ANATOMY OF A TRANSMISSION

Oil Flow in The Pump-PR-Converter-Cooler Lube Circuits

Remember the old nursery rhyme, "The hip bone's connected to the thigh bone, the thigh bone's connected to the knee bone …" Well, it's the same in a transmission, only the tune goes, "The pump's connected to the PR valve, the PR valve's connected to the torque converter, the torque converter's connected to the cooler, the cooler's connected to the lubrication circuit …"

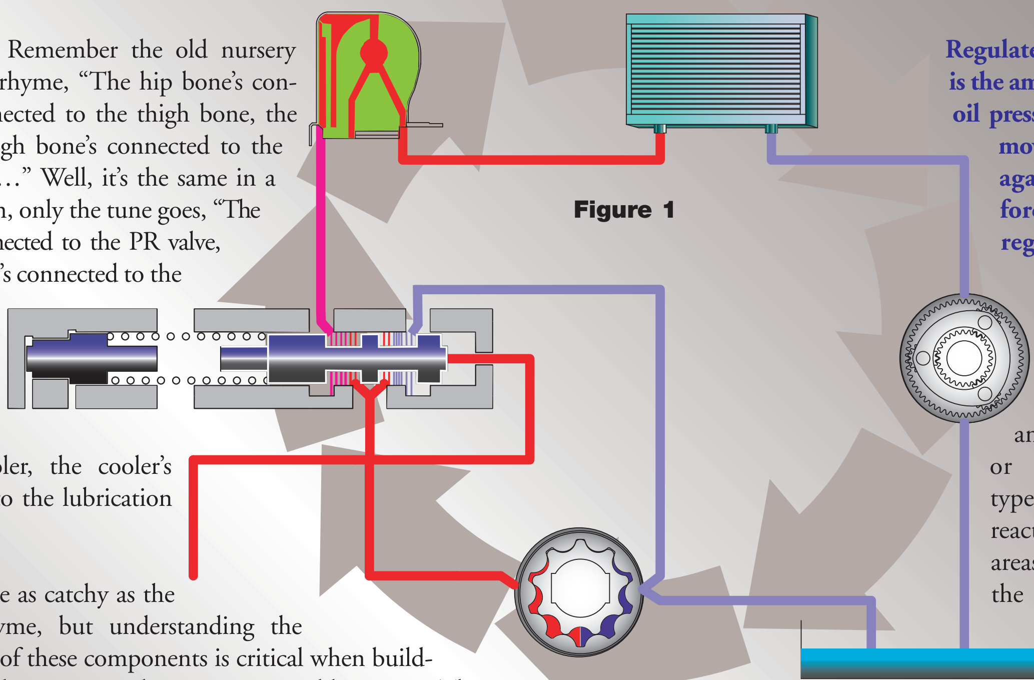

Figure 1

It's not quite as catchy as the nursery rhyme, but understanding the connection of these components is critical when building a healthy unit or diagnosing a problem one. The pump/pressure regulator valve and converter charge/lube oil follow in sequence and are literally connected in series *(see Figure 1)*. A change in any one of these areas has a direct consequence in others. Here we will dig into how these systems are connected, how the Sonnaflow® cooler-flow meter will help you monitor their operation, and how the parts throughout this catalog restore hydraulic circuits to keep the series from breaking down.

The pressure regulator (PR) valve is the central player in this series. A hydraulic pump is capable of making tremendous amounts of oil pressure. The PR valve limits or regulates pressures to the common 50-250 psi range seen in transmissions. The range of regulated line pressures is determined by a combination of spring and oil pressure forces at both ends of the PR valve. Typically the PR spring and boost valves push the PR valve in one direction, and balance pressure opposes or pushes the valve in the other direction into its regulating position. At start-up, the PR moves into its regulating position when there is enough oil pressure on the balance area(s) of the valve to overcome spring (and typically boost valve) forces. Once the pump creates enough line pressure to move the pressure regulator valve into its regulating position, the PR valve then directs excess pump volume to exhaust, or back to the intake/suction side of the pump.

Regulated line pressure is the amount of balance oil pressure required to move the PR valve against opposing forces and into its regulating position. This is true whether the PR is a simple valve with spring and boost valve, or more complex type with multiple reaction and balance areas at both ends of the valve. Here we will refer to the PR as being in balance when there is enough pressure to keep the PR valve in its regulating position, and we will refer to it as out of balance when there is not enough oil pressure to keep the PR valve in its regulating position.

In many transmissions, the PR valve has another, less well-understood function. The main line pressure regulator valve also controls the volume of oil that is fed to the torque converter: This, in turn, has a direct effect on converter release/fill pressure, cooling, lubrication and, in some cases, TCC apply pressure. In controlling converter feed, the PR valve is a type of priority valve. That is, it gives more priority to line pressure and LESS priority to converter/lube pressure. While there are some units that are exceptions to this, the majority of common transmissions have either the converter fed directly from the PR valve or the flow to the converter controlled by the PR valve.

Figure 2 illustrates a simple main line pressure regulator valve in two positions: in balance (with converter feed open) and out of balance (with converter feed restricted). Regardless of the valve configuration, the concept of in balance and out of balance applies to all types of main line pressure regulators that control converter charge. The key to remember is that for the PR valve to remain in balance (with the converter circuit open), the forces

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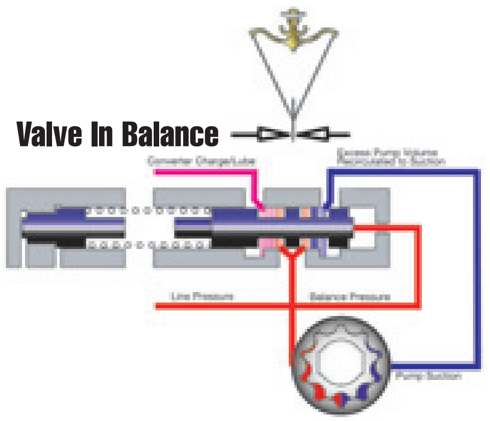
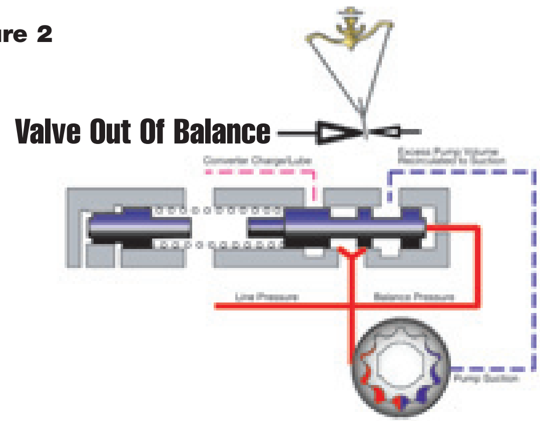
Figure 2



The PR valve is in its "normal" regulating position, what we will refer to here as "in balance." In this position the converter charge/lube oil is not restricted, and excess pump volume is redirected to the suction side of the pump.



Here the PR valve moved over to the right. In this position converter charge/lube oil and the oil recirculated to the suction side of the pump are restricted and at times completely cut off. This is what we call here "out of balance."

at both ends of the valve must be near equal. If the PR valve stays out of balance for extended amounts of time, converter/lube oil will be restricted. Once this critical threshold is crossed and the PR valve is out of balance for any length of time, everything falls apart (I mean the transmission).

An example of how the PR valve controls converter/lube oil can be seen in the graph *(Figure 3)* showing line pressure and cooler flow during a shift. One thing we have all seen while pressure testing is that slight needle twitch or momentary pressure drop when shifting. If you watch line pressure and cooler flow at the same time, when line pressure drops, you will see a corresponding change in cooler flow. This is because the pressure drop makes it all the way back to the balance end of the PR valve, and the forces at the other end of the PR valve overcome the reduced balance/line oil pressure and the PR valve moves out of balance. This restricts converter charge and the oil being recirculated to the intake side of the pump. Priority is given to line pressure until line pressure returns to the level that is sufficient to move the PR valve back to its in-balance regulating position. When everything is healthy and normal, this happens in an instant, and is the way the system is supposed to work. Problems begin when the PR valve stays out of balance.

The priority valve characteristic means that if the PR valve is near that critical balance threshold, converter charge and lube oil are restricted. In effect, it's choking off the oil flow, ultimately leading to overheat, TCC slip, or lube failure.

Problems at either end of the PR valve can put it out of balance. One end of the PR valve can have too much spring or boost pressure, putting extra load on the pump *(see Figure 4, examples 1a, 1b, 1c, 1d)*. At the other end, there may not be enough balance pressure due to leaks or a weak pump *(see Figure 4, examples 2a, 2b, 2c, 2d)*. Picture a diesel truck lugging a load up a long incline: RPMs are low and desired line pressure is high. If pump output cannot maintain line pressure, the PR valve will move out of balance. Remember, the PR gives priority to line pressure, so it is conceivable under these circumstances to have near normal line pressure (and clutch holding capacity) but have little or no cooler/lube flow due to the PR being out of balance. Imagine watching cooler flow drop off to nothing right at this critical time!

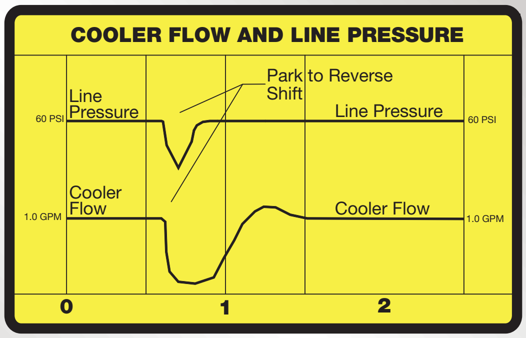


Figure 3

1 EXAMPLES OF EXCESSIVE SPRING OR BOOST PRESSURE

- **a** RWD Chrysler/E4OD and others, too strong a PR spring or overadjusted.
- **b** 4L80-E and others, worn boost valve, cross leaks causing high reverse line pressure.
- **c** Any unit in failsafe with max EPC boost pressures.
- **d** 4L80-E, with too low idle and high EPC amps.

2 EXAMPLES OF LOW BALANCE PRESSURE

- **a** 400/200C, worn PR bore.
- **b** CD4E, PR bore wear.
- **c** 4L80-E, PR end plug leak.
- **d** Any unit with weak/worn pump or excessive internal leaks.

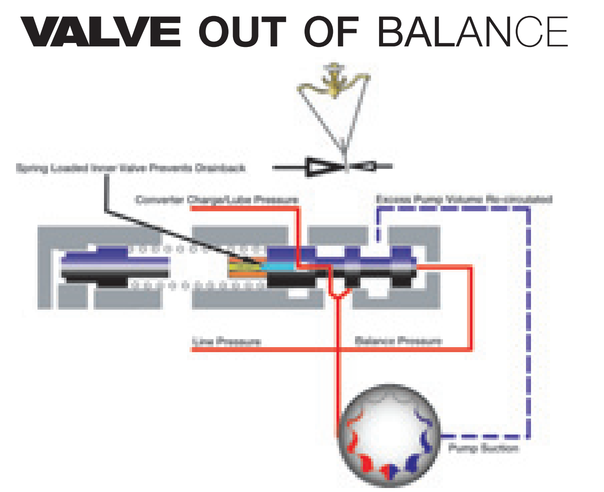
FIGURE 4

I know you have seen the results – another set of melted planets, or that mysterious black ring around the converter. Or picture the commercial unit that spends a lot of time idling in gear. Usually the most demanding time for a pump is hot, at idle (when RPMs are lower), in reverse when the desired pressure is higher. At this point, relative load on the pump is at its highest. Converter release/fill oil flowing through the converter is required to keep the TCC piston away from the front cover. An out-of-balance PR valve means little or no flow inside the converter, allowing the TCC piston to drag against the front cover leading to idle surging, engine stall, or glazed TCC friction material. Once glazed or overheated, the friction lining's ability to hold against engine torque is reduced.

Whether a low 60 psi at idle, or 160 psi under load, the specific line pressure is not as significant as the pump's ability to maintain that line pressure and keep the PR valve in balance in its regulating position. While this applies both to vane- and gear-style pumps, vane-type pumps are variable displacement and can increase their volume to maintain line pressure. Gerotor or gear- and crescent-type pumps are more of a concern because they are fixed displacement and have lower output at low RPM and idle speeds.

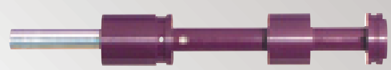
The pump's ability to maintain desired line pressure and keep the PR valve in balance also has variables. You can have a good pump, but leaks in other oil circuits inside the transmission will consume oil pump volume and reduce the pump's ability to create pressure. On the other hand, no internal leaks plus a worn or inefficient pump will exhibit the same problem maintaining line pressure. Think in terms of your air compressor volume/CFM and air tools. The compressor's ability to maintain pressure is related to how many air tools you run at the same time. Too many air tools and your compressor will not have enough CFM (volume) to maintain pressure and air pressure will drop below its normal range.

Due to fuel efficiency concerns, the typical transmission pump does not have much reserve capacity. Pump volume is needed to maintain pressure: Pressure is needed to keep the PR valve in balance. Internal leaks throughout the transmission waste pump volume. All those little leaks that build up over time end up consuming available pump volume and reducing the pump's ability to build/maintain line pressure, keeping the PR valve in balance. Some approaches attempt to compensate for wear by recalibrating with springs and enlarging orifices with drill bits, etc. This is only a temporary fix and does not address the root causes of wear or compensate for continued internal leakage. As you look through this catalog, you will see the majority of the parts reduce internal leakage. All the o-ringed sleeves and end plugs, valve bore repairs, oversized valves and precision bushings work in concert to minimize internal oil leaks. This not only alleviates symptoms related to the part, but also has the advantage of conserving pump volume.



Sonnax Line-to-Lube Pressure Regulator Valves

22771A-02K Chrysler Rear Wheel Drive
U.S. Patent No. 6,712,726
Page 210



36424-04K Ford E40D/4R100
U.S. Patent No. 6,826,908
Page 170

34200-14K GM 4L80-E
Patent Pending
Page 34

Figure 5

Line-to-Lube

To line-to-lube or not to line-to-lube, that is the question. Line-to-lube modification is adding an oil path between the line pressure and converter feed circuits, kind of bypassing the PR valve, so even if the PR valve is out of balance there is always an oil path for oil to enter the converter feed circuit. So why don't manufacturers build line-to-lube into the transmission? In fact, many do! On the 4L60-E it's that little flat on the PR valve land. Some other units feed through a designed-in orifice or slot in a gasket. Can you drill your own line-to-lube passage? Yes, but all too often the resulting hole is too large and allows too much oil to the converter, leading to overpressurizing, converter drainback and customer complaints. The Sonnax PR valves shown in Figure 5 have an internal line-to-lube passage and also feature an anti-drainback valve that prevents converter drainback when the vehicle is shut off.

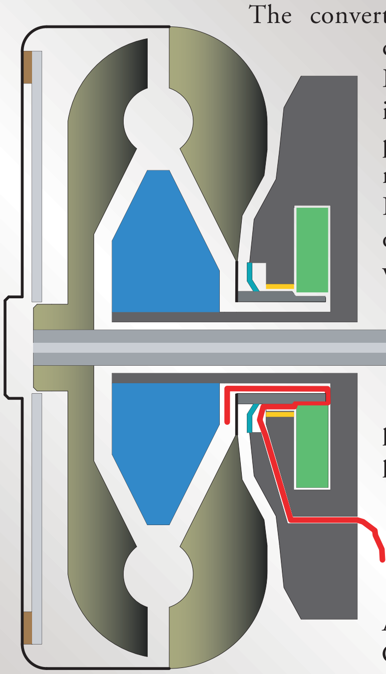


Figure 6

The converter hub/pump bushing deserves special attention. Excessive converter bushing clearance causes pump noise, wear and reduced pump efficiency. In addition to supporting one end of the bulky converter and keeping the inner pump gear on center, the hub/pump bushing helps prevent converter oil pressure from bleeding off and exhausting through the front seal drainback hole. This is a common issue with AXODE, AX4N and Chrysler units. Figure 6 shows a cross section of a typical torque converter with pump and shows the path converter oil can take from inside the converter through the pump bushing to exhaust. Excessive converter oil flow past the converter hub bushing contributes to front seal leaks and allows converter oil pressure a direct path to exhaust. This can lower converter/lube pressure and, in some cases, TCC apply pressure.

This is one reason why some manufacturers have moved toward putting a seal between the inner pump gear and the converter hub (4R44E & others), or between the stator tube and inside of the converter hub (48RE). These features help keep pump oil in the pump, and converter oil in the converter. As an example of how excess clearance can get us in trouble, consider a 2'' diameter converter hub with an extra .003'' hub-to-bushing clearance. The area of the extra .003'' clearance has essentially the same area as a .100'' hole, allowing converter pressure to bleed to exhaust. While there are other factors to consider with this example, a .100'' hole is a lot of leak to overcome.

When dealing with any transmission, keep in mind the connection between the components discussed here and how checking cooler flow gives insight not just to the cooler and lube, but the whole series all the way back to the PR valve and pump and when checking parts and clearances, what the combined effect can be when things loosen up and allow internal leakage.

Sonnaflow®

The Sonnaflow is a simple way anyone can check cooler flow under all driving conditions. The old method of checking cooler flow by removing the return line and measuring flow into a bucket doesn't tell you anything about what happens under normal driving conditions. Think about it: When was the last time you heard of a lube failure when the vehicle was NOT MOVING? The Sonnaflow kit includes a sensor that is quickly and temporarily installed in the cooler lines and has a digital read-out in gallons per minute (GPM) in the driver's compartment. This is especially helpful for monitoring cooler flow when TCC engages, and making sure flow does not drop off to critical levels under load or at idle. This ease of use is what makes the Sonnaflow such an effective tool for verifying cooler/lube flow and also the overall health of the entire series pump, PR valve, converter, cooler and lube.

SonnaFlow® Kit FM-01KA - page 216
U.S. Patent No. 6,655,197