A Type Overdrive, Part I - Theory

Overview: The A type overdrive (OD) unit described here was manufactured by Laycock-de-Normanville and was a factory option on the TR2, TR3, TR4, TR5/250 and TR6 Triumphs through 1972. The function of the OD is to change the overall reduction ratio between the engine and rear wheels. It operates in two modes, the direct dive mode where there is no change is reduction ratio and the OD engaged mode where OD provides a 22% rpm increase in the output over the input rpm (i.e. overdriven). This means that for a given engine rpm, the road speed is 22% greater when the OD is engaged. Another way of saying this is that when the OD is engaged, the engine rpm is reduced by 18% for a given road speed. The OD is operator controlled via an electrical switch on the dash or steering column, depending on the model. The OD could be engaged only in 4th gear in the early TR2 application. The operation was changed after TR2 s/n TS5980 so that it could be engaged in the top three gears.

Five models of the A type overdrive were fitted to the TRs. The following are the model numbers and a brief description of the changes with each model. These data is taken from the Moss Catalogue, input from Randall Young, Triumph Service Bulletins supplied by Fred Thomas and data from a telephone conversation with an employee of Overdrive Repair Services in the UK (staffed by ex Laycock employees). Randall says he thinks the 22 refers to the gear ratio, in this case, 22% increase. He says other models with a larger increase were provided for other applications such as big Healeys. The Moss catalogue lists all these models with a leading 6 (i.e. 22/61275). Randall thinks the 6 was added when the factory rebuilt a unit. He has also seen models with a leading 2 --- maybe the indicates a different manufacturing location.

- #22/1275 TR2 to TS5979
- #22/1374 TR2 from TS5980 to TR4, October 1964. The major change in this unit was to increase the diameter of the operating pistons from 1 1/8 inches to 1 3/8 inches. A Triumph Service Bulletin dated August 1955 states that in response to requests from Triumph owners, OD capability was added for 2nd and 3rd speeds in addition to 4th speed The operating piston diameter was increased to handle the additional torque of the lower gears. Additional changes were required to the gearbox top cover to accommodate the isolator switches for 2nd and 3rd speeds.
- #22/1712 TR4 from October 1964 through TR4A solid rear axel. The only change I'm aware of with this model is the use of operating pistons with rubber O rings rather than steel rings. The pistons are the 1 3/8 inch size and may be substituted for the steel ring pistons in model #22/1374, but not in model #22/1275 that used the smaller pistons.
- #22/1753 TR4A IRS to TR6 3/71. Three changes were made in this model. One change was to use a different filter. A second change was to use a 1/4 inch instead of a 5/16 inch ball in the non-return valve. The most important change was the replacement of the 1 3/4 inch diameter accumulator piston with a smaller 1 1/8 inch diameter piston. An employee of Overdrive Repair Services told me this change was made to to soften the engagement. He said the accumulator of the earlier models had so large a capacity that the pressure dropped very little when the OD engaged. This caused a very hard engagement that sent such a shock to the drive train that it tore up axels in the IRS cars. With the smaller accumulator, the pressure drops during engagement and then builds up quickly. This lower pressure allows a small amount of clutch slipping that softens the engagement. He also told me the pressure for the early large piston accumulator was 350 to 370 psi while the pressure for the later small accumulator models should be about 450 psi. It is my guess the pressure was increased to provide a higher torque capability to match the 6 cylinder engines in the TR5/TR250 & TR6.
- #22/1985 TR6 from 4/71. The only change I found for this model was a different filter.

The OD unit is attached to the rear of a regular gearbox in place of the rear extension as shown on the right. The only changes required to the basic gearbox to use an overdrive (OD) are a different mainshaft and the addition of switches in the gearbox cover.

A reproduction of the SERVICE INSTRUCTION MANUAL for the LAYCOCK - DE - NORMANVILLE OVERDRIVE UNIT WITH ELECTRICAL CONTROL purchased from The Roadster Factory (TRF) was used in the preparation of these notes. The original date of publication is not listed but only the TR2 is referenced so I guess it to be late 1950s. Interestingly, the drawing accompanying the parts list appears to be essentially identical to that shown in a TR250/TR6 Haynes manual and current TRF and Moss catalogs.

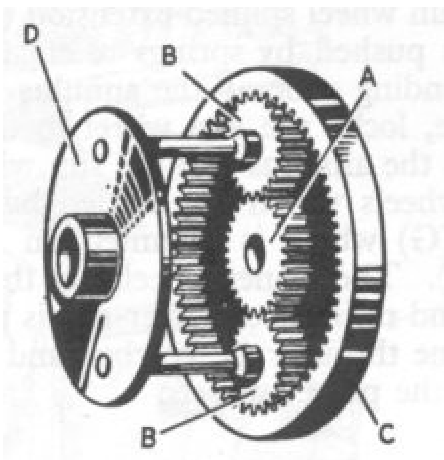
This part describing how the OD operates is divided into three sections:

1. The mechanical components including the gears and the two clutches
2. The hydraulic components that control the shifting.
3. The electrical components that control the hydraulics.

Section 1 - Mechanical Components

Epicyclic Gear: The heart of the OD is the epicyclic gear shown in the diagram (taken from the Service Instruction Manual) at the right. The parts are:

A: Sun gear
B: Planet gears
C: Outer ring gear or annulus
D Planet gear carrier



The word annulus has several meanings, some relating to rings and others to anus. As we see later, the OD annulus is the component at the rear of the OD that both provides output and contains the ring gears, so maybe both meanings apply.

I admit to staring at the diagram for quite a while trying to figure out how it works. Then spent a much longer time trying to come up with an explanation that hopefully is easy to understand. So here goes -----

The four things to remember when trying to understand the epicyclic gear are:

1. Input rotary power is applied to the planet gear carrier (D).
2. Output rotary power is taken from the annulus (C).
3. For direct drive (no speed change) the sun gear (A) is locked to the annulus (C).
4. For an output that is a higher speed than the input (overdriven) the sun gear (A) is locked stationary.

For this discussion, let's assume all rotation is clockwise, the normal Triumph propeller shaft rotation for forward gears. It should be fairly easy to see that if the sun wheel is locked to the annulus, the planet gears can't rotate on their axis. Therefore, the planet carrier is essentially locked to the annulus and the output will turn at the same speed as the input.

It's a little more complicated to envision what is going on when the sun gear is locked stationary. First, observe that when the planet carrier is rotated clockwise with the sun gear stationary, the planet gears will rotate clockwise on their axis. If the sun gear and planet gears have exactly the same number of teeth, when the planet carrier is rotated one revolution, the planet gears will rotate one full revolution around the sun gear resulting in one full rotation of the planet gears on their axis.

Next, observe that if the planet carrier is stationary and the planet gears are rotated clockwise, the annulus will rotate clockwise. In the diagram, the annulus has about 4 times as many teeth as the planet gear so one revolution of the planet gears will rotate the annulus about one quarter revolution.

Let's now restate the two effects:

1. When the planet gears don't rotate on their axis, the annulus turns at the same speed as the planet carrier.
2. When the planet carrier is fixed and the planet gears rotate at the same speed as the input, the annulus rotates at about one quarter the input speed.

When the two effects are added, the output speed will be about 125% of the input. The number of teeth on gear will be listed later and the precise speedup computed.

The photos below show the annulus. (Unless noted otherwise, all photos are of a TR3 OD unit, model #22/1374.) The output flange slides over the splines on the left side of the left photo. The spirals milled in the center of the shaft drive the speedometer gear. The shaft has two bearings, one over the splines and the other next to the shoulder on the right side of the shaft. The bearing on the shaft is in position to be pressed pass the spirals to the shoulder. The right photo shows the large end of the annulus with the ring gear. The annulus is still installed in the rear casting here. The rollers in the center are part of the unidirectional clutch discussed later.

The epicyclic gear without the ring gear (annulus) is shown below. The left photo shows the sun gear in position. The middle photo shows the gears on the mainshaft. The splines on the inside of the planet gear carrier mate with the mainshaft so that input power is always applied via the planet gear carrier. The right photo shows one of the planet gears removed from the carrier. These gears are composed of two gears locked together and have two roller bearing cages pressed inside. The shaft the gears revolve on is pressed into the planet carrier. The washer with the tab is a thrust washer.

The number of the teeth on each of the gears is as follows:

- Sun gear = 21 teeth
- Larger planet gear = 24 teeth
- Smaller planet gear = 15 teeth
- Ring gear in annulus = 60 teeth.

When the planet carrier rotates one revolution, the larger planet gear rotates around the fixed sun gear once and will have passed all the 21 teeth on the sun gear. Since the planet gear has 24 teeth, it will have rotated 21/24 = .875 revolution. The smaller planet gear meshes with the ring gear. The smaller planet gear also rotates .875 revolution when the planet carrier does one revolution, but since it has only 15 teeth, the total number of teeth meshed with the ring gear per revolution or the planet carrier is .875 X 15 = 13.125 teeth. The amount the 60 tooth ring gear rotates due to the one planet gear rotation is 13.125/60 = .21875 revolution. This is added to the one revolution caused by the planet carrier rotating with the planet gears not rotating giving a total of 1.21875 or rounded to 1.22. This means that when the OD is engaged, the road speed for a given RPM is 1.22 times the direct drive road speed. Another way to say it is that the engine RPM with the OD engaged for given road speed is 1/1.22= .82 times the direct drive RPM. (Randall Young suggested that other applications of these ODs such as the big Healeys use different ratios, some as low as 0.75 to 1.)



The three photos above show the assembled epicyclic gear. The left photo shows Whiteout marks on the sun gear shaft, on the planet gear carrier, and on the annulus. In the middle photo, the sun gear has been held stationary and the planet gear carrier has been rotated about 45 degrees clockwise. Note that the annulus seems to have rotated a bit further. The right photo shows the situation after the planet carrier has be rotated one full revolution with the sun gear held constant. Note that the annulus has rotated one full revolution plus nearly a further quarter revolution, exactly as computed above.

Case: The case is composed of two parts, the main casting and the rear casting. The main casting contains hydraulic components to switch the OD between the direct drive and overdrive. The rear casting contain the annulus & associated rear shaft bearings and speedometer gear. The photo below shows the main casting on the left, then the sliding clutch, then planet carrier with sun gear and planet gears then the rear casting with the annulus installed inside.

Sliding Clutch: The sliding clutch performs the task of locking the sun gear to the annulus in direct drive and locking the sun gear stationary in overdrive. That is, the clutch has two engaged positions. The main part of the clutch is a cone shaped component called the sliding member. The sliding member is fitted over the splines on the sun wheel shaft (refer to previous photos) and as the name implies slides between two positions. When in the rear most position, clutch material on the inside of the sliding member is held against the outside of the annulus hence locking the sliding member and the sun gear to the annulus. This is the direct drive position. In the forward most position, clutch material on the outside of the sliding member engages a stationary brake ring attached to the rear of the main casting, locking the sliding member and the sun gear stationary. This is the overdrive position. The surfaces on the sliding member and mating surfaces on the annulus and brake ring are slightly coned shaped.

The photo at the right shows the end of the clutch sliding member. The thrust ring is to the rear. The clutch material is visible on the cone shaped outer and inner surfaces of the sliding member. There is a bearing (the thrust bearing) between the thrust ring and the sliding member that allow the sliding member to rotate. Splines are visible on the inside of the sliding member. These splines mate with similar splines on the sun gear shaft (see previous photos). Note that the thrust ring doesn't rotate. The sliding member rotates with the annulus when in direct drive and doesn't rotate in overdrive.

The thrust ring is pushed back by eight clutch release springs and via the bearing forces the sliding member onto the cone part of the annulus for direct drive. This is shown in the left photo below where the main casting has been removed. The thrust ring is pulled to the front by two hydraulic pistons when in OD. This in turn pulls the outside of the sliding member into the brake ring at the rear of the main casting. This is shown in the right photo below where the rear casting and annulus has been removed.

Unidirectional clutch: This clutch fits into a recess in the annulus as shown on the right. ***The roller cage and one of the rollers has been removed to show how the clutch works.*** The splines on the inside mate with the gearbox mainshaft. If the inside of this clutch (the mainshaft) tries to rotate faster in the clockwise direction than the annulus, the rollers will go up the little ramps and be forced against the annulus in turn forcing it to stay at the same speed as the mainshaft. Conversely, if the annulus is rotating faster in the clockwise direction that the center part, the rollers are forced down the ramp relieving the force against the annulus hence disengaging the clutch. In summary, for clockwise rotation, the output can rotate no slower than the input, but may rotate faster than the input.

For counterclockwise rotation, the opposite is true. If the annulus is rotating slower than the mainshaft, the rollers go down the ramps and the clutch is released. If the annulus tries to rotate faster than the mainshaft, the rollers go up the ramp and lock the annulus to the mainshaft

Now consider what would happen if the OD were to be engaged in reverse; the annulus will try to rotate 22% faster counterclockwise than the mainshaft. However, as stated previously, the unidirectional clutch prevents the annulus from rotating faster than the mainshaft in the counterclockwise direction. Lets say that again, the epicyclic gear is forcing the output to turn faster than the input while the unidirectional clutch is preventing the output from turning faster than the input. What happens? If we're lucky, the sliding clutch slips and the problem is discovered quickly and fixed. If we're unlucky, something breaks. The message: **THE OVERDRIVE MUST NOT BE ENGAGED IN REVERSE!**

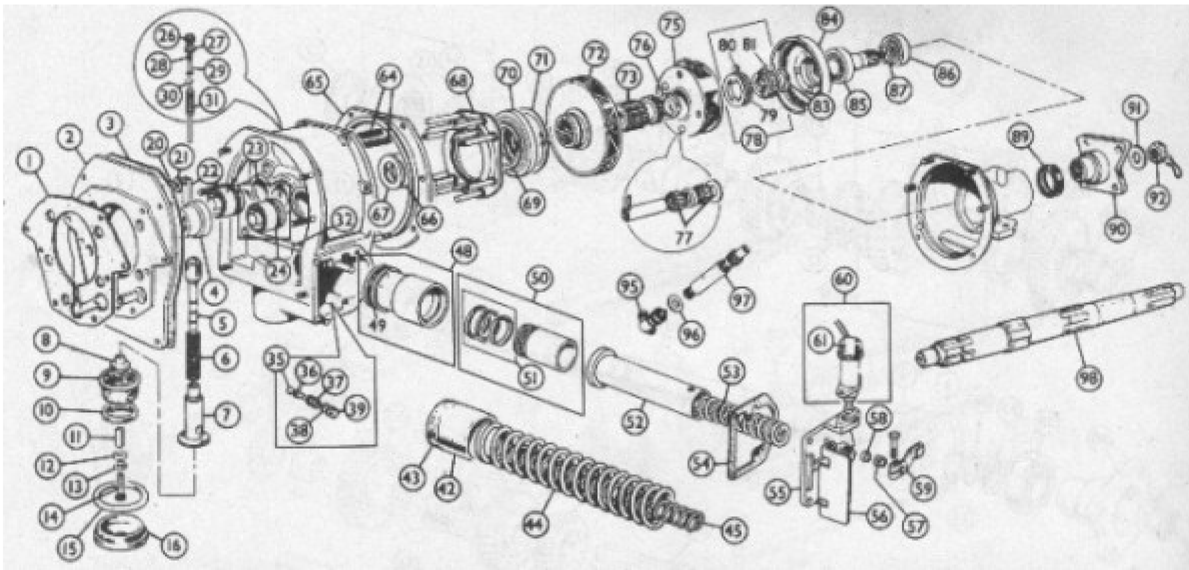
According to the early literature, the design intent was for the unidirectional clutch rather that the sliding clutch to be the primary way power is transferred to the rear wheels in direct drive. This allowed much less force to be applied to the clutch in the rear position by the clutch release springs (1/2 to 1/3, depending on the model) than to the front position even though the torque requirements for direct drive are more than twice that of overdrive because of first gear startups, made only in direct drive.

The unidirectional clutch also serves to keep the engine loaded when shifting the OD in and out. For example, when the OD is switched in, the clutch sliding member must move from the annulus to the brake ring. There will be some time during this transition that the sliding member is not in contact with either, and no power is transferred through the epicyclic gears. If the unidirectional clutch weren't there, the engine rpm would increase significantly and then drop down again when the OD was engaged. The unidirectional clutch essentially keeps the system in the direct drive mode until the clutch sliding member has completed it's travel and the OD is engaged at which point the annulus speed increases relative to the mainshaft and the unidirectional clutch disengages. When switching out of OD, the engine speed will increase as soon as the sliding member disengages from the brake ring but will only increase ~22% till the mainshaft speed equals and then tries to exceed the annulus speed at which time the unidirectional clutch engages.

Now that it is clear that the unidirectional clutch provides the direct drive feature, why is the direct drive position (rear) on the clutch sliding member needed? The answer is engine braking and reverse. During deceleration, the annulus tries to turn faster than the mainshaft which disengages the unidirectional clutch. The sliding clutch keeps the mainshaft connected to the annulus through the epicyclic gear in this situation so that the engine can brake the motion of the auto. When the shaft is rotated counterclockwise as when the gearbox is in reverse, the unidirectional clutch doesn't function necessitating the use of the sliding clutch.

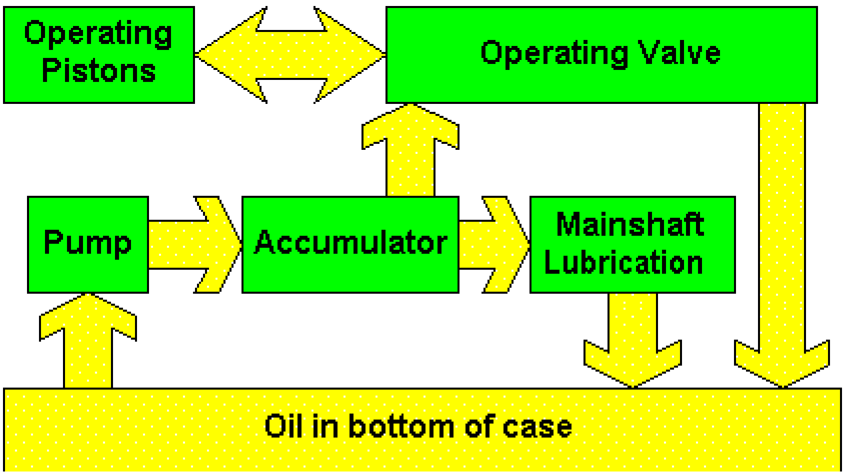
Section 2 - Hydraulic Components

The following exploded view of the OD unit taken from a Moss catalogue should help in understanding how the OD fits together.



The hydraulic components are housed in the main casting and consist of the following:

- A hydraulic pump (4-8 & 35-39)
- An accumulator (42-45 early or 48-53, later)
- An operating valve (26-31)
- Two operating pistons (23 & 24)

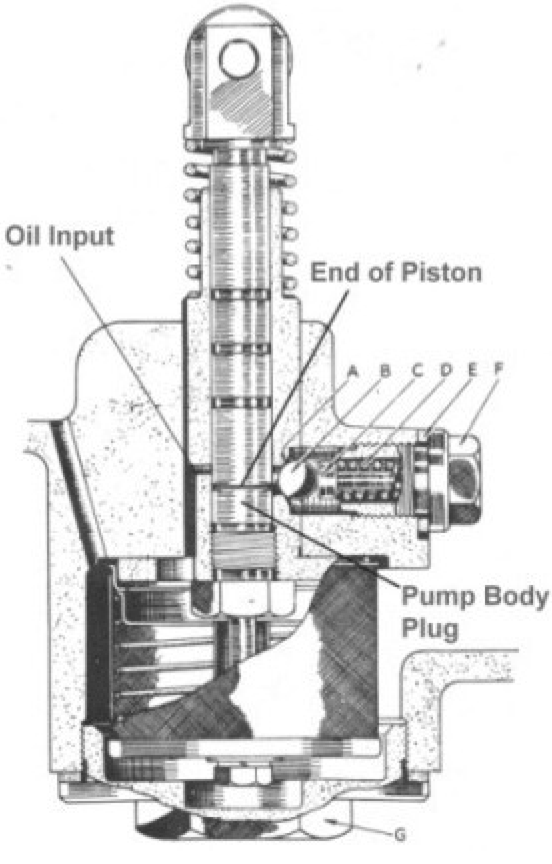


The block diagram above shows the interrelationship of the hydraulic components. The basic operation is as follows: A cam on the mainshaft drives the pump whenever power is transmitted to the rear wheels. The gearbox oil is the hydraulic fluid.   The accumulator is a spring-loaded piston/cylinder chamber where the fluid is pumped for storage. The accumulator has an internal pressure relief valve set to about 360 psi (early) or 450 psi (later); oil from the pressure relief goes through internal passages in the main casting to the gap between the large mainshaft bushings. The oil then enters radial holes in the mainshaft and travels through an axial drilling in the mainshaft and exits through radials holes under the sun gear providing lubrication to the sun gear, planter carrier and thrust washers before returning back to the bottom of the case.   The control valve, operated by an external electrical solenoid, controls the flow of hydraulic fluid from the accumulator to the operating pistons. When the control valve is operated, the fluid will push the operating pistons forward pulling the clutch sliding member into the brake ring.   When the valve is released, the clutch release springs push the pistons back into their cylinders and the clutch sliding member back into the annulus. As the pistons go into their cylinders the oil is pushed back through the released operating valve and then on to the bottom of the gearbox.

The Pump: The top photo on the right shows the front of the main casting. The vertical rod with the spring around it is the pump piston. The top of the piston is fitted with a roller to ride on a cam on the mainshaft. The heavy rod protruding from the cam is a dummy mainshaft. The round objects on each side the cam are the operating pistons discussed later. The large horizontal spring on the lower right of the photo is the outside accumulator spring, also discussed later.

The second photo shows the pump components. The pump body is top left with spring and then piston below it. The pump body is pressed into the main casting and secured with the two screws. The spring is used to force the piston up --- the mainshaft cam forces it down. The lower end of the cylinder is sealed with the large threaded pump body plug in the upper middle. The screened cup is a filter secured to the plug by the screw in the lower right.

The diagram, taken from the Service Instruction Manual, shows the pump cross section. The piston is shown in the full down position, nearly touching the pump body plug. Oil is supplied from the screen filter at the bottom up through a milled flat section on the outside of the pump body and into the cylinder through a slit. The slit and flat section can be seen in the photo of the pump components.



Components labeled A through F form the non-return valve. The photo following the diagram shows these components. The hole from the right side of the pump body near point A leads to the accumulator (discussed next). Part A is a valve seat machined in the side of the pump body opposite the input slit. The hole is sealed by ball B and held by plunger C and spring D. The copper washer E and plug F seal the valve chamber. Two sizes of balls were used in the non-return valve, the earlier valves used 5/16 ball and the later ones used1/4 inch balls. The ball size must be matched to the seat on the pump body.

When the piston is in the upper most position, the bottom of the piston is about even with the top of the input slit allowing oil to flow into the pump body. When the piston starts to move down oil is forced back out the input slit until the bottom of the piston passes the bottom of the slit sealing off the input. Further downward movement of the piston will force the non-return valve ball away from the seat allowing the fluid to exit to the accumulator. Once the piston reaches the bottom of it's travel, the pressure on both sides of the ball equalize and the valve spring forces the ball into the seat closing the valve. The spring at the top of the piston holds the roller against the cam and forces the piston back up as the cam rotates to the low spot.

The pump runs all the time that the mainshaft is rotating. The pump is pushing against the pressure in the accumulator, limited by the pressure relief valve to about 360 psi (early accumulator) or 450 psi (later accumulator). The late TR6s used the J Type Overdrive. In a recent comparison between the A and J types on the Triumph email list it was pointed out that the J type OD pump doesn't consume power in the direct drive mode since the pump output is opened to the main case so that the pump pushes against zero pressure. It was further claimed that the A type OD pump consumed about 25 HP at high speeds. I pointed out that the OD would melt in a few minutes if it had to dissipate that much power (25 hp ~ 18kw). When the OD was apart the following measurements were taken so the pump power could be computed.

Piston diameter = .53 inches.
Piston travel = .15 inches, ~ .1 inches below input slit.
Spring force ~ 10 pounds (it can easily be pushed with a thumb)
Nominal relief valve pressure ~ 450 psi (for later accumulator).

This is all that is needed to apply high school physics to compute the work per stroke and then input power for a given shaft rpm.

For each cycle of the piston, it moves down .05 inches pushing against only the spring and then after the input slit is sealed, an additional .1 inches pushing against both the spring and the force due to the 450 psi accumulator fluid pressure.

Lets first compute the force of the hydraulic pressure --- the area of the piston is multiplied by the pressure:

Hydraulic force = π (.53 inches/2)^2 450 psi = 99 pounds

Work is the product of force and distance. The per stoke work is the sum of the work over the first .05 inch of travel and the work over the last .01 inch of travel.

Work per stroke = (.05 inches)(10 pounds) + (.1 inches)(10 pounds + 99 pounds)
= 11.4 inch pounds = .95 foot pounds.

Power is work per unit time. At 1000 RPM the pump will be consuming (1000 RPM)(.95 foot pounds) = 950 foot pounds/minute.

Since one horsepower (HP) equals 33000 foot pounds per minute, the power consumed at 1000 RPM in HP is

950/33000 = .0288 HP or about .03 HP

At normal driving engine speed of 3000 RPM, 3 X .03 or about 0.1 HP (about 50 watts) will be consumed. The OD might get a little warm but certainly will not get hot due to the pump energy. Note that this is not a precise calculation but probably has an error less than 25%, so it shows that the power consumed by the pump is negligible. There are other sources of power loss (heat) such as friction in all the bearings, bushings and thrust washers so the OD likely gets pretty warm if operated for an extended period.

Accumulator: The early accumulator consists of a cylinder in the main casting fitted with a piston and held by a pair of springs. The top photo on the right shows the piston being extracted from the cylinder. The next photo shows the piston and the two heavy springs. The smaller spring fits inside the larger one.

Oil from the pump goes through a passage in the main casting into the bottom of the accumulator cylinder. As oil is pumped in, the piston is pushed out of the cylinder compressing the two springs. The pressure builds as the springs are compressed.

There are a series of holes along the cylinder wall that connect to a passage to a chamber around the mainshaft for lubrication. The holes are exposed when accumulator is pushed past these holes, allowing fluid to escape from the accumulator. These holes are the pressure relief mechanism. The nominal pressure required to push the piston to the holes is 360 psi.

The later ODs (models #22/1753 & #22/1985) use a different accumulator as shown in photo on right. An "accumulator housing" (top left in the photo) slides into the cylinder in the casting in place of the piston in the early accumulator. A smaller piston (top right) fits in the housing. A spacing tube (middle of photo) holds the accumulator housing in position (otherwise, when fluid is pumped into the cylinder in the casting, the accumulator housing would be pushed out just like the piston in the earlier design). Pressure relief holes are located in the recess just to the right of the O ring, one of which is visible in the photo. A somewhat smaller spring is required to hold the force exerted by the smaller piston, even at the higher nominal pressure of 450 psi.

It is possible to replace the earlier accumulator with the later accumulator (the housing, piston, spacing tune and spring are all required). The Victoria British Catalog suggests this option if replacement springs, piston or rings are required for the early accumulator.

Before leaving the accumulator, a comparison of some of the properties is appropriate. The early accumulator uses a 1.75 inch diameter piston that moves about 0.8 inches to uncover the relief holes. The later accumulator uses a 1.125 inch radius piston that moves about 0.5 inches to uncover the relief holes. The force on the piston is the product of the piston cross sectional area times the hydraulic pressure.

For the early piston at a 360 psi pressure, the spring force is:

π (1.75 inches/2)^2 (360 psi) = 866 pounds (yes, that's nearly half a ton)

For the later piston, at 450 psi pressure, the spring force is:

π (1.125 inches/2)^2 450 psi = 447 pounds, about half the early style.

The approximate volume of the early accumulator is:

π (1.75 inches/2)^2 0.8 inch movement = 1.9 cubic inches.

The approximate volume of the later accumulator is:

$$\pi\,(1.125 \text{ inches}/2)^2\, 0.5 \text{ inch movement} = 0.5 \text{ cubic inches.}$$

An article at tells Healy owners how to remove the later accumulator and replace it with the "big piston and spring" Triumph parts. The apparent motivation is to get a faster shifting and lay a strip of rubber (or suffer whiplash). He says that one can achieve an accumulator pressure of nearly 600 psi using the large piston early accumulator. This contradicts both the information from the ORS employee cited earlier and my experience discussed in part IV. The large piston early unit operates at about 360 psi. I tried to contact the author Del Border, but the email address listed is no longer in service. I suspect that he replaced the short, weak inner spring in the early accumulator with the stiffer spring from a later accumulator. The combination of the outer spring from an early unit with the spring from a later unit used as the inner spring will give the nearly 600 psi pressure he mentioned.

Operating Pistons: The operating pistons are located in the main casting as shown in the photo on right. The right piston has been removed and the left piston is being lifted out.

The piston shown is the earlier design with steel rings. The later design uses a rubber O ring. Both type of pistons are shown in the middle photo. Replacement steel rings are no longer available but the new design piston with O ring can be used in the earlier #22/1374 model but not the #22/1275 because it used smaller operating pistons.

The bottom photo shows the main casting with the clutch thrust ring assembly in position. The eight springs press against the adaptor plate at the front of the main casting and push the thrust ring to the rear position engaging the cone clutch into the annulus --- the direct drive position as discussed earlier.

The two bars are held to the thrust ring pins by nuts are called bridge pieces. When the OD is switched to the engaged position, fluid enters the rear of the operating piston cylinders and pushes the operating pistons forward into the bridge pieces and then pushes the bridge pieces and connected thrust ring and clutch forward until the front cone clutch mates with the brake ring.

The nominal 360 (early) or 450 (later) psi fluid pressure is maintained on the pistons as long as the unit is in overdrive.

When the unit is switched to direct drive, the fluid is allowed to slowly leave the operating piston cylinders. When this happens, the springs push the bridge pieces, the pistons, the thrust ring and the clutch toward the rear until the rear cone clutch engages the mating surface on the annulus.

Excepting the earliest model that I've chosen to ignore, the operating piston diameter is 1.375 inches. The force exerted at 360 psi hydraulic pressure is:

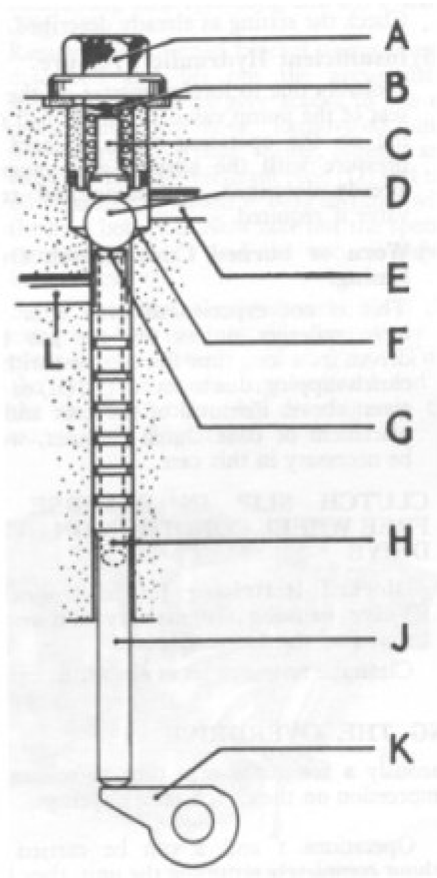
π (1/375 inches/2)^2 (360psi) = 538 pounds per piston for a total force of 1076 for both pistons. The later version with a 450 psi nominal pressure produces a total force of 1346 pounds

The pistons move about a tenth of an inch between the two clutch positions, so the total fluid required to operate the clutch is about:

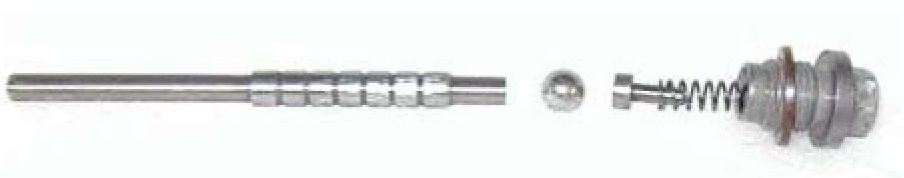
2 π (1.375 inches/2)^2 (0.1 inch) = .3 cubic inches

With accumulator volumes of 1.9 (older) and 0.5 (newer) cubic inches, there is more than adequate fluid in the accumulator to operate the clutch essentially instantly. As discussed earlier, there will be a larger initial pressure drop in the newer unit with the smaller accumulator, which will allow some slippage and smoothing of the engagement..

Operating Valve: A diagram of the operating valve (taken from the Service Instruction Manual) is on the right. A photo of the components is below. The valve is on the right side of the main casting with the plug (A) on the outside near the top of the casting. Passage E connects to the accumulator that normally contains oil at a pressure of about 360 psi (early) or 450 psi (later). Passage L connects to the operating pistons. Parts A, B, C & D are identical to components (same part numbers) of the non-return valve discussed previously. All operating valves use the 5/16 ball whereas the later non-return valves use a 1/4 inch ball. When the valve is released as shown, the spring and plunger press the ball against the seal (F) machined into the main casting preventing the fluid from flowing to the operating pistons.



When the external solenoid operates, lever K pushes the operating valve spindle J up which in turn pushes the ball away from the seal. Oil then flows from the accumulator around the narrow end of the spindle and out passage L to the operating pistons, which in turn moves the clutch to the OD engaged position. The fluid initially comes from the accumulator and the pressure drops when the valve operates but quickly recovers as the pump re-supplies the accumulator. There is also a passage through the machined seal G at the top of the hollow spindle to a small hole at H. When the OD is engaged, the spindle is pushed up so that the ball seals the top of the passage.



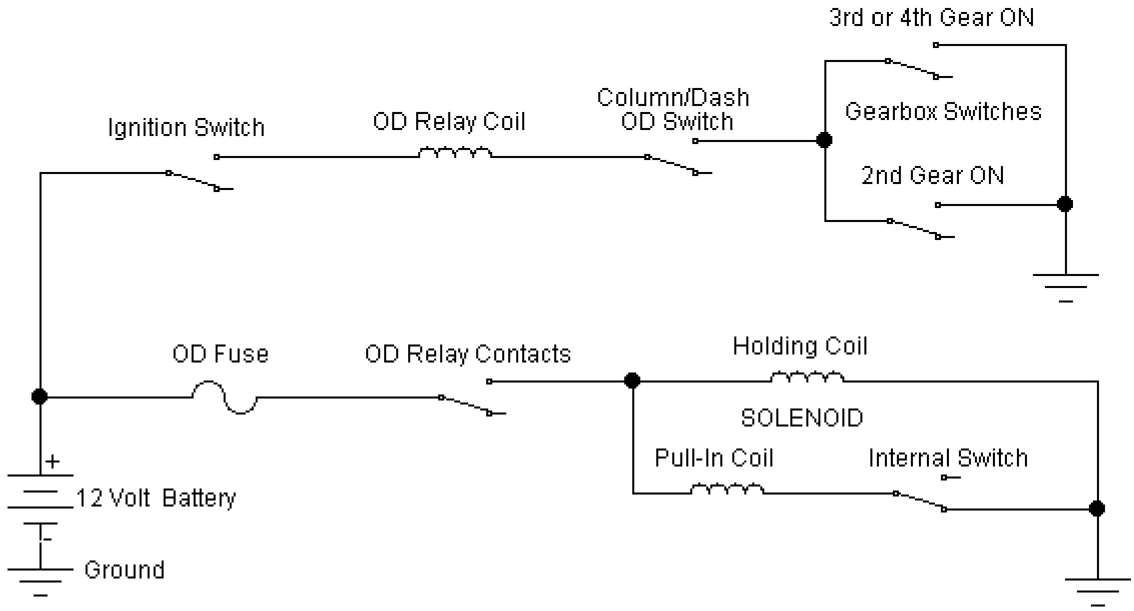
When the solenoid is switched off, indicating the OD should switch back to the direct drive mode, lever K and operating valve spindle J drop to the lower position.   The ball seals the passage from the accumulator. The spindle drops far enough so that the top is no longer sealed against the ball allowing the fluid from the operating pistons to escape down though the hollow spindle and out hole H and into the bottom of the main casting. The hole is very small so it takes about a half second for the springs to push the clutch back to the direct drive position.

The lever (K above) is connected to a shaft that extends beyond the main casting on both sides. (See photo below where a finger is pointing to lever K with the operating valve J setting on the lever.) The solenoid rotates this shaft via a lever on the left side of the main casting (right side of the photo below).

Section 3 - Electrical Components

Solenoid: The solenoid is the cylinder with the wire coming out the top in the photo on the right. The rod extending from the bottom of the solenoid is called the plunger.   The shaft end to the left of the plunger is the same shaft in the previous photo that controls the operating valve.   The lever clamped to this shaft is called the actuating lever.   When 12 volt power is applied to the solenoid (via the dangling wire) the plunger moves up, pulling the end of the actuating lever with it.   This causes the shaft to rotate and via lever K pictured above, the operating valve to lift in turn engaging overdrive. When power is removed, the solenoid plunger drops allowing the operating valve to close and the unit to shift to direct drive.

Electrical Circuit: The schematic of the electrical circuit is shown below.



The upper part of the circuit controls the OD relay. The relay operates when there is 12 volts on the left end of the relay coil and ground on the right end of the relay coil. 12 volt power is supplied to the left side via the Ignition Switch (turned ON). Ground is supplied to the right side via the OD Switch on the dash or steering column and one of the Gearbox Switches. The Gearbox Switches are ON when the gearbox is in the indicated gear. All Triumph applications except the first model used on the TR2 have two switches, one switch for 3rd & 4th gear and another one for 2nd gear. In summary, for the relay to operate:

- the Ignition Switch must be on,
- the OD Switch on, and
- the gearbox in a forward gear for which OD operation is permitted

The relay circuit is relatively low current, drawing much less than one ampere. The solenoid draws a much higher current. That is why the relay is used --- the switches are not capable of carrying the higher current reliably whereas the relay contact is. The fuse shown in the solenoid circuit is not original equipment. I prefer to use the spare fuse box position on TR250s and TR6s to fuse this circuit. A 10 amp fuse is satisfactory. The main reason I use the fuse is to protect the wiring should one of the wires become grounded or to protect both the wiring and the solenoid should the solenoid internal switch fail to open.

The Service Instruction Manual states that the relay coil and contacts are not connected through any fuse for the following reason: *Should the fuse blow when the engine is driven at peak revs. in overdrive second gear, the overdrive unit would immediately return to normal second gear. The car running at high speed would then turn the engine at speeds for which it was not designed, with consequent risk of damage to connecting rods, valve gear, etc.* My first comment on this is that there is nothing unique about the engine speedup when leaving OD in second gear, it is a 22% speed up in third and fourth gear also. My second comment is that if the fuse blows, there is likely a short circuit that will cause the insulation to melt on the unfused circuit followed by the wire melting and releasing the solenoid with the same speed up noted above except that the wiring harness will have been destroyed. My third comment is that the fuses are about the only electrical things that have never failed on my TR fleet. The switches and connectors are much more likely to fail.

The solenoid case contains two coils, a pull-in coil that draws 15 to 20 amperes and a holding coil that draws about one ampere. When the relay contacts close, current is supplied to both coils and the plunger moves up very rapidly, taking a tenth of a second or less. When the plunger reaches it's upper most position it operates a switch inside the top of the solenoid that opens the current path to the pull-in coil. Once operated, the holding coil supplies sufficient magnetic force to hold the plunger in the operated position.

After once operated, the solenoid stays operated until the ignition is turned off, the OD switch is turned off, or the gearbox is shifted out of one the permitted gears, any of which cause the relay to release followed by the solenoid.

A Type Overdrive, Part II - Disassembly

Before we start: The A type OD unit is very rugged and not prone to internal failure. I've had a half dozen open and discussed problems with friends on their OD units covering another half dozen. In all these only one has had a major failure, and that is the one that is in most of the pictures in the following. That unit was of the TR3 vintage so it was over 40 years old. It was taken from a junkyard about ten years ago and never used by the present owner. When we opened it up he was glad he never tried to use it as we will see later.

Because this unit had a failure that ground some parts into unrecognizable bits that were scattered throughout the unit, the unit was completely disassembled except for the planet carrier and everything was inspected. The large bearings were replaced as well as the broken parts.

On a unit that has been working or has not suffered a major failure (the typical situation) I do a partial disassembly and through cleaning. I don't do a bearing replacement unless they are found to be rough. There are no other wear components other than the clutch sliding member. I understand that the clutch material does wear after several 100K miles or, more likely, the OD has been slipping for an extended period. The springs tend to shrink with age so they require special attention as we found out.

I replace the rear seal unless I know it has been replaced recently and is not leaking. The only other required materials are the gaskets.

Special Tools: Several special tools are required to disassemble and assemble the OD. These tools are easily constructed from material readily available at the hardware store. Pullers of various sizes and a hydraulic press came in handy.

Cleaning: The OD and gearbox are removed from the car as one unit. Most Gearboxes and OD are covered with oil and grease. Either the engine or the gearbox is leaking oil (most likely both) that has covered the gearbox & OD and then dirt mixes with the oil making a black gooey mess. The whole unit should be cleaned thoroughly before it is opened. The spray degreasers stocked at the discount auto stores work pretty well. I spray the stuff on, let it set for 15 minutes or so and then use a stiff brush to loosen the difficult parts and then hose it off. In most cases some areas have to be degreased again and maybe a third time. (A couple cans of degreaser are usually required.) After all the grease is off I scrub the outside with hot water and dish detergent to get the film from the degreaser off. This process can make a real mess in the yard. I'm fortunate to have a rough wooded area to do this stuff in. If I lived in the city, I might haul it to a self serve car wash to clean it up. After everything is clean, the oil is drained from both the gear box and OD. The oil flows between the gearbox and the OD unit but it is difficult to drain the oil without removing the drain plugs from both units. The OD drain is the large brass plug.

Gearbox Stand: I use a gearbox stand made from scrap pieces of 2X4, 2X2 and a short piece of steel angle as seen in the photos below. The gearbox bolts to the angle at the front. The 2X2 near the rear of the main gearbox casting has a shim tacked to the top to adjust the gearbox so that it is horizontal. The stand took about 30 minutes to make and proved its worth in about 15 minutes of use.

Remove the small parts: It's convenient to remove several small parts from the OD unit before detaching the OD from the gearbox, starting with the solenoid. The solenoid sticks up and makes a nice handle. Unfortunately, using it for a handle nearly always breaks the bracket to which it attaches. At ~ $75 per bracket, an expensive handle. (That small aluminum casting is known both as the solenoid bracket and the cover plate. The term cover plate is used from here on.) It's best to get the solenoid off and in a protected place first thing. The following photos show the solenoid attachment screws being removed (left). The solenoid, plunger, actuating lever and collar are then removed. When new there was a rubber boot around the end of the solenoid to prevent debris from entering the cylinder in which the plunger slides. The boots have long since cracked and fell off on most these old units. Replacement boots are not available so we do without. I've operated several without boots for about 15 years with no problems.

As parts are removed they are thoroughly cleaned and inspected. To keep track of the parts, associated groups of parts are placed in small zip lock plastic bags. For example, the parts in the lower right photo were put in the same bag.

The cover that retains the humongous accumulator spring was removed next. It is secured by two bolts to the rear and two nuts on studs toward the front and must be removed properly so that it is not bent or distorted. **Caution, the operating valve must be operated and released a half dozen times using the lever or solenoid to relieve the pressure before removing the operating valve plug or the cover plate.** The nuts on the studs on the forward side of the bracket were removed first. Then the two bolts were unscrewed alternately a little at a time such that the plate comes off relatively straight (left photo below). The center photo shows the spring of the early style accumulator being removed. There was a bunch of metal parts in the sump under the accumulator, including several little ball bearings, an ominous sign. The right photo shows the removal of the spring and spring tube from a later style accumulator. (Another OD was setting nearby that is a future project. The accumulator was pulled from it from it to show a comparison. Later on you'll find we borrowed some parts from it.)

The speedometer bearing & pinion were removed next. This need be removed only if one plans to disassemble the rear casting to replace the two rear bearings. The retaining bolt was removed first, and then the nut from the end of an old speedometer cable was screwed onto the speedometer bearing and a large screwdriver was then used to pry against the lip of the speedometer nut to remove the bearing (left photo below). The parts in right photo were bagged together.

Removing the rear casting: I prefer to separate the rear casting from the main casting while the overdrive is still attached to the gearbox. Six studs hold the two castings together. The eight springs between the gearbox and the OD unit push against the annulus that helps separate the rear casting. This time, the castings didn't come apart when the nuts were removed. The ends of the studs were tapped with a punch to break the seal as shown in the middle photo below. The brake ring also came loose from the main casting so the hammer and punch were used to drive it back into the main casting. The brake ring can't be removed until the bridge pieces are removed from the thrust ring. The right photo shows the rear casting ready to slide off. Once the rear casting was off it was clear that the thrust bearing had failed --- more about that later.

After the rear casting was removed, the planet carrier with planet gears and then the sun gear were removed as shown below. The planet carrier was cleaned and the bearings in each planet gear were tested by rotating the gears. All three gears rotated smoothly and there seemed to be no play in the bearings. It was decided that the planet bearings would not be replaced so it was not necessary to disassemble the planet carrier further.

Removing Main Casting: The nuts and lock washers from the two bottom studs were removed first. Next, the nuts on the two top studs were loosened; these nuts can't be removed until the main casting is separated from the OD adaptor plate (left photo below). The nuts on the two long studs were then backed off a quarter inch or so. The casting didn't separate so I tapped it with a hammer and wood block. Once the casting separated, there was sufficient clearance to remove the nuts from the two top studs. The nuts on the two long studs were then backed off together to keep the main casting straight eight springs were pulled out and bagged.

Adaptor: Before leaving the gearbox the adaptor plate surface that mates with the main casting was cleaned and a straightedge used to check to see if it was bent or bowed. If the OD had been previously forced onto the adaptor by tightening the nuts on the studs it is possible that the adaptor is distorted. This will lead to leaks. A severely bent or distorted adaptor can't be used. There have been reports of some success filling minor low spots with epoxy based fillers. The adaptor plate was OK.

Removing Bridge Pieces: The nuts were removed from the bridge pieces next. These nuts were originally equipped with locking tabs. I prefer to not reuse these because the tabs usually break off after they have been bent once. These tabs are NA so both the tabs and nuts were discarded and replaced with 1/4-28 nyloc nuts. Once the four nuts were removed the bridge pieces were pulled off the thrust ring and the trust ring was slid out the rear of the main casting. A bronze thrust washer and an adjustment washer were also removed from a recess behind the main shaft bushing in the main casting.

As mentioned earlier, a bit of a disaster was discovered when the OD was dismantled. The thrust bearing, that large bearing between the thrust ring and the clutch sliding member failed --- the balls fell out and the two parts separated. The eight springs then forced the thrust ring (doesn't rotate) into the rotating clutch sliding member. It must have made a hell of a racket. The left photo below shows the back side of the thrust ring where much of the metal has been worn off. The circlip retaining the bearing outer race was also damaged. The center photo shows the front side of the clutch sliding member where again, much of the metal has been worn off. The dark area indicates that it got very hot. The right photo shows the remains of the bearing. The pieces in the lower left hand corner of the right photo are the remains of the thrust washer between the sun gear and the planet carrier. It was decided to reuse the clutch sliding member since the clutch surfaces, the splines and the collar that mates with the bearing inner race were not damaged. The thrust ring was so heavily worn that the lip retaining the bearing outer race circlip was missing in some places. The thrust ring and circlips in addition to the destroyed thrust washer and bearing were replaced. Because some of these metal pieces were floating around the OD it was decided to also replace the two annulus bearings in the rear case.



Removing Accumulator Piston: This OD was an early model with the Accumulator cylinder machined into the main casting. The center of the piston has a hole threaded 3/8-24 (this was previously reported as 5/16 -24 - thanks to Dan Shockey for the spotting the error). A puller was made by turning down the end of a 1/2 inch treaded rod (had a stack of these left over from a church project ten years ago) and then threading 3/8-24. A length of 3/8-24 threaded rod would have worked just as well. Not much force was required to remove the piston. The photos below show the puller in action. After the piston was removed, the rings and the cylinder walls were examined for defects. We were lucky; the metal pieces from the bearing failure didn't seem to have made it to the accumulator.


The photos below show removing the later style accumulator. An extraction tool that expands an O ring into the end of the accumulator piston housing where the spring tube fits was fabricated. The tool and spring tube are shown in the left photo below. The O ring and tool outside diameter is 1.5 inches. The inner diameter of the end piece is 1.25 inches, the ID of the O ring. A 3/8 inch bolt extends the length of the tool. Tightening the wing nut pulls the end cap into the main piece and squeezes the O ring out to grasp the accumulator piston housing. Both the tool body and wing nut had to be grasped with pliers to tighten the nut sufficiently to grasp the housing. In the process, the plastic end piece cracked. (Next time I'll make the end piece of steel or aluminum). Once the housing was removed, the piston was easily pressed out the top of the housing. Everything was in order and no problems found. One interesting note, the washer in the right photo is a low quality hardware store type, obviously added well after manufacture. Putting a washer behind the spring is the accepted way to increase the accumulator pressure.



Removing Non-Return Valve: The pump non-return valve is located beside the accumulator cylinder as shown in the left photo below. After the plug was removed the spring, plunger washer, and ball were removed, cleaned, inspected and stored (right photo).

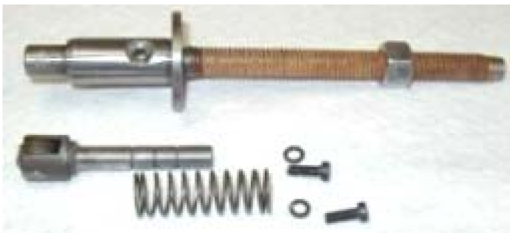
 

Removing Pump: The drain plug and screen filter must be removed to expose the pump.. The photos below were taken after the gearbox had been cleaned up. Much of the oil evaporated from the heat generated when the bearing failed. The outside of the screen was covered by black goo mixed with metal parts. (The later models use a larger plug and the screen is retained by the plug rather than the screw as shown in photos below.)

The pump is pressed into the case and requires quite a bit of force to remove. **Caution - the non-return valve must be removed before the pump body is extracted**. The two screws and plug shown in the middle photo below were removed first. A threaded rod screwed into plug hole was then used to pull the pump body. The threads are 7/16-20. The end of another one of those 1/2 threaded rods was turned down and threaded to make a puller --- right photo below. A length of 7/16-20 threaded rod would have worked just as well. A pipe fitting was used to provide a space to draw the pump into. The pump body came right out as the nut was tightened.

The extracted pump body is shown on the left and with the piston and spring on the right. The hole in the side of the pump body is the seat for the non-return valve ball. The pump components were examined for signs of wear and the valve seat for nicks. The free length of the spring was measured and found to exceed the 2 inch minimum spec.

Removing Operating Pistons: The operating pistons were removed by grasping the ends with pliers and rotating the pistons back and forth while pulling out. Upon inspection one of the piston rings was found to be broken. Quite possibly it was broken when initially installed. These rings are no longer available so the new style piston with O ring seal had to be purchased.

Removing Operating Valve: The last thing removed from the main casting was the operating valve. The valve plug is on the upper right-hand side of the casting. Unfortunately, the corners on the hex room to get another type of wrench on it.   A 1/2 inch nut was driven over the top of the plug and welded. The nut and plug were then removed together. The plug with the large nut attached is shown at the right.


The operating valve components are shown below.   The plug and copper washer are new replacements.

Disassembling Clutch: As was discussed earlier, the bearing was shattered in the clutch so it was only a matter of removing the races from the thrust ring and sliding member. The inner race was removed from the sliding member using the same spreader that was used on the annulus bearing shown later. An air die grinder was used to cut the outer race to get it out of the thrust ring.

A working bearing can be removed using the following procedure.   Remove the circlip holding the inner race on the sliding member. Make two new longer bridge pieces from steel stock. The pieces should extend to each side of the thrust ring far enough so that they an be positioned on blocks in the hydraulic press. The press is then used to push the collar on the sliding member out of the inner race. Once the sliding member and thrust ring are separated, the circlip retaining the outer race in the thrust ring can be removed and pressure can be applied to the inner race to press the bearing out of the thrust ring.   I'll update this section with photos the next time I replace one of these bearings.

Removing Unidirectional Clutch: The unidirectional clutch sets in a recess in the large end of the annulus in the rear casting (left photo). It is removed it by rotating the center part counterclockwise and lifting up.   The rollers came out of the cage so then we had a bunch of pieces as show in photo on right below. The bronze thrust washer is located behind the clutch.


OD Stand: A stable base to hold the OD on end during reassembly is very useful. The old piece of 2X12 used previously had disappeared so the new stand shown on the right was made from scrap lumber. A 1 1/2 inch hole in the center provides clearance for the end of the annulus shaft and nut. Two 3/8 inch holes provide for bolts to hold the rear flange.

Annulus End Float: The annulus end float was measured before the rear casting was disassembled. The end float is adjusted by changing the adjusting washer between the rear bearing and a shoulder on the annulus shaft. If the end float is within spec before disassembly, then it should be within spec even if new bearings are installed because the bearings are made to a very close tolerance.

The rear casting was secured to the stand and a dial indicator was positioned as shown with the point against the annulus. The casting was then pushed down for the first reading. The second reading is taken after the casting has been pulled up by placing one hand on each side the top of the casting and pulling up while pushing down on thumbs pressing against the outside of the annulus. The required end float is .005 to .010 inches. If the end float is out of spec, refer to the discussion near the beginning of Part III. This end float was right on .005 inches.

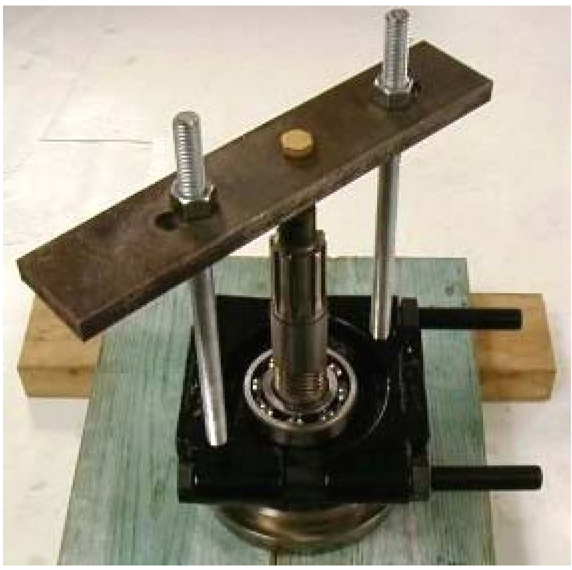
Rear Flange Removal: A "flange removal tool" made from a two foot length of 1/4 inch by 1 1/4 inch steel bar (a 1 inch bar will probably work as well) is used to hold the flange when removing the nut. A 3/8 inch hole is drilled close to the edge near the end for attachment to the rear flange. A second bolt is installed in the flange to rest against the edge of the tool to keep the flange from turning as shown in left photo below. This bar is also a "flange installation" tool. It can also be attached to the flywheel using one of the clutch pressure plate bolts to become a "flywheel removal or installation tool". The cotter pin was removed from the flange nut and then a breaker bar was used with the tool to loosen the nut.

A puller was used to remove the flange as shown in the right photo. The black object is one of the cats that live in the workshop. This is the dumb one; she is so dumb her fur should be blonde.

Removing the Annulus: The annulus was pressed out of the rear casting using the hydraulic press as shown on the right. The sides of the casting were blocked up off the press cross members. A scrap piece of 2X4 was placed under the casting to stop the annulus from slamming into the steel press cross member if it came loose with some velocity. This was a well behaved annulus that came out gently with minimum force applied. The annulus is shown in the photo below. The middle bearing must still be removed from the annulus shaft.

Note the watch cat sleeping in the background. The mice that live in the work shop must have kept her awake the the night before.

Middle Bearing removal: This bearing is also known as the annulus head bearing. A large bearing separator (available from Harbor Freight, ~$20) was used to first push the bearing away from the shoulder on the annulus by tightening the two black bolts in the left photo below. Next, the bearing was pulled along the shaft by tightening the nuts on the threaded rods. The right photo shows the bearing nearly off the shaft. The press fit is only on the shiny section very near the shoulder.



Rear Bearing & Seal Removal: A length of threaded rod, some washers and spacers were used to pull the rear bearing (aka annulus tail bearing) and seal from the rear casting. This is the same stuff used to press rear bearings and seals out of the gearbox extension of non OD gearboxes. The rod was secured in the vise as shown on the left. The rear casing and then a spacer and washer were slid over the rod and a nut threaded on and tightened. The lower washer on the rod pressed against the under side of the rear bearing. As the nut was tightened, the spacer pushed the casting down off the bearing. The freed bearing is shown on the right. The rear seal has been pushed up into the spacer; the bottom edge of the seal is visible.



Setting Lever O Ring: There is a small O Ring behind the setting lever on the right hand side of the main casting. The lever must be removed to get at the O Ring. The lever on the later units is secured by what the Brits call a spring dowel (roll, tension or expansion pin in the US) that can be easily driven out with a suitable size punch. The earlier units as that shown on the right have a solid dowel pin. I drilled it out using a sequence of 5/64 - 3/32 - 7/64 drills. The holes are 1/8 inch. The photo shows the lever pulled to the end of the shaft and the O ring pulled out of the recess. I used a sharp scribe to pry the O ring out of the recess The lever was pulled off, a new O ring slid into position and the lever reinstalled and secured with a 1/8 inch tension pin. The tension pin on the later units seems to be a little smaller, possibly 3/32 inch. I'll update this when I take one of those apart next time. This section was added on 10-9-01 after Mike Kitchener mentioned that these O rings were missing from the parts list. I then realized that hadn't replaced the O ring under the lever on the unit described here. The battery was dead on the hand drill when I first took it apart, so I deferred it and then forgot. I replaced it today on the fully assembled unit --- no problem.

All the parts: The photo below shows all the parts extracted from the OD unit after they had been cleaned up and packed with associated components.

Parts List: The following lists the parts used for various levels of maintenance plus the additional parts needed for this job.

For inspection and cleanup the following parts are required:

- Gasket, adapter to gearbox (if the adapter is removed
- Gasket, adaptor to OD (I buy 2 in case I have to tear it apart again)
- Gasket, cover plate to main casting (I buy 2 in case I have to tear it apart again)
- Washer, oil drain plug.
- Rear shaft seal (unless seal is not to be replaced).
- 2 Valve Operating Shaft O rings.
- 4 - 1/4 inch 28 nyloc nuts if the nuts securing the bridge pieces use locking tabs and the nuts are removed.
- Tube of Hylomar HPF Gasket & Flange Sealer by Permatex, available from local auto pasts store.
- 2 quarts of gear oil (see discussion in part IV)

For a major overhaul the following parts in addition to those listed above are required:

- Bearing, annulus head
- Bearing, annulus tail
- Bearing, thrust (between clutch sliding member and thrust ring)
- Unidirectional clutch roller set

Because the OD discussed here was damaged due to the bearing failure, the following parts in addition to the previous two lists were required:

- Thrust Ring
- Thrust bearing large circlip
- Thrust bearing small circlip
- Thrust washer between sun gear and planet carrier
- Operating valve plug (the one we welded a nut to so that it could be removed)
- Operating piston (broken ring)

Other parts that are subject to deterioration and may be required:

- non-return and operating valve balls
- non-return and operating valve springs
- Clutch return springs
- Accumulator spring
- Clutch sliding member

I usually buy parts from The Classic Car because of a long relationship and good service.

A Type Overdrive, Part III - Reassembly

Everything was disassembled and cleaned and the parts needed for the rebuild were determined in Part II. The reassembly is described in this part. The annulus was installed in the rear casting first. The clutches and epicyclic gears were dealt with next. The final step was to reassemble the hydraulic components in the main casting and then mate the rear casting to the main casting.

Installing Annulus Heard Bearing: The annulus head bearing (or OD middle bearing) was pressed onto the annulus shaft until it was snug against the shoulder. A hydraulic press as shown in the photo on right was used.

Before installing the annulus in the rear casting, the distance between the bearing outer races was measured by driving the old head bearing into the rear casting and then measuring the distance from the outer race of the head bearing to the shoulder that the outer race of the tail bearing rests. This is a good use for a depth gauge. Lacking a real depth gauge, the part that slides out of a dial caliper was used as a depth gauge. Several measurements were taken until a repeatable result was obtained. The dial caliper was used again as a depth gauge to measure the distance from the head bearing inner race (just installed on the annulus shaft) to the shoulder on the annulus shaft that the adjustment washer rests. The difference between these two measurements is the ideal size of the adjustment washer. These measurements are not very precise so there will likely be some error. The size of the adjustment washer calculated from these measurements was used as a rough estimate.

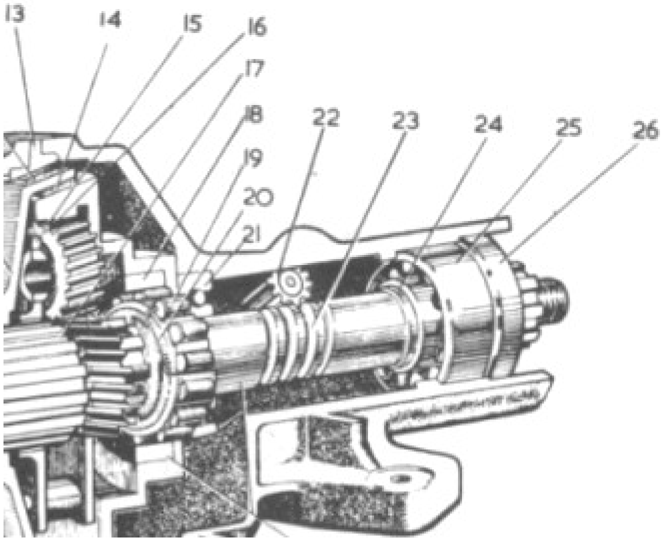
Installing Annulus in rear Casting: The press was used to push the annulus into the rear casting. First, the rear adjustment washer was slid on the tail end of the annulus and then the annulus was fed into the rear casting. (There was no confusion as to which washer was the annulus adjustment washer and which was the washer under the nut, the adjustment washer has smooth sides and the one under the nut has gouges from the nut being tightened.) The tail bearing was then slid over the tail end of the annulus and into the end of the rear casting (the casting diameter is larger near the end to accommodate the rear seal, the bearing slides easily into the first half inch or so). The tail bearing was put in at this point to keep the shaft aligned during the pressing operation. Everything was then put in the press as shown on the right. Care was taken to assure that the head bearing was starting into the recess properly before applying heavy forces. Also, no more than the minimum force required to seat the bearing was applied to minimize any stress on the bearing.

Installing Annulus tail Bearing: A large thrust washer (originally from a gearbox) was placed over the end of shaft and against the side of the bearing and a pipe coupling spacer was slid over the shaft as shown in the photo on the right. This is the same as the previous setup except the annulus is being pressed into the tail bearing instead of the rear casting. The press force was limited to that necessary to get the bearing seated.

The rear flange was then slipped on the shaft followed by washer and nut. Note that the rear seal was not installed yet. The nut was tightened to ~ 100 foot pounds using the same flange retaining bar discussed in Part II and then the rear flange was bolted to the OD stand.

Measuring Annulus End Float: The annulus end float was measured again using the same procedure described in Part II. The dial indicator tip was positioned against the annulus. The casting was then pushed down and a first reading taken. A second reading was taken after the casting had been pulled up by placing our hands on each side of the casting and pushing down on the annulus with our thumbs. The difference between the two readings is the end float. The end float was within the .005 to .010 inch specification before the unit was disassembled so it was expected to be within specifications after reassembly, even with new bearings. In this case it was. If it were not, one of the bearings might not be seated. The first thing I'd try is to to use a punch to drive the tail bearing outer race a little further into the rear casting. The next most likely problem is that the head bearing inner race isn't seated against the annulus shoulder. One might have to go back to the first step above to make sure the head bearing is seated properly. Another possibility is that the old bearings were worn and sloppy. If the bearings are seated properly and the end float is still out of specs, read on.

Annulus End Float Out of Specifications: The sectional view on the right is part of a diagram in the Service Instruction Manual mentioned in Part I. Component 14 is the Annulus, 21 and 25 are the head and tail bearings, 24 is the adjustment washer and 26 is the rear seal.



New head and tail bearings have some end float between the inner and outer races. I don't have specifications on the bearings but expect it is about .010 inch. Note from the sketch above that the outer races on the two bearings are pressed against shoulders in the rear casting. The inner races are squeezed together by the annulus head and the rear flange. The adjustment washer (24) rests against a shoulder on the shaft and keeps the inner races apart

If everything is perfect, the distance between the two outer races is exactly equal to the distance between the two inner races and the annulus end float will be equal to the lesser of the two bearing end floats. On the other hand, if the distances between the two inner races and the two outer races are different, the end float will be less. In the extreme, if the difference in these two measurements is too large, there will be no annulus end float and the bearings may have a pre load ---- a lateral force applied to the bearings. Pre load will likely lead to early bearing failure.

If the end float is out of specifications, it can be too large or too small. If it is too large, then there is probably too much end float in both bearings, they are probably very sloppy (possibly caused by an an incorrect adjustment washer) and need replaced.

If there is too little end float, then a different adjustment washer can be used to get the distance between the inner races to match the distance between the outer races. Washers are available (or were available 30 years ago) in .005 inch increments between .146 and .181 inches. Lets say that the end float is .002 inches. The next size washer should bring the end float to .007 inches, in the middle of the specs. Should a thicker or thinner washer be used? You can't tell from these data. If one has a stack of washers, a thicker one and then a thinner one can be tried, etc. There are 8 washer sizes and if one starts with no end float, this can take some time. There is a factory tool that allows one to measure the distance between the inner and out races and compute the correct size washer. I don't happen to have that tool and it looks like too much work to make one to use it once in a lifetime.

Since this unit worked at one time, it is hoped that the original adjustment washer was close to the right size. There is of course the possibility the worker that originally assembled the unit had been up all night watching football (soccer) on the telly or had too much Guinness for lunch. The TRs are notorious for having incorrect parts installed by the DPO or his mechanic. Since the adjustment washer is relatively hard to get at, this is unlikely, but not impossible.

Data was collected before the rear casting was assembled and a rough estimated of the correct washer thickness was calculated. This is a substitute for the factory tool. That estimate together with the actual size of the adjustment washer can be compared to estimate whether a thicker or thinner washer is needed.

To determine the correct size washer I would shim either the outer or inner race of the tail bearing. Suitable .005 inch steel shim stock can be obtained from the local machine shop or machine shop supplier. Another source is McMaster Carr (see links page).

If the adjustment washer is thought to be too thin, I'd cut a washer out of the shim stock the same size as the adjustment washer and add it beside the adjustment washer. If the end float increases, it is clear that a thicker washer is required. If there was no end float to begin with, I'd start with enough thickness to match the estimated washer size. Consider following examples:

If the original end float was .003 inch and a .005 inch shim was added and the end float increased to measured .008 inch, an adjustment washer .005 inch thicker is required.

If the original end float was .003 inch and a .005 inch shim was added and the end float decreased to zero, then a .005 inch thinner adjustment washer is required.

If the original end float was zero and a .010 inch shim was added and the end float increased to .006 inch, then a .010 inch thicker adjustment washer is required.

If the original end float was zero and a .015 inch shim was added and the end float increased to .002 inch, then a washer either .010 or .020 thicker adjustment is required.

If a thinner washer is required, I'd cut a .005 shim washer the same size as the tail bearing outer race and insert it between the outer race and the shoulder on the rear casting. I'd use the same procedure as above to determine the correct thickness of shim to start with. In this case, the thickness of shim is the amount ***smaller*** the adjustment washer should be.

Once the annulus is shimmed so that the end float is correct, the exact size of the adjustment washer is known. However, why not just leave the shim(s) in place rather that trying to secure a different size adjustment washer? I wouldn't have any problem with leaving steel shims between the adjustment washer and the tail bearing. I don't think I'd leave shims behind the outside bearing race because the shoulder in the rear casting is narrow and the shim might work out. The shims behind the outer race are used because the adjustment washer is too thick. I'd probably try to remove some material from the washer. Assuming that the washer is not hardened, I'd put it on my little mill and remove the required material. One could probably also use a file if only a small amount need removed.

Installing Rear Seal: After the adjustment washer was installed and the end float found in spec, the shaft was rotated to make sure it turned smoothly and freely. The rear flange was then removed and the rear seal installed. An ounce or so of oil was poured over the rear bearing to make sure it was lubricated at startup. A small amount of grease was spread around the outside of the seal and also on the inner lip. The seal was inserted lip forward and tapped into place using a punch. The front of the seal rests against a shoulder in the casting as shown in the previous sectional drawing. That is the current owner of the OD (undoubtedly someday to be unjustly know as the DPO) busy at work. Don't you love his shirt?

The rear flange was installed again. This time a little gasket sealer was put under the washer to prevent turned on to the next slot for the cotter pin. After everything was together, the shaft was rotated again to make sure it turned smoothly and freely.

Installing the Speedometer Gear: The speedometer bearing with gear was inserted and rotated until the hole in the bearing aligned with the hole for the locking screw hole. The locking screw was then inserted and tightened.

Washers: There are a total of 6 washers that fit over the mainshaft and annulus shaft. Each washer was carefully bagged with the associated parts so that they wouldn't get mixed up. However, along the way they got all mixed up. No reason to panic, they are all different and easy to tell apart. The three washers shown below all go on the mainshaft. The left washer is the bronze thrust washer that goes between the unidirectional clutch and the annulus. The center washer is the bronze thrust washer that goes between the sun gear and the main casting. The right steel washer is the adjustment washer that also goes between the sun gear and the main casting. Note that the left thrust washer is much wider with a smaller ID. The right two washers have the same ID & OD. There is one more thrust washer that fits and is held inside the planet gear carrier. It is easy to identify because the edges on one side are beveled. The two steel washers that fit on the annulus can be differentiated from the right adjustment washer in the photo because they have a slightly larger ID; the right adjustment washer in the photo is too small to slide on the annulus shaft. (Sorry that I forgot to take a photo of all six washers together; when I thought of it the other three were already in place and I was not about to take them out.)

Assembling the Unidirectional Clutch: The parts of the unidirectional clutch in the left photo below are inner member (upper left), cage, spring, thrust washer and rollers. The spring was connected to the inner member first as shown in the middle photo. There are two ways to connect the spring, only one is correct. Next, the other end of the spring was slipped into the hole in the cage, followed by the inner member. The inner member was then rotated against the spring and locked into place by the cage tabs shown in the right photo. The end of the spring can be seen sticking out of the cage in the right photo.

The 12 rollers must be inserted into the cage next. One way to do this is to wrap a heavy rubber band around the cage and then lift it and feed the rollers into position one at a time. The manuals show photos of a Churchill tool to help assemble the clutch. A similar tool was fabricated using a plastic pipe coupling and bushing as shown in left photo below. The inside was turned to a diameter just less than the inner diameter of the recess for the clutch in the annulus and to a depth slightly less than the clutch thickness. The slot in the side is just wide enough for a roller to pass. The cage with inner member is placed in the tool as shown in the middle photo and the rollers fed into the cage. The inner member is rotated clockwise after each roller is inserted. If an attempt is made to turn the inner member counterclockwise, the clutch will lock. (If it doesn't lock, then the the ramps are probably not positioned as shown in photo and it must be taken apart and reassembled, making sure the spring is installed in the correct direction.) The assembled clutch is shown in the right photo.

Installing the unidirectional Clutch: The rear casting was still mounted to the OD stand. The thrust washer was positioned (left photo), the tool with clutch inside was placed over the recess and the clutch pushed into the recess (center photo), and the tool lifted away (right photo). If one used rubber bands to assemble the clutch, then the procedure is the same and the rubber band would slip off as the clutch was pushed into the recess.

Dummy Mainshaft: Several of the procedures require the use of the mainshaft or a suitable fake. If one has the mainshaft out of the gearbox or has a spare, great! The gearbox for this project had already been assembled so I took measurements from the part protruding from the rear of the gearbox and turned a shaft of the same diameter from scrap mild steel. A slot was milled in the shaft and one spline installed to aid later in aligning the unidirectional clutch and the planet carrier. While installing a clutch several days later using a plastic dummy mainshaft I thought --- why didn't I make this dummy mainshaft from plastic or nylon, etc --- it would have taken one tenth the time. Suitable materials are available from McMaster-Carr. A wood dummy should also work fine.

Testing the Unidirectional Clutch: Before proceeding the clutch was tested by inserting the dummy mainshaft in the clutch and rotated in both in both the clockwise and counter clockwise. (If a shaft wasn't available, one could have done the same thing by using fingers to push the top of the cage). Everything was working properly, the clutch rotated easily in the counterclockwise direction and locked to the annulus when clockwise rotation was attempted. If it didn't do this, then the clutch was assembled backwards and would have to pulled out and reassembled. After everything checked out OK, an ounce or so of oil was poured over the unidirectional clutch and also between the annulus and the rear casting.

Planet Carrier: Each of the planet gears was rotated to make sure the bearings were smooth. Normally there will be no problem and nothing else need be done to the planet carrier. In this case the mainshaft thrust washer retained in the center of the planet carrier was destroyed and the new washer couldn't be installed without removing one of the gears. The photo on the right shows a gear, the little shaft and associated tabbed thrust washer. There is a hole in the top of the shaft. A 3/32 mild steel pin is driven through a matching hole in the carrier and into this hole to retain the shaft. The pin was drilled out using a 5/64 bit.

The shaft was tapped out with a hammer and punch and the gear and washer removed. (If it was necessary to replace the planet gear bearings, this procedure would have been followed to remove the gears. There are two roller bearing cages pressed into the gears. These would be pressed out and new ones pressed in. These bearings weren't removed this time for fear they might be damaged and spares weren't in hand.)

The thrust washer was positioned in the recess in the center of the carrier. The top of the washer is beveled to provide clearance for the planter gear teeth. (If the top of washer isn't beveled, one can try turning it over.) The planet gear thrust washer was then positioned with the tab in the hole, the gear slid into position and the shaft tapped home using a small hammer. The photo on the right shows a drill bit in the hole in the shaft to help keep it visually aligned with the hole in the carrier. A 3/32 steel retaining pin didn't seem tight enough so a 3/4 inch long 3/32 expansion pin was ground down to a length of ~ .6 inches and used instead. The expansion pin is tempered and will likely ruin a drill bit if one tries to drill it out. However, if the shaft is pressed out, the pin will shear off and the pieces can then be tapped out with a small punch. (I tried it to make sure it works.)



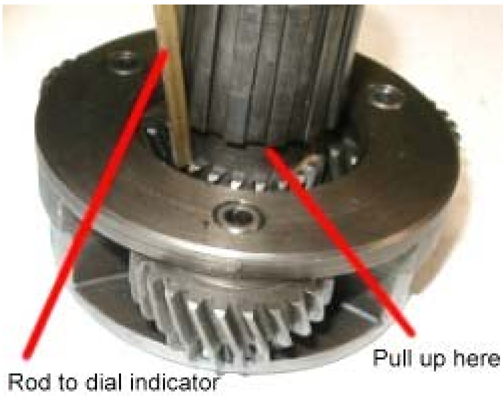
Installing Epicyclic Gear: The sun gear can be installed in the planter carrier with the planet gears in various positions. If the gears are not in the correct position, the sun gear shaft will be off center. This would be recognized when it was impossible to pass the mainshaft through the sun gear, the planet carrier and the unidirectional clutch. There are indexing dots stamped into the top of each of the planet gears. Each gear was turned so that the dot is on the outside and a line through the dot and the center of the planet gear shaft also passed through the center of the planet carrier as show in the left photo below. The sun gear was inserted with the planet gears aligned as indicated. The dot alignment was verified after the sun gear was in position. The three dots didn't line up as indicated, so I did it over and got it right. The planet carrier with sun gear was then inserted into the annulus. The sun gear was rotated back and forth slightly to get the gears to mesh properly so that the planet carrier would drop into the annulus..



Measuring Sun Gear End Float: A thrust washer and adjustment washer fit between the sun gear and the bushing in the rear of the main casting (left photo below). When everything is put together, the sun gear must have an end float of between .014 and .020 inches. The books tell you to put an extra washer (thickness over .025 inches) on the mainshaft, pound the brake ring in the main casting and slide the main casting into position. Because of the extra washer, there will be a gap between the brake ring and the rear casting. Measure that gap with feeler gauges and subtract the measured value from the size of the extra washer to determine the end float. For example if the gap is .025 inch and the washer is .040, the end float is .015 inch. I was unable to get a repeatable measurement using this method --- the brake ring was on crooked, slid down from the main casting, or main casting tilted, etc.

The method used to measure the annulus end float with the dial indicator worked well so a way was found to do something similar here. Unfortunately, it's six inches or so between the only surface on the sun gear one can position the indicator point and the body of the indicator. Point extenders are available, but not in this workshop. Instead, a piece of square brass tube (available at hobby stores) was used as an extension. The scheme was to install the two washers (no extra washer this time) and then slide the main casting with brake ring into position. The two castings went together with the brake ring in-between.

Nuts were tightened on a couple studs on opposite sides of the case to make sure everything was seated. I was able to reach through the gap in the main casting and feel the sun gear shaft, rotate it and try to feel some end play -- but found none. Next, one end of the brass tube was positioned on one of the sun gear teeth and the other end slipped under the dial indicator point. A couple hooked tools were then used to lift the sun gear up. The change in the indicator reading was the end float. The center photo below shows where the rod and hooked tools were positioned and the right photo shows the lifting tools; a scribe and a screwdriver with a bent tip (also used to install door top weather seal clips).



The left photo below shows the actual setup. A fairly large steel bar was used to secure the indicator magnetic base and provide stability. The right photo shows a young LBC mechanic wanabe at work.

No End Float! When the end float was measured with the dial indicator there was none. That was the same result I got using the extra washer method --- but the problems mentioned earlier caused variations of about .010 inch so I didn't know for sure. A problem was suspected because the thrust washer had a grove worn in it. Also, remember that the thrust washer between the sun gear and planet carrier had been destroyed.

Closer examination of the trust washer and sun gear revealed that the bushing pressed into the sun gear was not flush with the top of the gear --- it stuck up at least .010 inches. This bushing has a steel outside and brass or bronze inside. The steel outside part had cut a grove in the thrust washer as shown in photo on right. An attempt was made to press the bushing in further --- wouldn't budge. The protruding part was then filed off smooth. (Photo is after it was filed.) The thrust washer grove was positioned away from the sun gear in the earlier measurements, which explains the lack of end float.

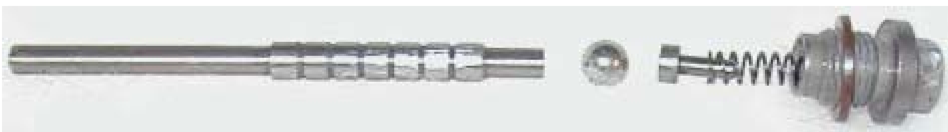
After filing off that ridge, everything was put together to measure the end float again ---- it was about .012 inches this time. Still a little short. There was no hurry this time (I was waiting for a motor to arrive for a test stand --- see next part) so the next size smaller adjustment washer was ordered. A replacement for the damaged thrust washer had been purchased when parts were ordered parts earlier. Unfortunately, I couldn't find the damn thing. Maybe the workshop cats ate it -- or the mice carried it off. The rough against the adjustment washer --- should work fine. That new washer was found later and installed when other problems were encountered necessitating disassembly again as discussed Part IV.

Why no end float to begin with? Could this have anything to do with the failure of the thrust washer between the sun gear and planet carrier? Could this have caused the thrust bearing to fail? Note that the thrust bearing slides over the shaft on the sun gear. One possibility is that the thrust washer failed first and a piece of it got in the thrust bearing causing it to fail. Why wasn't the lack of end float and the problem with the end of the sun gear found at the factory --- British Quality? Maybe half the parts have been replaced by some PO in this baby's 40 year life. We'll never know.

Assembling the Sliding Clutch: This job as illustrated in the photos below was fairly straightforward. The outer race was driven into the thrust ring and then the circlip installed. This circlip is a biggie and takes a lot of force to compress to get it into position. We made sure the circlip was fully seated. Next, the thrust ring with bearing was placed over the clutch sliding member and the inner race driven onto the sliding member. The final step was to install the inner race circlip. Fred Thomas (the young man who helped me get started powder coating) had his TR3 OD quit and when disassembled the only problem found was that the circlip had come out. It was reinstalled and the OD tested and found to work fine. Message: **make sure the circlips are seated!**




Installing the Operating Valve: The main casting was assembled next. The operating valve parts are shown in photo below. Before installing the valve, a little oil was poured into the area of the main casting housing the valve. The valve spindle (the long shaft) was installed first, then the ball, followed by the spring with the plunger inside. The plug, with copper washer was then fed over the spring and screwed down. Torque specs for the plug were not available but the case is aluminum so one shouldn't go to tight. On the other hand, there is ~ 450 psi and one doesn't want a leak. I decided to use 20 foot pounds and see if it leaked. The valve was tested by operating and releasing the lever on the outside of the case beside the valve. The spring pushed the the lever back when it is released as it should.



Installing the pump: The next step was to press the pump into the main case. The ends of two 2 inch long 3/16 steel rods were threaded 12-32. These rods were then screwed into the pump retaining screw holes to guide the pump housing into the correct position (left photo below). The rod used to extract the pump was then screwed back into the pump. Both the inside and outside of the pump body were lubricated, the spring slipped on the piston and the piston with spring slipped into the pump body. The end of the piston is asymmetric as seen in the middle photo. The thin side is positioned next to and slides beside the steel pin in the main casting. The pump with piston was slid into position over the pins. Before pressing the body in, the thin side of the top was verified to be next to that pin and the hole in the pump body was on the correct side to match up with the hole for the non-return valve. After everything was positioned correctly, the pump home was driven home using a hammer on the end of the threaded rod. The large threaded rod and two smaller rods were then removed. A little oil was poured into the pump housing and then the plug was installed followed by the two small screws. The screen filter was installed next, and then the drain plug with a new washer/gasket. This OD didn't have the magnets under the filter that are used on the later ODs.

Installing the Accumulator Piston: The threaded rod used to remove the older style accumulator piston was screwed back into the piston and the piston and cylinder in the main casting were thoroughly lubricated and a little extra oil poured into the accumulator cylinder. The threaded rod was then used to position and press the piston back into the main casting. Care was taken to not damage the rings in this process. The threaded rod was removed after the accumulator was in position. If the later style accumulator were used, the piston would be carefully inserted into the housing from the top end (the book says don't insert through the bottom with the conical recess because the rings may scrape the aluminum when entering the the housing). The removal tool would then be attached to the housing and used to insert the housing with piston.

Installing Accumulator Spring(s) & Cover: The two accumulator springs were inserted into the accumulator piston. (If the accumulator was the later type, it would have been one spring and the spring tube.) Both sides of the cover plate gasket were coated with sealer, the gasket was positioned between the cover plate and the main casting and then the sealing O ring was placed on the operating valve shaft. The cover plate was then drawn down using the two long bolts, alternating tightening each a few turns to keep the cover square as it compressed the spring. When the cover plate started to slide over the two studs, it was tapped it in the area of the studs to make sure it wasn't hanging up on the studs. After the two bolts were tight, the dust shield and lock washers were slipped on the studs followed by the nuts. Mounting the actuating lever and solenoid was deferred until after the unit was tested.

Installing the Pump Non-Return Valve: The pump non-return valve is identical the the operating valve installed earlier except there is no long spindle. The parts were lubricated and then the ball, plunger and spring were dropped into the hole. The plug with copper washer was then screwed in and tightened.

Mating the two castings: The sliding clutch was positioned over the sun gear shaft on the rear casting that was still mounted to the OD stand. A small amount of sealer was spread on the surface of the brake ring that mates with the rear casting and the ring was driven home with a hammer and punch (left photo below). A small amount of sealer was then spread on the surface of the brake ring that mates with the main casting. The dummy mainshaft was still in place and the thrust washer and adjustment washer in front of the sun gear were still in position. The main casting was then positioned on the rear casting/brake ring with the four threaded end thrust ring rods going though the holes in the main casting. The main casting was tapped into position (wood block & hammer) and drawn tight with six nuts and lock washers on the studs. The center photo below shows the two castings in position. Some sealer may ooze out after everything is tightened. The Hylomar sealer stays sticky for weeks and makes a big mess. The excess was removed using a paper towel dampened with mineral spirits. The last thing was to position the two bridge pieces on the thrust ring rods and secured them with nyloc nuts (right photo).



Preliminary Test: Prior to installing the OD on the gearbox a test was run using compressed air to make sure the valves and pistons were working. An adaptor with 1/4 pipe threads on one end and a plug for the operating valve on the other (top photo) was made . This adaptor was used first for injecting air into the hydraulic system and later for a gauge to measure the hydraulic pressure. The adaptor was made such that the operating valve spring, plunger & ball were positioned properly and the valve operated with the adaptor in place. A damaged operating valve plug and a 1/8 inch pipe tap were available to do the job. The first plan was to drill and tap the plug for a 1/8 inch pipe nipple. Unfortunately, the 1/8 inch pipe thread was nearly 0.4 inches in diameter and the plug head was a 7/16 inch hex --- insufficient clearance. Instead, the plug was drilled and tapped 1/4-28. Next, an adapter from 1/4-28 to 1/8 inch pipe threads was made from a 1/2 inch bolt. The length of the 1/4 inch part threaded into the operating valve plug was such that depth of the recess in the plug for the valve spring was unchanged. A 3/32 hole was drilled through the adaptor for fluid flow. A 1/8 inch nipple and a 1/4 inch to 1/8 inch reducer completed the setup. The nipple was of sufficient length so when later used with the gauge, the gauge was above the gearbox top cover so that it could be installed and removed easily.

Next, the eight springs were installed over the rods on the the thrust ring as shown in the middle photo. The long springs go on the outside and the short ones on the inside. A couple holes were drilled in a plywood scrap and it was bolted it to the front of the OD to simulated the adaptor plate, compressing the 8 springs in the process (bottom photo). The air line was connected and the lever below the operating valve plug was pushed down. There was an audible clunk as the clutch shifted into OD and a slow air escaping sound when it returned to direct drive.

In direct drive, the output flange rotated easily in either direction. In OD, the 1:1.2 step up between the input and output was observed for clockwise rotation (as viewed from the front). The output couldn't be rotated in the counterclockwise rotation as expected. This is the easiest way to tell that the OD is engaged --- it wouldn't rotate counterclockwise (recall that the OD must not be engaged in reverse).

For this system, something around 100 psi was required to operate the clutch. If the clutch hadn't operated with the available air pressure, the nuts holding the plywood board would have been loosened to reduce the spring force to see if it would switch then.

If there had been a hissing sound from air escaping inside the unit the unit would have then been examined for the source of leaks, starting with the operating valve and non-return valves as discussed in Part V.

A Type Overdrive, Part IV
Final Assembly & Testing

Part III ended with a nearly assembled OD. We pick up here with attaching the OD to the gearbox and finishing the OD assembly. The OD was then tested and several problems were uncovered and solved.

Installing the OD Adaptor: The OD adaptor was bolted to the back of the gearbox using the same holes as the rear extension for a non OD gearbox. A gasket (same gasket as non OD gearbox) with sealer was placed between the adaptor and the gearbox. A second check was made on the surfaces that mate with the OD using a straight edge to make sure all were flat. The bottom received special attention since a bowed or bent adaptor plate in this area will leak. The plate was then secured with 6 bolts. The earlier gearboxes like this one use safety wire on these bolts while the later versions use lock washers. The pump cam was then slid onto the mainshaft with the cam part to the rear as shown in the left photo below.

OD to Adapter Gasket & Leaks: The joint between the OD and the OD adaptor plate seems to be the most prevalent location for leaks. In many cases, this joint leaks but the oil flows back and drops off the large drain plug leading folks to think the leak is around the plug. I've seen reports of people going to great lengths to fix nonexistent leaks around the plug. (Sometimes the plug really does leak, as discussed later.) The adaptor plate leak is typically along the bottom where there is a fairly large distance between studs. A very slight bow in the adaptor plate in this area is usually responsible for the leak. Ronnie Babbitt used epoxy successfully to fill the low spot on his adaptor plate. Others have noted that there are two types of gaskets available, one very thin and another about 1/32 inch thick. There was one report on the Triumph List of an OD that leaked with the thin gasket but not with the thick gasket in conjunction with the Hylomar sealer. The Hylomar seems to penetrate the gaskets in a way I've not seen with other sealers. I've observed that a joint can be tightened a few days after a gasket with sealer has been installed and both sealer and gasket material squeeze out of the joint. If the surfaces don't mate perfectly, this action may result in a better seal. **Caution: The studs go into aluminum and use fine treads; over tightening the studs can strip the threads in the casting.**

Getting Ready to Mate: The gearbox was engaged in 4th gear, the mainshaft rotated till the pump cam was positioned with minimum height at the bottom and the mainshaft was positioned with a spline pointed up; this position was then marked on the rearmost gear in the gearbox (Whiteout on the tooth at center top). Next, gasket sealer was applied to both sides of an OD to adaptor gasket and the gasket placed on the OD. The pump piston was then pushed down and a piece of 20 gauge wire used to hold it depressed. The wire was run in front of the little wheel at the top of the pump and then around the drain plug. This allowed the pump to slide past the low point on the cam when the OD was mated to the gearbox. The eight springs were then slipped over the thrust ring pins. The four shorter springs go on the pins closest to the center. Our springs seemed to have a continuum of lengths from about 3.8 to 4 inches. According to The Service Instruction Manual, the springs should have free lengths of 4 1/4 (short) and 4 1/2 inches (long). The springs seemed robust and we assumed they were a bit compressed due to old age. I selected the longest and put them on the outside. (This came back to bite later).

The dummy mainshaft was then rotated so that the spline was at the top and this position marked by putting a dab of Whiteout on the rear flange opposite the parting line at the top of the rear casting. The dummy main shaft was removed and a small amount of oil was poured into the main shaft hole.

Mating OD to Gearbox: The OD was slid over the gearbox mainshaft and the back end was shored up with blocks as shown in the left photo below. The OD was then pushed toward the gearbox (or as the manuals say, offered up) while rotating the mainshaft back & forth till the splines on the mainshaft mated with the planet carrier and then the unidirectional clutch. Lock washers and nuts were put on the two long studs and used to draw the OD to the gearbox. The nuts were tightened alternately a couple turns each while rotating the mainshaft back & forth. When the mainshaft became hard to turn, both nuts were loosened until the shaft turned freely and then the back of the OD was wiggled --- the other studs seem to bind entering the adaptor plate and wiggling the OD freed them. A very minimum torque was used on these nuts. If the nuts are hard to turn, they should be backed off because something is hung up. Once the OD was closed within an inch or so, a screwdriver was used to push the springs forward and over the nipples on the adaptor plate (center photo below). The OD was then drawn further toward the gearbox until enough of the short studs were protruding so that lock washers and nuts can be screwed on. The top nuts must be screwed on before the OD is against the adaptor plate, there will be insufficient gap at that time to slip the nut over the end of the stud --- see right photo below. The wire holding the pump down was clipped and removed when there was about a 0.1 inch gap between the OD and the adaptor plate. The OD was then pulled to the gearbox by tightening the nuts on the two long studs. Once the OD was against the adaptor plate, the other four nuts were tightened. (Tightening the lower two nuts before the the OD is against the gearbox is one way to bend the adaptor plate.)



Filling with Oil & Installing Top Cover: I use GL4 gear oil in all my gearboxes and ODs -- see separate note on gearbox lubricants. The drain plugs were checked to make sure they were in place and tight and then 1.75 quarts of oil was added --- poured in the gearbox top over the gears. The gearbox was then tilted back so some oil flowed into the OD unit. The oil should be level with the bottom of the side fill hole on the later gearboxes. The correct fluid level can be checked with the dip stick on the early gearboxes.

Gasket sealer was applied to one side of the top cover gasket and it was then positioned, sealer down, on the top of the gearbox. The cover was then installed, being careful to make sure the shifting forks engaged the shifters properly and then secured with the eight bolts and lock washers. The two longest bolts go in the rear two holes on the cover.

The Test Motor: Ronnie Babbitt had been having trouble with the OD leaking in his TR3. After taking it out several times he decided to motorize a test stand so that he could exercise the thing for an extended period to check for leaks. His setup is in the left photo below. He also made an adaptor to secure a pressure gauge. He found his pressure was a little low; we'll talk about that in the next section. The test setup allowed him to find his leak (bent adaptor plate), which he subsequently repaired. I was very envious of Ronnie's setup and decided to copy it..

Ronnie had used a spare 1.5 HP 1800 (1740) RPM motor. To attach as shown the motor must turn counterclockwise (the gearbox input turns clockwise as viewed facing the front of the gearbox). He said the motor loafed and stayed cool so a smaller motor would be sufficient. My calculations in Part I suggest a 1/2 HP motor would work with plenty of margin. The late TR6 OD specs call for testing at 25 mph (1200 RPM). With these data I went looking for motors. The cheapest I could find locally was about $125. I then checked Harbor Freight and found prices starting at under $60. I ended up getting a 1.5 HP 115/230 volt reversible 3600 (3500) RPM motor for $85; figured I could use it for something else later. This motor has good starting torque and is rated for air compressor duty. (The 2 HP version for $5 more would have been purchased if it had been in stock.)

My setup is shown in the center photo below., An inexpensive 5 inch die cast pulley mated well with the OD output flange. I tried to get a1 3/4 inch pulley for the motor but the smallest size the local stores had was 2 inch. I had a bunch of belts from some previous long forgotten project that were just the right length but too narrow for the pulleys. Used them anyway, worked fine and reduction was 2.7:1 so had ~ 1300 RPM. The board holding the motor is hinged were it attaches to the stand. This was intended to be sort of a clutch ---- lift the motor and let the belt slip to start. Turned out that is was not required since the motor had lots of starting torque, the load was light and the wrong width belt slipped a bit when starting. The motor can be removed when not in use by slipping out the hinge pins.

Ronnie had found a 0 to 800 psi gauge locally (in central Georgia) for less than $10. After a few telephone calls I found that our welding supply store stocked a similar gauge for ~$9. The gauge input is a 1/4 inch male pipe thread. (I understood that a liquid filled gauge would be better because it wouldn't vibrate as much; I planned to try to find one later.) The gauge screwed into the adaptor discussed earlier for injecting compressed air. **Caution, operate and release the operating valve using the lever or solenoid a half dozen times to relieve the pressure before removing the operating valve plug.**

The Test Spin: The test spin went fine --- started with the gearbox in neutral and no funny noises. I let it run for a few minutes --- everything stayed cool. No leaks! --- bet it was waiting for the first full moon. The pressure read about 250 psi and no bouncing like Ronnie said he had. Maybe air in system. Operated and released the the lever below the gauge. Could easily hear the OD engage and release (this setup was very quiet). The pressure dropped ~30 psi when the OD engaged but came back practically instantly.

When the motor was shut off the pressure fell to ~200 psi and then held. the operating valve was turned on and off pressure dropped maybe 30 psi each time till it got to less than 100 psi and then faded to zero. As the valve was turned on and off air could be heard escaping --- probably air that was trapped in the passages.

Fired it up again and this time the needle bounced back & forth with a total swing of maybe 30 psi. Must have lost the air cushion. Ronnie reported a larger swing on his needle. He had a later OD unit with a smaller accumulator piston that may experience a greater pressure change per pump stroke (pump volume should be the same). This time after the valve was operated and released a few times there was no longer the clunk of the OD engaging and the pressured didn't drop. The motor was shut off and the valve operated and released --- no change in pressure. Suspected the little hole in the operating valve spindle was plugged and OD was held engaged. To confirm this I tried to turn the output flange counterclockwise --- wouldn't turn ---- the OD was engaged.

Time to go get a snack while the pressure bled off. Came back a little later ---- no change in pressure. I then loosened the adaptor with gauge carefully. The plan was to loosen it enough so that it would leak and bleed off the pressure that way. It worked and not too much oil escaped, there was still a lot of air mixed in --- the oil was frothy. (The oil was observed to be nearly free of air after more operation indicating that most the air worked out of the fluid). The plug, spring & plunger were then removed. The ball was easily picked out with a magnetic pickup tool. The end of a length of ~19 gauge soft steel wire was bent slightly and then pushed into the end of the valve spindle then pulled up --- the spindle come out easily (photo on right). The top of the spindle was cleaned and blown into --- no air passage. --- it was plugged. A suitable drill bit was slid down the inside of the spindle and turned a few times then removed and wiped on a clean paper towel. Didn't see anything in the fluid but it had a lot of air mixed in it and not sure if I would have been able to see anything anyway. This time when the top was blown into, the passage was clear. (This left an after taste nearly as bad as beets.) The spindle was then cleaned thoroughly and reinstalled: everything worked fine then.

So, where did the dirt come from? It was probably in some of the internal passages in the main casting. Recall that this OD had a major internal failure and it is quite possible part of the debris got in the passages during the cleaning process. It appeared that little made it pass the screen, so if it was exercised a bit, hopefully anything else will work itself through the system, and no problems will be encountered in the future.

Another test run and everything worked fine except:

1. once in a while the pressure dropped about 50 psi for a short period and,
2. the pressure was too low, ~310 psi, and it should be over 450 psi (I found out later that the target should be 350 to 370 psi, not 450 psi ---- read on).

Fixing the Pressure: Ronnie Babbitt had trouble with low pressure --- about 360 psi. He called an expert and was told to put a 1/16 inch washer behind the accumulator spring, it would raise the pressure 50 psi. (As mentioned previously, there was a washer behind the spring in my late model A type OD.) Ronnie tried it and it worked --- pressure increased ~ 50 psi. He also had access to a calibration lab and found his gauge read about 50 psi low, so the washer got him to about 460 psi ---- great.

One worry I had was whether the pressure was limited by the pressure relief or whether the pump output was just matching the leakage. So, went to the store and got eight 1.5 inch fender washers (1/4 inch hole - 1/16 inch thick), now called packing washers. Also got a 4 inch pulley to speed up the OD. First, tried the bigger pulley on the motor. No significant change in the pressure but the gauge needle really fluctuated --- maybe plus and minus 50 psi. The speed was about 2600 rpm, it vibrated a lot (that pulley fastened to the flange was slightly off center). Found that speed was not the problem so went back to slower speed.

The pressure continued to be irregular, dropping significantly for short periods. That sounded like a valve problem. Both the operating and non-return valves were pulled and the balls and seats inspected again. The seats looked good but one of the balls had some very fine scratch marks. Don't know which valve it came from since the parts had been mixed. Went to the bearing store for replacements; had to buy a box of 65 balls for \$6. When the operating valve was installed, the lever on the outside was turned too far and the valve spindle dropped to the bottom of the case. Used that bent wire to retrieve it and pull it up. The new balls cured the sudden change in pressure --- hard to believe. Next time I'll replace the balls to begin with since I have 63 spares.

Another concern was whether the gauge was correct. I don't have a way to calibrate it but did connect it to the airline and compared to two other gauges on the line ---the gauge read about 20 psi higher than the other two gauges at 120 psi and was at about 20 psi when no pressure was applied. The gauges had been compared earlier and they had read the same at that time.

The pressure was at about 310 psi and needed to get to be 450psi, so needed an increase of 140psi. Decided to try two washers behind the spring. Turned the gearbox on the front to let oil drain out of the OD (this is a test that needed to be run anyway to see if front seal leaked -- it didn't - yet). The cover plate was removed (nuts on studs first, then the bolts beside the spring, slackened together). **Caution, operate and release the operating valve using the lever or solenoid a half dozen times to relieve the pressure before removing the cover plate.** Then put in two washers (photo on right), put it back together and fired it up. Pressure went to about 360 --- about 25 psi increase per washer. The washers were 1/16 inch thick just like the one Ronnie used, but this is a different type accumulator and spring.

Next tried 6 washers and got a pressure of above 550 psi, an increase of over 240 psi, or a little over 40 psi per washer.

Next, removed one washer, leaving five. Tried it again. It started with no pressure and took a few minutes before any pressure build up. Probably no oil in the OD. This time pressure went to over 550 psi again, then fell back and went back & forth a couple times then headed to over 600 psi. What was going on? Maybe a valve sealed better, maybe there was some air someplace --- a mystery! Getting about 50 psi increase per washer with five washers.

Tried again with four washers, pressure was a little over 400 psi.

Tried again with three washers, pressure about 390 psi. Something happens with more than four washers ------ finally figured it out ---- with more than four washers, the spring must be fully compressed before the piston can move far enough to expose the pressure relief holes. Duh!

Measuring the Accumulator Springs: It was time to take some accumulator spring measurements:

Accumulator Spring Measurements (inches)

Description	OD	ID	Free Length	Compressed Length
Early Accumulator Outer Spring	1.48	.88	6.37	~4.9
Early Accumulator Inner Spring	.78	.48	5.46	~4.1
Late Accumulator Spring	.86	.42	6.3	~4.4

The distance from the bottom of the inside of piston to the underside of the cover plate is about 6 inches. The piston moves about 0.8 inches to get to the relief holes. That left about 5.2 inches between the bottom of the piston to the cover plate when the piston has reached the pressure relief holes. These measurements could each be off 0.1 inch, so they are only a rough indicator, not precision data. These rough data however indicates that the maximum size of spacer that can be used without cutting off the pressure relief is about 0.3 inch or about five of those packing washers, which is consistent with our experimental data that the maximum size is .25 inches or four washers.

From the chart it was noted that the spring from the later unit would fit inside the big spring (it was snug). This spring was longer and much stiffer than the original inner spring. This late spring was substituted for the inner spring and the unit reassembled with no adjustment washers. Read about 470 psi! We had a solution!

The reason I was screwing around trying to use the old spring is that the major suppliers listed these early accumulator springs as NA. Victoria British suggested one convert to the later accumulator (piston housing, piston, tube & spring) for about $180. They did stock the later spring for $25.

I preferred to not substitute an incorrect spring if a correct replacement could be found. The Triumph email list was asked for help. Fred Thomas called and suggested Moss UK (011 44 208 867 2020); he had good luck getting parts from them that are NA here. (Several other suggestions of parts sources were also received and are listed at the end of Part II.) Gave Moss UK a call --- they had it (25 pounds plus ~4 pounds shipping, about $42). It was ordered on Friday afternoon UK time; they said to expect delivery in about a week. They shipped it airmail (Royal Mail - then USPS) on Monday and it arrived Thursday. Not bad, and the shipping charges were 4 pounds or about $6. A new spring for the later accumulator was also ordered from Victoria British.

The dimensions for the new springs are listed with the originals below. The free length of the new outer spring was about 0.2 inches longer which should get the pressure up to near normal. Note that the late spring was a little different. The TRF catalog indicated that a change was made in this spring in mid '69. They list the earlier spring as NA. Both Moss (US) and Victoria British, who supplied the spring, listed only one spring that I guessed was the later spring. Substituting that late spring for the original inner spring in an early accumulator might be a good solution for low pressure, this spring had about the same OD as the original early spring so there should be no concern of it binding. The cross-sectional area of the early accumulator piston is about 2.4 times that of the late one but the early piston moves about 0.8 inches and newer about 0.5 inches. When these two effects were combined it was calculated that the late spring should give about 2/3 the maximum pressure on an early accumulator as on a late one. That would be 2/3 of 450 psi or about 300 psi increase, which would be too much of a boost. It was clear that I was going to take more pressure measurements. The dimensions of all the springs are shown in the next table.

Accumulator Spring Measurements (inches)

Description	OD	ID	Free Length	Compressed Length
Early Outer Spring (original)	1.48	.88	6.37	~4.9
Early Outer Spring (new)	1.48	.84	6.57	?
Early Inner Spring (original)	.78	.48	5.46	~4.1
Late Spring (original)	.86	.42	6.3	~4.4
Late Spring (new)	.77	.36	6.4	?

New Gauge: Unfortunately, the cheap gauge had become erratic, the no pressure reading had increased to about 40 psi; hours of 50 psi fluctuations 1300 times per minute must have been too hard on it. A liquid (glycerin) filled gauge was found at McMaster Carr via the internet. It was ordered at midnight and they sent an email the next morning saying they had shipped it UPS from Cleveland --- less than 200miles away. It arrived the following day. The gauge was what they call Grade A that is calibrated to within 1% around the middle of the scale. A 2 1/2 inch dial, 0 to 1000 psi gauge, part number 49053K79 had been selected. The cost was $21.34 plus 1.28 sales tax plus $3.15 shipping, $25.77 total. This outfit doesn't seem to pad the shipping like some of the others and will get more of my business.

The new gauge is pictured on right. Notice the liquid level. The needle was steady on this one, what a difference!

An Alternative Gauge: Some months after writing this note I noticed the following on one of the Triumph email list: *I have those gauges already made up as a tool, incorporating an original operating valve plug and a glycerin filled 600 psi gauge ready to fit on the overdrive in place of the operating valve plug. I sell them for $55.50 including shipping in the US. They are invaluable for not only testing the overdrive on a test stand but, more importantly, one can test the overdrive for proper pressure while still in the car! Most of the time the problem with a non-working overdrive is related to insufficient pressure. Bill Bolton, Bolt-On Healeys, Oregon. We sell parts for Healeys of all types.* A subsequent email pointed out: *We do not produce a catalog nor price listing as it becomes obsolete too soon and is so expensive. Simply tell your members that if they cannot find the part to email to call on 541-895-5576 or fax to 541-895-4091 and ask. It helps if they have the BMC or Moss part number.* This seems to be a very good price for gauge and adapter.

More Accumulator Pressure Measurements: With a new gauge and a stack of accumulator springs, I first tried that new outer spring with the original inner spring and found the pressure to be 360 psi. That was still a little low, but 450 psi looked reachable with a couple packing washers. I had a bunch of questions about what if "this spring" was used or "that spring combination" so I made out a list of things to test and set about the task. I got pretty efficient changing the springs ---- about three minutes by tilting the unit up part way on it's side so the oil wouldn't leak out as shown in photo on right. The dust shield and the nut on the top stud were left off. The solenoid and actuating lever were not used during these tests.

Rather than adding the packing washers immediately, the old outer spring and then that spring with the two available late OD springs used as the inner spring were measured first. Part of the reason to do this was to get good comparisons with a gauge that is easy to read and thought to be relatively precise. These are the first three measurements listed below. (The reading with the new gauge were 20 to 40 pounds lower that with the old gauge.) Note that the used late spring adds 205 psi and the new one adds 265 psi (I calculated earlier that this one would add 300 --- close). Also, the decision to not buy a late spring to be used as a replacement for the original inner spring looks good since this combinations gave 515 psi (test 3), a little high.

The new outer spring was then tried with and without the original inner spring, tests 4 & 5. That inner spring seemed to have very little effect on the pressure ---- it was worthless!. In hindsight, a new one of those should have been purchased too. The 0.9 inch plug spacer was then added to give a total 65 psi contribution from the inner spring (test 6 vs. test 4).

Next, tests 7 through 10 were made using the .060 thick 1.5 inch diameter packing washers purchased earlier. For example, 2 washers gave about 465 psi. Some other tests were made and then that pressure was checked again --- down to 450 psi. What is going on? Time for bed. Plugged it in again the next morning ----- 465 psi. Got it, the oil got warm and the pressure went down. Rats, another variable.

Later that day tests 4 through 10 were repeated very quickly when the oil was cool. The results of those tests are recorded below.

At this point the setup of test 9, the 0.9 inch plug and the 3 washers looked like the best choice. It did seem a shame to have this thing all fixed up like new and use that many washers. An attempt was made to secure a replacement inner spring. Called Moss UK, they didn't have any and none were on order. Then called Overdrive Repair Services (011 114 248 2632) to see if they had one. The guy who answered the phone asked "why do you want one of those?" I explained that I had low pressure and since I had a new outer spring, figured we should get a new inner spring to increase the pressure. He said that the inner spring has little effect on the pressure (I noticed that), it is there to to support the outer spring --- help keep it straight. I said that the pressure was only about 350 psi. He said that was what it's supposed to be, 350 to 370 psi. He then explained the 350 psi and the big accumulator provided near instant engagement that tore up the axels in the later IRS cars so easily that the design was changed to the smaller accumulator on the later units to make the OD engagement softer. That made sense since Ronnie Babbitt's data showed that the pressure drops when engaged much more in the later units, and then built up in a second or so. Further, the later J type has no accumulator and has a much softer engagement. After the call I got to thinking ----- what pressure should the later A type unit be? Called the guy back and he said about 450 psi for the later units with the smaller accumulator pistons. The smaller accumulator makes for slower engagement but the higher pressure holds it in OD harder and should allow for higher torque without slipping. The later engines were 6 cylinders that had greater power and torque so it all fits together.

After considerable thought and consultation with a fortune teller, I flipped a coin and decided to make a small plug for the inner spring to compensate for any loss of strength due to old age. I also thought it would give a little margin. This combination is test 11 in the following chart and shown in the photo after the chart.

I decided to include the data on the other tests, even though most produce a pressure much higher than required. The effects of the various number of washers may be useful in the future should it be necessary to fix a unit with a weak spring or I want to operate the unit at a high pressure. Some weeks after these tests were run I had a conversation with Brian Schlorff of Power British at the 2001 TRF Summer Party. He said he always shimmed both the early and late accumulators to give 450 psi. I asked him about the higher pressure in the early accumulator increasing the shock to the drive train due to the rapid engagement. He said he handled that by tuning the operating valve ---- see discussion of operating valve.

Accumulator Pressure Tests (1300 rpm with cool oil)

Test	Spring Configuration	Pressure (psi)
1	Early Accumulator Outer Spring (original)	250
2	Early Accumulator Outer Spring (original) + Late accumulator spring (used)	455
3	Early Accumulator Outer Spring (original) + Late accumulator spring (new)	515
4	Early Accumulator Outer Spring (new)	350
5	Early Accumulator Outer Spring (new) + Early Accumulator Inner Spring (original)	360
6	Early Accumulator Outer Spring (new) + Early Accumulator Inner Spring (original) + 0.9 inch Plug	415
7	Early Accumulator Outer Spring (new) + Early Accumulator Inner Spring (original) + 0.9 inch Plug + 1 Washer	440
8	Early Accumulator Outer Spring (new) + Early Accumulator Inner Spring (original) + 0.9 inch Plug + 2 Washers	465
9	Early Accumulator Outer Spring (new) + Early Accumulator Inner Spring (original) + 0.9 inch Plug + 3 Washers	485
10	Early Accumulator Outer Spring (new) + Early Accumulator Inner Spring (original) + 0.9 inch Plug + 4 Washers	510
11	Early Accumulator Outer Spring (new) + Early Accumulator Inner Spring (original) + 0.5 inch Plug	380

The pressure was measured again at both 1300 and 2600 rpm after the oil cooled over night. The unit was then run for about 30 minutes at which point the case was pretty warm (maybe 140 degrees F) and then the pressure again at the two speeds again as shown below.

Accumulator Pressure - Speed & Temperature Sensitivity

Early Accumulator Outer Spring (new) + Early Accumulator Inner Spring (original) + 0.5 inch Plug

	Cool	Warm
1300 RPM	380	360
2600 RPM	390	375

Earlier, using the first gauge, the shaft was turned by hand after the pressure had built up using the motor. The pressure was steady and then pulsed up 20 psi or so when the pump pushed more oil in. The new liquid filled gauge indicates the average of the steady value and the pulses. As the shaft speed increases, a slight increase in the pressure reading was expected because there would be more of the pulses ---- exactly as observed. If the pressure had increased significantly, a pump or valve problem would have been suspected.

The first though was that the temperature affected the hydraulic pressure in the same way that a hot engine has lower oil pressure; the warm engine oil is thinner and slides by the surfaces being lubricated easier. If this were the case, different results would be likely using different lubricants in the OD. These tests were conducted using 80W90 GL4 gear oil from TRF. In the engine, the pressure builds back up if the RPM is increased. With the OD, doubling the speed produced only a minor pressure change, that likely due to more of the short pump pulses. It was then concluded that the pressure change between hot and cold was due to the accumulator springs exerting less force when warm --- the pressure relief occurs at a little lower pressure.

At this point the accumulator topic had been beat to death and it was time to move on.........

New Problem: The next thing was to make a number of test observations. The first step was to verify that the OD was shifting. The motor was turned on and the pressure ran up and the shifting verified by operating and releasing the lever below the operating valve and listening to the piston move. The motor was then stopped and the valve operated to verify it was really in OD (there was still ~ 300 psi hydraulic pressure). The piston could be heard to move, but it wasn't locked in OD because the shaft could be turned counterclockwise. Checked and rechecked several times. While turning clockwise there seemed to be a little increase in output over input but not a solid consistent 20%. It was concluded that the OD wasn't engaging. Rats! Tear it apart again.

The plan had been to replace the oil anyway in an effort to remove any possible dirt that may have been in the internal passages. Once the OD was removed, the shifting was tested with compressed air --- worked great. Put it back on, leaving the cam off to make job quicker ---- failed on compressed air. Slackened the nuts so that it pushed back ~ 1/8 inch from adaptor --- worked! It was then clear that something was stopping the sliding member from going all the way forward. Pulled OD off and measured all the clearances --- seemed like there was plenty of room, no way could it interfere. Next, pulled the rear casting off and just put on the main casting and tried to shine a flashlight through from the back to see if the rods or nuts on the thrust ring were hitting anything. Couldn't tell for sure so tried again without the eight clutch release springs --- worked fine. Must be something with those springs.

After the previous bout with the springs it was decided to investigate the clutch release springs more carefully. There were clearly two different types, four had a smaller spring wire diameter. Both the free length and compressed length of all eight were measured. That old thrust ring was used to hold the spring straight in the hydraulic press to measure the compressed length. The four in each group were very similar. The average measurement for the springs in each group is in the table below. It became clear that the short springs on the center 4 rods couldn't be compressed as much as the longer four springs on the outer four rods.

Original Release Spring Measurements (inches)

Group	Free Length	Compressed Length
Smaller Wire	4.0	2.6
Bigger Wire	3.8	3.0

The longer springs (smaller wire) had the shorter compressed length and probably originally had the shorter length. The springs were put back in, this time with the springs made from the smaller wire on the inner rods. (The base for the outer rods is about 1/4 inch toward the rear than the base for the inner rods, hence the outer rods can accommodate a longer compressed length spring). While attaching the OD to the gearbox the springs seemed pretty weak. (The OD had been taken off and on so many times at this point that wing nuts were under consideration.) The OD engaged perfectly but the springs in this position were too weak, it was very slow to release from OD and finally stuck in OD. Time to order new clutch release spring!. TRF & Victoria British wanted $40 for a set and Moss (US) wanted $70. TRF was out and no idea when they would get any. Victoria British had them in stock and got the order. They arrived two days later via Priority Mail.

The new springs were carefully measured and compared with the original springs. The original springs with the thinner material were clearly the short springs that go on the inner rods. The summary data is shown in the following chart.

Clutch Release Spring Properties (all dimensions in inches)

Spring	Free length	Compressed Length	OD	ID	Wire OD	Turns
Short (new)	4.48	2.57	.51	.35	.084	31.5
Short (original)	~4.0	~2.6	.54	.37	.083	31.5
Long (new)	4.54	2.96	.53	.34	.094	31.5
Long (original)	~3.8	~3.0	.53	.34	.094	31.5

The photo above shows the original and new springs together. The ends of the new springs are painted, red on the short ones and yellow on the long ones. All the springs had about 31.5 turns. Note that the new short springs were wound in the opposite direction from the others --- doubt that the winding direction was part of the original specification. The right 3/4 inch or so of the original springs were clearly collapsed. All of them were that way and they were pretty uniform, so much so that I thought they were manufactured that way. Recall that the release bearing had failed on this unit and these springs pressed the thrust ring into the rotating clutch sliding member. The thrust ring and sliding member got very hot. It was then concluded that the ends of these springs also got very hot, hot enough to remove the temper and allow the springs to collapse. And here I was thinking the PO had substituted the wrong springs. Shame!

Before the new springs were installed the pressure required to operate the clutch using the original springs installed in the correct positions was measured; it took 80 to 85psi. This measurement was repeated using the new springs found to be 140 to 160 psi. This time the OD couldn't be pushed onto the gearbox far enough for the mainshaft splines to engage the planet carrier splines as with the original springs; the nuts on the long studs had to be used to draw it to that position. The mainshaft was rotated back and forth a few degrees each side of the center mark as the OD was drawn onto the gearbox and no difficulty was encountered and a minimal force was required on the long studs. The OD engaged without difficulty and released quickly with the new springs.

One last thought on the release spring subject ---- why did it work and then stop? At some point the nuts on the studs between the gearbox and the OD were tightened. A leak between the adaptor plate and the OD was suspected --- turned out it was oil from around the adaptor screwed into the operating valve for the gauge --- it wasn't tight enough. The Hylomar stays soft and actually penetrates the gaskets. When the nuts were tightened later, some Hylomar squeezed out and the gasket seemed to flatten and some of the gasket squeezed out too. Apparently the OD was right on the edge of engaging so tightening it must have been enough to make it fail. Lucky it was found before putting it in the car.

Valve Springs: With all the shrunken and limp springs it was decided to verify the condition of the non-return valve and operating valve springs. Both valves seemed to work great, but I wanted to avoid any future problem. A new spring was ordered with some of the other parts and the spring was also pulled from the later OD that that had been opened to remove the accumulator. The measured free lengths are shown below. It was difficult measure the free length reliably because the springs are pretty weak so there is likely some error in the measurements. I didn't know which spring went in which valve in the early OD. The spring from the later OD came from the non-return valve. It was decided to put the new spring in the non-return valve and secure another new spring and put it in the operating valve which is accessed from outside the case.

Valve spring free lengths (inches)

Early OD	Early OD	Late OD	New
.67	.73	.73	.775

Del Border, in that article on Healy ODs had a problem with low hydraulic pressure he cured by modifying the non-return valve plunger. He fabricated a new plunger with the thickness of the end increased from 0.125 inches to 0.219 inches. This preloaded the spring. He felt that this was better than getting a new spring that might in time become weaker. I have a lathe in the workshop and could turn out a new plunger in a few minutes. However, I'm very reluctant to put non standard parts in the OD. I'd much prefer to shim the plunger so that when taken apart later, it would be obvious to both me and anyone else what had been done. A shim could be machined the exact size required to met Del's 0.094 inch increase in thickness. Checking around the workshop I found that split lock washers for #6 screws have about the right ID and OD and are a little over 0.040 inches thick. A couple pair of pliers were used to bend two washers at the split so that the washers were flat. The washers are shown on the plunger in photo to right. The combined thickness of the washers and the end of the plunger is 0.215 inches. It was decided to not to shim the plunger in this unit.

Solenoid Test: The solenoid current drain was measured before installing it. The solenoid should draw 15 to 20 amperes with the plunger removed (do this for only a few seconds, the solenoid is not designed to carry this current continuously). The current drain should be about 1 ampere with the plunger in place. I used an inexpensive multimeter for this test. One of these is also a good tool to help solve Lucas mysteries. They cost $10 or less, not a precision instrument, but won't make you cry if you step on it or drive over it.

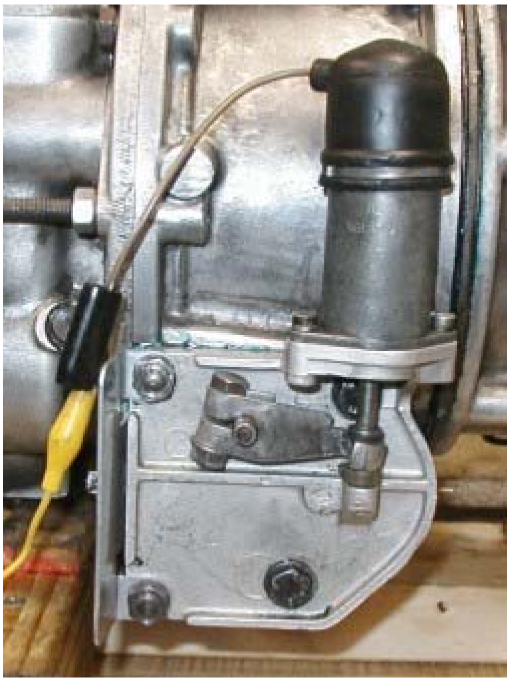
My able assistant (an Electrical Engineer) allowed herself to be photographed if I agreed to make no sexist or blonde comments. I agreed (but I lied). This young woman was a terror in a '73 TR6 at Engineering College more years ago than she's willing to admit. (She has a neat mom that I've been flirting with for years.)

The engineer set the multimeter to the 20 ampere current range and connected the negative (black) probe to the solenoid lead using the yellow clip lead. The positive (red) probe was held against positive battery terminal and the solenoid case was touched against the negative battery terminal. The first test was made with the plunger removed. We read 16 amperes on one and 17 amperes on a second solenoid. Next, she measured the current with a plunger in the solenoid. When the current was applied this time, the plunger snapped into the solenoid and the current read about one ampere, just as it should. She explained that with the plunger in the solenoid, the initial current is about 17 amperes until the plunger reaches the back of the recess and operates a switch to remove the high current pull-in coil and leave only the low current holding coil in the circuit. She must have checked out the schematic at the end of Part I.

Installing the Solenoid: Installing the solenoid was straightforward. The operating shaft collar was slipped onto the end of the shaft followed by the actuating lever (also called solenoid lever). The plunger boot was rotted away, so the plunger was pulled from the solenoid and slipped into the hook on the end of the solenoid lever. If the boot were still there, the solenoid with plunger would have been fed through the hole in the bracket and over the hook. Originally there was a thin gasket between the solenoid and the bracket. The gasket may have been to minimize corrosion between the dissimilar metals. No one seems to stock the gasket now. One was cut from thin gasket paper. The two screws were then tightened.

Adjusting the Operating Valve: The manuals talk about putting a 3/16 drill through the hole in the lever on the outside of the case below the operating valve and in a matching hole in the main casting. This is supposed to position the operating valve open the correct amount. The solenoid is then operated, the actuating lever pushed down against the bottom lip of the plunger and the pinch bolt then tightened. This may have worked when new, but not on these old worn units. In most cases I've seen, the valve is still closed in the position with the drill in the holes.

It was decided to use a dial indicator to adjust the valve as shown in the right photo below. The plug and spring were removed and a length of 5/32 inch OD - 1/8 inch ID brass tube (hobby store) was placed over the end of the plunger and the combination then placed between the ball and the dial indicator. The solenoid was not operated without something over the ball --- didn't want to be dodging steel balls --- the solenoid is a very effective ball launcher (bit of experience speaking here). While messing around the lever was turned too far and the end of operating valve spindle (the long thin shaft) dropped past the lever to the bottom of case --- used that bent wire again to retrieve it.




The lift adjustment is made as follows:

1. Loosen pinch bolt
2. Position the plunger with brass rod in the center of the ball and record the dial indicator reading.
3. Push the solenoid plunger up as far as it will go and then operate the solenoid (don't operate the solenoid with valve released --- shock is not good for the indicator).
4. Move the lever on the operating shaft (below operating valve) to the position where the dial indicator reading is different from the reading in Step 2 by the desired lift.
5. While holding the lever in this position, push the actuating lever down against the bottom of the solenoid plunger and tighten the pinch bolt (this takes three hands).
6. Release the solenoid, push the brass rod down and verify the reading is the same as Step 2.
7. Take the operated and released readings several times to verify the lift is set as desired. (Remember to lift the solenoid plunger before operating the solenoid.) If the setting is not as desired, readjust as required.

Note that this adjustment can be made in the same way with the OD installed in the car.

I couldn't find a specification for the amount the ball should be lifted when the valve is opened; a fairly small lift should give nearly instant operation. Del Border says the Healy spec is for 1/32 to 1/16 inch --- .031 to .062. That sounded a bit large. Ronnie Babbitt was told the proper setting is .015 to .017 inch. I had a long conversation with Brian Schlorff of Power British at the 2001 TRF Summer Party and he said he started with an adjustment of .010 and then tuned it in the car if necessary to get the correct feel. (Power British has a reputation for high quality work so Brian's advice should not be taken lightly.) After returning from the summer party I made measurements at several different lift settings as recorded the below.

Operating valve characteristics as a function of valve lift (on test stand)

Valve Lift (in)	Time to Shift (sec)	Pressure Drop (psi)	Time to min press (sec)
.006	Won't Shift	-	
.008	~2.5	No Change	
.010	~1	~30	~2
.013	<1/2	~35	~1/2
.016	<1/4	~40	<1/2
>.016	<1/4	~40	<1/4

The above measurements were taken after the OD was run enough to become hot. The OD didn't shift at all when the lift was set at .006 inches. There must be enough flex in the mechanical linkage so that the valve couldn't open against the hydraulic pressure when the no pressure lift is .006 inches. At a lift of .008 inches, the unit shifted in 2.5 seconds and the pressure held constant. The shift was detected by the change in the pitch of the gearbox noise. When the lift was increased to .010 inches, it shifted in about 1 second and the pressure dropped gradually to a 30 psi reduction after about 2 seconds and then recovered as the pump supplied fluid. Note that the pressure continued to drop after the unit shifted. It is my guess that the radial play in the clutch sliding member allows it to drag on the brake ring before it is seated. There may also be some air in the system that causes the pressure to build after the sliding member has seated. Both of these would cause the unit to shift early under no load but to slip under load until the pressure builds in the operating pistons.

As the lift was increased further, the unit shifted faster and reached minimum pressure faster. For lifts of 016 inches or greater, the unit shifted and reached minimum pressure in less than 1/4 second -- essentially instantly. For these larger lifts, the OD probably has a very firm shift that sends a shock through the drive train.

A second measurement was taken with a lift of .010 inch after the OD had cooled. The results were nearly identical to the results for a .008 inch lift on the hot OD.

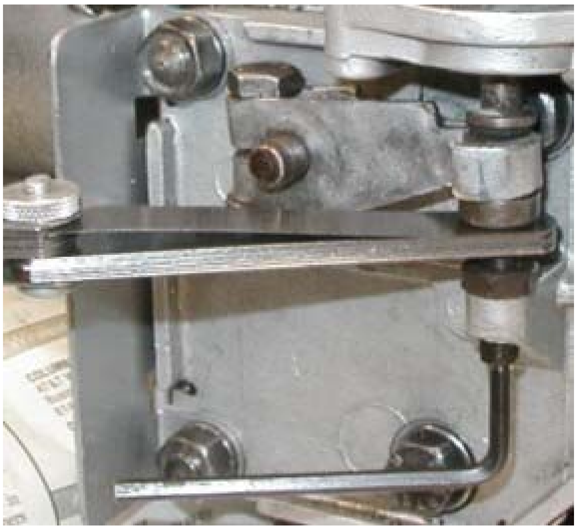
So -- what is the correct lift setting? I don't believe that the designers intended that the operating valve lift adjustment be used to control the firmness of the clutch engagement. This is in part supported by the fact that subsequent changes were made to the accumulator design to soften the engagement. If the designers had intended to control the engagement by the valve, it would have been a simple matter to control the flow by altering the clearance between the diameter of the upper portion of the operating valve spindle and the diameter of the cylinder it slides in. This is probably what limits the speed of fluid flow for a valve lift equal to or greater than .016 inches. I believe that the factory adjustment was large enough to make sure that the operation would be independent of temperature, oil viscosity and reasonable change in pressure and wear. That suggests that a lift adjustment of .016 inches or slightly more is what the factory originally did.

If one wants to use a smaller lift to create a softer engagement, go to it. It will probably reduce the wear and tear on the entire drive train. This is especially important if one increases the pressure on the early large piston accumulators. The only drawbacks I can see is that periodic readjustment may be required and the engagement speed may change as the gearbox heats up.

I think I'll use the .016 lift and rely on the spindle dimensions to limit the fluid flow.

After fooling with this adjustment, I took a test drive in my TR250 that has the later style accumulator and is set for a fairly large operating valve lift. The switch in and out of OD was about the same, about a half second each way and it didn't seem too hard. I then tested my '76 TR6 with J type OD. The first thing I noticed was that it shifted out of OD much quicker, in like a quarter second. The shift into OD took nearly two seconds at 30 mph and about one second at 60 mph. The firmness of the shift, once it happened, seemed about the same as the TR250. If accelerating, you get a jerk with both when they switch in. The switch from OD to direct drive actually seemed a little harsher in the J Type, especially if accelerating. I've never driven a car with the early large piston accumulator so I can't compare. I'll add something here as soon as this one is in and running.

Actuating Lever Stop: I noticed that there was no adjustment screw in the stop below the solenoid plunger like on the later A type ODs on my TR250 and TR6. The hole in the stop was not threaded either. One of the catalogues indicated that a rubber stop (NA) was used on the early models. The plunger was pushed down as far as it would go and then the solenoid was powered ---- it wouldn't operate. This must not be allowed to happen The OD will fail to engage and worse, the high operating current will quickly burn up the solenoid winding (~$100). The hole was drilled and tapped 1/4-28 to match the later models and the 3/4 long set screw and jam nut from a later unit was installed since the hardware store wasn't open at that time of the night. The Haynes TR250-TR6 manual says the gap between the top of the screw and the bottom of the operated plunger should be 0.150 - 0.155 inch, see photo on right. The solenoid then operated reliability. Note that too small a gap may cause the OD to not disengage when the solenoid releases. Fred Thomas said an insufficient gap caused him to remove the interior of his TR3 eight times this past spring. Fortunately, his OD was not damaged.



The Haynes manual also specifies an end float on the operating shaft of approximately .008 inch. The end float was checked with the dial indicator and found to be within the approximate .008 inch specification that was interrupted rather broadly.

More Test Observations: The test observations were started again, this time with new release and accumulator springs. Unless otherwise noted, the motor was turning the output shaft at about 1300 RPM and the new pressure gauge was in place.

These tests could also be run with the OD in the car. If I were doing that, I would unbolt the the drive shaft at the back of the gearbox rather than running the car for an extended period with the back blocked up and the wheels powered. It would probably takes me less time to disconnect the drive shaft then to block it up anyway.

When starting from zero pressure, the pressure built to about 180 psi very quickly, in a second or so and then built linearly (as best I could tell) to maximum pressure in about 10 seconds. This suggested that the accumulator springs exerted a force corresponding to about 180 psi when the accumulator was empty (accumulator piston all the way in). This also suggested that the total change in pressure caused by the accumulator piston moving was from 180 psi to ~ 380 psi, about 200 psi.

When the solenoid was operated, the pressure dropped about 40 psi and then recovered in a little over 2 seconds. The 40 psi change was about 1/5 of the pressure change for the full accumulator piston movement suggesting that the fluid required to operate the clutch was 1/5 the capacity of the accumulator. In Part I, I calculated that it would take about 1/6 the accumulator capacity to operate the clutch. This difference is a reasonable margin of error of my ballpark estimate and rough measurement of transient pressures.

When the power was shut off, the pressure dropped quickly at first then at a slower rate, reaching 300 psi in 10 seconds and then 200 psi after 10 minutes. The pressure was 180 psi 12 hours later.

The gearbox and OD was then scrubbed thoroughly and fresh newspaper was placed under it and it was run for four one-hour stretches with a 10 to 12 hour break in between to let it cool. This heating/cooling was an attempt to detect any possible leaks. The tests were run with the gearbox in 2nd gear most the time to stir up things a bit in the front. There were no drips and no oil on the outside of the case; it shouldn't leak for at least a month.

While running these tests some of the previous pressure measurements were taken again. Differences of 3% to 4% were noted in some cases probably due to temperature effects and errors in reading the gauge. The gauge is marked every 20 pounds, which is 4% at 500 psi. I tried to record pressure readings in 5 psi increments but in reality that is probably beyond my capability; in hindsight I'd been better off to record the pressure readings in 10 psi increments. Excepting those slight pressure differences, there were no other changes in the observed operation.

J Type OD: The J type OD from my '76TR6 was put in the test stand to find a small leak. Before firing it up, a small leak from the countershaft cover plate in the front was noted, but it hadn't yet made it to the drain hole; the cover plate was bowed so it was reversed. The rear seal was replaced (again) because there was a one drop drip on the bottom. The motor was then run for an hour. There was a stream of oil from one of the studs near the top that hold the front and rear casting on each side of the brake ring. There is a copper washer then lock washer and then nut on the stud. The lock washer had distorted the copper washer,. The fix was to replace the copper washers on the two top studs and then add a flat washer between copper washer and lock washer. Joint sealer was also used around the stud.

While the unit was on the bench the hydraulic pressure was measured. The gauge was attached to a hole just to the front of the solenoid. The plug for the hole is setting beside the hose in the photo. The hole threads are 3/8-16. An old rear brake hose from a TR6 was used to connect the gauge. One end was threaded 3/8-24. A 3/8-16 die was run right over the old threads -- worked great. The other end had an inch of so length of 1/2 inch cylinder and then the smaller part threaded 3/8-24. The threaded part was cut off and the larger section was then turned down to 3/8 inch and threaded 1/8 inch pipe threads which then screwed into the reducer on the end of the gauge. (While doing this it was observed that the 1/8 inch pipe thread is nearly identical to the 3/8-24 piece cut off, except the pipe thread is slightly tapered. In hindsight, the 3/8-24 will probably mate with the 1/8 inch pipe thread in the reducer if a couple layers of Teflon joint tape are used.) The pressure was 450 psi at 1300 rpm and 460 psi at 2600 rpm. (The solenoid must be operated to record any pressure; this system has no accumulator.) The specs call for 460 psi to 490 psi. The pressure relief spring was probably a little weak due to age, but this was close enough.

Temperature Measurements: It was also observed that the J OD got very hot so a comparison temperature test with the early A type was conducted. Both units were run in high gear at 2600 RPM output (~54 mph) with OD engaged. Near the end of the run the front was elevated for two minutes at a 12 degree angle, then the same to the back and then let run level for a few minutes. This was to mix the oil from the front and back in an attempt to equalize the temperature of the oil. The temperature of the oil in the gearbox was then measured and recorded in chart below. The J type solenoid also seemed hotter than the A type so the power for each was computed and included in chart below.

The fact that the temperature in both gearboxes reached the same final temperature is a coincidence. The ambient temperature was a few degrees warmer when the A Type was tested because the widow was open to disperse fumes from curing a powder coated exhaust manifold. There were probably a half dozen other parameters that affected the results so all that can be said is that the temperature rise is similar, a little over 1 degree F per mph. There are all kinds of other effects when the gearbox is in an auto carrying a load. For example, the surrounding temperature is much higher because of engine & exhaust heat. There is much better ventilation when one is going down the road at 80 mph, the bearing load is higher when transferring power through the gearbox/OD, etc.

OD temperature & solenoid power after one hour operation at

2600 RPM output in high gear with OD engaged

Type	Oil Temperature	Solenoid Power
A Type	138 degrees F	12 watts
J Type	138 degrees F	21 watts

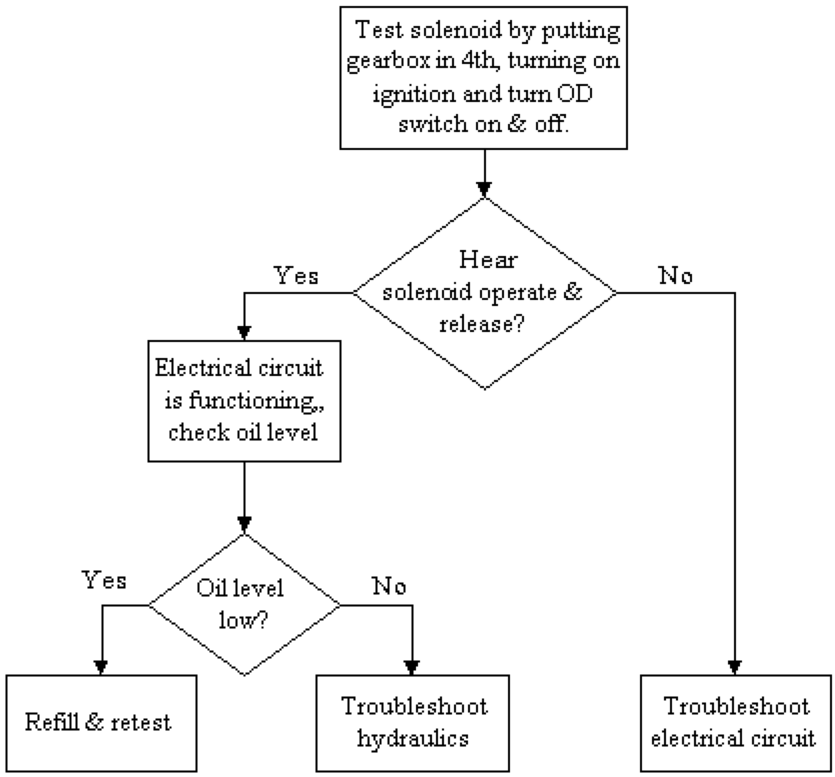
After this last test the A type OD was pronounced healthy and ready to be installed. The TR3 in which it goes is months away from as test drive. I'll update this with road test results when that data is available.

A Type Overdrive, Part V Troubleshooting Tips

The following is the procedure I use to diagnose and fix OD problems. A problem in this context is that the OD is not shifting properly, or slips in OD. If the gearbox is making noises that sounds like bearings grinding and teeth breaking, or general whining, I pull the gearbox and open it and, if necessary, the OD to assess the damage.

Preliminary test: The flowchart below shows the first steps to isolate a problem. The solenoid is tested first because it's easy. The gearbox is shifted to 4th, the ignition turned on and the OD switch turned on and off. There should be an audible clunk when the solenoid operates and a clack when it releases. This clunk-clack is not to be confused with the sometimes audible click of the OD relay operating. The solenoid makes a resounding clunk-clack. Turn the OD switch on and off several times just to make sure it's operating and releasing. If it's not clear that the solenoid is operating, raise the left side of the car and slide under and see if the solenoid is operated. If it is operated, the plunger is in (up) as far as it will go --- it can't be pushed in any further. If it is operated, turn the switch off and to make sure it releases. **If it doesn't release, I don't attempt to drive the car in reverse!** If I found a problem with the solenoid I move on to the electrical trouble shooting section

If the solenoid is operating and releasing the fluid level is then checked. If the fluid is low, it is filled as necessary and the operation of the OD is retested. If the solenoid operates and releases and the oil level is correct, I move on to the hydraulic troubleshooting section.



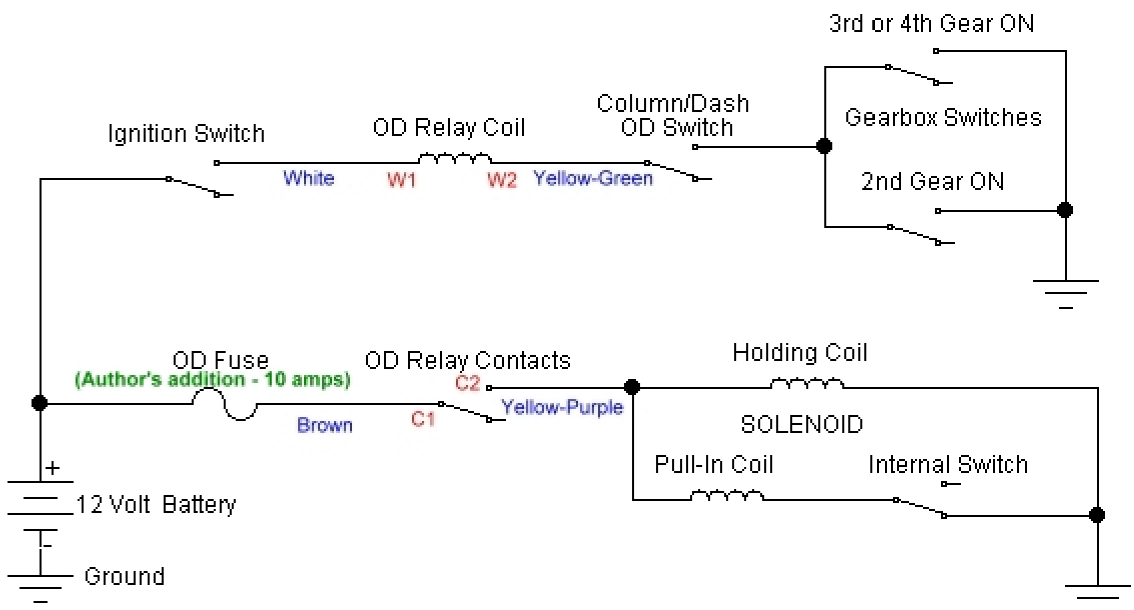
Electrical Troubleshooting

Before going further, it should be noted that one doesn't get shocked from the 12 volt auto circuitry. One can get shocked from the high voltage wires on the sparkplugs, coil and distributor, but only if the engine is running.

Most of us have experienced this, and while it is unpleasant, it usually doesn't hurt unless we bump into something when we jump back. The main hazard is that one of the unfused 12 volt wires gets grounded causing the wiring to overheat and the insulation to melt. This easy to avoid --- don't connect ground to any wire carrying 12 volts.

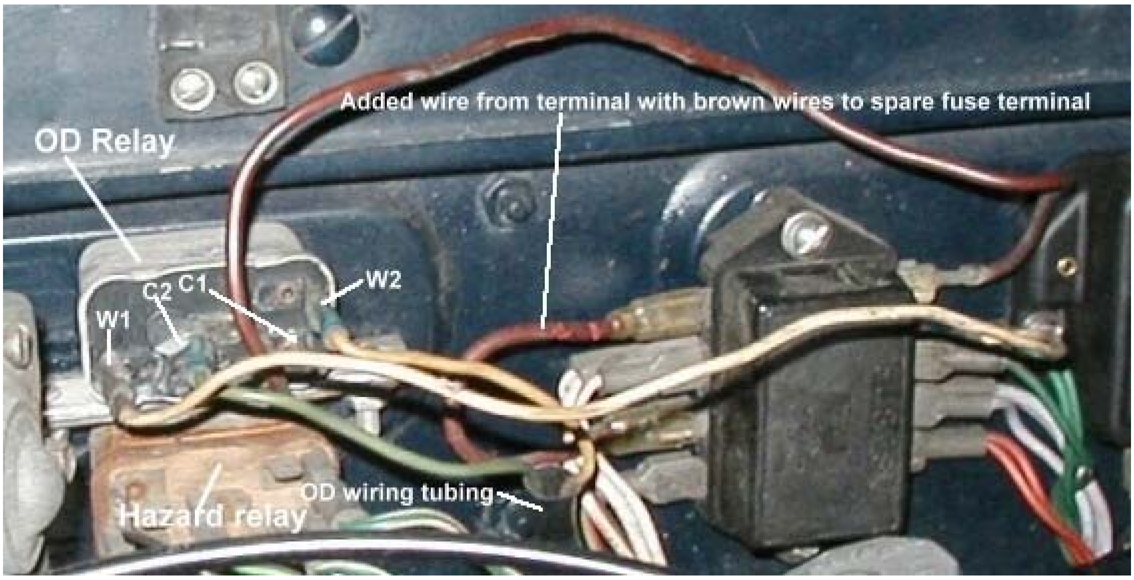
Another problem is that while troubleshooting one problem, problems in other areas are created. This doesn't happen if only one wire or one terminal at a time is disturbed and then reconnected before moving on to another wire or terminal. Sometimes failure to follow this procedure leads to problems that show up later as another *Lucas mystery*.

Schematic: The TR6 and TR250 wiring is used as the example because I'm familiar with the specific components and their location. The approach should also be applicable to other models but the relay is in a different location. The schematic below is the same as shown in Part I but augmented with the typical wire colors (in blue) and the relay terminals (in red) for the TR250 & TR6. The wire colors are what one would expect to find on factory wiring, but the colors on my TR250 are different; maybe the supplemental harness is non standard. The relay terminals are labeled the normal way that they are connected but the wires on the W1 and W2 terminals may be reversed and the circuit will still operate properly (the W stands for winding, another term for coil). The wiring on on terminals C1 and C2 can also be reversed and the circuit will still work (the C stands for contact). The circuit will not operate properly if wires are reversed between the W and C terminals.



The OD Relay: The OD relay and associated wiring for my TR250 is shown in photo below. The terminals for the relay are marked and as indicated on the photo. I always check each relay to make sure the terminals are as indicated. In some cases the position of the OD relay and the Hazard relay are reversed so I'm careful to identify the OD relay as the relay that the wires from the supplemental wiring harness (in this case a tube with two wires in it) attach. The schematic shows the wire from relay contact C2 to the solenoid as yellow-green; that wire in my TR250 is green. The schematic shows the wire from relay terminal W2 to the OD switch as yellow-green; that wire in my TR250 is yellow.

The brown wire from relay contact C1 to the fuse block normally connects to the terminal on the rear side of the fuse block that the other brown wires attach. The brown wires are unfused. I added the strap from the brown wire fuse block terminal to the top fuse position which was spare and connected the brown wire from OD relay terminal C1 to the other side of the spare fuse position. A 10 amp fuse is adequate for this circuit.



Multimeter: A test instrument is required to troubleshoot the OD electrical circuit and other Lucas mysteries. I prefer an inexpensive multimeter as shown in photo. Several of these were purchased for less than $5 each at the electrical market in Bangalore, India several years ago; just couldn't pass up the bargain. A package of clip leads (Radio Shack) like the yellow one in the photo are also very useful.

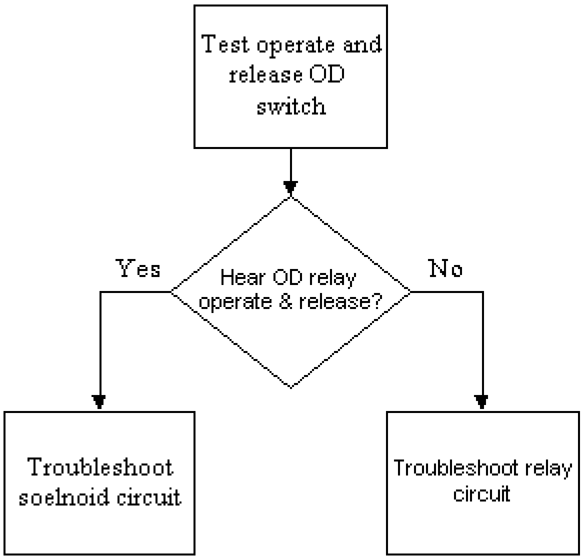
For all the tests except the solenoid current test, the meter is set to a DC voltage scale greater than 14 volts. This one had a 20 volt scale, others may have a 15 volt scale. The black lead is connected to the common or ground terminal on the meter and the red lead is connected to the red voltage-current-resistance terminal on the meter.

Test for 12 volts: To test for 12 volts at a point in a circuit, one end of a clip lead is connected to the to the black meter lead and the other end of the lead to electrical ground. For these tests, the braided cable on the negative battery terminal makes a good ground connection. The probe at the end of the red lead is held against a terminal to see if 12 volts is present. The positive battery terminal should be checked first to verify that there is a good connection to ground, the meter is turned on, and the battery is charged. The battery should read a little over 12 volts --- 12.57 volts for the battery in the photo above.

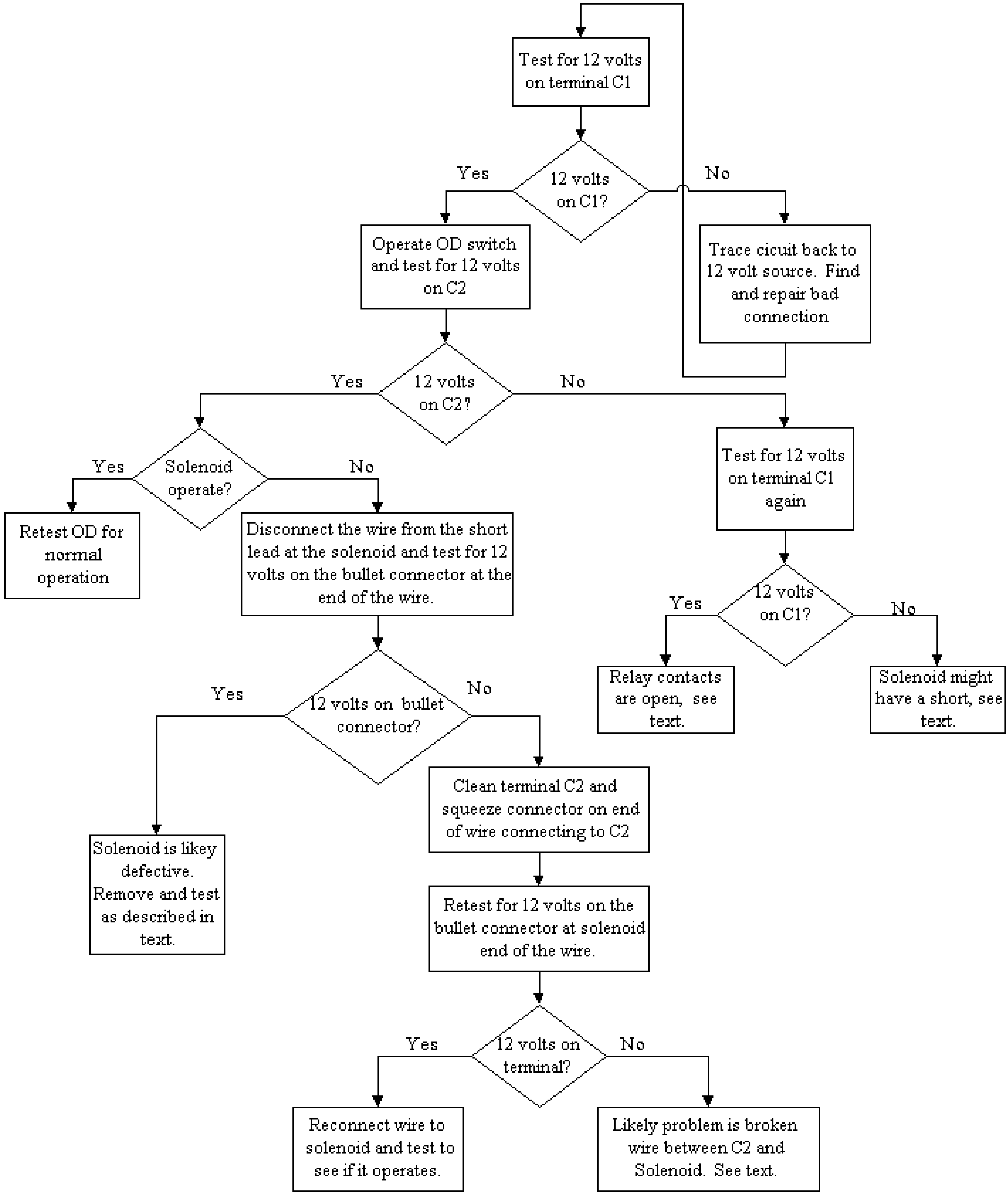
Test for Ground: The other required test is for ground. To do this, one end of the clip lead is connected to the red meter probe and the other end to a source of 12 volts such as the positive battery terminal. The end that is attached to the probe must be covered so that it isn't inadvertently grounded leading to hot wires and melted insulation on the clip lead; masking tape around the exposed metal parts at the clip lead-red probe connection works fine. The black probe is then used to test for ground. If the probe is held against a terminal that is connected to electrical ground, the meter will read about 12 volts. The negative battery terminal should be tested first to verify everything is set properly.

Lets go over that again --- two tests are used, one to test for the presence of 12 volts on a terminal and the other to test for ground on a terminal. To test for 12 volts, the black meter lead is connected to ground and the red probe touched to the terminal under test. The meter will read near 12 volts if 12 volts is present. To test for ground, the red meter lead is connected to a source of 12 volts and the black probe is touched to the terminal under test. If ground is present on the terminal the meter will read 12 volts again.

Does the OD relay operate? We got to this point because the solenoid didn't operate. The next thing to do is determine if the OD relay operates. The gearbox is put in 4th gear, the ignition turned on (don't start the engine), stand near the OD relay and listen while the OD switch is turned on and off. If the OD relay is operating and releasing one should hear a soft click from inside the relay case. Respond to the result as indicated by the flow chart.



Troubleshooting the Solenoid Circuit: At this point the multimeter is used to take a few measurements. The ignition is turned on, gearbox put in 4th and the OD switched off and then the voltage at terminal C1 is measured. This is the terminal with the brown wire that goes to the fuse block . This measurement is made with the black meter lead connected to ground and the red probe on the relay terminals. It should read 12 volts. If not, the voltage at the other end of the brown wire is measured, then continue to work back to the other side of the fuse block, etc. until 12 volts is found. Once 12 volts is found, that terminal and the next one toward the relay are cleaned and pliers are used to compress the female connector terminals on the wires so that they grasp the male terminals firmly thus making a good electrical connection. Sometimes the clips that grasp the fuse in the fuse block are corroded and must be cleaned. Oh -- forgot to mention that the fuse added to the circuit could be blown. If there is 12 volts on the rear fuse terminal and no voltage on the front terminal, replace the fuse. Continue to work on this part of the circuit until 12 volts is measured at relay terminal C1. Once there is 12 volts on C1, the OD switch is operated to see if the solenoid operates. If it does, this problem is fixed and the OD is tested again. If the solenoid doesn't operate, check for 12 volts on terminal C2 and follow the flow chart.



Broken wire to solenoid: If 12 volts is measured on OD relay terminal C2 and there is no voltage at the bullet connector on the other end of the wire to the solenoid, a broken wire is suspected. Before replacing the wire, string enough of the clip leads together to reach from the OD relay terminal C2 to the wire on the solenoid. The solenoid should operate when the relay operates. If not, verify that there is 12 volts on the wire at the solenoid end and if not, trace back over everything. If there is 12 volts at the solenoid and it doesn't operate, pull the solenoid and test it.

Testing the Solenoid: If the solenoid is suspect, it is tested as described in Part IV and repeated in modified form here. Because there is a possibility the solenoid is shorted, the first test is to connect a clip lead to the solenoid wire, put the plunger in the solenoid and then touch the end of the clip lead to the positive battery terminal and the solenoid case to the negative battery terminal. There should be a spark when the case is touched to the negative terminal. If the solenoid operates as indicated by the plunger snapping into the solenoid, then the solenoid doesn't have a short and it's safe to test with an ammeter in the circuit. If there was a big spark and the solenoid didn't pull the plunger into the case, the solenoid probably has an internal short.

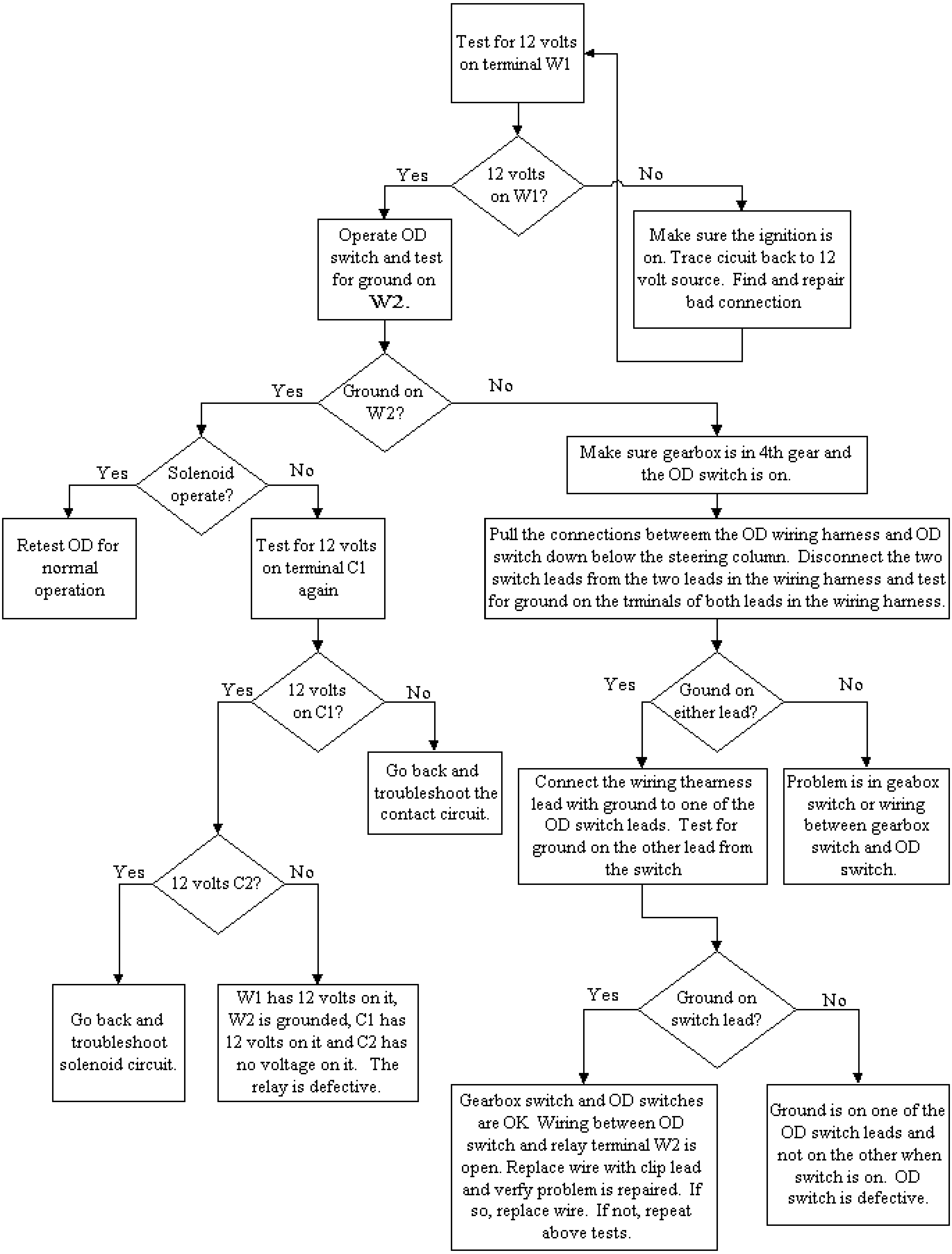
The solenoid should draw 15 to 20 amperes with the plunger removed (this is done for only a few seconds, the solenoid is not designed to carry this current continuously). The current drain should be about 1 ampere with the plunger in place. The multimeter is set to the 20 ampere current range for this test (the red lead is moved to the high current terminal). The negative (black) probe is connected to the solenoid lead using the yellow clip lead and the positive (red) probe is held against positive battery terminal and the solenoid case is touched against the negative battery terminal.

The first test is made with the plunger removed and should read 15 to 20 amperes. Next, the current is measured with a plunger in the solenoid. When the current is applied this time, the plunger should snap the solenoid and the current should read about one ampere; the initial current is 15 to 20 amperes until the plunger reaches the back of the recess and operates a switch to remove the high current pull-in coil and leave only the low current holding coil in the circuit. If the meter reads no current, the solenoid coils are likely open.

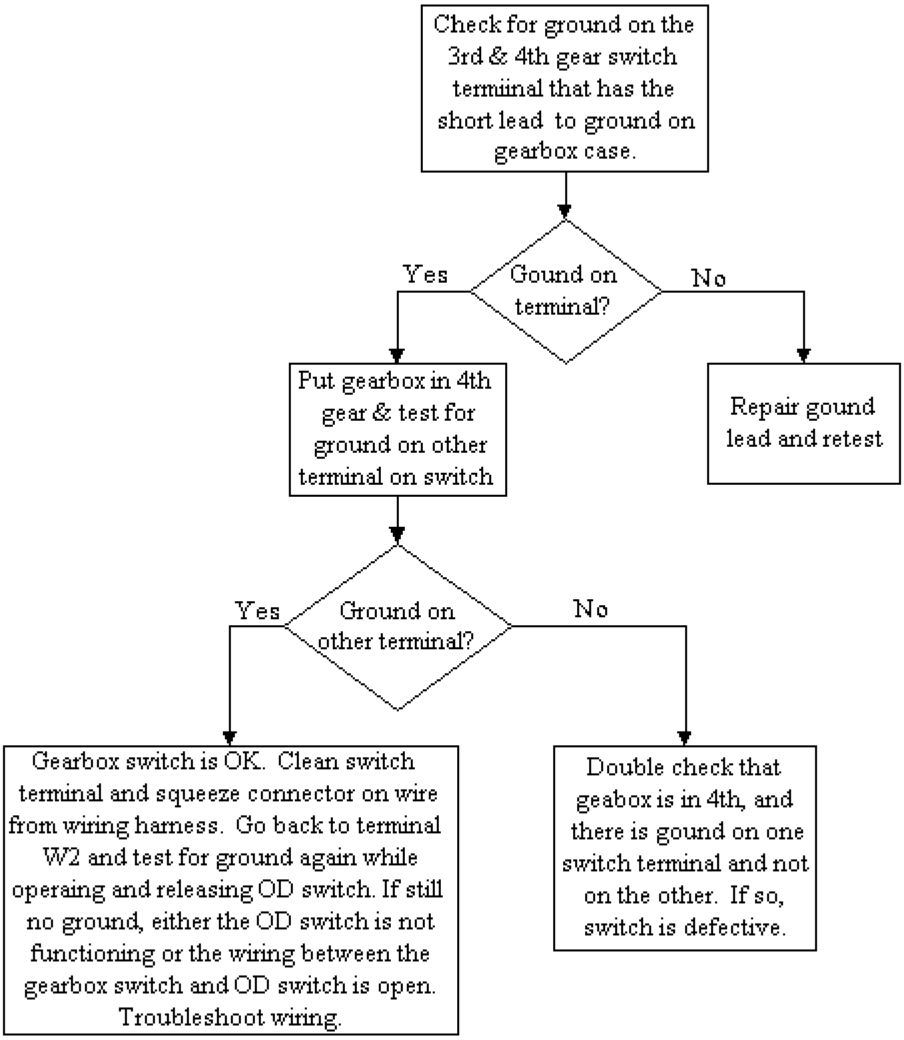
If the solenoid has an open or short, I remove the top cover and see if there is a problem with the internal switch that I can possibly repair.

If the solenoid can't be made to pass this test, it should be replaced.

Troubleshooting the Relay Circuit: We got to this point if we didn't hear the relay operate or if the contacts appeared be open when the relay was operated. The next flowchart is hopefully self- explanatory.



Troubleshooting Gearbox Switches: The gearbox cover must be removed to get at the gearbox switches. The next flowchart shows how to diagnose a problem with the 3rd/4th gear switch. If the electrical circuit works when the gearbox is in 3rd & 4th and not 2nd gear (and there is a switch for second gear) use the process as below to diagnose that problem, after putting the gearbox in 2nd gear instead of 4th substituting the 2nd gear switch for the 3rd/4th gear switch in the flowchart.



Troubleshooting the Clutches & Hydraulics

Overdrive Doesn't Engage: We got to this point after verifying that the solenoid operates and the gearbox fluid is at the correct level. The next easy thing to test is the the operating valve adjustment; merely push the lever on the operating valve shaft down to see if the OD then engages. To do this, remove the gearbox cover and then disconnect the drive shaft. The lever is on the RH side of the OD. Start the engine and put the gearbox into 4th gear, accelerate until the speedometer reads about 25 rpm and then push down on the lever. The speedometer will jump about 20% if the OD engages. If the OD engages by pushing on the lever, verify again that it doesn't engage using the solenoid by turning the OD switch on and off.

If there is any question the solenoid not causing the OD to engage, run the following test. Turn the OD switch off and then hold the solenoid plunger down and then turn the OD switch on. If you are able to keep the plunger from snapping into the solenoid with your fingers, either the gap between the engaged plunger and the stop is too great or the solenoid pull-in coil is not working. Measure the gap first and adjust it if necessary. If you can keep the plunger from engaging with a correct gap, test the solenoid as described above ----- the pull-in coil is likely not functioning.

One of my ODs was intermittent; sometimes it would shift, sometimes not. I found the solenoid pull-in coil was not functioning. The rubber cover and then the solenoid cap were removed exposing the internal switch that was found to have dirty contacts. After the contacts were cleaned it worked fine (and is still working).

If the OD can be engaged by pushing the lever and you aren't sure whether it engages reliably with the solenoid, readjust the operating valve lift using the procedure described in part IV.

OD doesn't disengage: If it is suspected that the OD isn't disengaging properly, make sure the OD is engaged by comparing the speedometer and tachometer. For 10 mph in 4th gear the rpm should be 482 with OD disengaged and 383 with the OD disengaged. For 20 mph, multiply the rpm by 2, etc. Switch the OD off and see if the rpm increases for the same speed. The switch should take place in a couple seconds or less. If it takes much longer than that to disengage or doesn't disengage at all, then the little hole in the operating valve spindle may be obstructed. The operating valve plug, spring and plunger must be removed to get at the spindle that contains the little hole. **Caution, operate and release the valve using the lever or solenoid a half dozen times to relieve the pressure before removing the operating valve plug.** Use a magnet to remove the ball and a bent wire shoved into the end of the hollow spindle to lift out the spindle. Photos of this procedure are in Part IV. Once the spindle is out, the inside of the spindle can be thoroughly cleaned and air blown through the hole to verify it is not plugged.

If the OD still appears to stick in the engaged position I would connect a pressure gauge to the top of the operating valve using the adaptor described in Part IV. **Again, caution, operate and release the valve using the lever or solenoid a half dozen times to relieve the pressure before removing the operating valve plug.** Disconnect the drive shaft, start the engine, put gearbox in 4th gear and engage the OD, then shut off the engine, put the gearbox in neutral and release the OD switch and then try to turn the OD output flange counterclockwise (as viewed from the front of the gearbox). If the flange can't be turned, the OD is still engaged. Otherwise, the OD has released. Then put the gearbox in 4th gear again and operate and release the OD switch several times (ignition switch on) while observing the pressure. The pressure should drop each time the switch is turned on and off. If it doesn't, that hole in the spindle is still plugged or the operating valve is misadjusted such that it is engaged even when the solenoid is released. Check the hole again and also verify the valve and actuating arm stop adjustments. If the pressure drops to near zero but the OD stays engaged, then it is likely the clutch release springs are too weak to push the clutch sliding member out of the brake ring -- the same problem I encountered and described in Part IV.

Clutch stuck in OD: The sliding clutch sometimes sticks in the OD position even though the operating valve has been released. Apparently this occurs after the OD has been engaged when the gearbox is cold and left engaged as the gearbox warms. One explanation for the sticking is that the clutch and brake ring expand as the temperature changes in such a way that the forces between the two increase to the point that the friction force holding them together exceeds the force provided by the clutch release springs. A clutch stuck in this way usually releases as the gearbox cools. The clutch also usually releases if the brake ring is given a sharp rap with a hammer. If the gearbox sticks in this way frequently, then the clutch release springs are probably too weak and should be inspected.

Checking the pump operation: The easiest was to check pump action is to remove the gearbox cover and the operating valve plug. **Caution, operate and release the valve using the lever or solenoid a half dozen times to relieve the pressure before removing the operating valve plug.** Oil should be present under the plug and some will likely flow out as the plug is removed. Next, disconnect the drive shaft at the OD output flange and turn the output flange by hand. The oil level at the top of the operating valve opening should increase a small amount with each revolution of the output flange and should overflow after a half dozen revolutions. If not, the pump is not working at all. This could be caused by a defective non-operating valve, defective pump, or most likely the pump piston stuck in the down position. A stuck pump piston can be fixed by removing the drain plug (drain the oil in the process) then removing the filter screen and the pump body plug. If the pump piston doesn't move when the rear flange is rotated, then it is stuck or broken. Gently tap the piston up as the flange is rotated. If it comes free and seems to work properly, reassemble it and good luck. If it can't be freed or sticks again, then the pump must be pulled and all parts examined including the spring. **The non-return valve must be removed before the pump body can be removed - see 'Checking the Accumulator, Non-Return Valve & Pump"**.

Checking Hydraulic Pressure: The best way to check the overall health of the hydraulics is to check the hydraulic pressure. The gauge and adaptor are described in Part IV. The operating valve plug is removed and replaced with the adaptor. **Caution, operate and release the valve using the lever or solenoid a half dozen times to relieve the pressure before removing the operating valve plug.** To do this the gearbox cover must be removed. Also disconnect the drive shaft at the OD output flange. The car is started, gearbox put in 4th gear and run the speed adjusted to 25 mph. The correct pressure is 350 - 370 psi for the early units and 450 psi for the later unit (models 22/1753 & 22/1985). When the OD switch is operated, the pressure should drop and then recover in a couple seconds. If the pressure doesn't drop and the OD doesn't engage, there is probably an electrical or operating valve adjustment problem --- see previous discussion. If everything seems to operate properly but the pressure is low, then the accumulator spring is probably weak. See the accumulator discussion in Part IV.

Pressure vs. mainshaft RPM: The next thing to do is to rev the engine so that the speedometer reads about 50 mph and observe the effect on the pressure both with the OD engaged and not engaged. If the pressure changes 10 to 20 psi, then the pump, valves and rings are all in good shape --- there are no major leaks in the system. If there is a significant change in the pressure, there is probably a leak.

Checking the Operating Valve: If the pressure is low when the OD is not engaged, but much higher when engaged, then the problem may be in the operating valve ball or seat --- it is leaking when the valve is not operated but seals the end of the hollow spindle when operated. Conversely, if the pressure is higher when the valve is released, then the valve may be not sealing the end of the spindle. If the pressure is low when OD is both operated and released, then the spring may be weak and not be sealing either. Pull the spring, plunger, ball and spindle and inspect all the parts. **Caution, operate and release the valve using the lever or solenoid a half dozen times to relieve the pressure before removing the operating valve plug.** Examine the ball for scratches and measure the spring length and compare with the new spring length of ~ 0.775 inches. If the spring is 0.75 inches or less in length, replace it --- for $2, it's not worth the hassle of opening up the unit, replace the ball too. Carefully inspect the valve seat for any signs of roughness, scratches. If it appears the valve is leaking when not engaged, and not leaking when engaged, try to improve the seat surface. The Service Instruction Manual suggests one can improve the seat by tapping the ball on the seat using a soft copper drift. I use a spare ball and a steel punch -- and then discard the ball. If the valve appears to be leaking when operated, then try to improve the valve seat in the end of the spindle by using a fine abrasive paste to grind in a spare ball --- and discard this ball afterwards too. Reassemble the unit and test again. If the pressure is low only when engaged, and you're sure that the operating valve is in order, that there is likely a leak in the operating pistons and the unit will have to be removed and disassembled.

Checking the Accumulator, Non-Return Valve & Pump: If the pressure is low when the OD is engaged and not engaged and the work on the operating valve didn't fix the problem, and the pressure increases significantly when the mainshaft rpm is doubled, then the problem is likely in the pump, accumulator or non-return valve. Check out the accumulator and non-return valve first. The oil must be drained from the OD, the solenoid, activating lever and cover plate removed. **Operate and release the operating valve using the lever or solenoid a half dozen times to relieve the pressure before attempting to remove the cover plate.** When removing the cover plate, be careful to remove the nuts from the two studs first and then back out the two long bolts together so that the cover plate stays perpendicular to the accumulator spring. Take a look at the non-return valve first buy removing the spring, plunger and ball. Examine the ball for scratches and measure the spring length and compare with the new spring length as described previously for the operating valve. If the spring is 0.75 inches or less in length, replace it, and also the ball. Then pull and inspect the accumulator piston (early accumulator) or the accumulator housing (later) and inspect the piston rings and cylinder for signs of scoring. The procedures to remove and install the accumulator components are described in Parts II & III. If no problem is found with non-return valve or the accumulator, pull the pump next . The pump is extracted through the drain plug hole using the puller described in Part II. Examine the pump carefully for scratches on the cylinder or piston and check the spring length (minimum free length 2 inches). If the pump is damaged it must be replaced, the same for a too short spring.

OD slips in OD engaged: If the OD slips when it is engaged, then either the force holding the clutch to the brake ring is too small or the clutch is damaged. If the hydraulic pressure is very low, that is the likely problem. If the pressure is at or above the ~ 350 psi specification of the early units, then the problem is likely that the clutch material on the sliding member has worn thin or part of it has broken off.

OD slips in direct drive (forward): If the OD slips in direct drive in the forward direction, then the unidirectional clutch is likely damaged. Recall that the sliding member is not designed to carry the torque of forward speeds, especially 1st gear startups; the unidirectional clutch is the primarily responsible for transferring that torque.

OD slips in direct drive (reverse): If the OD slips in direct drive in the reverse direction, then the sliding clutch is likely slipping in released position. The most likely cause of the slipping is weak clutch release springs. Another possibility is a damaged clutch sliding member. Wear of the clutch material is unlikely since the load on the clutch in the rear position is very small relative the forward position so any wear problems would likely show up in the forward position (OD engaged) first.