

THE DEEP BREATHERS

Ford's sohc V-8 and Chrysler's Hemi are Milestone Engines

BY ROGER HUNTINGTON

SINCE FORD fielded the single-overhead-camshaft 427 Hemi-head engine to challenge Chrysler's famous 426 pushrod Hemi, car enthusiasts have argued the comparative performance potential of the two designs. However, valid comparisons could not be made until detailed dynamometer test data from the factory labs became available. This material recently was presented in two SAE papers on the engines by engineers at Ford and Chrysler.

These two basic engine designs, milestones in the performance evolution of the American automobile, actually are quite similar except for valve gear. Similarities are in hemispherical combustion chambers, fully machined, with central spark plugs (slightly offset), and large, well-streamlined intake and exhaust ports. Valve inclination angles (with respect to the cylinder axis) also are similar. Valve head diameters are nearly equal. Both engines use 2.25-in. intake valves. Exhaust valve diameter is 1.94 in. on the Chrysler, compared with 1.90 on the Ford. Both engines used forged pistons with highly domed tops to provide a compression ratio of 12:1.

There also is much similarity in the lower end. Both engines have nearly equal bore and stroke dimensions and equal displacement. Bearing sizes, and the layout and balancing of the crankshafts are similar. Weights of pistons and connecting rods are fairly close. There shouldn't be any great differences in the friction losses suffered by the two engines. The Chrysler Hemi has somewhat longer, heavier rods than the Ford; but this effect may be offset by reduced piston side thrust with the longer rods. Lower-end friction apparently is equal.

The most important difference between an sohc and pushrod engine is the lower valve gear reciprocating weight on the sohc. This is accomplished by eliminating the weight of lifters and pushrods. Lower reciprocating weight allows the sohc to turn at higher rpm without "floating" the valves, other factors being equal. Valve spring pressure necessary to make the valve motion follow the cam is a function of the valve acceleration rate and the reciprocating mass, with the acceleration rate increasing as the square of the rpm. Theoretically it might seem

possible to increase the valve spring pressures on a pushrod engine to raise the valve-float speed to match that of the sohc engine, or at least put the valve-float speed so high that the lower end would become the critical factor in limiting crank speeds. It's not that simple. Super-high spring pressures bend pushrods and cause premature rubbing failures between cam lobes and lifters. There is no way that a pushrod engine can match an sohc in rpm potential.

The difference in valve gear reciprocating weight between the two engines, however, may not be as much as one might guess. Chrysler engineers have gone to great effort to reduce this on their pushrod Hemi. Light tubular pushrods and simple, light barrel-type lifters are used. By comparison, the sohc Ford uses massive rocker arms with rollers on the inner ends that follow the cam.

Another advantage of overhead cams is in valve acceleration. Valve acceleration rates are somewhat limited on a pushrod engine because there is an inherent flexibility or springiness in the "linkage" that sets up synchronous vibrations that are excited by high acceleration rates. These valve gear vibrations alternately expand and collapse the entire lash-up and prevent the valve motion from closely following the theoretical cam motion. This flexibility doesn't exist on an sohc engine. Most of the experimental cam designs for the sohc Ford engine have used maximum acceleration rates 50% higher than equivalent cams for the Chrysler Hemi. By opening and closing valves more quickly, more area under the valve lift curve and better effective breathing over the full rpm range are obtained. Of course valve acceleration rates aren't the entire goal in cam design. Wonderful things can be done with low-rate cams, but it's another plus factor when basic engine design permits much higher valve acceleration rates.

ANOTHER PRIME advantage of Ford's sohc layout is that, without having to make room for pushrods passing up through the head castings, the designers had much more freedom in port design. Ports on pushrod engines generally must twist around the pushrods to some extent, which restricts breathing. The sohc Ford engine uses huge circular ports, which are said by some designers to provide better breathing characteristics than rectangular ports of equal cross-sectional area. A circular duct has the least amount of surface area in relation to cross-sectional area. This tends to reduce skin friction losses in breathing. Gas flow is said to fill a circular duct more completely than a rectangular duct, due to the natural tendency of the gas mass to pull into a circular pattern. In effect, each square inch of cross-

sectional area in a circular duct passes more air than in a rectangular duct.

How much this affects performance is debatable, but Ford seems to hold the edge in this area. Not only does the Ford engine have circular ports, it actually has somewhat greater port cross-sectional area.

An area in which differences in valve gear could affect overall performance is in cam drive friction losses. Certainly the Ford engine, with its long cam chain and multiple chain sprockets, would lose more than Chrysler's simple pushrod mechanism with its short chain drive to the central cam. The SAE papers have no specific figures; but a difference of 5-10 bhp in favor of the Chrysler pushrod Hemi can be estimated.

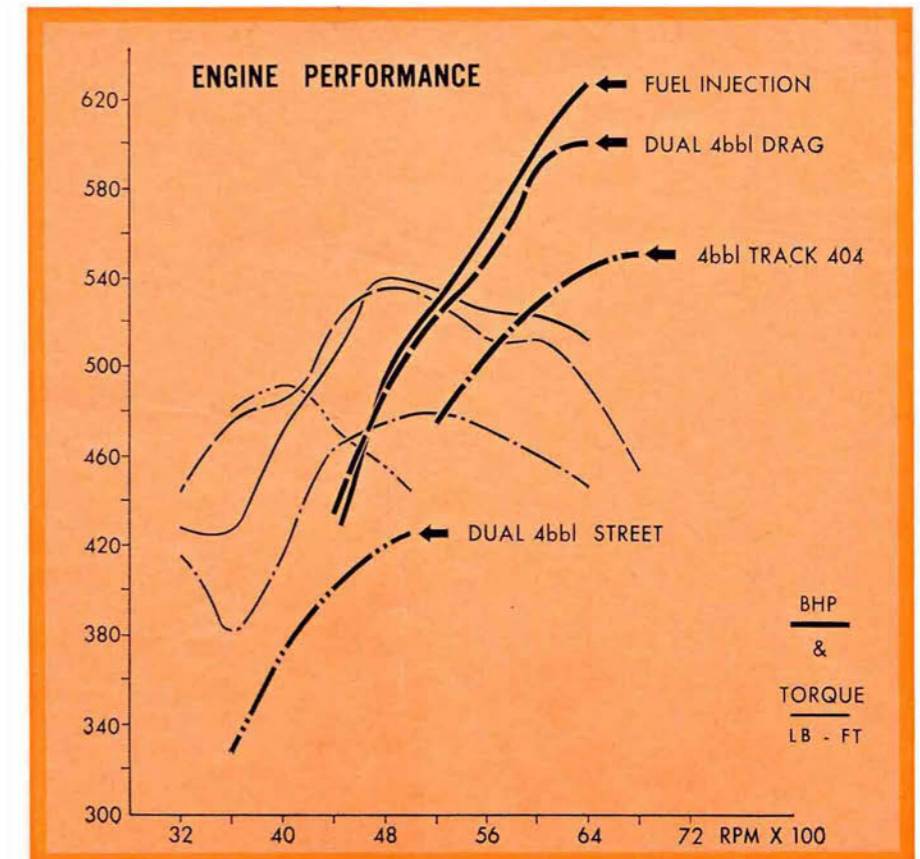
Comparison of actual dynamometer test figures must be done carefully because of possible differences in the way the engines were set up. Variables could exist in cam timing and lift, carburetion or exhaust scavenging efficiency. If the two engines could be compared with exactly equal cam timing and carburetion, true differences in breathing efficiency at the ports could be isolated. In the tests, the sohc Ford engine used regular in-line 2x4 drag racing carburetion (Holleys) and cams of 328° duration, 112° overlap and 0.565 in. lift. The Chrysler 426 Hemi used similar carburetion, but on a crossover ram-type manifold, with a cam of 312° duration, 88° overlap and 0.54 lift. Compres-

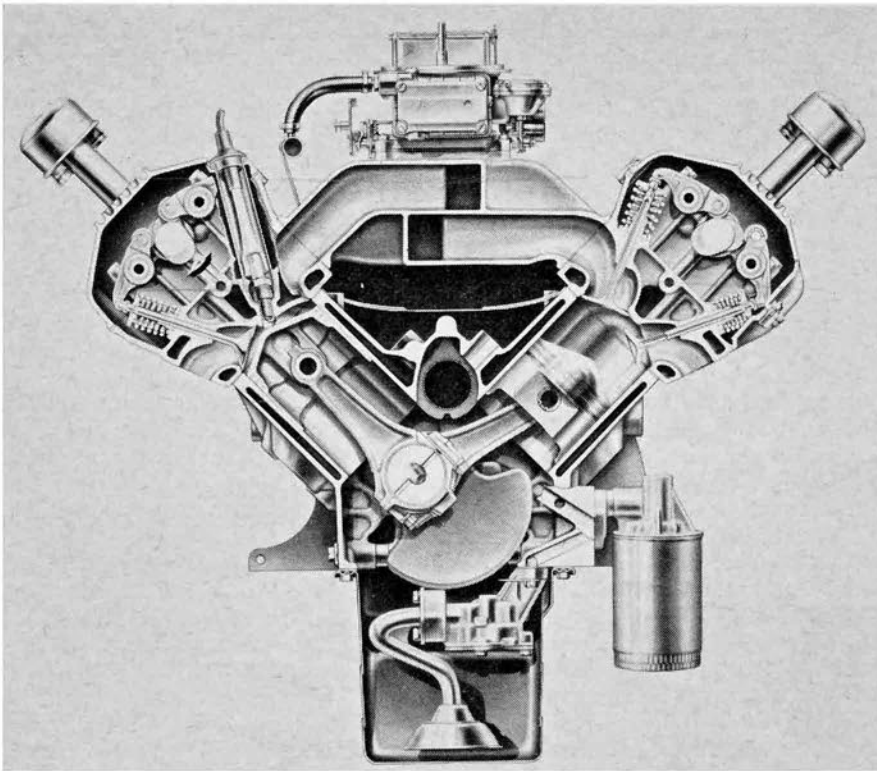
sion ratio was approximately 12:1 on both engines. Both engines carried standard scavenging-type exhaust headers with individual pipes for each cylinder. Maximum test rpm was limited to 7000 on the Ford engine and 6400 on the Chrysler, mainly because factory dynamometer equipment was not up to sustained testing at higher speeds and loads.

UNDER THESE conditions, then, the Ford engine showed an output of 616 bhp at 7000 rpm, compared with 600 bhp at 6400 for the Chrysler 426 Hemi. This was the peak of the power curve for the Chrysler, but the Ford curve was still going up slightly and might have peaked a bit over 620 bhp at about 7400 rpm.

The Ford shows the expected slight edge in top-end performance on these tests, but what is not so expected is the peak of the power curve of the Ford coming nearly 1000 rpm higher than the Chrysler. What's the reason? The rpm at peak power is primarily a function of breathing efficiency and internal friction losses, which rise approximately as the square of rpm. Earlier it was suggested that both engines are nearly equal in friction losses at a given rpm. Hence it must be a breathing phenomenon. Perhaps the ram-type intake manifold on the Chrysler actually is choking off breathing at 6500 rpm. The "tuned" passage length, from the plenum cham-

POWER AND torque curves for various versions of the Chrysler Hemi show the effects of ram manifolding on bhp (vertical axis) and rpm.



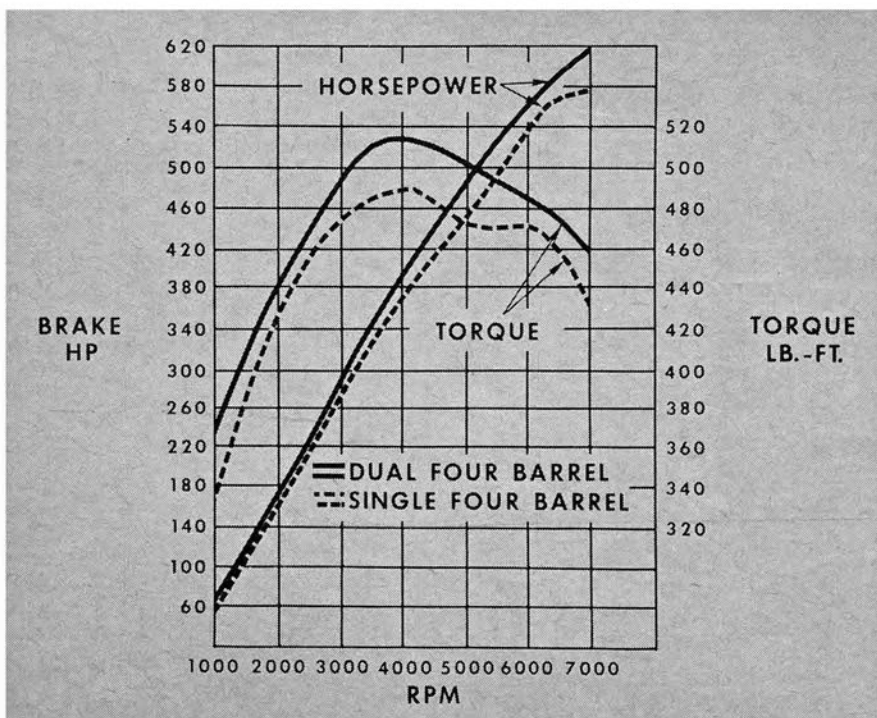


FORD'S SOHC 427 Hemi-type competition engine develops 600 bhp at 7000 rpm on gasoline with dual 4-barrel carburetion. Torque is 515 lb.-ft.

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ber under the carburetor to the inlet valve, is 12.4 inches. According to formulas developed by Chrysler engineers in the 1950s, when they were working on ram manifolds for street engines, this length would provide its major resonant ram boost in the speed range from 6000 to 6500 rpm. Apparently above 6500 the long passages

IMPROVEMENT OF 40 bhp at the top end with dual 4-barrel carburetion is shown in torque and power curves for the standard sohc 427 Ford Hemi engine.



actually hamper breathing as the power curve peaks off quite sharply at this point.

THIS EFFECT of the ram manifolds on breathing can be observed by studying the torque curves of various Chrysler Hemi engines. Note the humps at various rpm. These are primary and secondary resonant points, at which natural acoustic pressure waves moving along manifold passages literally supercharge the cylinders at certain speeds. Note on the 2x4-carburetor drag engine humps occur at 6200 rpm, 4800 and 3600. The hump at 6200 is the primary boost. The engine pulls its maximum torque at 4800 rpm, which is 535 lb.-ft. The breathing at this point is reinforced by the tuned passages. Then the major secondary boost would occur at about one-half the primary speed, 3600 rpm.

The other engine curves provide opportunity for comparison. The fuel injection unit has 16.3-in. ram passage lengths, with tubes on top of the injector bodies. This combination shows 625 bhp at 6400 rpm, with the curve still rising steeply. In this case, the major ram boost would occur between 4500 and 5000 rpm, near the peak torque point, with considerably better breathing through the full rpm range than offered by carburetors and manifolds.

The 404-cu. in. NASCAR track engine was developed for the 1966 rule limiting Class II cars to 405 cu. in. on the fast speedways, a rule which has since been dropped. Because NASCAR engines are limited to one 4-barrel carburetor, Chrysler engineers have expended time and effort in development of a ram-type manifold that would take absolute maximum advantage of this situation. What they produced was one huge plenum chamber under the carburetor, with ram passages to the individual head ports sweeping across the bottom of the chamber. Inlets are located on the opposite sides from the ports they feed. Divider "dams" in the floor of the chamber spread the fuel/air mixture to the outside of the chamber where it can be picked up by the passage openings.

This unique manifold has proved extremely efficient for its intended use. The effective passage length is 14.4 in. for a major ram boost in the 5000-5500 rpm range. The volumetric efficiency of the engine in this range actually is above 100%! In other words, the cylinders are receiving a slightly greater volume of fuel/air mixture on the intake stroke than their theoretical piston displacement. The engine literally is supercharged by the natural acoustic pressure waves! This is a remarkable achievement and shows what can be done with ram tuning using standard carburetors. The science is easier with Weber carburetors or fuel injectors; but much re-

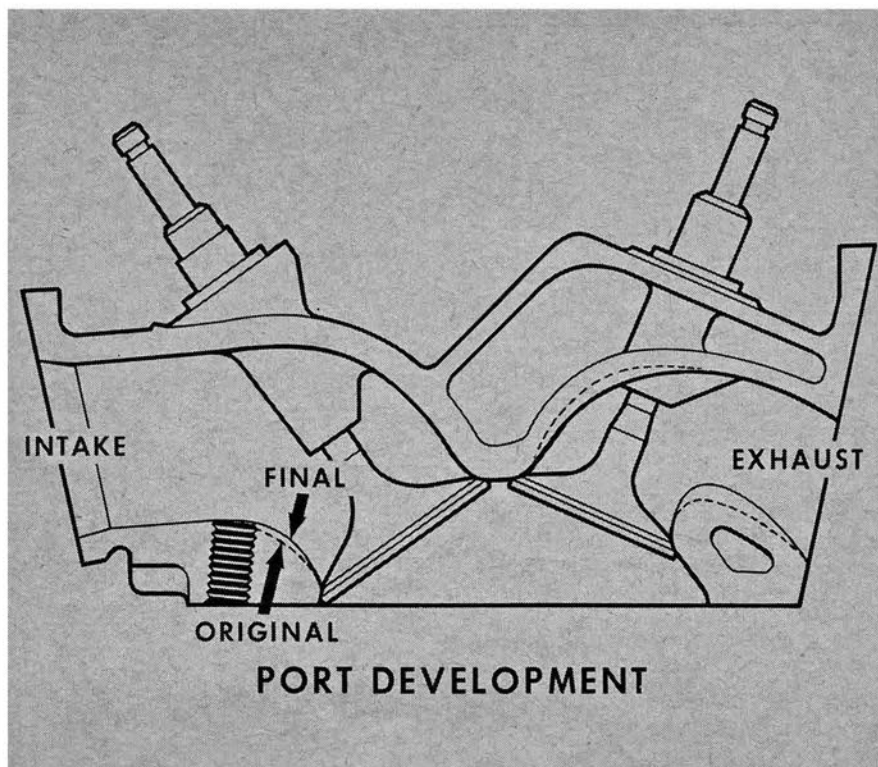
mains to be learned in applying the principles with 4-barrel units. Incidentally, the 404-cu. in. track engine, with the single 4-barrel carburetor and a 328° cam, delivers 550 bhp at 6800 rpm, which is very strong for that displacement. Furthermore, the 404 engines used by Richard Petty and Paul Goldsmith at Daytona last February were developing 600 bhp.

On the other hand, Ford engineers have barely scratched the surface of manifold design. Those crazy humps don't appear in torque curves for the sohc engine. Ford manifold designers concentrated more on getting nearly equal passage lengths between plenum and port, with smooth, gentle curves for optimum mixture distribution and minimum breathing loss at the top end. Tuned passage length wasn't given much attention. The result is that Ford manifolds appear to perform better above 6000 rpm, but produce less mid-range torque. Note that the peak torque on the dual-quad Ford engine is 515 lb.-ft. at about 4000 rpm, compared with 535 lb.-ft. at 4800 for the 2x4 Chrysler 426. Ford engineers believe this mid-range torque is not important in track and drag racing. Chrysler engineers believe it is.

This effect also is shown in volumetric efficiency curves for the Ford engine. A maximum of 91% efficiency is reached at 6500 rpm. The Chrysler Hemi produces up to 102% at 5600. But the Ford manifolds definitely produce better breathing above 6500 rpm.

WHAT is the maximum rpm potential of the engines? Chrysler engineers say their 426 Hemi will turn to 7700 rpm for very short bursts with the competition valve springs of 380 lb. of pressure at the valve-open point. This is right on the edge of float. Ford engineers haven't been able to take their sohc engine into a definite float range due to limitations in the dynamometer equipment. The engine was flashed to 8100 rpm once with no sign of trouble. This was with only 275 lb. of spring pressure at the valve-open point. Competition drivers using the sohc Ford engine hit 8500-9000 rpm regularly. There is no question that the rpm potential of the Ford engine is more than 1000 rpm above the Chrysler pushrod Hemi, but Ford doesn't yet have the cam and manifold designs to take full advantage of this rpm potential in terms of usable bhp and torque spread.

Another important comparison is in engine weights. The Chrysler people have been very secretive about the weight of the Hemi engine, apparently because the weight saving over the early Firepower Hemi was not as great as expected. Estimated weight for the 1966 Street Hemi with cast-iron heads and all accessories, but no flywheel, is 775 lb.



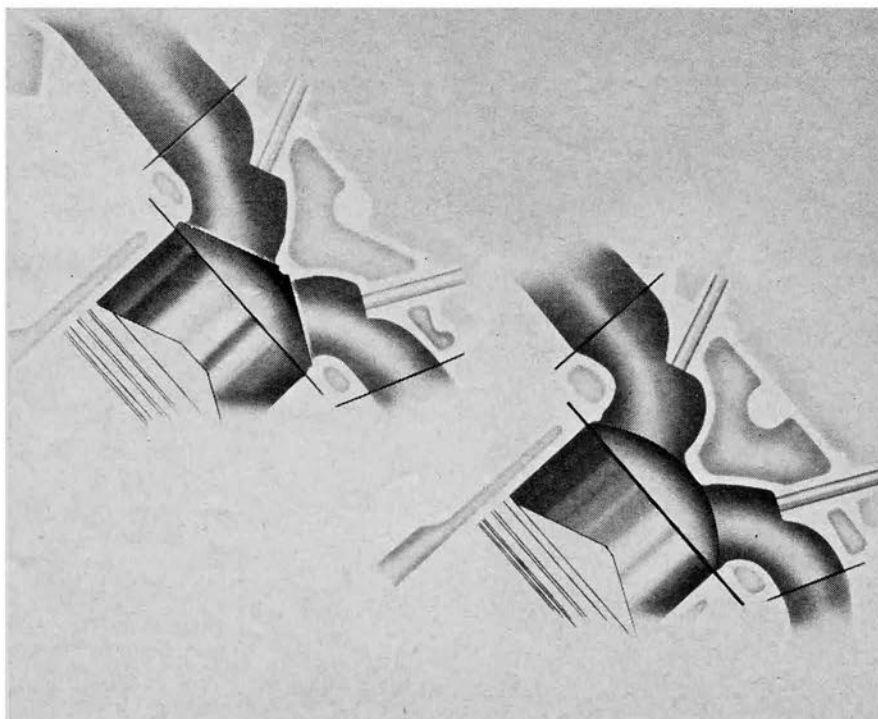
BREATHING FOR the Chrysler Hemi was improved by modification of port contours to provide more of a venturi shape and less abrupt turns.

This is almost the same as the old Firepower. The competition version of Chrysler's Hemi with aluminum heads and magnesium manifold, weighs 60-70 lb. less. The sohc Ford engine is a little lighter, partly because the block and lower end of the earlier 427 pushrod engine from which it is made are relatively light. Ford says the regular sohc

engine with original cast-iron heads, weighs just under 700 lb. with accessories. It's approximately 100 lb. heavier than the pushrod 427.

TO REVIEW comparisons briefly, the sohc Ford engine appears to be a shade stronger—3% to 5%—in top-end horsepower than the Chrysler Hemi, as a

ORIGINAL CONTOURS for the sohc Ford were broader where valve guides intrude. Final contour venturi action accelerates fuel/air charge.

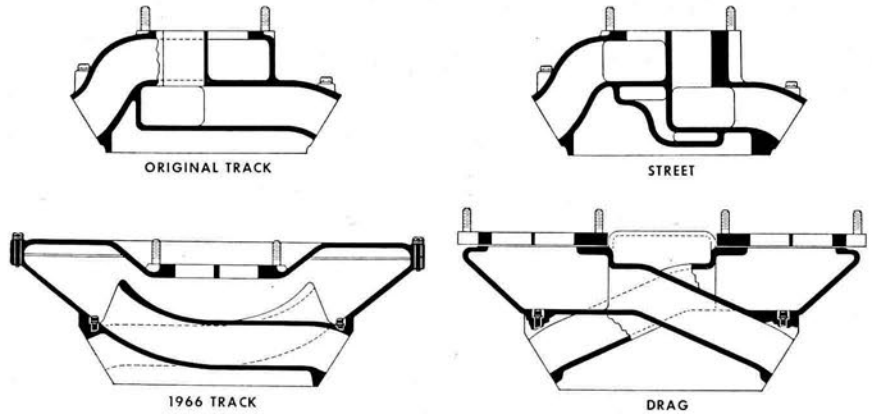
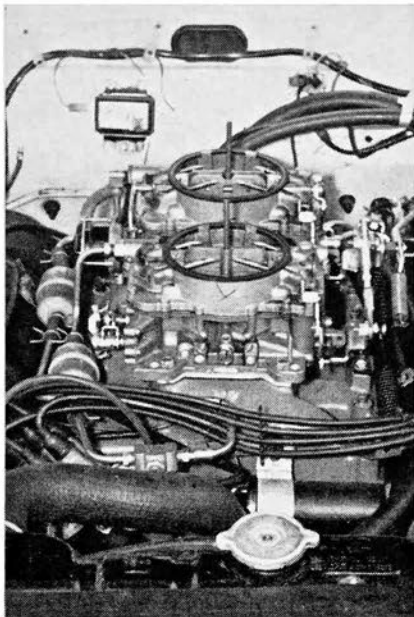


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result of better port breathing. And the Ford engine's rpm potential probably is at least 1000 rpm higher, offering possibilities for future power development that haven't yet been probed. The Ford engine also seems to be 50 lb. lighter than a Chrysler Hemi in equal trim. On the other hand, the Chrysler Hemi is a much more finished, sophisticated design in terms of producing the last ounce of available power. This is especially evident in port and manifold design. Thus it appears the Chrysler Hemi engines are staying with the sohc Fords today mainly through refined design. And there's the matter of long-run reliability. The Chrysler engine has been highly refined for hard 500-mile track races. The sohc Ford uses the block and lower end developed for the pushrod 427 racing engine, which also was very refined and reliable. But who knows how that extra 50 or 100 horses given by the better head breathing will affect this reliability when the engine is put on NASCAR tracks? Ford might have to start all over again.

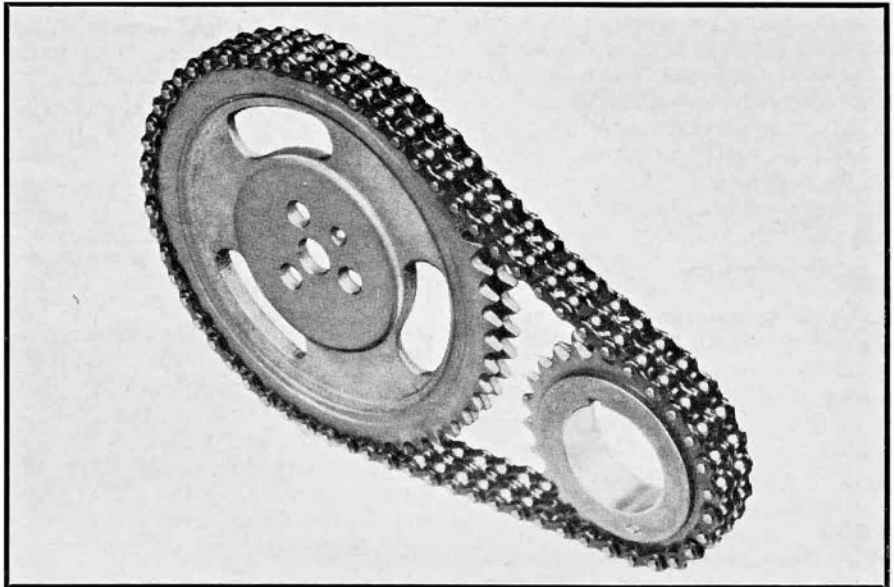
It can be summed up by looking at the Chrysler pushrod Hemi as a polished, finished, modern racing engine. The sohc Ford perhaps carries greater potential, but is very new and untried. ■

STREET version of Chrysler's Hemi carries pair of Carters.



INTAKE MANIFOLD SECTIONS

CHRYSLER HEMI manifolds include the 5200-rpm 1966 track model with ram tubes 14.4 in. long and the 6200-rpm drag version with 12.4-in. tubes.



CHRYSLER HEMI'S camshaft timing components—double roller chain, steel crankshaft sprocket and cast-iron driven sprocket—show great strength.

THOUGH CUMBERSOME in appearance, sohc Ford drive sprockets, idler and chain offer less valve train inertia than Chrysler Hemi pushrods.

