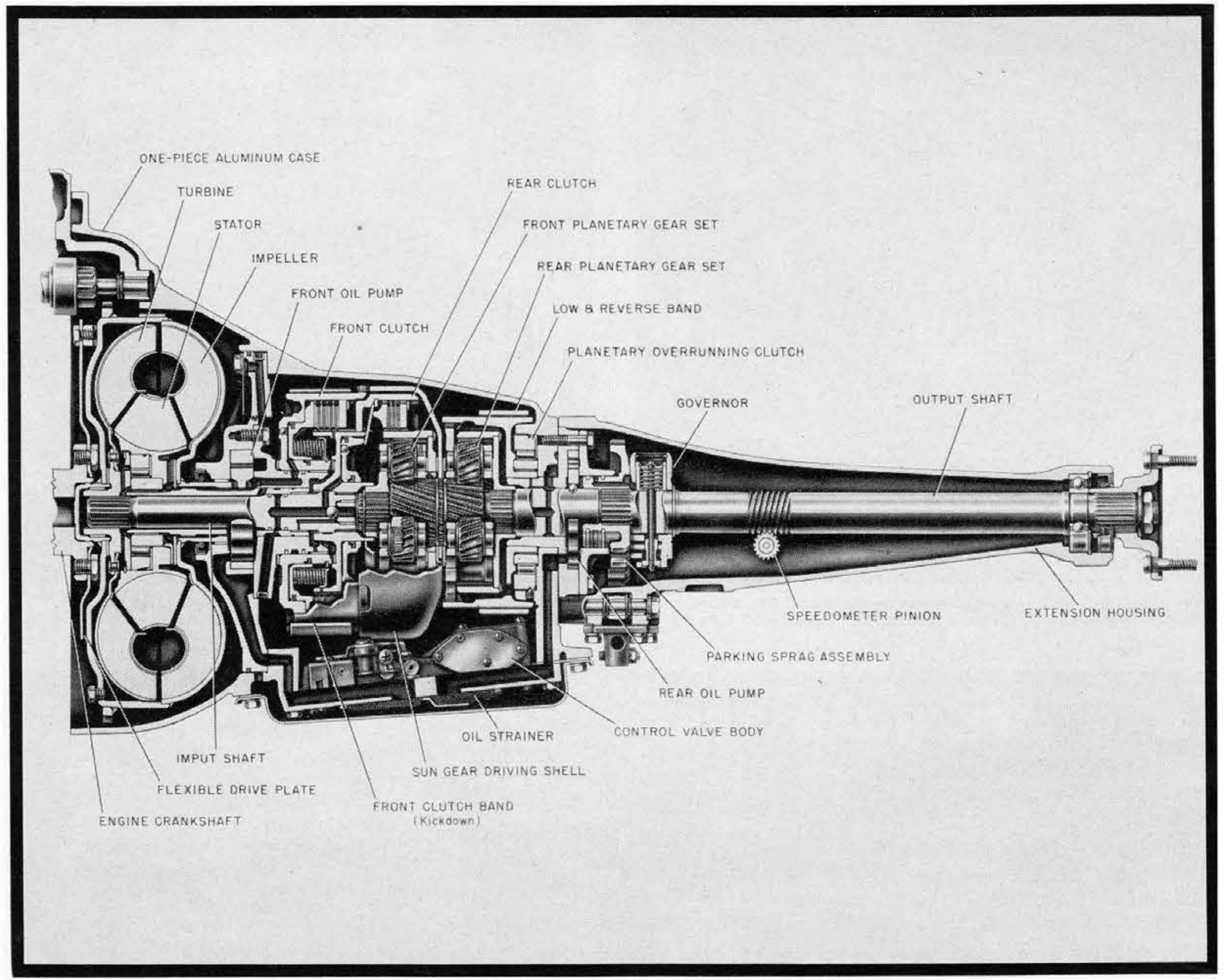

CUTAWAY OF the Chrysler TorqueFlite shows elements of converter and 3-speed transmission.

the great transmission controversy

COUPLING VS. CONVERTER

BY ROGER HUNTINGTON

THE AUTOMATIC TRANSMISSION has been an important feature of American passenger cars for over 20 years now, but many car enthusiasts still don't thoroughly understand the differences in operating characteristics between a fluid coupling and a torque converter. Automatics are complex things at best—and understanding this coupling-converter relationship is perhaps the toughest nut of all. And yet this knowledge will not only help select the transmission that best fits the needs, but might also give the reader some ideas on optimum driving and gearing techniques.

The internal-combustion piston engine must be rotating at a substantial speed before it can develop any useful torque. This means we need some sort of slip-coupling to connect the engine crankshaft to the back wheels when starting up from rest—so the engine can gradually pick up the car load while it is rotating. The first automobiles used vicious cone clutches to make this connection, through the wedging action of two mating angular surfaces. Later on, the smoother plate clutch was adopted—and still later the clutch plate was mounted to the hub through springs, to further cushion the load.

But from the very beginning auto engineers dreamed of picking up the load on a cushion of oil. The necessary equipment was already being used in the marine field. In the early 1900s a German engineer, Dr. Herrmann Fottinger, developed a fluid torque converter to connect the high-speed steam turbines to slow-speed propellers on ships. In 1912 the Vulcan Works in Germany took the reaction vanes out of Fottinger's converter and made a simple fluid coupling for ships. But it wasn't until 1926 that a British engineer, Harold Sinclair, finally adapted the fluid coupling to the automotive vehicle. He put it in some London buses. From then on the fluid-drive concept grew swiftly in Britain and Germany—though it was confined mainly to the fields of trucks, trains and ships.

In 1937 GM engineers designed an automatic planetary gearbox and installed it in some Buicks and Oldsmobiles with a conventional friction plate clutch to pick up the load. It didn't work very smoothly and there wasn't much public interest. Then a fluid coupling was added on the front of this transmission in 1939—and we had the Hydra-Matic. Automatics really took off from this point. The early Hydra-Matic was used on the Cadillac and Olds, and Chrysler got into the act by putting a fluid coupling on the front of a more or less standard gearbox and rigging it for vacuum shifting when the accelerator pedal was released.

Buick was first to put a true torque converter in a passenger car, in the form of the 1948 Dynaflow and Chevrolet followed with Powerglide in '49. The rest is well known. We've come a long way and made tremendous progress on automatic transmissions in these last 15 years. The principles are the same, but we've learned to overcome the limitations for greater efficiency and snappier performance. And any transmission engineer will admit that we haven't even scratched the surface of fluid drive potential yet.

Now to investigate the difference between a fluid coupling and a torque converter.

The Fluid Coupling

A fluid coupling might be called a "hydro-dynamic clutch." It picks up rotating load, just like a friction-plate clutch, but does not multiply torque.

Imagine a doughnut-shaped housing sliced in two lengthwise (that is, at right angles to the axis of the doughnut). Now put some radial vanes on the inside of each half of the "torus" (the technical term for a doughnut shape). Then let's put the two halves of the torus together again, so they're almost touching—then fill the inside with oil and house the whole thing in an external case (to retain the oil). This is a crude fluid coupling.

What happens when we rotate one half of the torus? In this case, the vanes in the "pump" half (the half we're rotating) will churn up the oil and throw it against the vanes in the "turbine" half (the section that is hooked to the output), causing the turbine to rotate. In other words, we're transferring torque, just like a plate clutch. As long as the pump torus is turning at a higher speed than the turbine torus, torque will be transferred.

Which brings up the matter of circulation. When the torus members rotate, and the vanes force the mass of oil to rotate with them, naturally this oil mass will be subjected to centrifugal force—which will tend to pull it toward the outside edges of the torus. But remember that the pump torus is rotating at a higher speed than the turbine, or output, torus. Thus the oil in this section will have more outward pull than the oil in the turbine. This will cause the oil to circulate automatically from the outside tip of the pump, into the outside tip of the turbine—then down around in the turbine, and back into the inner edge of the pump torus. And, of course, since the torus members are rotating at the same time, the actual path of a particle of oil would be a spiral whose axis follows a circular path.

The main reason for going into all this is to illustrate why there must always be some slip in a fluid coupling. Slip is defined as the difference in speed (or rpm) between the pump and turbine tori. If the speeds were exactly the same there could be no circulation of oil. Then the centrifugal force on the two oil masses would be the same, and they would merely fight each other where they meet in the center. When the pump turns faster, there is smooth circulation from the pump into the turbine, then back to the pump at the inner edge (where centrifugal force is less). This is how torque is transferred. Of course, the actual percentage of slip will vary widely. Starting out from a dead stop, it naturally would be 100%; but it might be only 2 or 3% when cruising down the road at constant speed. In other words, the output turbine would be turning at 97 or 98% of the pump rpm. Under these conditions the actual transmission efficiency would be over 95%.

A fluid coupling has fascinating operating characteristics. For instance, the torque capacity is proportional to the square of the rpm (in other words, it would be four times as high at 3000 rpm as at 1500). Thus, the slip decreases very rapidly as the speed builds up, assuming constant input torque. The stall speed of the coupling is the maximum rpm at which the engine can turn the pump when the turbine is stalled. This is the engine speed you'd reach if you brought the engine up to

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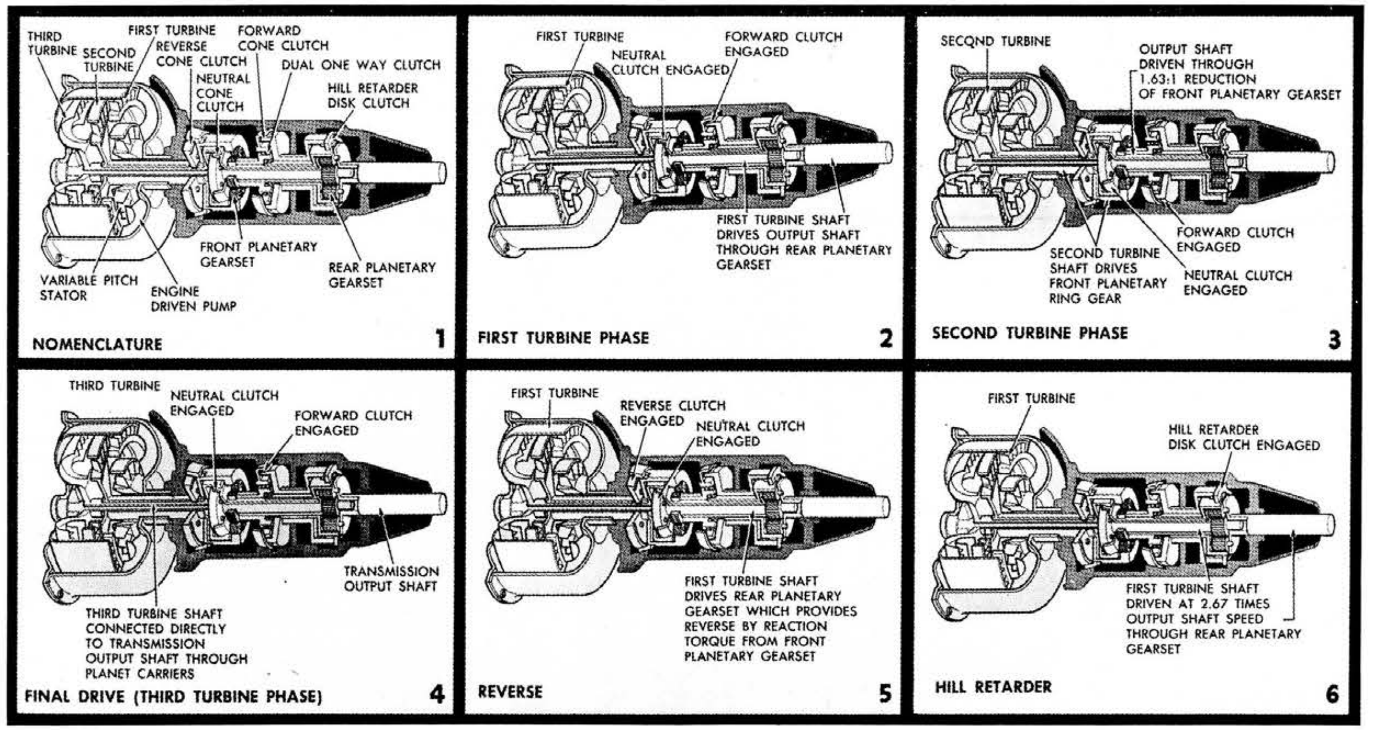
OPERATING PRINCIPLE of Chevrolet's triple-turbine Turboglide. Very smooth, it proved too expensive.



NOMENCLATURE 1

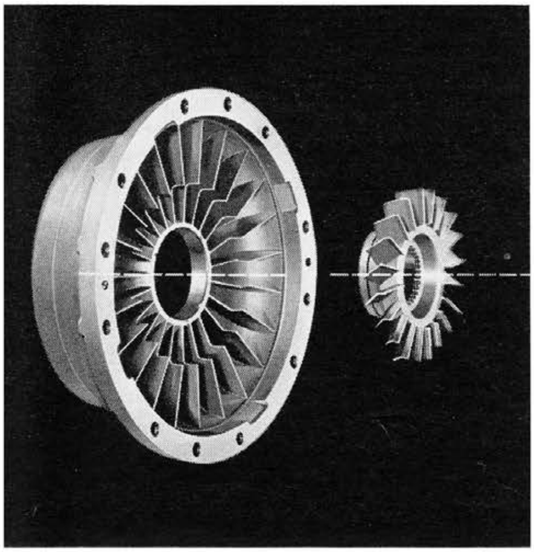
FIRST TURBINE PHASE 2

SECOND TURBINE PHASE 3

FINAL DRIVE (THIRD TURBINE PHASE) 4

REVERSE 5

HILL RETARDER 6



ACCEL-A-ROTOR (right) acts as stator.

COUPLING VS. CONVERTER

full throttle with the brakes locked. It generally varies from 1800 to 2200 rpm on the various Hydra-Matic models. It depends on many factors, including torque of the engine, coupling diameter, volume of oil, oil temperature, number of vanes in the torus, etc. The stall speed can be varied over a wide range by juggling these factors.

The engineers at B&M Automotive, who design modified Hydra-Matics for racing, adjust their stall speed by changing the number and width of the torus vanes. They have to shave the vanes quite a bit to give a small, low-torque engine a drag strip stall speed of 3000-3500 rpm. But, as torque capacity increases as the square of rpm, they could give a big, supercharged engine with 700 lb.-ft. of torque a stall speed of, say, 3000 rpm with nearly standard vanes (which would imply a capacity of around 300 lb.-ft. at 2000 rpm). This business of giving a specific engine the right stall speed with a fluid drive is very important in getting low elapsed times on the drag strip. The B&M people have made a fine study of it.

Actually, there's very little effective slip under normal operating conditions in a "tight" fluid coupling like the Hydra-Matic. Due to a split-torque arrangement in the gearing, only part of the engine power goes through the coupling—while part is transferred directly through the planetary gears. This cuts the slip under given torque and rpm conditions just about in half. In a full-throttle standing start with the 4-speed Hydra-Matic (without prior build-up of static rpm) the engine speed would jump up to about 1500 rpm at 2.5 mph, and would be up to 2500 by the time the car reached 10 mph. From 5 mph or so on the car is just about geared to the road, with just a few percent of slip. At cruising speeds, under part throttle, slip is only about 1% with the split-torque gearing.

The Torque Converter

Many of the operating principles of the fluid torque converter are identical to those of the fluid coupling—but with one vital difference: A torque converter has the ability to multiply torque. All a fluid coupling can do is transfer torque, like a friction-plate clutch. The same torque comes out of the turbine that goes in at the pump. But a converter can actually step up this input torque—multiply it just as gears do.

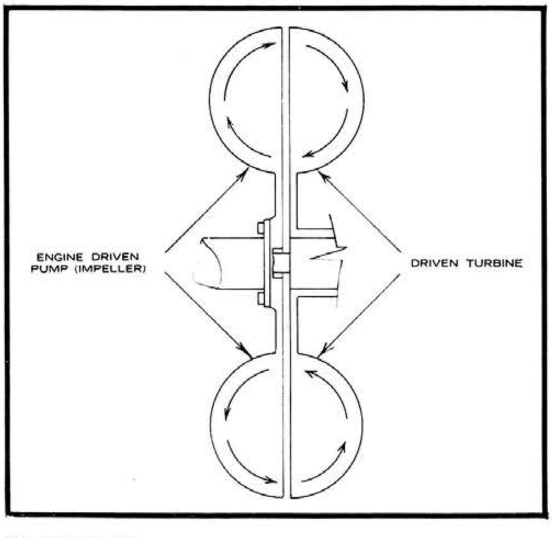
There are vital differences in design between couplings and converters. A coupling has straight radial vanes in the torus. A converter has either or both of the pump and turbine vanes curved, so the reaction to this angular deflection of the mass oil flow will add extra torque to the output shaft. But these curved vanes, in themselves, could not multiply torque. Any torque added in the turbine would be subtracted when the returning oil hit the pump vanes—because it would be going in the wrong direction and would act to retard the rotation of the pump.

What we have to do to multiply torque is to put a stationary reaction member between the turbine and the pump. Its vanes will bend the oil flow back in the proper direction so they won't retard pump rotation. Then any torque added by the turbine will go on to the output shaft. This reaction member is called the "stator," a name derived from the fact that it is a stationary member in its normal function—on most torque converters, that is—but it doesn't have to be. On some cars it is geared to the turbine or the rear wheels, so it is stationary only when the car is at rest. There are many possible variations, but the important thing to remember about this component is that it acts as a sort of fulcrum in an imaginary lever system that multiplies torque by bending the oil flow in a new direction.

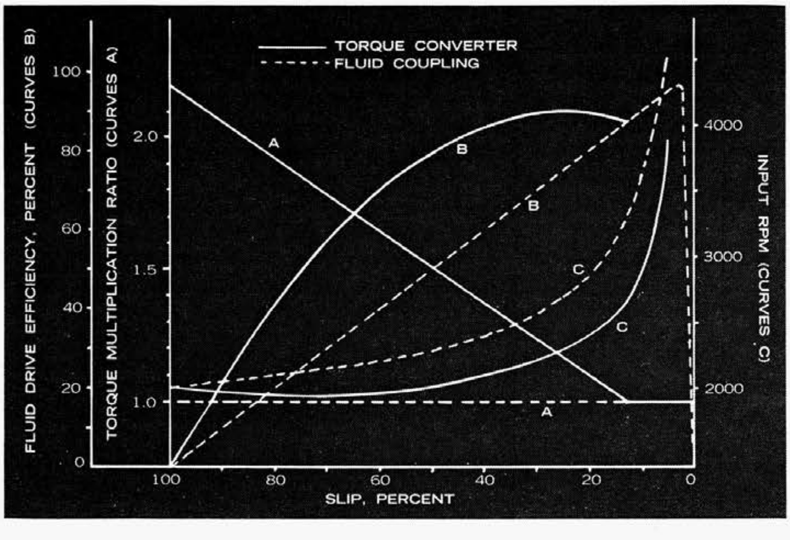
But now the problems begin. As the engine speed builds up after the car gets under way, and as the slip decreases as the output turbine speeds up, a point is soon reached where the oil flow from the turbine starts hitting the backs of the stator vanes. This causes the efficiency and torque multiplication to quickly drop to zero. For many years in the early 1900s this problem greatly limited the range of application of the fluid torque converter. They had to be designed to operate at all times in the high-slip region, before the oil angle reached this critical point—which, of course, reduced the overall transmission efficiency.

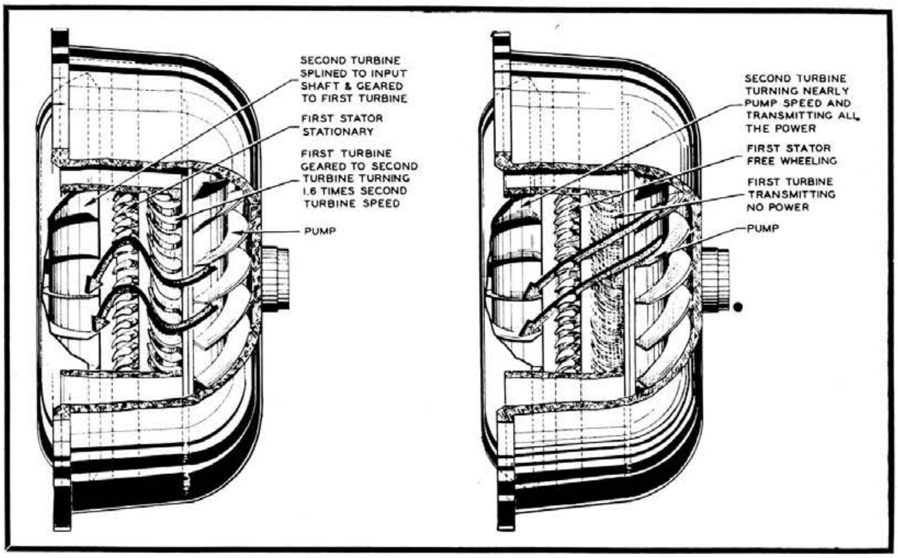
As it turned out, the solution proved to be quite simple: Mount the stator on an overrunning clutch, so it would start to free-wheel when the oil struck the backs of the vanes at high speed. At this point the converter would begin acting like a regular fluid coupling. There would be no reaction member (it would be free-wheeling), so there

ENGINE DRIVEN pump forces fluid against turbine in fluid drive system. Arrows show circulation of oil mass.



COMPARATIVE PERFORMANCE characteristics of typical 3-element torque converter and fluid coupling with constant input torque and stall speed of 2000 rpm.





TWIN-TURBINE Dynaflow has two turbines and a stator which free-wheels when first turbine matches pump speed, allowing direct transfer of torque.

would be no torque multiplication. At higher speeds the efficiency would go up and the slip would drop to 2 or 3% just as it did for the coupling. The free-wheeling stator idea is what made the torque converter practical for passenger cars.

Other than the above consideration, many of the operating principles of the torque converter are similar to those of fluid couplings. The circulation works the same. The full-throttle stall speed tends to be similar, generally running from 1600 to 2000 rpm on conventional 3-element converters (pump, turbine and stator). The maximum torque multiplication ratio is at stall condition, just as a gas turbine engine gives maximum torque at stall. This will average 2.2:1 on modern 3-element converters. From here the torque ratio drops in just about a straight-line curve as the output turbine speeds up in relation to pump speed. It reaches 1:1 at the coupling point, where the stator starts to free-wheel—which would normally be when the turbine rpm is about 85 to 90% of the pump speed. The transmission efficiency curve, of course, would be zero at stall—just like that of the coupling. But this curve humps up at higher speeds and reaches a peak of around 90% just below the coupling point. Then after the stator starts to free-wheel the efficiency goes on up to about 97% under cruising conditions.

This is how the very simplest 3-element torque converter works. There are numerous possibilities for more exotic layouts. Buick has been a pioneer in this field, bringing out the Twin-Turbine Dynaflow in 1953, and in 1955 putting a variable-pitch stator in it. The idea of using two turbines makes a lot of sense. The first turbine is geared up 1.6:1 with the second, so its torque at stall is multiplied by this amount. Then as the car speeds up the relative gear ratio on the planetary between the two turbines reduces and the first turbine eventually starts to free-wheel. The advantage of this is a higher stall torque ratio without any jerking shifts.

In 1957 Buick and Chevrolet carried this theory a step farther with their triple-turbine converters. Here the primary turbines were geared up about 2.8:1 with the main. These would start to free-wheel first, then the second turbines. Result: a still wider torque range, and still with dead smoothness.

Buick also introduced the variable-pitch stator during this period. The stator vanes were given two pitch positions, controlled by throttle position. The low angle gave more torque step-up at high converter slip values (near full throttle), while the high angle extended the effectiveness of the stator to multiply the torque under part throttle. Buick's large switch-pitch Dynaflow has a stall torque ratio of 3.2:1 at about 2700 rpm stall speed (in low pitch). The earlier Chevrolet and Buick triple-turbine converters, both with 2-position stators, had maximum torque ratios in the neighborhood of 4.5:1 in the 3000-3200 rpm range. (Keep in mind that these stall speeds don't really mean much. The transmission designer can put them anywhere he wants by juggling vane angles, width, converter diameter, etc. The reason they've been rising on these exotic transmissions is that our later V-8 engines develop their maximum torque closer to 3000 rpm—and it didn't require any compromise on other factors to put the stall speeds this high.)

Comparative Performance

On the face of all this evidence, it might seem that the fluid coupling couldn't possibly compare with the torque converter for accelerative performance—simply because it can't multiply torque within itself. From one aspect this is true.

Suppose there were two equal cars (equal horsepower, weight, axle ratio, etc.), but one with a simple 3-element torque converter and one with a fluid coupling—and with no planetary gears behind these fluid drives. If they started out side-by-side, obviously the torque converter would pull away. It would be starting with an additional 2.2:1 torque multiplication—and this would make the difference. Both cars would start out at about the same engine rpm and fluid slip, say somewhere around 2000 rpm. The coupling would build up engine speed with car speed a little faster. At 40 mph the coupling might be turning 2600 rpm, compared with maybe 2200 for the converter. Thus the coupling engine would be putting out more bhp at this point. But the converter would still be multiplying torque here, and the overall fluid drive efficiency would be higher. The effective forward thrust would be higher with the converter, and thus also the acceleration rate.

The late 3-speed Hydra-Matic has a unique "Accel-A-Rotor" in the coupling unit that helps to compensate somewhat for this difference. It acts as a stator when the car starts out, but is geared to the rear wheels so it speeds up and takes itself out of the circuit quickly as the car speeds up. At the start it has the effect of multiplying torque about 1.2 times. In itself it wouldn't have a big effect.

But when these fluid drives are connected to the rear wheels through a planetary gearbox the picture can change in a hurry. Compare the 4-speed Hydra-Matic with the 3-speed Chrysler TorqueFlite 3-element converter. Starting out from stall, the Hydra-Matic has a gear ratio of 3.97:1, but no fluid multiplication in the coupling. The TorqueFlite has a 2.45:1 low gear ratio and 2.2:1 fluid multiplication, giving a total torque ratio off the line of 2.45 x 2.2=5.4:1. The TorqueFlite beats the Hydra-Matic off the line. But that's not the end of the story. Due to the swiftly-decreasing slip on both fluid drives the TorqueFlite is just about out of fluid multiplication by the time it reaches 10 or 15 mph. From here up to 20-25 mph the Hydra-Matic still has its 3.97 ratio, while the TorqueFlite is down to 2.45 on just its gears. The Hydra-Matic catches up again.

So those are the essential differences between the fluid coupling and torque converter. But don't forget the effect of the gear ratios when selecting an automatic for top performance. Fluid torque multiplication peters out quickly after the car is rolling; gear multiplication holds on until the gears shift. Gears still can't be beaten for multiplying torque with maximum efficiency. ■