Torque Converters:
Ballooning, Full Time Lubrication, Crankshaft Thrust Washers

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Bob Ryan served a seven-year automotive apprenticeship in London, England, and attained the HNC Engineer standard before working at several dealerships (Ford, Vauxhall, and Jaguar). He also worked at a few enterprising independent operations before he started his own business in general automotive repair. He became involved in tuning engines, as well as some motor sport racing, before he “Saw the light,” as he said, and began specializing in the repair of automatic transmissions.

Bob admits to always having had a curious and inventive nature, and he soon put together the equipment necessary to allow his business to remanufacture their own torque converters. That led to specialty work for the “racing fraternity” and progressed to several automatic transmission transplants; the most notable being the Suzuki Jeep. A PC-based V/B testing machine was his last project before an illness forced him to sell his business. He now acts as a consultant for VMTP, the leading transmission parts distributor in Europe.

Figure 1

You will have heard or used those words at some time, but what do they really mean, and is there any truth in the rumors that conversion to transmission full time lubrication can cause the destruction of engine crankshaft thrust washers?

Let me establish some engineering terms commonly used and their meaning before moving on to attempt an explanation:

1. Three-element torque converter is the earlier, non-lockup converter; the three elements are (A) the impeller, sometimes called a pump, (B) the stator, and (C) the turbine.

2. Four-element torque converter is made up of the entire above plus (D) a lockup clutch and damper assembly.

See figure 1 for details of the above and other named parts that will be used in later explanations.
Force, Weight, Pressure and Torque

Force is the exertion of strength, or it may be the attraction or repulsion of an object or substance by another. Force never exists alone. It must be accompanied by another force of equal magnitude but in the opposite direction.

The weight of an object or substance is the attraction between the earth and the object or substance, or the force of gravity acting on either of them.

Pressure is sometimes considered to be synonymous with force, but as used here is force per unit of area, or pounds per square inch.

Torque is the product of a force and the length of a torque arm, the imperial system is expressed thus: Torque = force x distance.

Some other common terms:

- **Balloon**: To cause to expand like a balloon.
- **Crankshaft palm**: The flat-machined end of the engine crankshaft that a flywheel or flexplate is attached to (figure 2).
- **Axis**: A straight line around which an object or body rotates.
- **Axial**: Along an axis.

Converter ballooning is a term used to describe the physical distortion/growth of the converter front cover and/or the converter pump/impeller. The outer diameter of the converter will not balloon, as it is a hoop, the forces not being great enough to cause any movement. However, the front cover, due to its shape, is a prime candidate for permanent distortion, as is the impeller. In general, due to careful design of shape and material, this phenomenon is a thing of the past (C4 with the flat front cover), though the Allison 5 series and 4L80E are known to lean in this direction if constantly operated with excessive loads, causing the converter to operate in a semi-stall condition.

Ballooned converters will destroy the pump long before any significant damage is done to crankshaft thrust washers. Converters that have ballooned should be scrapped, as the clearances discussed later will be drastically reduced.

The mechanical components that go to make up a torque converter are not complex, but the forces within are, and need some explanation.

Accepting the theory that force cannot exist alone, let’s examine the most obvious force exerted by the converter in the direction of the crankshaft palm, requiring the crankshaft...
thrust washers to adequately contain it.

Converter charge pressure enters the converter via the annular space between the stator support shaft and the inner diameter of the converter hub. It eventually exits via the input shaft passage or elsewhere, depending on the particular system.

Charge pressure is maintained at the designed level by the diameter of the exit orifice (used to be by converter and lube valve but they saved money by deleting it).

The axial thrust exerted by converter charge pressure in the direction of the crank palm is calculated by multiplying the area of the annular passage between the stator support and the ID of the converter hub by the charge pressure.

Example: Stator shaft diameter = 2 inches; hub ID = 2.5 inches; converter charge pressure = 100 PSI

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\begin{align*}
\text{Area of stator} & = 3.142 \times 1 \times 1 = 3.142 \text{ square inches} \\
\text{Area of ID of hub} & = 1.25 \times 1.25 \times 3.142 = 4.909 \text{ square inches} \\
\text{Area of hub ID} & = 4.909 \text{ square inches} - \text{stator area} 3.142 \text{ square inches} = 1.767 \text{ square inches} \times 100 \text{ PSI} = 176.70 \text{ pounds of thrust acting against the crank thrust washer.}
\end{align*}
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This force reacts against the area within the pump at the area opposing the converter hub (figure 3).

You will see that increasing the flow of oil to the converter circuit will have a direct effect on the oil pressure in that circuit; how much depends on the orifice size drilled to effect the now fashionable “line-to-lube” modification. The chart in figure 3A will give an idea of the relationship: Simply place a ruler across the figures in the three columns to get an idea of the relationship between orifice size and flow versus oil pressure.

Figure 3A shows that a system with a pressure of ten bar and an orifice size of two millimeters will flow six liters of fluid per minute. To calculate any other system you need to know what one value is, then simply place a ruler across those to get the other figures. The example in figure 3B shows an increase of four liters per minute for an increase in orifice size of half a millimeter, while maintaining the same oil pressure of ten bar.

As stated earlier, there are, however, many more complex forces at work during the operation of the converter, some of which produce substantial thrust forces that are directed toward the crankshaft palm.

To try and give you an appreciation of some of these forces and when they are at their highest level, consider the oil circulation in the torque converter at stall.

An 11.5” converter stalled at 825 RPM with an engine torque input of 150 lb-ft has a flow velocity of 39 ft/second; this equates to some 2350 gallons per minute at stall. The flow velocity varies directly with speed, which, in turn, varies with the square root of engine torque, so that, at 300 lb-ft, the circulation rate is 3320 GPM.

The graphs (figure 5) show that the thrust loads are highest at stall. As the turbine speed starts to increase, in turn creating a pressure head, counter to the one created by the impeller, oil flow is decreased, as are the resulting thrust forces. The rotation of the turbine also causes the body of oil in the axial space between the outside of the turbine shell and
the impeller housing to rotate, thereby building up a pressure head opposing that of the impeller.

Axial thrust can be formidable, but providing the vehicle is not operating in or around the speed ratio that causes an imbalance in the internal thrust forces, there should be no cause for concern.

However, ensuring the following are in order will help avoid those arguments between the engine, converter and transmission disciplines:

1. The crankshaft thrust face finish is maintained at 0.4 RA or better (that is similar to the crank journal finish).
2. Use a good quality crankshaft thrust washer and maintain the correct thrust endplay.
3. Strive to maintain the minimum converter internal clearances.
4. Maintain the converter external dimensions as OEM. If you must remove material from the mounting pads, remove an equivalent amount from the area that would eventually butt the crankshaft palm, thereby maintaining the designed travel before the converter butts the crank.
5. If you must carry out a “line-to-lube” modification, check the cooler-in pressure before and after the modification. That way you will be sure just how much extra oil pressure is acting as a thrust force on the crank.
6. Be safe rather than sorry: use an OEM flexplate, check that the converter pilot is a sliding fit in the crank, and that the converter front cover does have enough clearance to move in an axial direction (figure 4A).

Figure 4A shows the provision made for converter movement in the direction of the engine crankshaft without making direct contact. This allows the flexplate to absorb a good deal of the thrust force developed during converter stall as shown in figure 5.

Fortunately, the problem does not end there as this thrust is transmitted through the flexplate (often referred to as a driveplate). Flex is a more accurate description of one of its more important functions. This plate is, in fact, a flat spring, and depending on the spring rate chosen, it will absorb a sufficient amount of the axial thrust we just calculated, for a given

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The text continues with diagrams and explanations related to engine and transmission components.
amount of travel (figure 4).

The optimum spring rate of the flexplate for this application, to allow the converter to move forward without bottoming in the crankshaft or adapter, is 10,000 lbs/inch ±2,000 lbs/inch. That is, with the flexplate bolted at the converter drive lugs and at the crankshaft or adapter, a load of 1,000 lbs. would be required to deflect the flexplate axially 0.10 inch.

The rate of the flexplate can be controlled by the thickness of the material or by using holes/windows to alter its spring rate.

For those of us that prefer practical examples to gain a better understanding of theory, the following simple experiment should demonstrate how a flexplate does absorb thrust forces.

Set up a weighing scale under your press; operate the press a given distance (careful, don’t break the scale) and make note of the distance and the force shown on your scale’s dial. Adjust the setup to allow room for a suitable spring between the scale and your press ram; extend the ram the same distance required for the previous force reading; note the much lower force reading for the same distance travelled.

You will have realized from your experiment that the spring rate (strength) of the flexplate is all important for the longevity of the engine’s crankshaft thrust washer: Too high a spring rate and the full force will simply be transmitted to the crankshaft thrust washer; too little spring rate and the force will overcome the flexplate and butt directly against the crankshaft palm. You should also be aware that altering any mechanical dimensions in this area could lead to increased thrust being transmitted to the crankshaft thrust washer. Reducing the dimensions of the converter mounting pads or increasing the height of the bolt heads used to bolt the flexplate to the crankshaft palm would have the effect of reducing spring travel before the converter made contact with the crankshaft.

The graph in figure 5 shows how the use of a flexplate in a floating pilot design reduces the thrust force acting on the crankshaft thrust bearings to less than 800 lbs. of force at 300 lb-ft of engine input torque at stall.

Compare that maximum force with the line showing thrust through a butt pilot at some 1700 lbs. of thrust during stall, and you will agree about the importance of keeping the correct spring rate, and ensuring that the converter pilot is not binding in the crankshaft pilot bore.

![Figure 5](image-url)