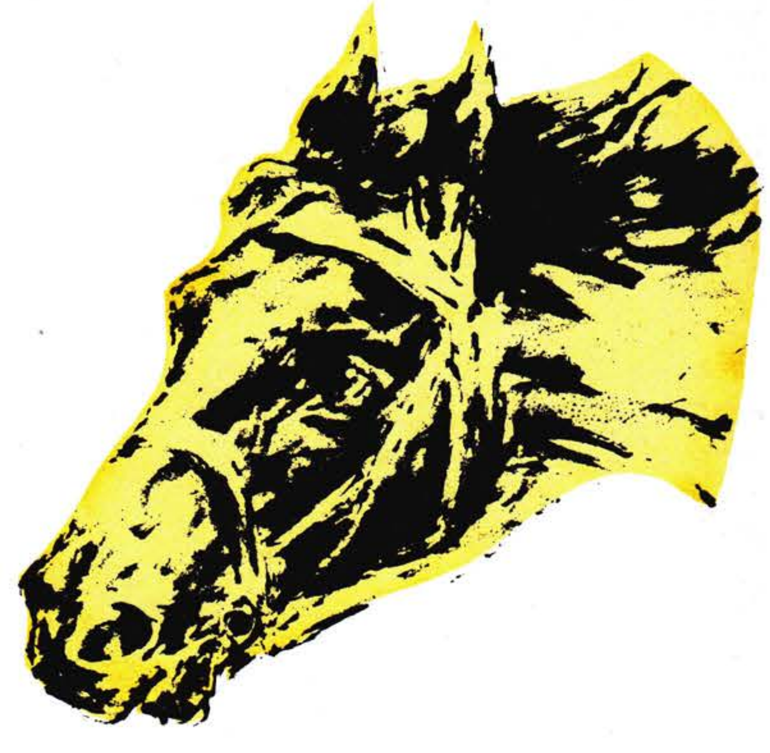
WHENCE COME THE HORSES?



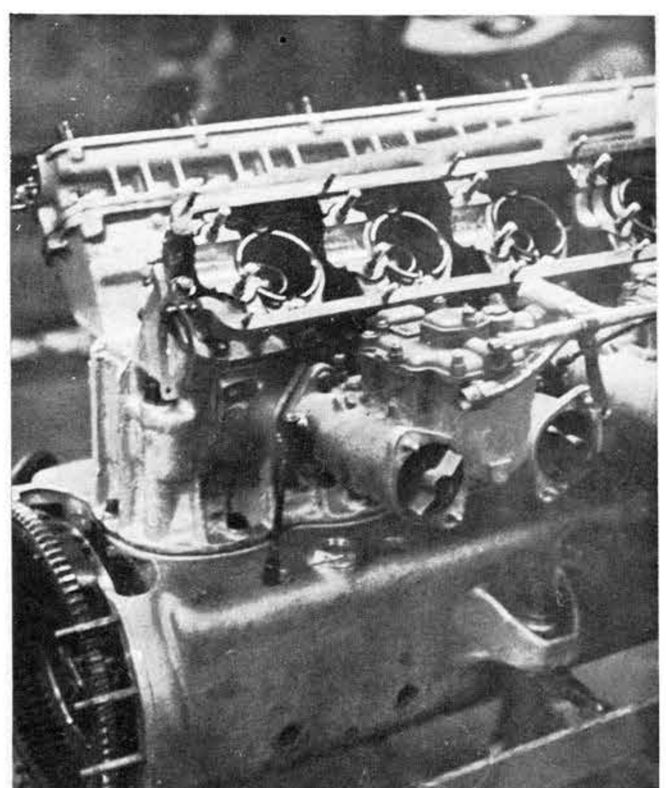
By KARL LUDVIGSEN

THE prototype Mercedes M196 engine was first run with normal carburetion (Webers). Surprisingly, moreover, halfway through their second postwar racing season Mercedes' Engineer Lamm remarked that carburetors *might still be better* than fuel injection for some courses. In detail, he felt that injection was a big help at low speeds and didn't harm top end output. From this and from the results in late 1954 we can guess that from their standpoint carbs might have been an asset on the *faster* European courses.

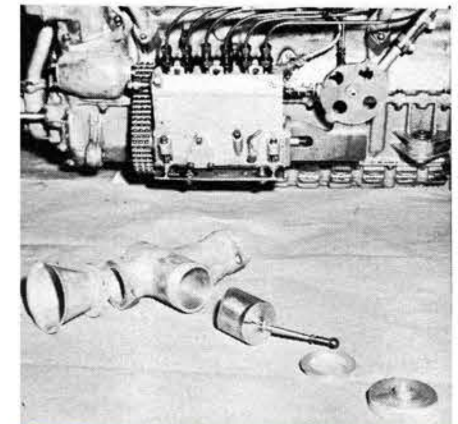
This is pretty startling in itself, and even odder when related to the unhappy struggles of other GP designers to equip their machines with fuel injection. One characteristic story is that of England's Connaught cars, for which Mike Oliver has carried out an extensive and intelligent engine development program. Financial problems, though, have kept him from holding the needle at the peg both long and hard on the dyno.

In 1952 Connaught rocked all the pundits by clamping Hilborn injection on their Lea-Francis-based Formula II engines, which had been burning alcohol since the previous year in contrast to the "petrol/benzol" mixtures then common. They'd been using four of those cranky Amals before, and they liked the easy mixture adjustment afforded by the simple constant-flow Hilborn system. At that time it was a good deal, but when they moved up to the 1954 2.5 liter formula, Connaught picked the Alta four-barrel and the much more complex SU timed-injection equipment. This injection has a comprehensive speed-density metering system, but in '54 tests they couldn't calibrate it properly for the Alta (which was nevertheless giving 240 horses at 6400), and reverted to the more familiar Hilborn gasworks. Both these layouts inject fuel in the *port*, the SU nozzle attempting to spray past the valve into the cylinder.

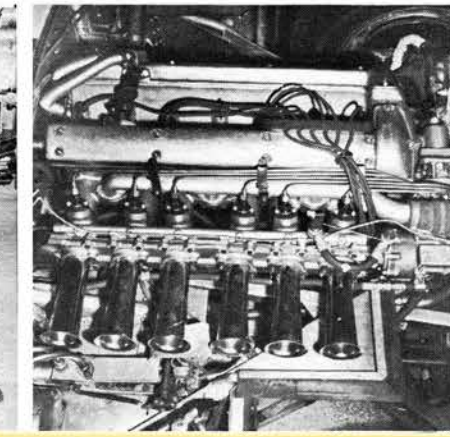
California honor was upheld until August, 1955, when Connaughts converted some pounds to lire and came home with the 48mm twin-choke Weber carbs mentioned earlier.



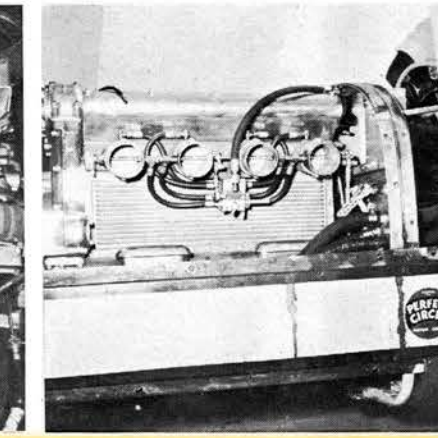
The 4.4 Ferrari engine was fine for sports car racing, but poor porting design proved to be a handicap at Indy. Hilborn injection might have been the answer had they used the right fuel pump.



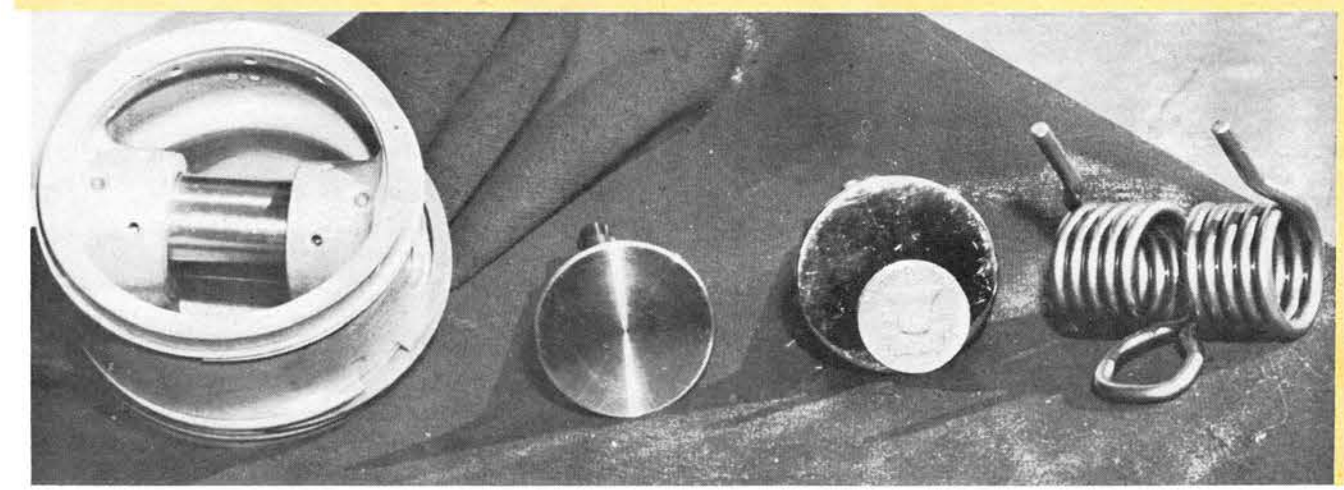
Maserati finally decided on vertical slide throttle which has the advantage of being fully out of the way at full noise.



Jaguar's Lucas injector has single horizontal slide throttle plate for all ports. The effect is the same as that on Maserati — no butterfly shaft.



The big 270 Offy is pushing 400 bhp almost, thanks to Hilborn injection and the biggest ports in the field. Four valves per cylinder are used.



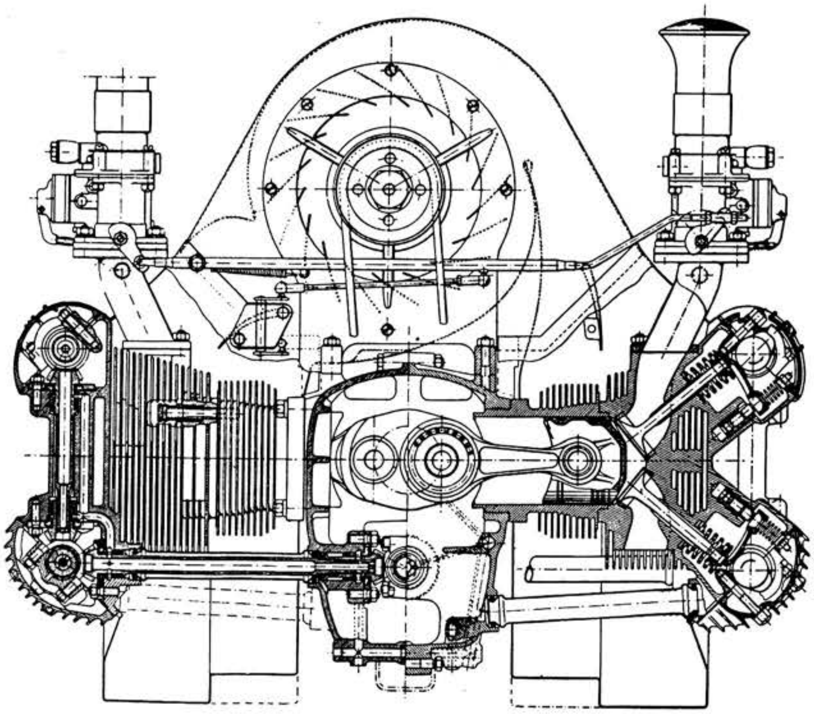
Components of 3.5 Ferrari are marked by huge piston pin and enormous size valves. Intake valve is compared to half dollar. At right is extra heavy tensioned valve spring of hairpin or mousetrap design.

Only then did the car show the speed that it needed to wipe up the full Maserati team at Syracuse two months later. It had always been easy enough to set the injection systems for maximum power, but neither setup could fill in the middle and lower sections of the torque curve.

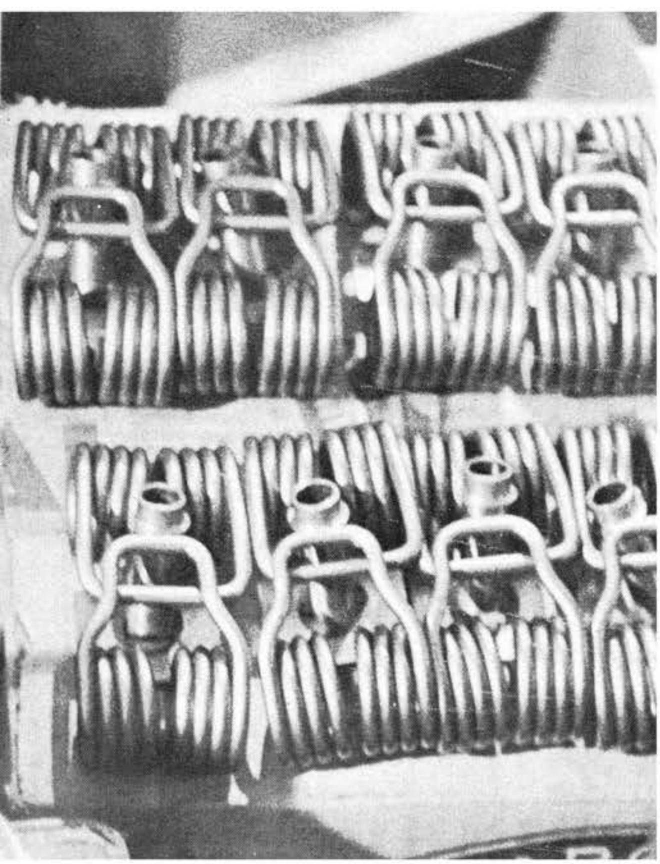
Similar agonies are being endured in the Maserati camp, which is split wide open over the issue of fuel injection. Pioneering work was actually done by Alf Francis on the 250/FI Grand Prix car owned by Stirling Moss Ltd., which was fitted with the SU system in the spring of 1955. On the bench in England and breathing through 42mm Webers, Moss' engine gave 215 horses with 50 percent methanol. The same fuel mixture squirted through the SU nozzles gave a peak of 232 bhp, and 80 percent methanol injected produced 253, but *both* injected curves were well below the carbureted figures over the important range from 4500 to 6000 revolutions. Naturally enough the Webers went back on for the short English sprint races, and the same problems have cropped up on the works-injected Maseratis.

Due to their metering requirements, most SU installations (including those above) draw air through a single big throttle valve into a collector box which supplies the tuned lengths to the cylinders. Exceptions are the early Alta test-bed setup and the Turner 2-liter, which carry separate throttles for each of their four cylinders. Turners say that this gives them more precise control. Whatever the justification, the factory-injected Maseratis, Vanwalls and D-Jaguars have a tuned intake and a vertical or horizontal slide throttle for each cylinder. The first two use modified Bosch pumps, while Jaguars have been the first to benefit from the much-improved Lucas injection.

Maseratis have tried both pivoted and vertical-slide throttles, finally settling on the latter which has the big advantage of being fully out of the way on full bore. For the first half-year they injected in the port above the valve, and only after the Belgian GP of 1956 did they use the Bosch-type O.M. pump to the full and inject directly from a point just below the exhaust valve, the diametrical opposite of Mercedes placing. A triple roller chain drives the pump, and its metering rack is controlled by a cam rotated by the main throttle rod. Even now it's still a highly experimental rig, and has yet to be trusted in a *Grand Epreuve*. Injected output has improved under development from 270 to 285 horses, which isn't a big margin over the Webered engines, and like Moss' trials the low-speed torque and response are actually worse, as is fuel consumption. They're going to



Very light valve train and good straight-through porting mark the Porsche 550 engine. Only 91 cubic inches, it consistently outperforms and outlasts bigger machinery. Further improvements within the design limits are entirely possible. Such things as direct fuel injection and desmodromic valve gear are well within the realm of reason here and could further increase the already respectable 140 bhp given by latest model.

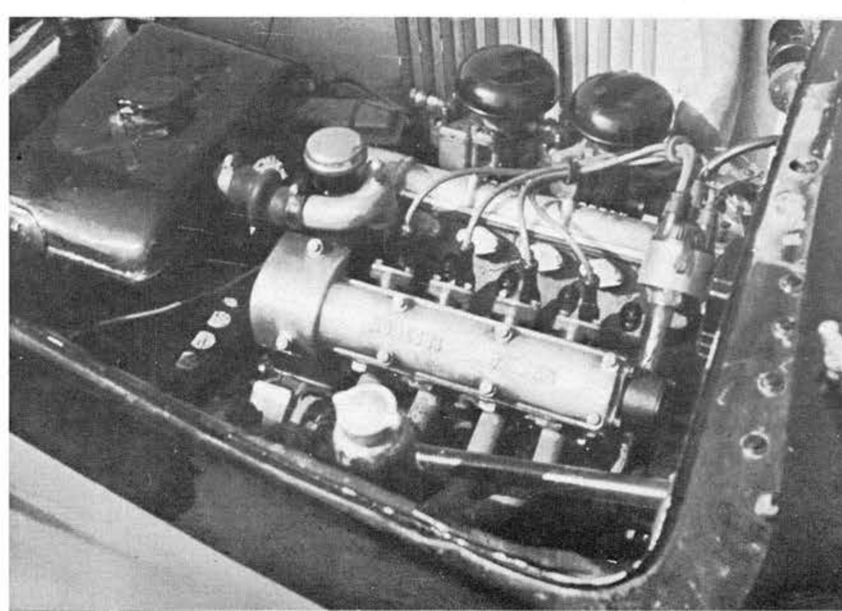


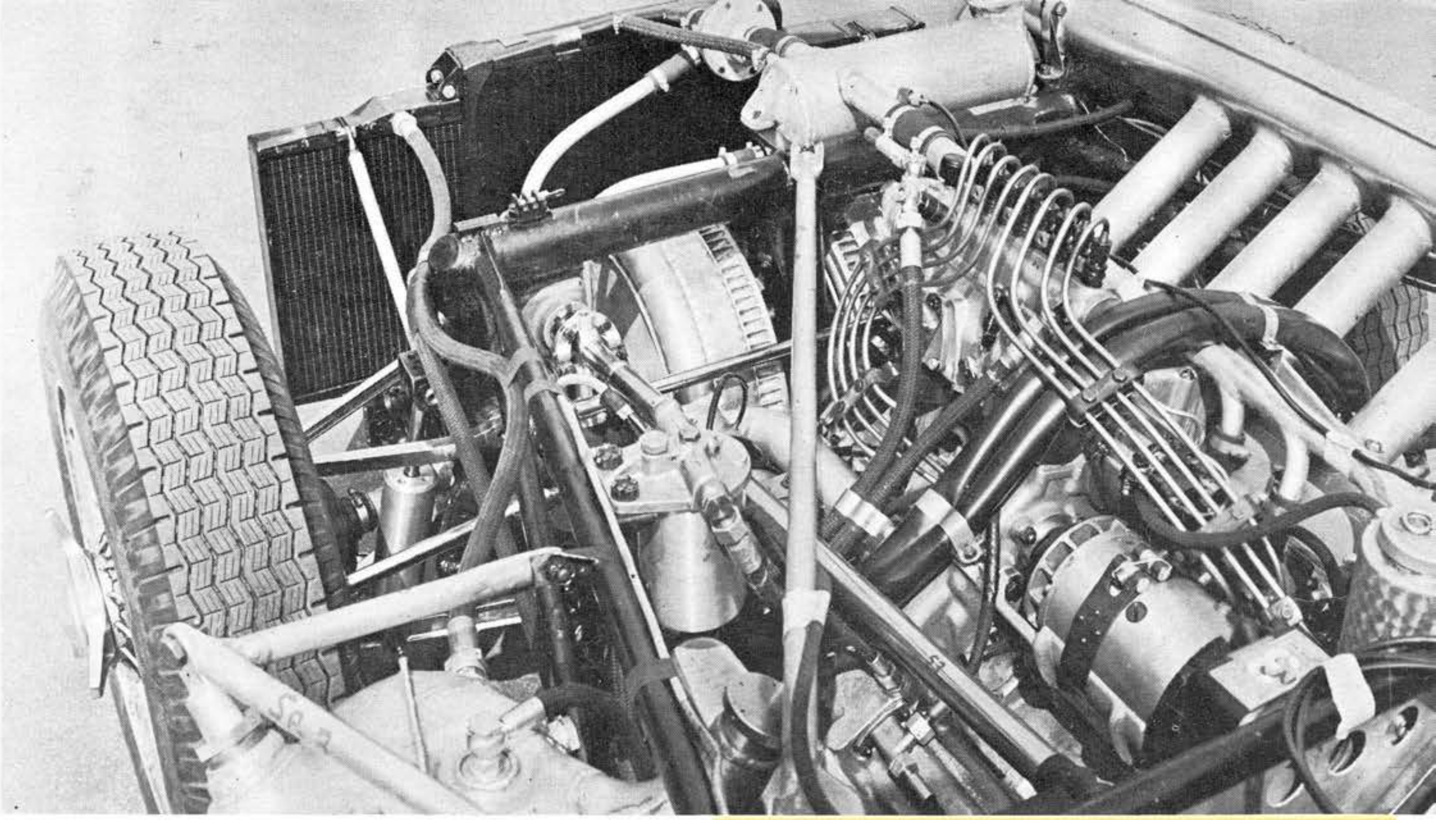
ABOVE: Much like torsion bar valve springs, these mousetrap springs are free of heavy surge periods, and two can be installed without increasing stem length. RIGHT: Moretti engine totals 750cc, puts out 76 hp at 7000 rpm with two dual Webers. Better figures could be realized with a pipe for each cylinder and injection.

Bosch equipment in 1957.

A Bosch pump, vertical slides and separate intakes are found on the Vanwall. Amal carburetor bodies (without venturis) supply the throttles, and the nozzles are placed in the ports very close to the intake valves. Once set, this layout was extensively tested under the supervision of an ex-Norton designer, and they now claim 292 horses at 9000 for this interesting four-cylinder, which would qualify it as the best injected GP engine now running. Problem now is to make the rest of the engine stand up to this power, which may prove embarrassing to bearing manufacturer Tony Vandervell.

Sebring was an impressive debut for the Lucas-injected works D-Type Jag, and since that time it's proved to have the same characteristics as the Connaught and Maserati attempts: Faster than standard on fast courses and inferior on slower tracks. They've produced a ridiculously simple horizontal slide throttle, which is little more than a single strip with six holes punched in it. As a result of several years' bench testing by Lucas, their nozzles are placed in the intake ports a couple of inches from the valves and make no attempt to spray directly into the combustion chambers.





Mercedes' success depended largely on the remarkable combination of fuel injection and positive control of the valve gear. Bosch pump metered exact fuel by instruction from a bleed-pressure line connected to a large venturi at the throttle. Fuel metering was directly proportional to the volume air at all speeds.

More emphasis is placed on proper vaporization before the valve seats. Lucas' pump matches the cleanness of the throttles, and the whole unit looks like a good bet for production.

Conspicuous for their absences from this list are Ferrari cars, which haven't been linked by rumor to fuel injection. They, of course, are now running the very potent Lancia V-8's, which were tested with direct cylinder injection back in the planning days. Too much trouble was required to get the right spray pattern and keep fuel off the walls and out of the oil, so they didn't bother. In the spring of '56 Ferrari was unhappy with the performance of Hilborn injection (which they had tried in Italy with the wrong fuel pump) on their 4.4 liter six for Indy, and were busily machining a modified type, with tapered orifices, when the boat sailed. That was the least of their problems.

In slashing contrast are the experiences of Mercedes-Benz, who were able to build an engine from scratch for injection and thus use it to the full. Their extensive war experience with Bosch equipment was no hindrance, and there was little groping in the dark. As we mentioned, their engineers feel strongly that injection offers the most in the lower regions of the power curve, and isn't a significant factor in the *maximum* output of a racing engine. No one else has been able to put this into practice, though all benefit from certain common advantages of f.i.

Uhlenhaut mentions that injection has the effect of raising the octane rating of the fuel, and the 300SLR is running on pump gasoline at a compression ratio of roughly 12 to one, while the M196's special mixture allows much higher figures. As remarked under intake tuning, the cleaned-up induction piping offers much less resistance to resonance in the system, and Mercedes join Ferrari in claiming *better than* 100 percent volumetric efficiency at certain speeds. Finally, a system of positive injection is capable of supplying accurately metered fuel to the engine at speeds so low that the carburetor can't vaporize and meter properly.

The key word is "accurately", and it's here that Mercedes held an edge. Like most SU rigs they brought all the air in

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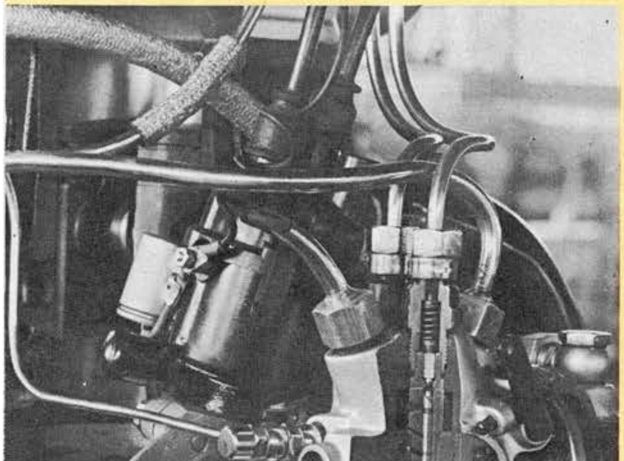

Operation of Bosch pump is shown in cutaway. Cam lobes at bottom operate separate controlled pistons, one per cylinder. Pump pistons are rotated by metering bar to measure precise fuel "shot."

Last Mille Miglia?

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class vaporized. All things considered, then, Moss was the favorite on the basis of past performances and on the basis of the 4.5's fine showing at Sebring. The young Englishman was talking about having a "go" at his '55 record of a 97.9 mph average in the Mercedes 300SLR, but this seemed a super-human task considering the diffrence between Italian and German pit work. The new Maserati has more acceleration than the Mercedes and it had been fitted with an additional two-speed transfer case mounted just behind the engine with a "high" and "low" cog to gear the car down for the mountains as well as give it an additional 15 mph on the long straight stretches. (As a point of interest here, Moss said after he got back into Brescia that the Maser reached its maximum speed just after leaving Brescia, whereas in the Mercedes, they didn't get the thing up to its limit until close to Verona, 41 miles out).

Another point in Moss' favor was the fact that he had drawn the final starting number, so as you move out you always know where you stand in relation to your competition while they never know how close behind them you are until picked up in their mirror. As far as top speed was concerned the Ferraris and the 4.5 Maser were on equal terms—an honest 185 mph for both with the Maser having an edge with its extra box. Ak figured he could turn 170 mph on the long straight back into Brescia from Mantova, as the surface was new and smooth, but for the rest of it he couldn't possibly exceed 150.

That night, Brescia was really jumping. The first car, a baby Fiat, rolled down the ramp at 11:00 pm, and at succeeding intervals of one minute a piece 301 starters were flagged off.

At 3:49 am, Umberto Maglioli roared off into the night in the Porsche; at exactly the same time, Ak and Doug were eating breakfast in their hotel and preparing to bring El Caballo to the starting line. They walked to the garage, rolled her out of the stall and turned over the starter; nothing happened. Again they tried—again—still nothing. A Fiat was enlisted to tow the race car around the garage which, incidentally, was two stories underground. Finally, at about five am, just 24 minutes before they were due to be off, El Caballo decided to cooperate and fired up. The two Americans, usually the picture of relaxed composure, were spitting nails by the time they pushed their way through the milling crowds at the starting line.

Flockhart's Jag went down the chute at 5:18. The Cooper-Jag of Steed and Hall set off at 5:20, then came Ak's turn. The powerful Chrysler motored calmly up to the line on the ramp where Castegneto and Count Magi with the mayor of Brescia stood with the starting flag. It was fantastically exciting; the impressive Chrysler

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Horses Part II

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through a single throttle valve, but instead of trying to measure air density by a combination of temperature and pressure, they put a big venturi at that throttle and bled off a pressure line which was directly sensitive to the volume of air being consumed. This told the injection pump exactly what it needed to know, and avoided seasons of cut-and-try between races.

Mercedes also seems to have licked the knotty problem of nozzle placement in a unique manner. Their outlet was screwed into the cylinder wall just below the intake valve, where it was covered by the top land of the piston at top dead center. Its spray was directed across the incoming air stream, to improve vaporization, and against the face of the exhaust valve to cool that hot surface. Injection was timed to take place over the 120 degrees before the piston covered the nozzle, which meant that fuel entered largely during the compression stroke and was still being injected as combustion began if the ignition was well advanced. This kept the fuel-air mixture as cool as possible up to the last minute, and allowed complete freedom in valve overlap since fuel couldn't be lost down the exhaust pipes.

The remarkable smoothness and power of the Merk straight-eights at all speeds is testament enough to the potency of this injection system, which rounded out every flat spot. Unless the job's done just right, though, the curve will be full of lumps and a handful of Webers or Solexes would be a better investment. The major problem, as we recall, is the passage of the maximum weight of air per unit time, equalled in importance by precise fuel metering. Pounds of air that can be pumped through depend on all the foregoing factors but probably most of all on valve timing, which is more closely intertwined than ever with compression ratios and combustion chamber design.

VALVE GEAR

If the racing engine designer could have his way, his valves would open instantly and close just as fast. He's constantly pushing back the barriers of material strengths and space restrictions to approach this goal, and direct injection has helped by eliminating some of the variables in the overlap period. It has hindered just as much, though, by allowing higher compression ratios which severely limit the piston-to-valve clearance margin at top dead center. Those valves *must* be seated fast, or risk summary decapitation.

As hinted above, there are many limitations on both positive and negative valve acceleration. Kicking the valve open is by no means as tough as closing it, but the first step can directly influence the ease with which the second is executed. If durability of the valve gear isn't important, the opening contour can be quite arbitrary, but for long life the cam shape must be matched to the tappet type, shape and material, the spring pressures and the weight of the components to be lifted.

Converting the rotating motion of the cam into the valve's reciprocation motion introduces some side thrust at the junction point, and to keep this from wearing the valve guides unduly, some form of tappet must be interposed. The shapes of the tappet faces determine the actual motion of the valve as opposed to the plotted cam lobe. A cam for a roller tappet, for example, will look more extreme than that for a flat tappet giving the same valve opening diagram.

In spite of this, a round or curved tappet surface allows the cam designer much more latitude, and the roller is the ultimate development of this. There has been much discussion over whether or not they actually roll, and in Ricardo's day there was reason to doubt it, but Chet Herbert's modern experiments show that they do rotate. This is beside the point, though, the function of the roller being to allow an improved valve opening diagram, which must be enough better to offset the added weight that the use of a roller brings.

With a few notable exceptions, most of the world's top racing engines have used a finger-type tappet. This is a short, shaped sliver of metal placed between the cam lobe and valve stem, with one end pivoted so that the finger trails in the direction of the cam rotation. (It can actually be either direction.) All lateral thrust is thus taken by the pivot bearing, and the finger can be as thin and light as the designer dares, once he's presented the cam with the type of tappet contour that it requires.

Actual pivoting methods vary, but Maserati is typical in using a single shaft parallel to each cam. Porsche, with only two fingers per cam to deal with, rests the finger anchor on a spherical surface, supported by a vertical rod. The fingers themselves can be shifted, sometimes by eccentric pivots, to vary valve clearance, though most rely on tiny cups with shims over the valve stems, if they aren't finicky enough to grind the stem ends to suit.

More accurately called a "tappet" are the cup-type cam followers long familiar to Meyer-Drake mechanics. Both huskier and heavier than valve fingers, this type has been popularized in production engines from Jaguar, Aston-Martin and Alfa Romeo, not to mention the Crosley. All have valve adjustment by shims, the latter being the only version in which shims can be changed without pulling the cam.

Cup-type tappets aren't generally suitable for assaults on the two horse per cubic inch mark, since their working surfaces must be flat or nearly so, which restricts the cam designer. Liking the straight motion of the cup-type, though, Lampredi produced a mushroom-shaped variation of it for his Ferrari fours. He sank a narrow roller into its face, though, to allow faster valve accelerations, and his successor Bellentani has added rollers to the tips of the rockers in the single-cam V-12's. Even the finger-type followers are getting the treatment, the latest Maserati engines having rollers added, plus screw-and-locknut clearance setting. They may find it hard, with this system, to keep the roller surfaces parallel to the cam face under heavy stress.

Don't think, also, that the stresses are anything but heavy. Kicking the valve up at present-day acceleration rates produces a pretty heavy jolt, and bringing it back down rapidly calls for valve spring pressures in the 280-300 pound region. Finding room for such springs has always been tough, if the weight of the reciprocating valve gear is to be kept down. One big help has been the hairpin or "mousetrap" valve spring, which finds its origins in motorcycle practice, like so many high-output features. Like torsion-bar valve springs, these are virtually free of heavy "surge" periods, and several can be installed without increasing valve stem length. Coil springs alone can also be used, but at least three per valve are usually needed.

Loads can be lessened, of course, by lightening the valves; just talk to any BRM designer about that! The first BRM taught us that wet liners and detachable heads didn't go too well with a 70 pound boost pressure, and the second one has shown that, with present materials, you can't have a huge valve and a light valve at the same time. With a valve head diameter of roughly 2¼ inches on the intakes of their way-over-square four cylinder, adequate strength could only be obtained by making the valve so heavy that the increased loadings held the top revs down and cut power. Very frustrating, but full justification for the first layouts, which gave each cylinder four valves.

One of the best routes when trying to run a big-bore engine at high speeds, with the valve area necessary, is to use more and smaller valves. The individual cam and spring load is literally slashed, allowing much higher revs with mechanical complacency. There will be slightly higher fluid friction losses at the ports, due to the relatively smaller size, but this can be minimized.

Ricardo, that keen student of design "correctness," thus had good reason to fit a four-valve head to his 180-inch four cylinder Vauxhall. The big Offys, of course, are a classic example also, as were all the Mercedes GP cars of the thirties. A link over the war period is provided in Europe by the 4CL and 4CLT Maseratis, and today there is a 2½ liter unblown four under development at the Orsi Maserati firm, using 16 valves in classic pent-roof chambers. Keeping up the German tradition are Borgward, with their 16-valve 1½ liter four. Englishman Leslie Brooke heard the message, and effected a compromise in his GP V-8 design, which has two intake valves and one exhaust per cylinder.

Not satisfied by the good characteristics achieved by using four valves, Ricardo wanted still better valve accelerations without resorting to brutal valve springs. His solution was typically clever, and may be in use on some modern engines. He simply countersunk the intake valve seats a fraction of an inch, so that during the first small portion of their upward travel they were still effectively closed. Then, when they "broke the surface," the valves were already accelerating at a good rate, and later came down quickly in the same way. Using very long nominal duration periods

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Horses Part II

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and moderate ramping with mild springs, some quite hairy opening diagrams can be recorded this way.

Faced, in 1954, with a GP formula in which only unblown engines had a look-in, the Mercedes engineers realized that valve timing would have to be taken much more seriously than in the past. As mentioned earlier, also, the use of fuel injection meant that compression ratios could rise, which in turn would mean that there'd be much less space at the top end for floating valves to wander around in. They also wanted big valve area, without the port restriction of the old four-valvers. The only answer was to make the valve motion independent of valve gear weight and the whims of springs, so they set about developing a positively-closed poppet system.

Coined "desmodromic," the Mercedes device was the first practical manifestation of a long-cherished concept. To each valve they gave two cams, side-by-side on the same shaft. One, looking quite normal, opens the valve via a conventional tappet. The other cam is literally up wherever the opening cam is down, and presses a pivoted lever which pulls the stem up at the proper time, being notched into a necked section. Between them the two cams put the valve just where it's wanted at all times, which was a great relief to Uhlenhaut, Neubauer and Fangio, among others. *(For details see Sports Cars Illustrated, May 1957)*

With this under their belt, the M196 engineers could turn loose some formidable figures, one result being that the valves were seated just 228 per cent faster than the heaviest practical springs would allow. In fact, Uhlenhaut said, spring pressures of *1000 pounds per valve* would be needed to duplicate their speeds.

Desmodromic actuation is yet another valuable Mercedes feature which few have been able to adapt to their own purposes. This is for the very good reason that it's a complex, finicky and expensive devil to make, even for Daimler-Benz. Knowing that the stroked 300SLR engine wouldn't be capable of the same revolutions as the GP powerplant, they tried to save themselves some trouble by using ordinary springs on the prototypes. It worked, but the safety factor given by the positive rig was too inviting to pass up.

Only other firm to progress along this line is Osca. The Maserati brothers have done extensive testing with a valve gear very much like that of Mercedes, with the addition of rollers on the tips of the valve closing levers. Their method of clearance adjustment is different, as is their valve opening tappet. When this is going it may restore Osca to the Class F championship.

Even with the intake and valve gear problems solved, two horses per inch are far away unless the combustion chamber, exhaust and mechanical layouts are right. In the next and final installment we take up these important aspects of racing engine design.

—*Karl Ludvigsen*

Corvette

(*Continued from page 37*)

retired the car at Sebring. Rubber bushings are suspect in a suspension anyway, if very good steering is the goal, and one of them here did shift and destroy the alignment. Since this didn't show up on the much-flogged "Mule" it could well have been a material fault.

Springing at all four corners is by coil-shock units. The long small-diameter coils are carried in cups attached to the body of the tubular shock and its piston rod, giving a quickly demountable unit with a built-in bump stop. Rebound is limited by fabric straps. At first there was an additional housing around the coil, but this was tossed out to cut weight and allow quick access.

Probably the highlight of engine development on the SS was the use of aluminum cylinder heads for the basically stock 283 inch engine. These heads are very similar in design to the stock part, with only a slight repositioning of the intake ports to take advantage of some Weslake gas flow theories. They are definitely designed and run *without valve seat inserts.* Using the stock valve spring pressure of 210 pounds open and the slightly tuliped valves of the SS, pounding-in of the seats was very slightly more than normal, but not enough to cause any concern at all. If this technique can be reproduced, it could open up a brand new field in special heads for OHV engines. Only major structural change to accommodate the heads is the use of necked-down studs to compensate for the greater expansion of aluminum.

At Sebring it seemed that cooling troubles could be blamed on poor head gasket sealing, but it now looks like a subcontractor was to blame. Construction of the remote-mounted radiator header tank was farmed out, and a flow-control baffle was so misplaced that it cut off two thirds of the planned circulation. The tanks were peeled open and the baffles put in right. After that the ducted aluminum radiator performed as expected, as did the oil cooler incorporated in its base.

To the left of the radiator a Fiberglas duct scooped cool air into the Rochester injector machinery. The big air metering valve was faced forward instead of sideways to simplify the ducts and throttle control as much as possible. This injector requires a small air bleed to each nozzle for vaporization and idling, which is usually supplied by small pipes from the air cleaner. In this case there's a tiny individual filter for each adjacent pair of nozzles.

More important, nozzles for Chevrolet injection are now being built by the Diesel Equipment Division of GM, and are improved in two ways. First, the all-important nozzle size is determined by a thin calibrated disc instead of a lengthy sized hole, giving benefits in accuracy of distribution (which is still not so good with this system as it might be). Nozzle jet size is now .0135 inch instead of .0110. Second, each nozzle now incorporates a filter screen in addition to that at the pump. This has just