply some high school physics.

Pedal Assembly: The pedal assembly with master cylinder is shown below. These photos were taken on the workbench. If you observe the photos carefully, you'll see that the pedal is at the end of a long arm whereas the master cylinder push rod connects to the end of a much shorter arm. This means the the pedal moves a much greater distance than the master cylinder push rod and master cylinder piston. The length of each of the levers is shown on the right photo. This pedal assembly has been refurbished and there is no slack in the clevis pin area between the pedal arm and the push rod. The ratio of the two arm lengths is:

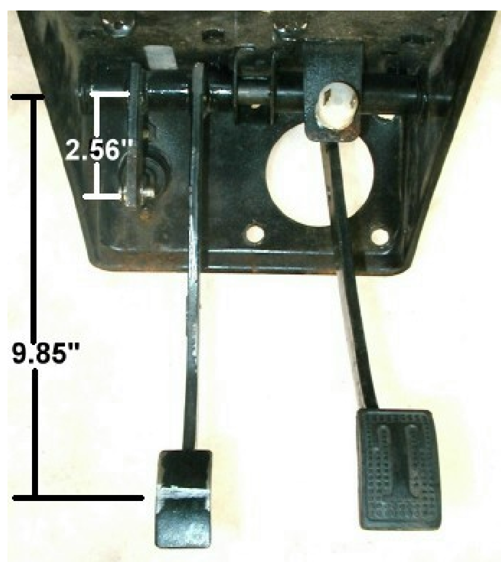
2.56"/9.85" = 0.260

The maximum travel measured on this unit was 5.0 inches for the center of the pedal and 1.29 inches for the slave cylinder push rod (and cylinder). This ratio is:

1.29"/5.0" = 0.258

in close agreement with the above calculation.

You all recall that if you have a hard time turning a wrench, you get a longer handle. The longer the lever arm, the greater the motion (as seen above) but the lower the force required. The ratio of the force between the pedal and the master cylinder is the inverse of the motion ratio. In this case, the force applied to the master cylinder is 1/0.258 = 3.86 times the force applied to the pedal. (This calculation ignores minor friction forces in the pedal arm bushes and clevis pin.)



Hydraulics: The key to understanding the hydraulic hydraulic system is remember that:

- The fluid pressure is constant throughout the system.
- The fluid is essentially non compressible (if all air is bled out of the system)
- The force on a piston is the product of the pressure and the piston area.
- The fluid displaced by piston motion is the product of the piston area and distance moved.

Digesting the above revels that a hydraulic system with different area pistons is similar to a mechanical system with different length levers. The smaller the piston, the greater the motion and the less the force --- a small piston is like a long lever. You all probably recognize this from a hydraulic jack--- the input is a very small piston that you have to move a lot and the output is a big piston that travels a much shorter distance put produces a much greater force.

The relationship between the forces and movement of two hydraulic pistons is the ratio of the piston areas. The piston area is proportional to the square of the piston radius and also to the square of the piston diameter. The TR250/TR6 use two different master cylinders:

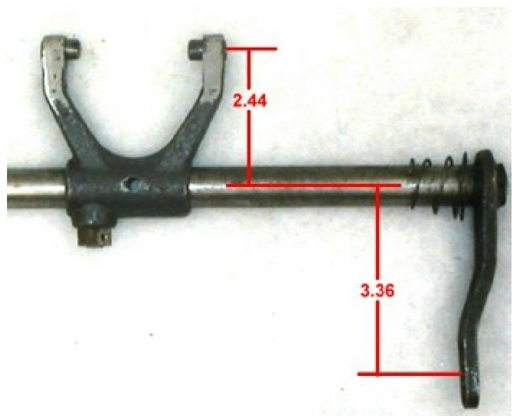
0.75 inch MC: The TR250 and early TR6 use a 0.75 inch master cylinder piston and a 1.0 inch diameter slave cylinder piston so the area ratio is $(.75/1)^2 = .56$. This means the slave cylinder piston moves 56% of the movement of the master cylinder piston. Conversely, the force ratio is $(1/.75)^2 = 1.78$. This means that the force on the slave cylinder piston is 178% of the force on the master cylinder piston.

0.7 inch MC: The later TR6 uses a 0.70 inch master cylinder piston and a 1.0 inch diameter slave cylinder piston so the area ratio is $(.70/1)^2 = .49$. This means the slave cylinder piston moves 49% of the movement of the master cylinder piston. Conversely, the force ratio is $(1/.70)^2 = 2.04$. This means that the force on the slave cylinder piston is 204% of the force on the master cylinder piston.

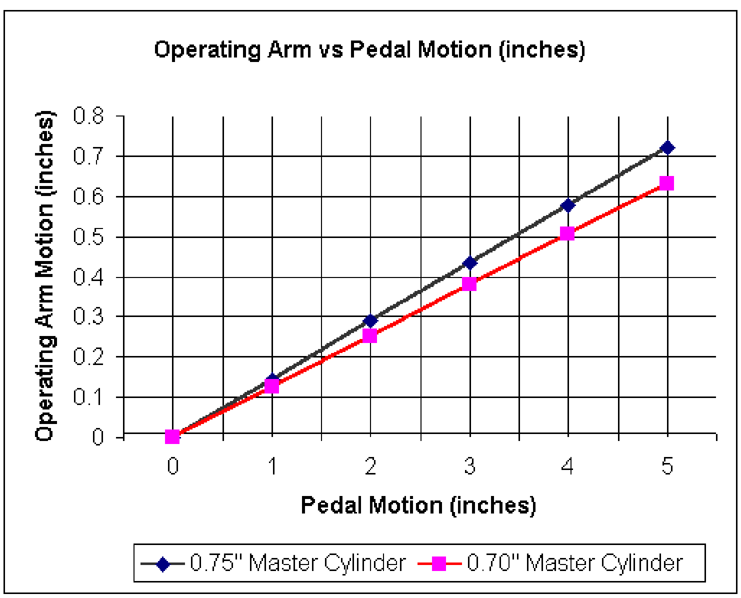
Operating Arm motion - 0.75" MC: The maximum pedal motion is 5.0 inches. The maximum master cylinder piston motion is 1.29 inches. Recall that some piston motion is required to close the check valve at the back of the master cylinder before pressure can build (see note on Clutch Hydraulics Overhaul). The motion required to close the check valve on the system pictured above was 0.06 inches leaving 1.23 inches productive movement. This translates to 0.56 X 1.23 inches = 0.69 inches at the slave cylinder. This is for a perfect system. A practical system will likely have a small amount of air, some slack in the links and and some flex in the arms and brackets, so the maximum slave cylinder and operating arm motion one can expect is ~ 0.6 inches. This is for a system with relatively little wear. About 10% less motion should be expected for an average system. (I measured a little over 0.6 inch motion on my TR250 that has essentially no slack in the pedal lever system.)

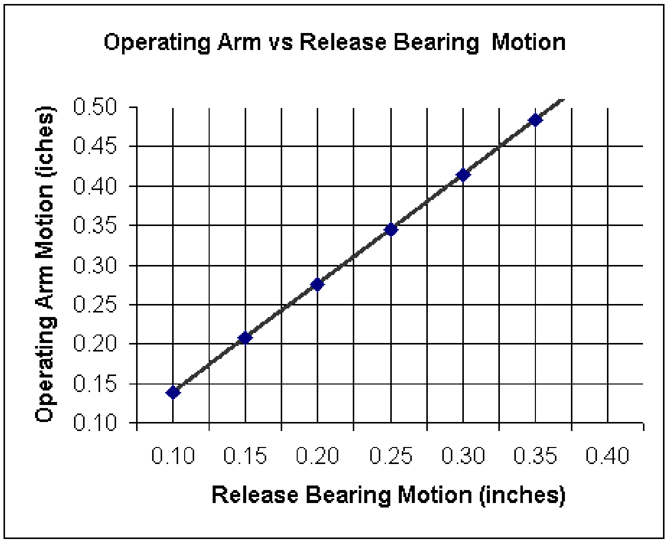
Operating Arm motion - 0.70" MC: The maximum pedal motion is 5.0 inches. The maximum master cylinder piston motion is 1.29 inches. Recall that some piston motion is required to close the check valve at the back of the master cylinder before pressure can build (see note on Clutch Hydraulics Overhaul). The motion required to close the check valve on the system pictured above was 0.06 inches leaving 1.23 inches productive movement. This translates 0.49 X 1.23 inches = 0.60 inches at the slave cylinder. This is for a perfect system. A practical system will likely have a small amount of air, some slack in the links and and some flex in the arms and brackets, so the maximum slave cylinder and operating arm motion one can expect is ~ 0.5 inches. This is for a system with relatively little wear. About 10% less motion should be expected for an average system. (I measured slightly over 0.5 inch motion on my '76TR6 that has essentially no slack in the pedal lever system.)

Operating Arm - Fork: The clutch fork pushes the release bearing via the little pins. The slave cylinder pushes the operating arm via the slave cylinder push rod that connects to the center hole of the arm with a clevis pin. Force and motion of the arm is coupled to the fork by the rotation of the shaft. The arm length to the center hole is 3.36 inches and the fork length to the center of the pin is 2.44 inches. Therefore, the center hole in the arm moves 3.36/2.44 or 138% of the distance the fork and release bearing moves. Also, the force on the center hole in the arm is 2.44/3.36 or 73% of the force on the fork and release bearing, assuming no friction in the pins and bushes.

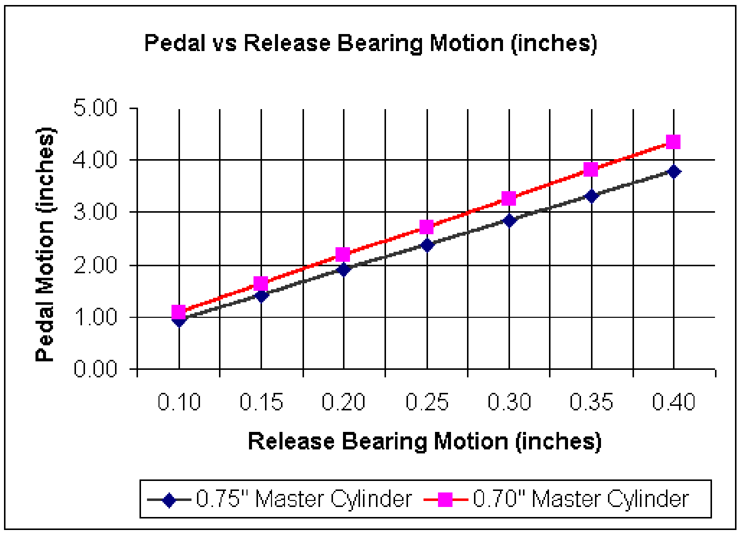


These data are summarized in the following graphs. The independent variable (abscissa or X axis) on all except the first graph is the release bearing force or motion. Typical maximum pressure plate forces are 250 to 350 pounds and typical pressure plate motions to release the clutch are 0.15 to 0.25 inches. Measurements of these values for some typical pressure plates are shown in the accompanying Clutch Measurement note. These graphs assume no friction or slack in the system. In a practical system, a slightly greater force on the pedal will be required due to friction and possibly a significantly greater pedal motion if there is slack in the mechanical linkage or air in the hydraulic system.

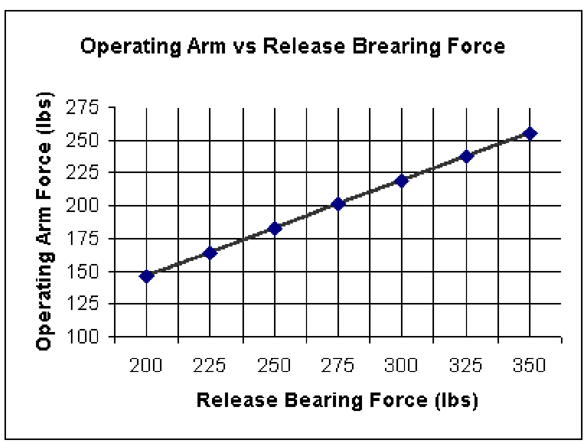




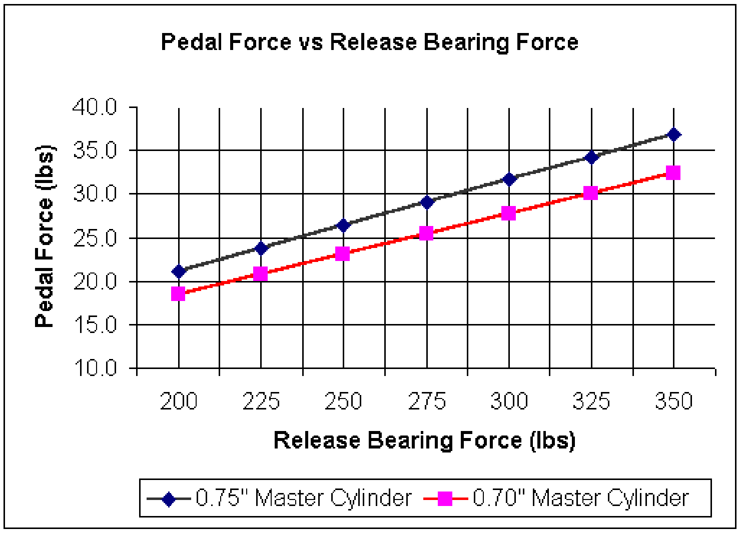
Operating Arm vs Release Bearing Motion
Operating Arm Motion (iches)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.10 0.15 0.20 0.25 0.30 0.35 0.40
Release Bearing Motion (inches)

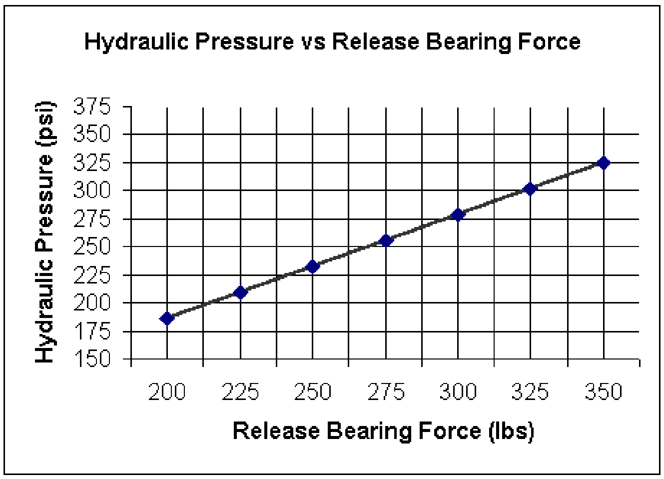


Pedal vs Release Bearing Motion (inches)
Pedal Motion (inches)
5.00
4.00
3.00
2.00
1.00
0.00
0.10 0.15 0.20 0.25 0.30 0.35 0.40
Release Bearing Motion (inches)
0.75" Master Cylinder
0.70" Master Cylinder



Operating Arm vs Release Brearing Force
Operating Arm Force (lbs)
275
250
225
200
175
150
125
100
200 225 250 275 300 325 350
Release Bearing Force (lbs)


Pedal Force vs Release Bearing Force
Pedal Force (lbs)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
200
225
250
275
300
325
350
Release Bearing Force (lbs)
0.75" Master Cylinder
0.70" Master Cylinder


Hydraulic Pressure vs Release Bearing Force
Hydraulic Pressure (psi)
375
350
325
300
275
250
225
200
175
150
200
225
250
275
300
325
350
Release Bearing Force (lbs)