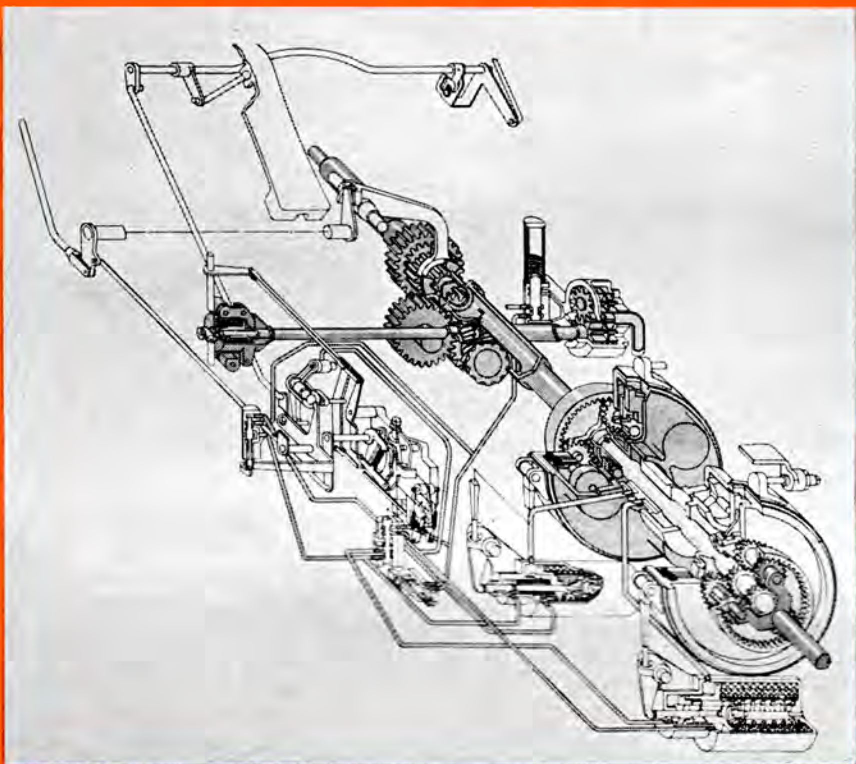
PUTTING THE AUTOMATIC IN TRANSMISSIONS



ENGINEERING EVOLUTION PART VIII

BY ROGER HUNTINGTON

GENERAL MOTORS' automatic shift transmission introduced on 1937 Oldsmobiles. It had a plate clutch for starting but other shifts were made automatically, modulated by the throttle.

FROM THE VERY earliest days of the automobile drivers have been plagued with the nuisance of shifting gears. And, since those days began, engineers have been dreaming of simple, efficient automatic transmissions. The idea of no-shift, no-clutch driving is not new. Designers were spending a lot of time on the problem even before 1910. But the automatic transmission was one of those mechanisms that had to await technological development in related fields (metallurgy, hydraulics, organic friction materials, gear-cutting and machining) before it could become a practical reality. This took about 40 years.

The first serious attempts at automatic driving in this country came around 1910 with the Carter friction drive and the Owen magnetic drive. The Carter drive was nothing more than a large disc, faced with friction material, that drove a roller wheel that was pressing against the drive disc. This roller could be moved back and forth on a shaft (at right angles to the drive disc axis) to change the effective rolling radius of the drive disc, thus changing the speed ratio. It looked wonderful on paper. In practice, though, the big problem was excessive wear of the driving surfaces because of high unit pressures and slippage. Of course, this type of friction drive is inherently limited in the amount of torque it can transmit without slipping. The Cartercar didn't last long.

The Owen Magnetic had an electrical generator and motor on the same shaft, with the motor section geared to the rear wheels. The generator field was driven by the engine flywheel and the armatures of both generator and motor were on the same shaft (connected to the rear wheels). When starting up the high "slip" or speed differential between generator field and armature would generate a high current and torque output from the motor. As speed increased this slip would reduce and the effective torque multiplication dropped, much like a modern torque converter. At cruising speed, the driver threw a switch to short-circuit the generator, so the whole assembly acted like a magnetic coupling (no torque multiplication) with the slip dependent on load. The latter range would be equivalent to the stator wheel free-wheeling in a hydraulic torque converter.

Actually, the Owen magnetic drive gave good torque multiplication for quick acceleration and the performance characteristics were as smooth as any modern fluid drive. The big problem—the one they couldn't design around—was that the weight, size and cost of the electrical equipment were excessive in relation to horsepower capacity. The generator-motor unit needed to handle a modern 300-bhp engine might weigh as much as the car itself! And if size and weight were trimmed to allow for short-period overloads on starting, trouble occurred. This basic type of engine/generator drive works beautifully for diesel railroad locomotives, where weight is no problem, but inventors have never been able to make it practical for cars—even though its performance characteristics look perfect on paper. The Owen Magnetic was the first and last commercial attempt.

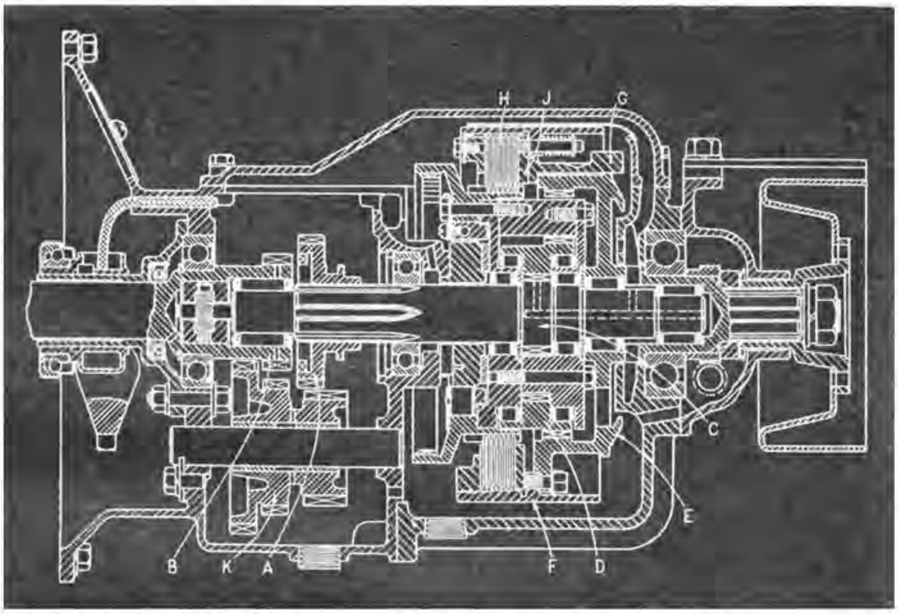
After the Owen Magnetic died in 1920 there wasn't much action on automatic transmissions around Detroit for several years. There was much more activity in Europe. Dr. Hermann Foettinger, of Hamburg, Germany, had invented the hydraulic torque converter for ship turbine engines in the early 1900s. The device was adapted by the Leyland Co. for London buses in 1926 and the Daimler Motor Co. used a fluid coupling version of the idea (no stator wheel, no torque multiplication) for its luxury cars in the late '20s. These were the first known adaptation of fluid drive for road vehicles. However, these developments would not necessarily be considered as automatic transmissions. Both designs used more or less conventional manually-shifted sliding-gear transmissions. A friction plate clutch was used to disconnect the fluid drive to shift gears.

About this time (1928) General Motors Research started work on another form of friction-drive automatic transmission. This design had a number of rollers rolling between two torus-shaped races—one driven by the engine and the other driving the wheels. By pivoting the rollers on their axes, the effective drive radius could be varied between the driven and driving races, thus giving an infinite number of speed ratios either underdrive or overdrive (depending on which way the rollers were pivoted in relation to horizontal). The drawing on Page 79 shows the layout. GM spent quite a lot of money on this idea in the next four or five years, running up more than 400,000 miles of road testing on 30 test units. But these had the same trouble that had hindered friction drives of the past: Excessive wear of the working surfaces when enough pressure was put on them to transmit a decent amount of torque. Some of the GM engineers felt the problems could be solved with a metallurgical breakthrough, but it was decided to drop the idea rather than spend more money on an uncertain future.

The Reo Motor Car Co. came up with the first automatic gear change in 1933, its "Self-Shifter." Reo used a compound internal gearset (similar principle as a planetary gear) to step up the gear ratio to 2.07:1 for starting. Then it was fixed so centrifugal weights would apply a multi-disc clutch at around 14 mph to couple the output shaft to the input, giving direct drive at speeds above this. There was also an emergency low sliding gear, engaged by a hand lever. And, of course, the driver had the usual foot-operated plate clutch for starting. It really wasn't too bad. He could start off briskly in the 2.07 ratio with just the clutch, then it would shift to direct entirely automatically. The worst problem was that there was no way to modulate the shift clutch action for different throttle openings. The action either had to be adjusted to give a lot of slip at full throttle, or a lot of jerk at part throttle.

General Motors brought the true automatic transmission to the American passenger car, but it didn't happen overnight. The two vital developments were made in entirely separate projects in 1937. Here's the background: In 1934 GM had built a number of rear-engine buses with air-shifted synchromesh transmissions to replace the streetcars on Manhattan Island. At that time the GM engineers were startled to find that the bus drivers were shifting gears on an average of every 11 sec. all day long. The wear and tear on men and machinery was fantastic—especially since the engine in the rear prevented the driver from timing his shifts by engine sound. Clutches and synchros took a beating. Research for an automatic bus transmission was immediately accelerated but GM ended up by using the British Lysholm-Smith torque converter (London buses), supplemented by a friction plate clutch, with no auxiliary gears. This type of torque converter did not have the stator on an overrunning clutch, so the efficiency would drop to zero when the slip got down below 10%. This made it necessary to couple the converter pump to the turbine with a plate clutch for cruising. The converter itself provided a torque multiplication ratio of over 3:1 at stall, which was considered adequate without any auxiliary gear step-up ratios. The fluid-drive buses were introduced in 1937.

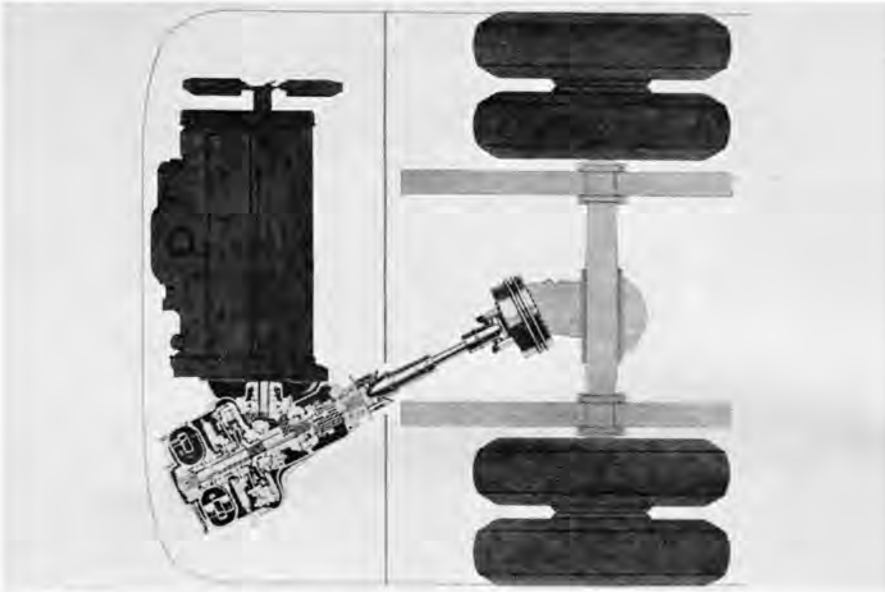
Also in 1937, GM released a new power-shifting 4-speed planetary transmission as optional equipment on Oldsmobiles (Buicks in '38). This was the direct predecessor of the Hydra-Matic. This had a foot-operated plate clutch for starting up; but the transmission shifted automatically once the car was rolling. There were two speeds in Drive range and two more in an Emergency Low range. This early planetary transmission had many of the features later used by the Hydra-Matic, like two oil pumps, shift governors, hydraulically-operated multi-disc clutches, throttle modulation and a kick-down gear for passing. This was not the first use of a planetary transmission on American cars as the Model T Ford had used a 2-speed foot-operated design for years. GM's breakthrough was to provide for automatic shifting under power through hydraulic servo clutch action. And, just as important, was the principle of modulating the timing of the shift and the severity of the clutch action in accordance with throttle opening. This was the big fault of the earlier mechanically actuated Reo Self-Shifter. It always shifted at the same speed (14 mph), regardless of throttle opening, and at light throttle the shift had to be very jerky—to prevent excessive slip at full throttle. GM employed hydraulics to smooth up this shift action, an extremely important development.



REO'S "Self-Shifter" of 1933 had 3-element internal gearset which gave a ratio of 2.07:1 for starting. Multi-plate centrifugal clutch locked it into high at 14 mph.

From this point it was a short step to adding a fluid coupling to the new GM 4-speed planetary gearbox, to do the job of the foot-operated plate clutch and evolve the first fully-automatic transmission. The first Hydra-Matic was introduced on the 1940 Oldsmobiles, and on Cadillac the following year. The shifts were phased to run through all four gears in Drive range. Another vital feature was the "split-torque" principle. The engine drove the fluid coupling pump through the front planetary gearset. This had the effect of reducing slip losses in high gear, since only about 40% of the engine torque was transmitted through the coupling (the rest direct through gears). Slip loss was only 0.5–1% in high gear. This also served to reduce coupling pump speed 40% below engine input speed, which was important in reducing the car's tendency to creep at stoplights. The Hydra-Matic was a tremendous engineering triumph.

Chrysler saw the handwriting on the wall and rushed out with a semi-automatic transmission at the same time the H-M was introduced. It used a fluid coupling with a more or less conventional 4-speed ▶



V-DRIVE torque converter transmission developed by GM for buses in late '30s had no auxiliary gears and used plate clutch to lock out converter slip at cruising speed.

AUTOMATIC TRANSMISSIONS

synchromesh gearbox. In Drive range it started off in third gear and shifted to high through an electro-vacuum linkage when the driver lifted his foot from the accelerator. The fluid coupling permitted starting without the foot clutch. A manual Low range gave shifting through first and second. This design was used through the early '50s, although later versions used hydraulic power for shifting instead of vacuum. Kickdown power-shifting was achieved by momentarily interrupting the ignition to relieve engine torque long enough for the power section to move the shift dogs. It was a compromise arrangement: These Chrysler fluid drives left no lasting mark on automatic transmission design.

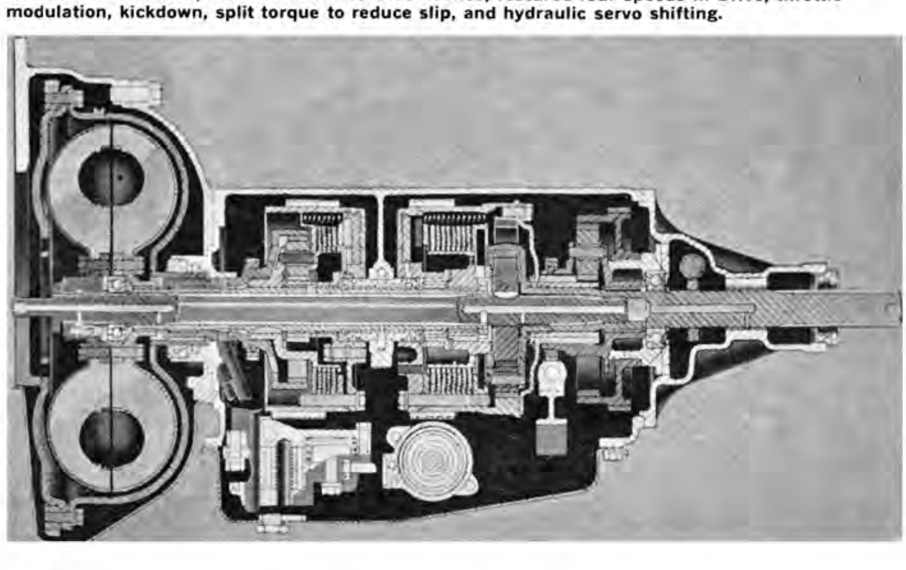
The next big breakthrough came in 1948 with the Buick Dynaflow. This was the first use of a torque converter in an American car. The big difference between the Dynaflow and some earlier bus converters was that the stator was mounted on an overrunning clutch, so it could free-wheel at high speeds and the whole unit would act like a simple fluid coupling. This eliminated the need for a lock-up clutch and perfectly adapted the torque converter to the light-load characteristics of passenger cars, where the stators were free-wheeling most of the time. Actually, this new Dynaflow torque converter had certain special features. There were two pump turbine elements and two stators. These had different blade angles, so it would start to free-wheel at different points in the speed range. The overall effect was to give a significant bulge in the efficiency curve at medium speeds and high loads, and a healthy stall torque ratio of 2.2:1. Buick engineers thought this would be plenty of torque multiplication for starting up, so they didn't use their planetary gear ratio of 1.82:1 in Drive range (this was available only with the hand lever into Low range). Needless to say the acceleration of those early Buick Dynaflows was pretty sluggish; converter slip was terrible around town and fuel mileage nose-dived. Then Chevrolet came out with its 2-speed Powerglide the following year, using the very same setup. This is when automatic transmissions gained their reputation for poor accelerative performance. They've barely lived it down, even today.

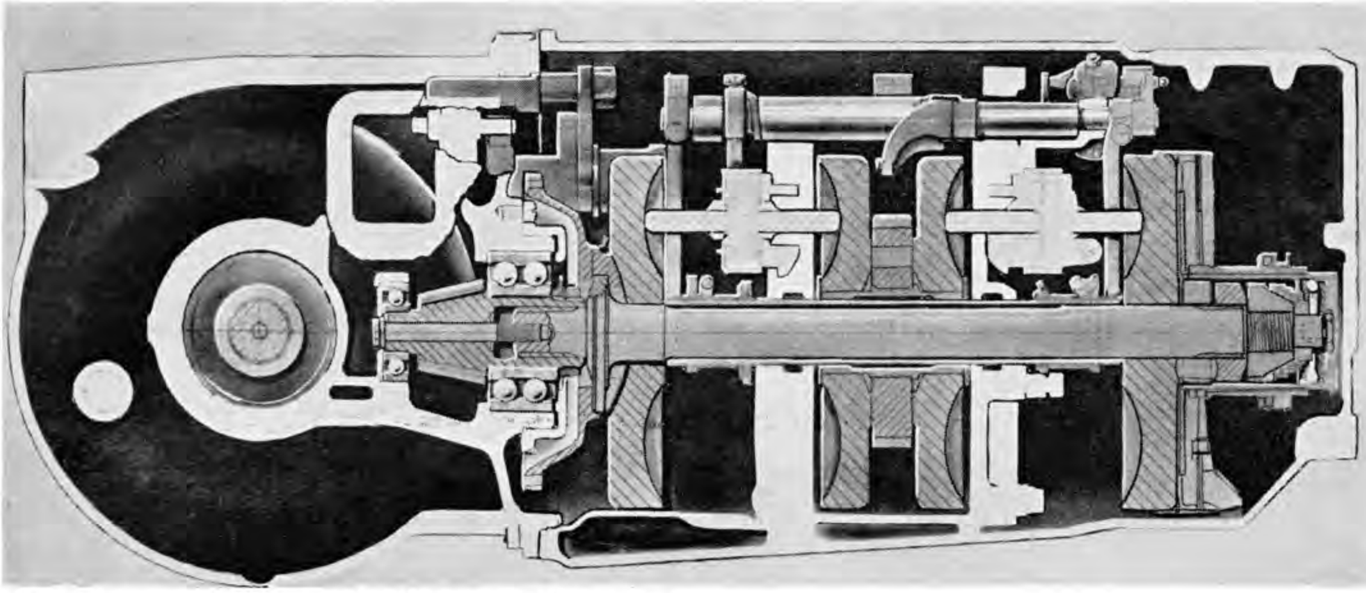
Ford and Studebaker took a different tack with their first torque converters around 1950. They used two planetary gearsets to provide three forward speeds and the transmissions would start out in second gear in Drive range, automatically shifting to high at a speed dependant on throttle opening. Studebaker even used an auxiliary plate clutch to lock out the converter at cruising speeds, for maximum response and fuel economy. Low range would give first gear on these designs. These transmissions gave much more satisfactory all-around performance.

The Chevrolet Powerglide was soon changed to provide the 1.82:1 gear step-up in Drive range and Ford and Studebaker countered by using all three forward speeds in Drive. This gave them the edge again. When Chrysler tooled up its new automatic in 1953, it used only two speeds, but in conjunction with a more sophisticated converter unit that gave a stall torque ratio of 2.6:1. Chrysler said this was an adequate compromise between performance, complication and cost. It probably wasn't, since Chrysler went to three speeds with the high-torque converter with its modern TorqueFlite.

Meanwhile, Buick engineers just wouldn't go along with the crowd. They didn't like the slight jerk that occurs when planetary gears shift ratios. They wanted a perfectly smooth transmission through the whole speed range. Their answer was a twin-turbine setup where the primary turbine was geared to the output through a planetary step-up that gradually phased out as the car speeded up (there was no distinct ratio shift). This was later supplemented with a variable-pitch stator element. The pitch on these blades would be changed through a mechanical linkage when the driver floored the throttle, giving a slight increase in torque multiplication ratio and a speed-up in engine input that added power. The two features together gave a very smooth, flexible transmission, with fair fuel economy and pretty decent

FIRST HYDRA-MATIC, introduced on '40 Oldsmobiles, featured four speeds in Drive, throttle modulation, kickdown, split torque to reduce slip, and hydraulic servo shifting.





FRICTION DRIVE automatic developed by GM Research in 1928; drive was transferred between torus-shaped races by rollers, which pivoted to vary ratio.

acceleration performance throughout the speed range, but still without using the emergency low gear behind the converter.

In 1957 Buick engineers further extended this design concept to include three geared turbines with the twin-pitch stator, to give a transmission with tremendous range, smoothness and performance. The stall torque ratio in low pitch was 4.8:1 at an engine input speed of 3200 rpm. On full-throttle acceleration the engine speed raised only gradually, not in phase with car speed as do conventional automatics. The intermediate turbine didn't start to free-wheel until car speed reached 88 mph, with the engine turning 3800 rpm. At all full-throttle speeds below this there was some hydraulic torque multiplication. This Buick Flite-Pitch Dynaflow, and the similar Chevrolet Turboglide that came out on the '58 models, were undoubtedly the most highly-advanced automatic transmissions ever developed and certainly the closest to giving ideal performance characteristics for a piston engine that can't develop torque when stalled.

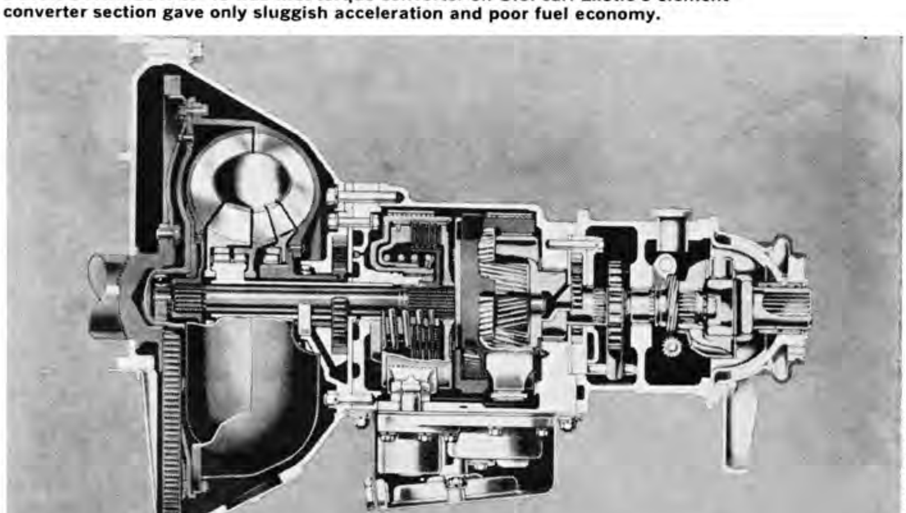
But perhaps it was too much of a good thing. These triple-turbine torque converters proved to be very expensive to produce. Drivers didn't like the "loose" coupling of the engine and the continual speeding up on small throttle openings. And the high slip at low speeds ate up a lot of gasoline. They never caught on with the public; Buick and Chevrolet soon went back to their original concepts. In fact, other attempts to "fancify" basic transmission concepts eventually failed. Look at the Hydra-Matic. GM engineers adapted auxiliary fluid couplings that could be filled and emptied to pick up the shifting loads on planetary gears. This smoothed the shifts a lot but added complication and cost.

So now the American auto industry is back almost completely to the simple 3-speed, 3-element torque converter, running through all three gears in Drive range. Stall torque ratios average about 2.3:1 at around 1800 rpm engine input speed, with a planetary gear ratio of about 2.5:1 in low and 1.5 in second. This combination gives excellent breakaway acceleration with heavy cars and yet the close ratio between second and high allows 70 or 75 mph car speed in the kickdown gear for passing on the highway.

GM gets extra shifting smoothness on its new 3-speed converter by picking up the planetary loads off overrunning clutches, so there is no problem of timing two clutch actions that might cause a jerk. Other than this, the above seems to be the winning combination in our complex civilization today.

Next month: Brakes. ■

BUICK DYNAFLOW of '48 was first torque converter on U.S. car. Exotic 5-element converter section gave only sluggish acceleration and poor fuel economy.



GM PHOTOGRAPHIC

THREE-ELEMENT torque converter like Oldsmobile's is now industry standard.