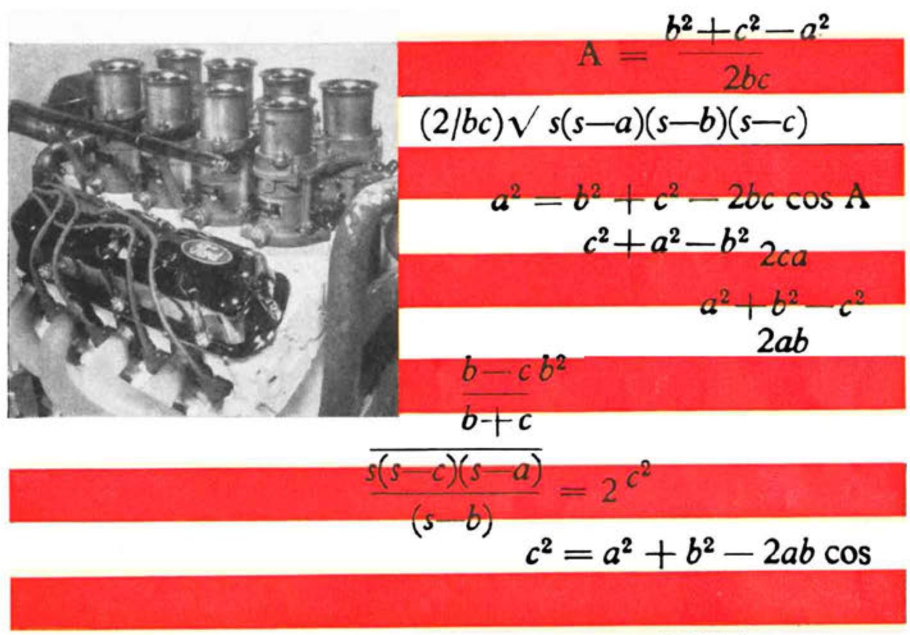

THE LIVELIEST LIVELY ONE

This year motor racing has been invaded by complete outsiders. A Rover turbine car finished 8th overall at Le Mans (although *hors classification*) and a Ford-powered Lotus nearly won at Indianapolis. In both cases painstaking and methodical preparation was substituted for experience, and special racing car builders were relied upon to supply suitable chassis. The decision to concentrate on the power plants paid off handsomely for both.

We decided to investigate the preparation of the Ford Indianapolis engine to find out how an American production engine can be transformed into a formidable competition machine—and how racing experience will be of value both in further development of existing engines, and in the design of new production engines.

Judging by the results of the Indy 500 last year, a car must be capable of lapping at 150 mph at least to be competitive. According to Colin Chapman, who was to supply the complete car except for the power unit, this could be achieved with 325 bhp *provided the engine weight did not exceed 350 pounds.* In standard form the Ford Fairlane 260 cubic-inch V-8 produces 164 bhp and weighs 455 pounds. This engine was chosen as a basis for the Indy project as it was the nearest in displacement to the 4.2-liter (256.2 cubic-inch) limit, and also the newest design in the Ford engine range.

Ford Division's management insisted that there should be the least possible deviation from standard, so changes were contemplated only when held to be necessary for performance, durability or weight considerations.

George F. Stirrat had designed the original 221-cubic-inch Fairlane engine and headed the development of the 260 and 289-cu. in. versions. He felt that the engine had the potential and placed Bill Gay in charge of the Indy project. Gay in turn received invaluable aid from Tom Landis and Ed Pinkerton. They set out on two routes simultaneously: increased compression ratio and improved breathing to get power, and substitution of light alloys

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for cast iron to get lightness.

The cylinder block was made by Alcoa in sand-cast aluminum from experimental wood patterns used by Stirrat in developing the 260 engine. Bosses were added to accommodate a six-stud-per-cylinder pattern in place of the four-stud standard pattern, and a different flange for the front cover. The chain camshaft drive was judged impractical in view of the high rpm expected, so a new front cover was designed to house a gear drive for the camshaft, and the oil, water and fuel pumps. It was cast in magnesium. Tests were made with aluminum gears; they chipped, so steel gears were installed.

Dry-cast iron liners with a light press-fit gave the required cylinder wall surface. The bore was 3.76 inches compared to 3.80 in the cast-iron block.

The cylinder heads were also sand-cast in aluminum, with alloy cast steel valve seat inserts and steel valve spring seats. Combustion chambers retained the normal "squish" shape of the Fairlane head, with special pistons giving a 12.5 to one compression ratio. The cooling water outlet was moved from the intake manifold face to the front of the head, and a boss was added for improved delivery of pressurized oil to the valve train.

Bill Gay is a great believer in high-lift cams, and a figure of .540 inch was settled on, with considerably enlarged valves: intake valve diameter 1.80 inches against 1.67 standard; exhaust valve diameter 1.50 inches against 1.45 standard.

Ford pioneered cast-iron crankshafts in 1933, when peak horsepower was developed at 3,200 rpm. Cast iron is still used in all Ford production engine crankshafts, including the Cobra version (with peak bhp at 5,800 rpm). But for Indianapolis the engine would have to operate continuously in excess of 7,000 rpm, and rather than run the risk of finding the limitations of a cast-iron crankshaft in front of 230,000 spectators, Stirrat and Gay decided to machine a crankshaft (with the same 2.87-inch stroke) from a solid billet of forged steel.

Because of space considerations, the normal crankshaft damper at the front end could not be used, and a new, flatter damper was designed, incorporating an inertia member with increased rubber contact area. It was tuned to a higher frequency because of the higher rpm expected. A lip-type rear oil seal was used in place of the standard rope seal to reduce friction at high speeds. All journals were cross-drilled for improved bearing lubrication.

Connecting rods remained standard, but were shot-peened and polished to remove surface stress raisers. Large-diameter cap bolts were fitted to withstand the higher inertia loading of very high crankshaft speeds. The bronze bushing for the piston pin is a standard Ford part—the heavy duty bushing for the 390 Y-block engine.

Indy regulations prohibit any addition of oil during the race, so a dry sump was decided upon, and a four-gallon oil tank installed. This move also gave a lower center of gravity and a reduction in frontal area. The oil pump is mounted on an extension of the first main bearing cap and driven at 0.727 crankshaft speed. The scavenge pump has a 50% greater capacity than the pressure pump.

The ignition system consists of Ford's recently developed breakerless distributor, a transistorized amplifier and a conventional coil giving uniformly high voltage output throughout the speed range.

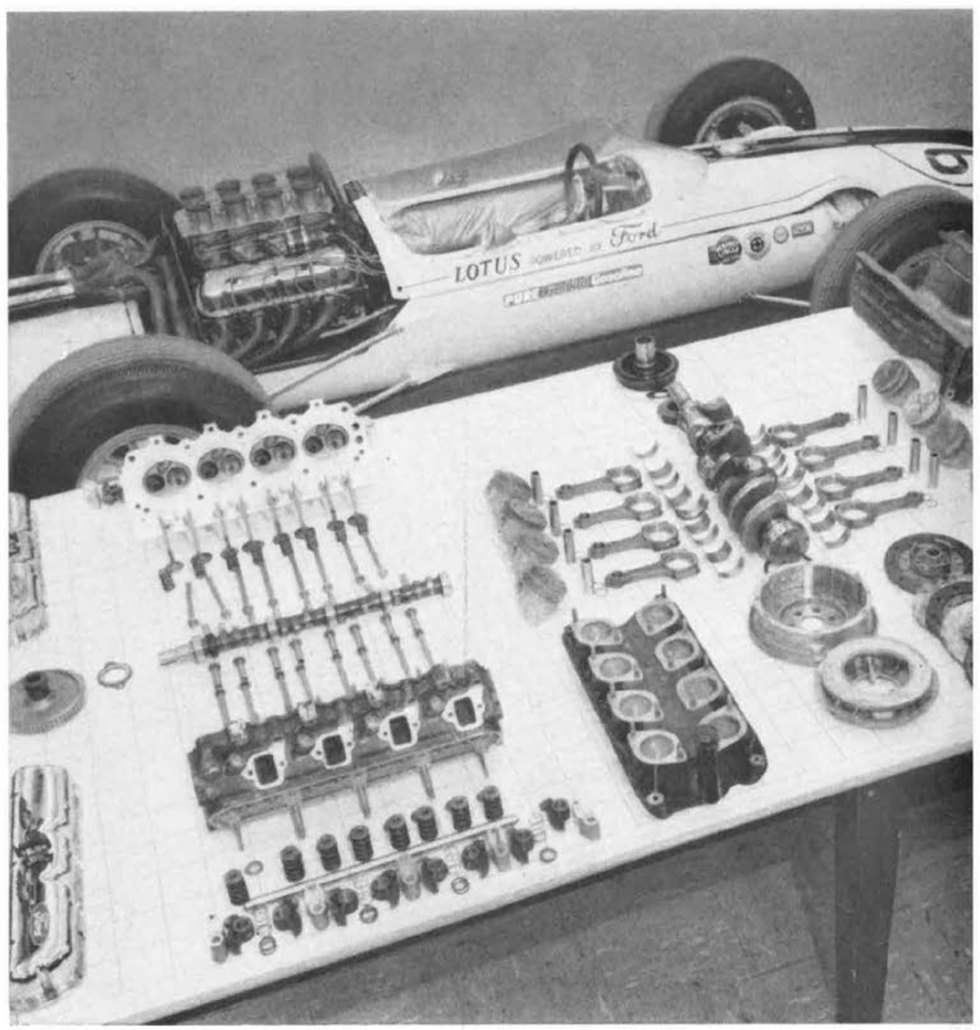
Stack exhaust pipes were used on early test engines, but experiments with "spaghetti" exhaust pipes (designed for Lotus by V. W. Derrington) showed these to give improved extractor effect which was particularly beneficial in mid-range torque.

At the early planning stage two radical changes to the production engine were considered—fuel injection and overhead camshafts. Bench tests with carburetors indicated that the 325 bhp goal was attainable without fuel injection, and tests at Daytona with alcohol injection vs. gasoline fuel and carburetors gave results which pointed in favor of the latter. Alcohol gave 2.22 mpg at an average of 154.8 mph and gasoline 6.41 mpg at 146.7 mpg with an Indy test engine installed in a 1962 Ford Galaxie. No tests were made with gasoline injection—the Hilborn equipment was put away and more Weber carburetors were ordered.

The twin-cam heads went the same way—as pushrod test engines seemed to give adequate power, the extra cams were judged an unnecessary complication which would emphasize the difference between the Indy engine and the production Fairlane V-8. Chapman's minimum requirement of 325 bhp was soon exceeded, and no specific new goals were set. Bill Gay and his helpers then set out to see just how far they *could* go. The development problems came under five headings: (1) Pistons, (2) Head gaskets, (3) Valve gear, (4) Carburetion, and (5) Installation.

The pistons were designed by Ford and made by Thompson Products of a high-silicon (11%) aluminum alloy. They carry two 1/16-inch compression rings and a 1/8-inch oil control ring. During bench testing all kinds of piston trouble was experienced; piston crowns burned through, ring gaps distorted and rings broke, and local overheating and scoring occurred. One important alteration seemed to cure all these troubles—the use of a free-floating wrist pin. The pin itself remained standard; it was just checked for length and secured in the piston with flat double-helical spring-steel retainers at each end. The piston problems were solved during the bench test period, and the team went to Daytona with the Galaxie test car in November of 1962, the whole crew feeling fairly confident.

Then gasket trouble set in. The solution was relatively simple—to seal the combustion gases, a groove was made in the cylinder liner



The post-race examination of Clark's engine showed remarkably little wear. The car in the background was raced by Gurney and will now become a show model—in full running order. New engines will be built for next year's season.

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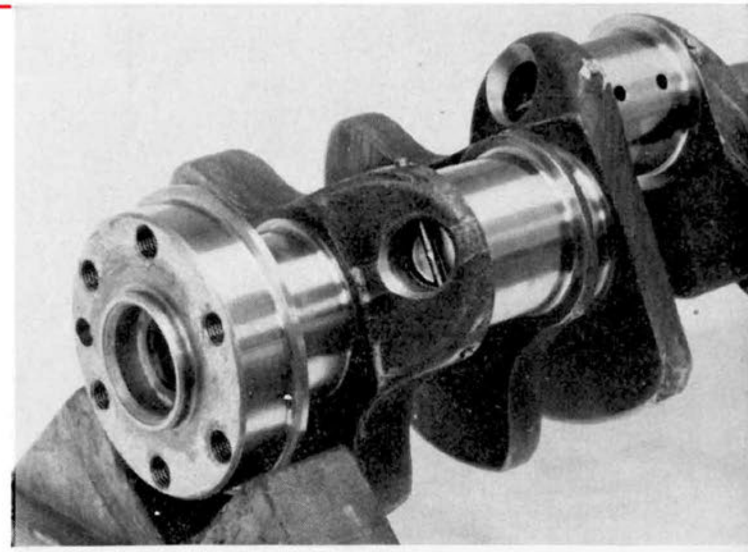
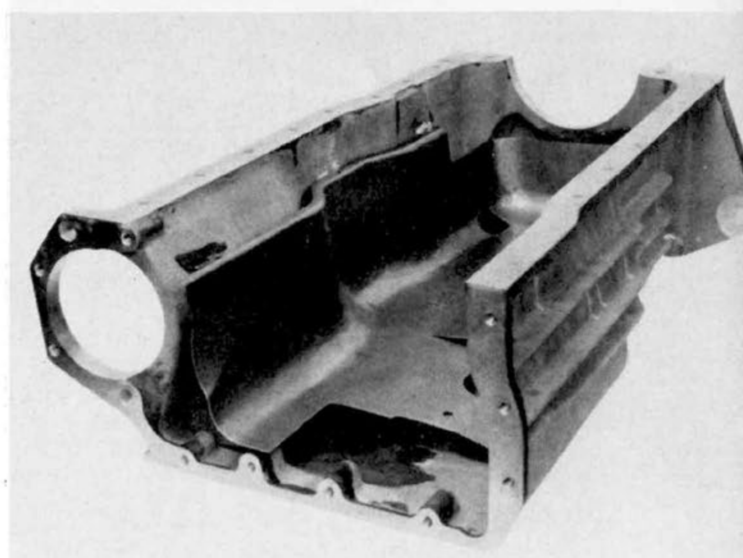
flanges for a Cooper gasket (consisting of five laminated steel discs in a flanged steel casing—somewhat like an O-ring).

The valve gear got through four days and 434 miles at Daytona without serious difficulties, but when the engine was installed in a Lotus chassis and shipped to the Ford proving grounds at Kingman, Arizona, in March, valve train problems developed. The ball-mounted rocker arms would oscillate in two planes with the result that rocker arms broke and studs pulled out, or broke off. The valve gear was redesigned with a conventional rocker arm shaft, providing a stable fulcrum for the rocker arms, and the pushrods were spring-loaded to relieve the double coil valve springs of some of their load requirements at high rpm. This design was tested up to 8,000 rpm.

The first carburetors tried were four double-throat 46 mm Webers. Then a similar setup with 48 mm Webers was tried, with better results, and two models of 54 mm Webers were next. A system with four side-draft carburetors and cross-over manifolds was tried but not developed, as the downdraft units of the same size seemed to give more power. But the best results were obtained with 58 mm downdraft Webers specially designed for Ford—although Weber maintained that they were really too big. And they would quite likely have been too big for road racing, but they gave the best gas flow characteristics within the narrow rpm range used at Indianapolis, so at least the carburetor size had been established.

But carburetion problems persisted. The engine had a flat spot about 4,500 rpm where the idle jet delivery was tapering off fast and the main jet had not yet got up to full delivery. During a period of 6-8000 rpm the engine was mainly dependent on the acceleration pump. This was





Forged steel crankshaft was fitted with new vibration damper tuned to a higher frequency and incorporating a larger rubber contact area. The dry sump is cast in magnesium and the lubrication is notable for absence of an oil filter.

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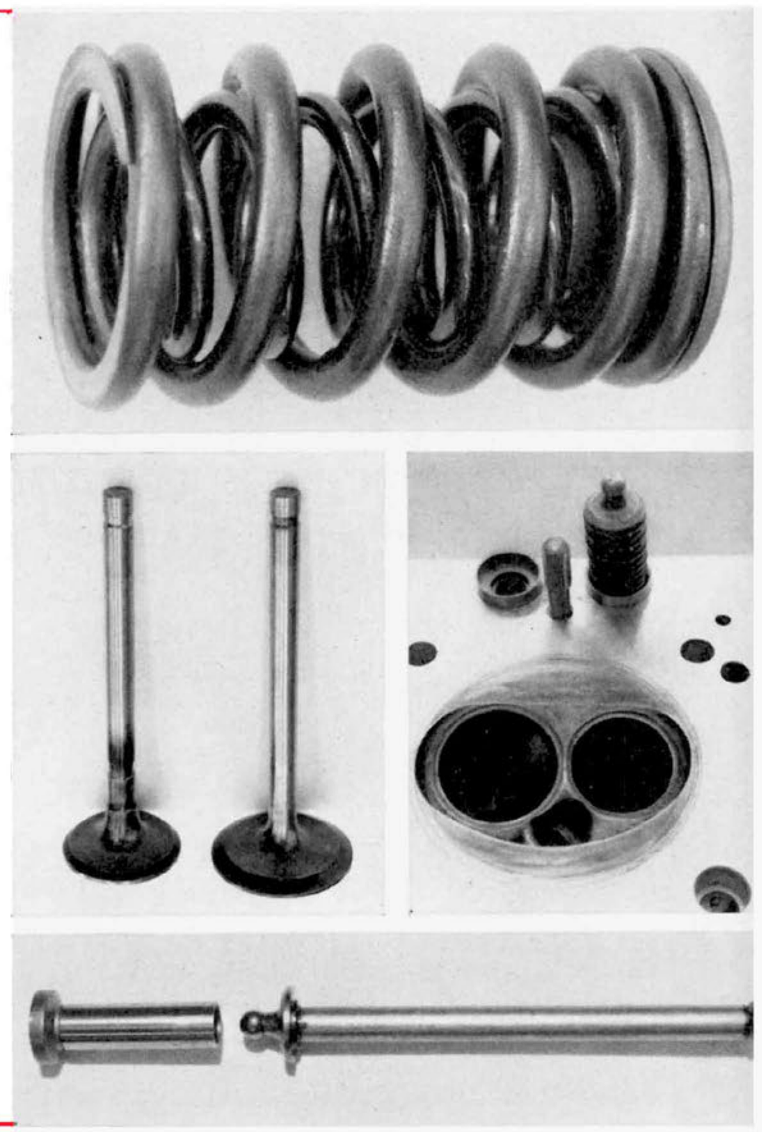
mainly a matter of adjustment, and bench testing failed to show up the main carburetion difficulties.

It was not until Ford got to Indianapolis, in March, 1963, that fuel starvation on turns became a problem. This was solved for the most part by going to higher float levels and different jetting, which in turn meant that the engine would run on a richer mixture on the track and use more fuel than initially had been estimated.

Indianapolis testing also showed a curious loss of fuel through the carburetor air intakes, caused by turbulence around the ram pipes. The amount of fuel lost this way has not yet been definitely established and may well turn out to be so small as to be of only academic interest.

Before the start of Indy trials Ford engineers had faced a number of installation problems. The Lotus frame imposed length restrictions on the engine, and the crankshaft damper was redesigned mainly for this reason. Then it was found that the car had no room for an external oil filter. Experiments were started with a flat filter incorporated in the sump, and engines were also tested *without* filters. As time was getting short and the sump filter could not be fully tested before the race, Bill Gay bravely decided to run the race *sans* oil filter.

In terms of lap times, Ford engineers knew pretty well what to expect before they ever went to Indy. Last fall they had bought a Meyer-Drake engine and studied its torque curve and rpm range. They also had long sessions with Rodger Ward, A. J. Watson and Chick Hirashima, trying to establish exactly what is required of an Indianapolis car and its engine, what rpm variations occur, and with what frequency. They used detailed maps of the track to plot the "line" and establish wheel load figures for the whole lap, aero-



The double coil valve springs (top) were combined with spring-loaded pushrods to reduce the load requirements at very high crankshaft speeds. The valve train was tested up to 8000 rpm. Exhaust valve (left) shows some signs of high temperatures, but no burning. Valve lifters (bottom) were mechanical, and pushrods very short. Valve seat inserts (right) are good as new dynamic drag and rolling resistance. They fed all the data to an electronic computer which came up with the answer that the Lotus-Ford, with the power/weight ratio and frontal area of the prototype Lotus 29, should be able to lap Indy at an average of 150.5 mph. This was as early as January 11th, 1963.

March 24th, 1963, was another significant date, as that day the Lotus-Ford was clocked at Indy, recording an average speed of 150.5 mph. On this occasion the car was fitted with a "black box" to record all relevant data on rpm and throttle openings on tape.

As bench testing was concluded, the V-8 put out 376 bhp at 7,200 rpm on 103.7 octane fuel. Engine weight was 357 pounds, and, since the chassis had also needed substantial reinforcement, the power/weight ratio was not much better than necessary to stay in contention despite the higher power output.

The race itself is history. Why didn't Lotus-Fords win the 500? Both Stirrat and Gay admit to having underestimated Parnelli Jones' improvement as a driver since last year, and possibly the improvements that had been made in the Watson-built Offy-engined car as well.

Instead of the stud-ball-mounted rocker arms that are standard on the production Fairlane V-8, the Indianapolis engine had conventional rocker arm shafts. The lower picture shows location of coil springs on the pushrods.

From this tape an exact test cycle could be established, and reproduced on the dynamometer for durability testing. After a successful five-hour run, the Ford technicians knew they had a power plant that could go the distance. All essential modifications had been completed, and a feeling of great confidence came over Stirrat and his men.

But looking at race results from the standpoint of mass-produced car design is far different from traditional racing philosophy. A racing designer counts an engine perfect if it falls apart as it crosses the finish line. If it falls apart sooner, it has been overstressed; if it lasts longer, it has been overdesigned. For a man in George Stirrat's position, how-

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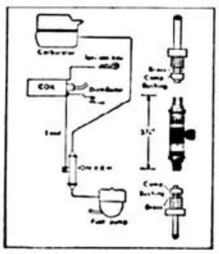


ever, there is no such thing as "over-design." Demands on durability in production cars are much higher.

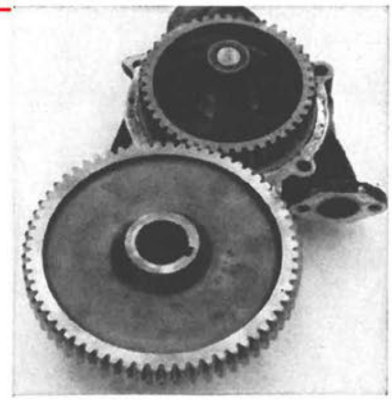
Judging from the way the Lotus-Fords ran at the end of the 500-mile race, and from the condition of the individual components when the engines were stripped down for examination last June, there can be no doubt that these cars could have done another 500 miles of racing with no other mechanical attention.

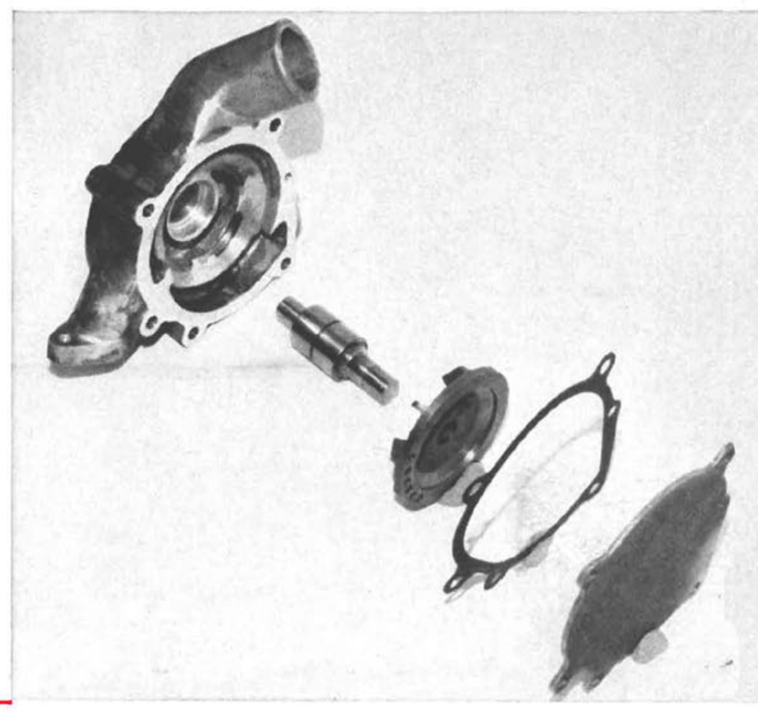
Jim Clark used 2½ quarts of oil during the race, and used fuel at the rate of 6.8 mpg (a conservative figure which does not take into account warm-up and a pace lap in addition to the 500 miles). While 7,800 rpm had been used during the qualifying runs, revs were kept down to 7,500 in the race, with 80 psi oil pressure and no oil filter.

What did the bearings look like afterwards? Well, you could tell they had been used, but apart from scratches from metal particles (which a filter would have eliminated) the shells had hardly been touched beyond the phosphating. Bore wear? Could not be measured. Valves? They had been hot but were not burned, and the valve seats were just beautiful, like silver rings. The camshaft looked as if it had hardly been touched, and apart from the higher lift, it was identical with production camshafts in all respects (material, hardening, etc.).

The pistons had stood up very well. Some dark shades had settled in the valve valleys and there were occasional marks on the skirts, not scoring marks but possibly burning marks from excess fuel caused by running rich. No broken rings, no distortion anywhere. The camshaft drive and oil and water pump gears were just about run-in, showing no signs of wear.

This examination proved that the race itself had brought no surprises for the Ford technicians, but they claim that valuable lessons were learned during the long period of





Water pump drive uses steel gears (top, left) and the balanced 3⅞-inch diameter cast iron impeller (below) runs in an aluminum housing with an extended shaft and a sealed bearing. The cover plate is steel. High-silicon alloy piston (top, right) shows minimal wear after 500 miles at very high speeds. The special crown with valve valleys gives a compression ratio of 12.5 to one.

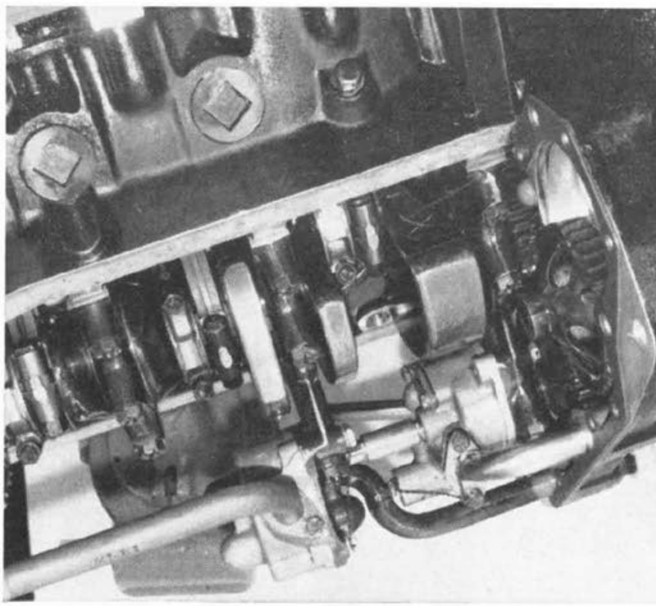
preparation. Some of the modifications undertaken on the Indy engine have already been adapted for the production 289-cube Fairlane V-8. The crankshaft vibration damper with increased rubber contact area is now fitted, the connecting rod cap bolts are larger, and while the rocker arm ball stud arrangement is retained, they are now screwed-in. The same modifications may be expected on the 221 and 260 cubic-inch Falcon and Fairlane V-8s, and we would not be surprised to see related developments on the Y-block Ford engines used in the big Fords, Thunderbird, and Mercury line.

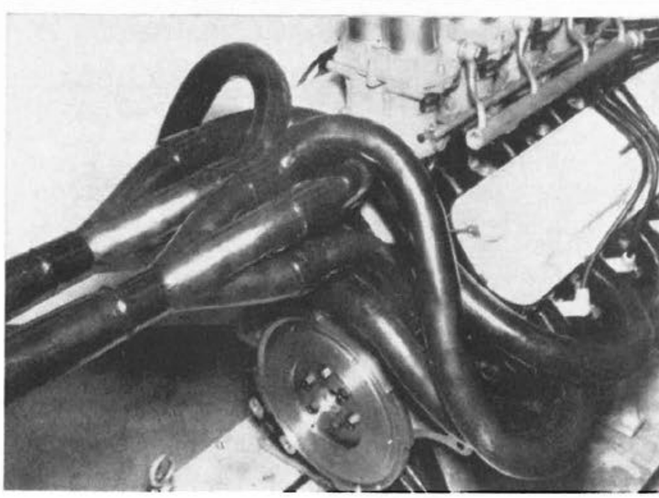
The near future will probably see the breakerless transistor ignition system made optional on the "hot" models (transistorized ignition systems are already available on the 427-cubic-inch 500-XL and a range of Ford trucks).

In long-term development, the effects of Ford's study in racing application of production engines will certainly lead to lighter power plants operating at higher crankshaft speeds, with higher specific output and higher thermal efficiency.

Ford's announcement that a small number of Indy-type engines would be made available has since been revoked, since this unit is now considered obsolete. A new series with further improvements will be built and tested this fall, and an improved engine may be expected to become available early in 1964. And of course Ford plans to be back at Indianapolis next year, with a team of at least two cars.

We believe that Ford will try to maintain a fairly close relationship between production and racing engines, but with the available time before the 1964 race, there is ample opportunity to try out all the ideas which were shelved early in 1963, such as fuel injection, twin-cam heads, and other refinements. None of these things may ever be seen outside of Dearborn, but it's likely that next year's Indy engines will have oil filters! C/D





Bottom end shows oversize connecting rod bearing cap bolts and special oil pump arrangement with gear drive from crankshaft to scavenge and pressure pumps. Exhaust system looks chaotic but proved to have best extractor effect.