two wheels

THE MAGAZINE OF MOTOR CYCLING

AUGUST, 1976
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THE MAGAZINE OF MOTOR CYCLING

Editor: Mac Douglas
Tech Editor: Mike McCarthy

OUR COVER: That's right — a scoop test of Honda's enduro 250 two-stroke — and it's the best Japanese off-road bike we've ridden! Match that up with our workout of Yamaha's not-so-secret IT400C (against our own Yamaha enduro project) and inside it's a damn good coverage of the Japanese bikes settin' up to challenge in European territory! You'll be surprised how good they are! Gone cold on riding? Check out page 37. Our special accessories feature this issue covers all the oversuits we could find in Australia! On page 46 there's the good oil on motorcycling's pollution-free four-stroke future, but part of tomorrow might be automatic. See page 16.

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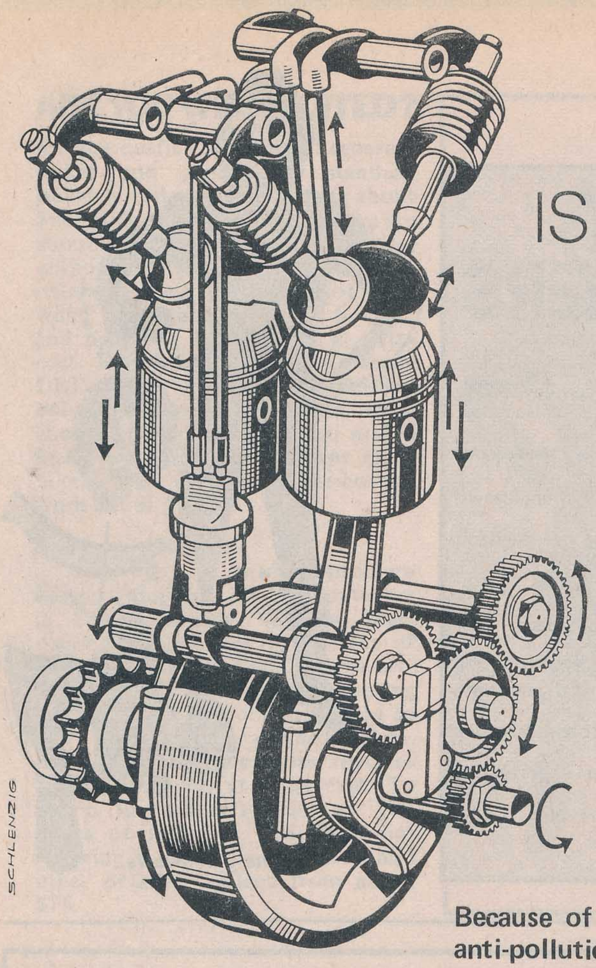


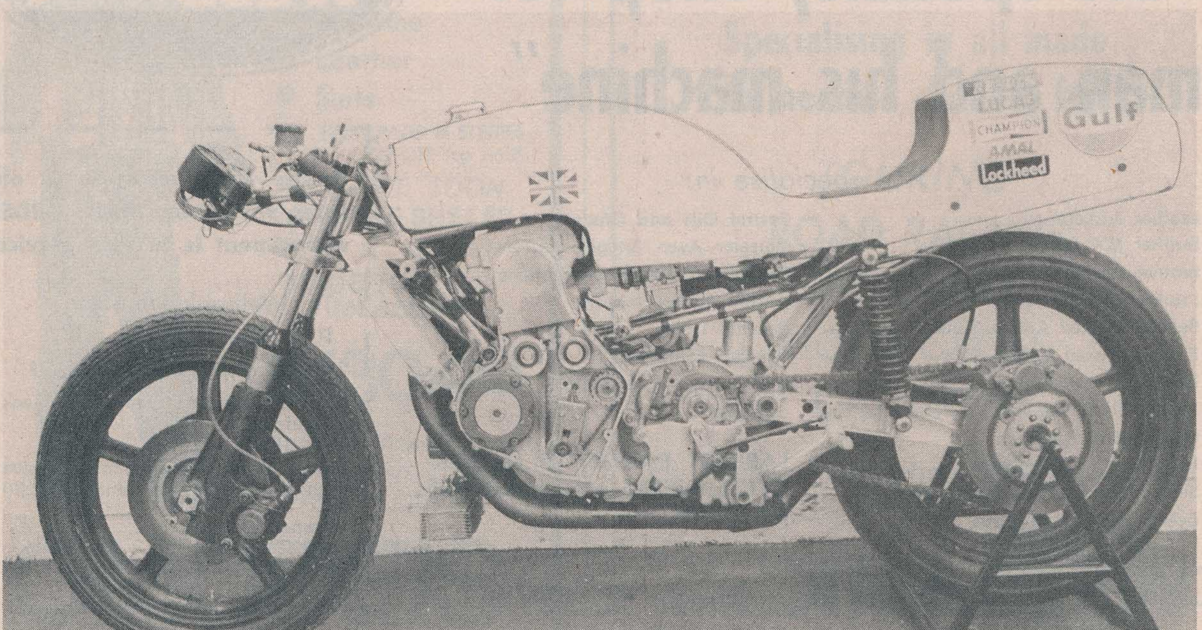
ENGINE DESIGN IS COMING TO A HEAD!

IT'S A FOUR STROKE FUTURE!

Below:
The ultimate big-banger four-stroke twin? Not yet it's not but the Norton-Cosworth is still ripe with promise thanks to advanced detail design including eight-valve head and water cooling. Engine's an integrated part of the bike's frame.

Because of vital fuel economy and the inevitability of tough anti-pollution laws for bikes as well as cars, makers are paying more attention than ever to engine design. As a result there's a clear swing towards the four-stroke — it's on its way to dominating the market.

That's why it's time to review the latest anti-pollution design developments and explain the important basic differences between four-stroke valve systems.



THE SWING is to the four-stroke engine!

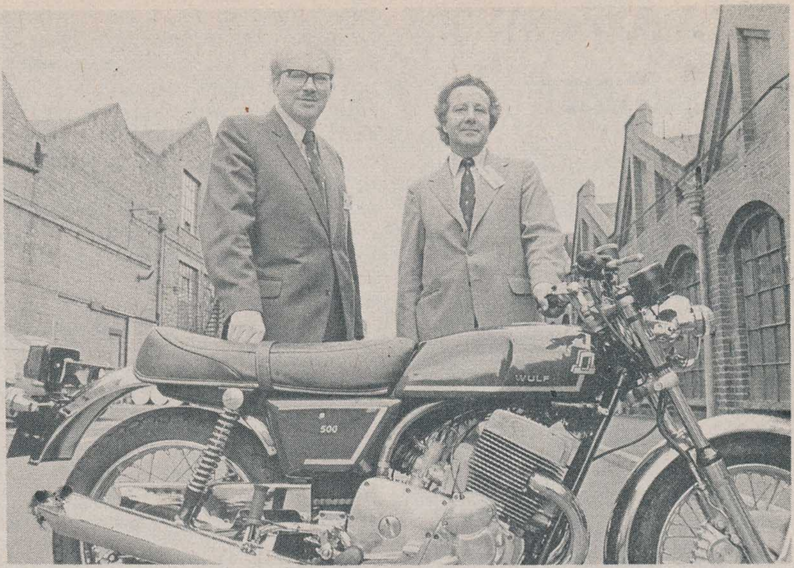
Deservedly or not, the two-stroke in its conventional design is receiving the cold shoulder from bike makers.

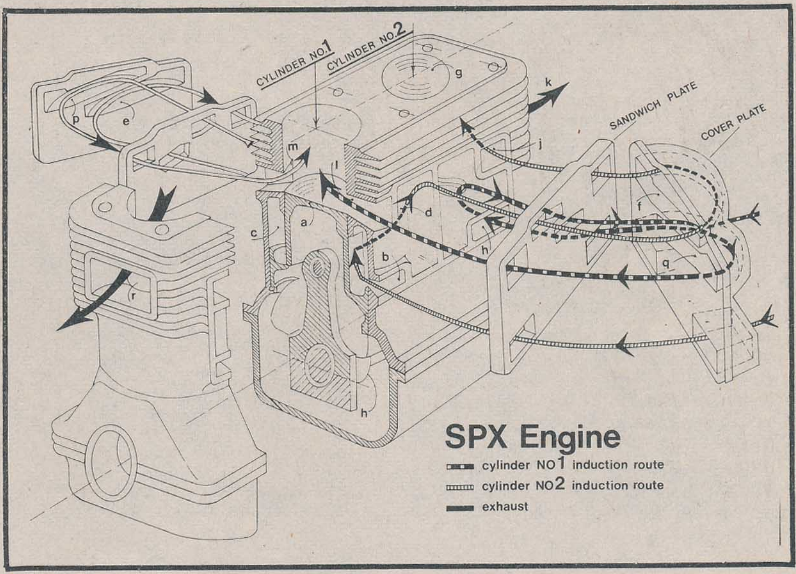
The "Big Four" are heading directly into four-stroke futures — and where Japan goes you can be sure the rest of the motorcycling world will sooner or later follow.

And not by coincidence — the bike makers are motivated by the old "survival of the fittest" rule. And soon the *fittest* bikes will be those that burn the least fuel the cleanest. Anti-pollution will determine the survivors, with fuel consumption also becoming an increasingly important factor.

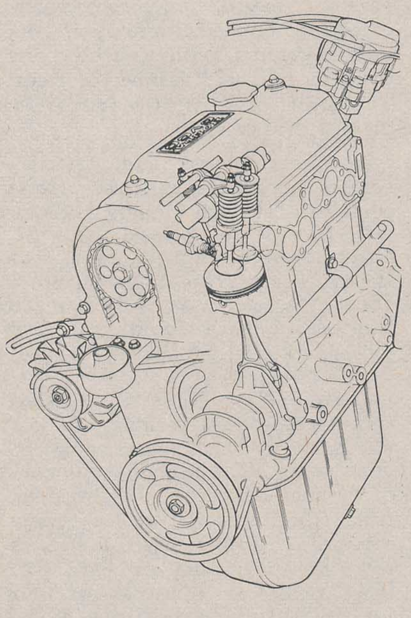
And those two issues are the conventional two-stroke's nemesis! That the ring-ding's a comparatively thirsty beast has long been known. Maybe that's okay while fuel's plentiful. But the two-stroke is also fairly "dirty" in noxious exhaust emissions (which have nothing to do with the burnt-oil smell as such) and that's become significant with the imminence of tough anti-pollution laws for bikes as well as other vehicles.

That's not to say the two-stroke can't be de-toxed. It's probable it will be. But it takes time, intensive research and fresh design features (including fuel injection systems





If the two-stroke engine is to survive on the road with reduced exhaust pollution it will have to be different to models made today. Motobecane has shown that fuel injection, instead of carbs, helps detox the two-stroke but more radical approaches such as the unique Wulf (shown at top with its NVAC creators Bernard Hooper [left] and John Farrell, who also designed the famous Villiers Starmaker) may be the only answer in the long run. Wulf uses double-diameter pistons and cross-charge porting to get straight air-fuel mixture into the cylinders. Bottom-end uses conventional four-stroke type lubrication. The above diagram shows the porting arrangements and induction routes in the prototype SPX engine. The routes aren't as complicated as they may first appear, when you remember that piston 1 inhales and transfers the air-fuel mixture for cylinder 2, and vice versa. In this cutaway drawing (a) is number 1 double-diameter piston and (b) the inlet port for pump chamber (c). As the piston rises the charge is transferred through ports (d) and (f) to cylinder 2's inlet port (j). The route from 1 to 2 is duplicated on the other side, indicated by (e), and is mirrored from pump chamber 2 to cylinder 1 by ports (h), (q) and (l) with corresponding ports (p) and (m) on the opposite side. Ports (r) and (k) are the exhaust outlets.



Honda's CVCC design, the first stratified-charge engine in production, is used in Civic car to meet anti-pollution laws in USA and Japan. Unique head has three valves and two chambers a cylinder. Normal inlet valve supplies very weak air-fuel mixture to cylinder. Tiny auxiliary valve feeds richer mixture to ignition chamber where it's fired by the sparkplug and, in turn, lights the main charge.

IT'S A FOUR-STROKE FUTURE!

and elimination of conventional crankcase pumping) to get its emissions down and fuel economy up to the levels demanded in the future. Because makers realise that such projects would be enormously expensive without any guarantee of success they're turning to the four-stroke instead — its thrifty fuel consumption is proven and its anti-pollution technology is already advanced and available.

Even so, there's no quick, easy and cheap way to hit the bull's-eye. Your ordinary common garden variety four-stroke can't do it. That's been shown by the American car makers, for example. With their customary reluctance to develop advanced and efficient designs they persevered as best they could with their existing engines since the US introduced emission limits in the late '60s. Instead of producing refined engines with clean-burning characteristics designed into them, Detroit's mainly adopted hang-on devices such as after-burners (which re-ignite the outgoing gas between the exhaust manifold and pipe) to cleanse the dirty vapors outside the cylinders. Their latest attempt in that direction is the catalytic muffler which de-toxes the poisonous emissions by chemical reaction. This was initially hailed as being the answer — in theory anyway.

But in practice the catalytic chamber looks like back-firing because it has been found to produce emissions and wastes which many critics claim are at least as undesirable as those it cures. It's also brought maintenance problems because its efficiency deteriorates with use and the chamber must be periodically cleaned and renewed. And owners of some models are warned against parking off the road because the terrific heat from the catalytic hot-box can set dry grass alight.

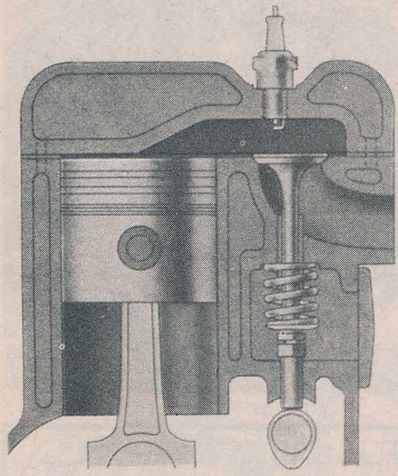
With mufflers like that on your bike you'd need asbestos riding boots!

Most European and Japanese firms have concentrated on new designs intended to beat the pollution problem at the source — within the cylinders. By refining the induction and ignition systems and revising combustion chamber design they're improving the combustion process to minimise the pollutants and avoid the need for hang-on exhaust-treatment devices. That's the way Detroit (and bike makers) will go too.

Most interest and activity centres around Stratified Charge engines. Though many design differences are possible in SC engines, the basic principle is that the air-fuel mixture in the chamber above the piston is very lean, so lean in fact that it couldn't be fired by a spark plug. So the plug instead fires a pocket of normal air-fuel mixture and the flame then spreads through the lean charge. It's just like using a match (spark plug) to light paper and kindling (the pocket of normal mixture) to light a log fire (the chamberful of weak mixture). For ~~low~~-emission engines the whole idea, and problem, is to burn very lean mixtures without the rough-running, misfiring, poor-performing traits that occur in ordinary engines when the air-fuel ratio is leaner than about 17 to one. They give the best compromise between power and economy with ratios from about 14 to 16 to one. Some SC engines run mixtures as lean as 22 to one with satisfactory results.

The first SC engine into production is Honda's CVCC

A



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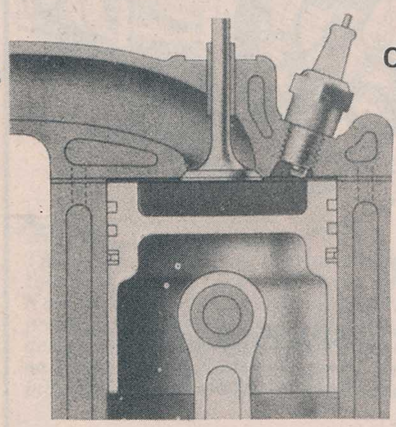

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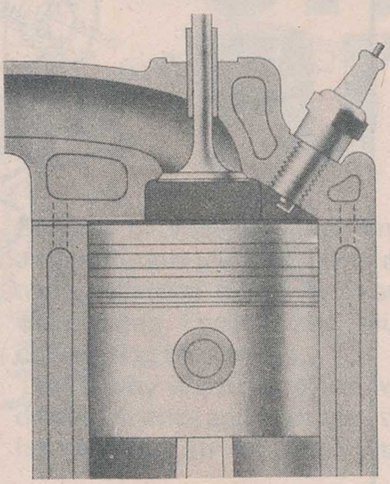

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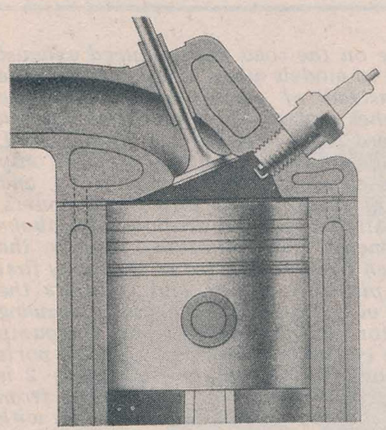

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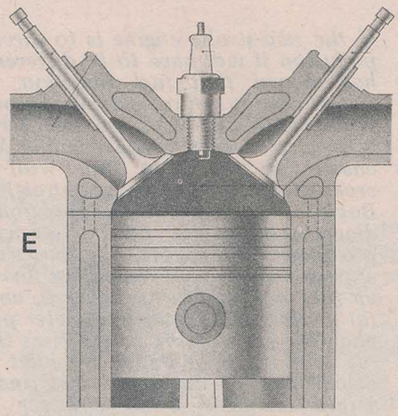
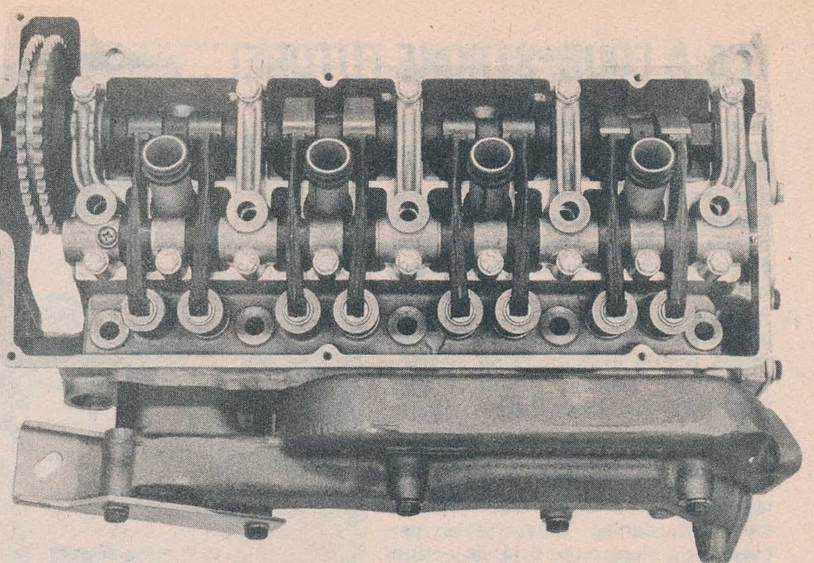


Varied valves. The diagrams show the basic layouts of five different chamber shapes and their related valve positions. The side valve system (a) is simplest, cheapest and most compact but least efficient. The chamber-in-piston design (b) offers a good compromise between cost and performance and is used in few bikes, including Morini 3½ vee twin. Widely used in cars but rare in bikes the bath-tub chamber (c) has vertical valves. A variation on the theme is the wedge chamber (d) in which the valves are inclined at an angle to the cylinder axis. The hemispherical chamber (e) with opposingly inclined valves is the most efficient arrangement (but also the most expensive and bulkiest) for two-valve systems.

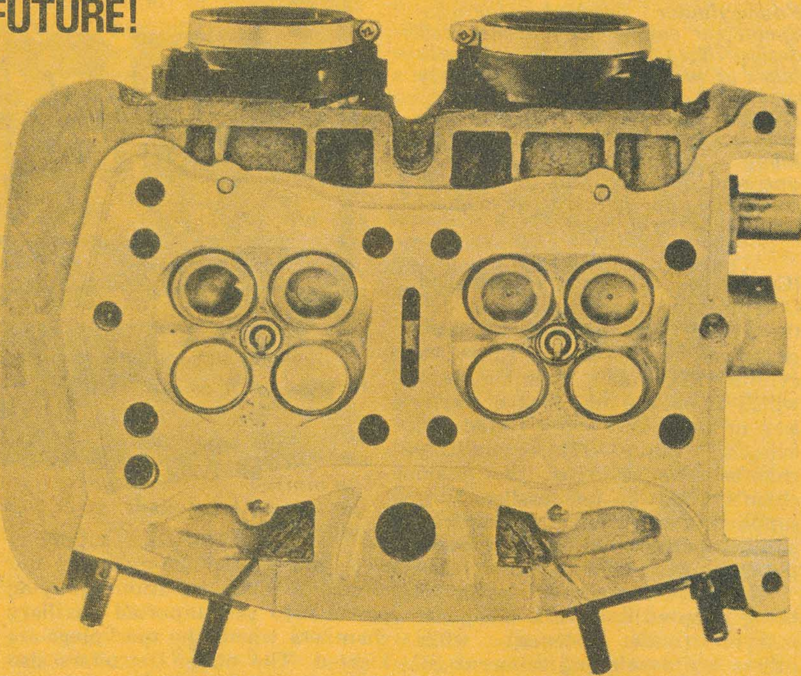


Four-cylinder Triumph Dolomite Sprint car engine has unusual head design that could find its way into bikes as well as cars. It's relatively easy and cheap to make but very efficient. The secret is that there's only one camshaft, with only two lobes a cylinder. But each lobe operates an inlet and an exhaust valve; the inlet directly, the exhaust via a rocker arm. Neat.

(Compound Vortex Controlled Combustion) four-cylinder model, the head of which has two chambers and three valves a cylinder. The main chamber, into which a special carburettor feeds lean mixture, has ordinary inlet and exhaust valves. The auxiliary chamber opens into the main chamber, but is far smaller. It is supplied with normal mixture by another part of the carb and holds the sparkplug and a tiny inlet valve.

Honda's successful design is being adopted by several major car makers (under licence), while others are developing different SC systems using three or two valves with fuel injection instead (or as well as) a carburettor. Among General Motors' SC prototypes, for example, is a promising two-valve unit with a carburettor supplying weak mixture to the cylinders and electronic fuel injection spraying petrol into the unported auxiliary chambers where the sparkplugs are located. The other Detroiters also have SC engines under development but none of them are expected to be in production before 1978.

Some makers are taking what's known as the lean-burn approach. Though such engines don't use Stratified combustion as such, they share the lean-mixture concept but arrive at it differently and are on the verge of becoming realities. Chrysler, for example, will offer LB engines in some of its models later this year. They are basically existing engines refined to accept mixtures as lean as about 18 to 1, or about two points leaner than



Known as a pent-roof, four-valve systems use an inverted V-shape chamber. This is the Yamaha TX500 head.

normal right through the operating range. Saab is one that has managed to comply with America's regulations with only relatively minor changes to the camshaft, carburetion, ignition and combustion chamber. Another is GM's super sporty Cosworth Vega coupe, an Anglo-American venture. In contrast to the plainly conventional single overhead cam Saab design, the Vega engine produced by England's ace Cosworth company (responsible for the famous Formula 1 racing V8 engine and the exciting Norton P86 "Challenge" motorcycle twin) has double overhead cams, four valves per cylinder, elaborate fuel injection and dry sump lubrication. By ordinary car standards it's a very advanced lump. But both the simple Saab and complex Cosworth prove that it's still possible for a standard engine to be satisfactorily clean when given really good basic design and careful development.

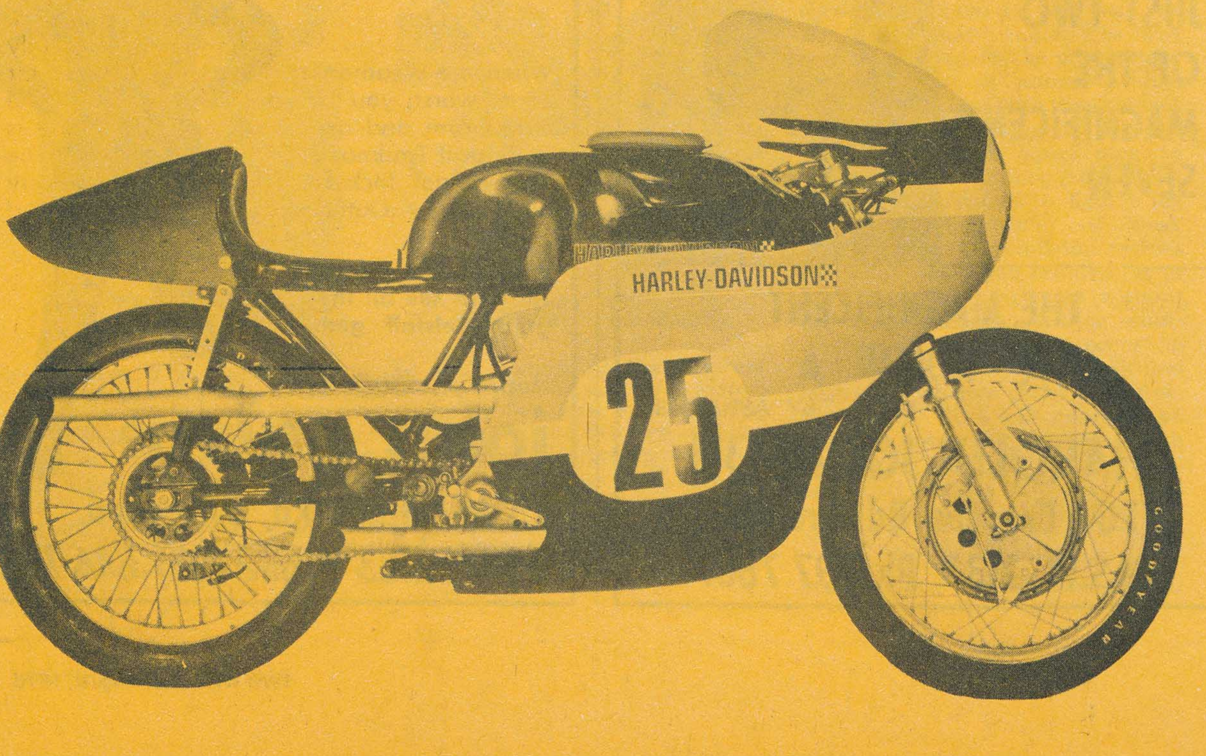
And that's the way street bike engines will be going in the future, with the emphasis on absolute modernity and thorough refinement. If bikes aren't to become undesirably bulky, heavy, complicated, costly and difficult to maintain, the engines that meet tomorrow's clean-burning requirements will have to have anti-pollution measures designed in rather than added on. It's also the reason that sidevalve engines are dead, pushrod overhead valve units are dying, sohc models are the norm and dohc versions are becoming increasingly popular, as are four-valve heads.

Why?

Because even without the anti-pollution factor, efficiency has become the name of the game. And the valve train and combustion chamber are where it's at!

It's been that way since pioneer internal combustion engines coughed and spluttered into life about 100 years ago, of course. All that time it's been no secret that advanced engine design is its own reward in power and economy. But it's taken most mass-producing bike and car makers about 60 years to catch up.

Though some hopefuls still explore unconventional means of opening and closing the ports (in attempts to exploit the undeniably attractive potential of rotary or sleeve valve systems), the old faithful poppet valve reigns supreme — the best compromise to date in spite of inherent problems which include reciprocating motion, multiplicity of parts in the operating train, obstruction of the port, and the adverse shape and hot spot it may confer on the chamber accommodating it.



Last of the red hot sidevalvers. Harley-Davidson's mighty KR750 reached the peak of its career with about 41 kW (55 bhp) on tap but ran out of development in 1968.

Mechanically, sidevalves are the simplest and cheapest poppet system, which explains why they predominated among mass-produced bikes until the late '30s and to the early '50s in cars. The basic sidevalve engine has its poppets standing upside down with their heads seated on the cylinder's top deck next to the bore. The camshaft operates the valves directly with only a simple follower or tappet between each lobe and stem. Thus the valve train has fewest possible parts and lightest possible weight, so the mechanical action in itself can be excellent. But other things conspire to limit the sidevalve engine's overall efficiency.

With a side-draught carburettor, for example, the ingoing charge experiences three changes of direction as it passes through the port, emerges from the valve seat and enters the cylinder proper. Vice versa for the exhaust gas.

Also the combustion chamber must extend over the valves to allow them clearance, and the relatively large chamber prevents desirably high compression ratios being obtained and gives a lot of surface area to absorb heat during the combustion phase.

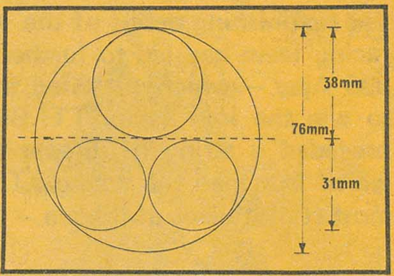


Figure 1 shows how two smaller valves fit into the same space as one larger valve and combine to give more port area. A 38 mm circle takes half a 76 mm bore, for example, and has 1134 mm^2 area. But the same size semi-circle also takes two 31 mm circles which have 1509 mm^2 area combined. Four-valve chambers also give good central spark plug location.

As a result of those factors the sidevalve engine, even when given very long valve timings, has fairly poor volumetric efficiency; in given conditions it can't inhale as much fresh mixture as a comparable valve-in-head engine. The sidevalve engine's breathing and combustion handicaps are reflected in lower power outputs.

Harley-Davidson's famous KR750 cm^3 V-twin racer, probably the most highly developed sidevalve engine ever, reached the peak of its career with about 41 kW (55 bhp). At that it could keep its 500 cm^3 ohv rivals honest under America's old system where the capacity classes were staggered according to engine type: sv, ohv, ohc and two-stroke. But the 1969 change to straight capacity classes, regardless of engine type, killed the KR which simply couldn't live among other 750s.

The next step along the evolutionary trail for mass-produced models was the adoption of pushrod overhead valve systems, chosen by most as the least expensive means of obtaining at least some of the improved efficiency available from valve-in-head designs. Here the camshaft remains below cylinder head level, running in the crankcase or on the side of the cylinder, and the valves are mounted stem up in the head where the action of the cam followers is relayed to them by pushrods and rocker arms.

Immediate advantages of this layout even in its most basic forms

(Continued on page 68)

IT'S A FOUR-STROKE FUTURE

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include more direct inlet and exhaust tracts, more compact combustion chamber, high compression ratio, and improved volumetric efficiency. This means that the cylinder not only inhales more fresh mixture, but squeezes it tighter on the compression stroke and burns it better during combustion.

The ohv layout also lends itself to every conceivable valve arrangement and chamber shape. Both valves may be vertical, for example, or one veritcal and the other angled, or both angled together, or angled opposingly in a V formation. The chamber's usually formed in the head as a hemisphere, tub, wedge or whatever shape suits the disposition of the valves (or vice versa), but with vertical valves it's possible for the head to have a flat face with the chamber incorporated in the piston crown, as in Moto Morini's 3½ model for example.

That ohv systems can be made to work very well has been proved by innumerable sports engines in bikes and cars both. But there are drawbacks. The pushrods and rocker arms add complexity, weight and wear points to the valve train and so increase the difficulty of finely accurate valve action.

It's almost impossible for the action prescribed by the cam lobe to be transferred to the valve with very precise accuracy because of the unavoidable flexibility existing in the system. No matter how stiff the pushrods and how rigidly supported the camshaft and rocker arms, the valve action almost inevitably deviates to some extent when the engine's working hard.

Don't think such misbehavior has to reach the valve float stage before it becomes critical. Though undetectable to the rider at lower speeds, inaccurate valve action adversely affects the performance, economy and pollution more than you might imagine. And that situation is becoming intolerable.

Yesterday it was enough for engines to run. Today it's enough that they run reliably. Tomorrow it'll only be enough for them to run reliably with durable precision!

Car emissions standards, for example, don't only require that engines are clean when tested in near-new condition. The limits must also be met at intervals up to 80,000 km. So engines have to be designed to stay in tune with minimised wear and deviations over extended periods. And that's why most recent four-stroke engines, and those now on the drawing boards or in the pre-production testing stages have ohc systems.

The better examples have direct-acting trains with inverted-bucket type followers. Though one of the oldest designs, this arrangement remains the lightest, most accurate and most durable. It's the standard system among racing four-strokes and is also found among many top quality street engines. The inverted bucket fits over the valve spring and rides in a bore machined into the cylinder head or camshaft carrier to take the side thrust imposed by the cam lobe. Tappet clearance is usually adjusted with shim washers inserted between the valve stem tip and inside end of the bucket, but a few examples have threaded screw type adjustment.

It follows that when a designer opts for a direct-acting system with a single camshaft he must use an inline valve layout with both valves either upright or angled to the cylinder. Though popular with car designers that layout's not common among bike engines. If the valves are inclined at different angles in a direct-acting system there must be two camshafts, as on the Kawasaki 900. That's the most efficient route but also the most expensive. So many street engine designers who want the excellent breathing and combustion qualities promoted by opposingly inclined valves favor a simplified variation. Production costs are lowered without much loss of efficiency when one camshaft operates both valves via rocker arms. That system's found in many bike engines including the Yamaha 650 and most Hondas.

The obvious trend towards overhead camshaft engines is one indication of the growing concern for improving all aspects of engine performance. Another is the increasing use of four-valve heads with two inlet poppets and two exhaust for each cylinder. This design was formerly restricted to very advanced racing engines but is now appearing on more and more production models which already include the XL 250/350 Hondas, Yamaha's 500 twin and 750 triple, the Norton Cosworth P86 twin and Laverda 500 twin. Ideally both pairs of valves are actuated directly by a dohc system, as in the Yamahas and Cosworth, but good results can also be obtained with sohc and rocker arms, as in the 250 and 350 single-cylinder Hondas.

A refreshingly innovative design has been introduced in the Triumph Dolomite Sprint car engine and is attracting interest from other car and bike makers. In the Sprint's four-valve head a single cam operates directly on the inlet valves and actuates the exhaust poppets through long rocker arms. That's a bit unusual in itself and helps reduce production costs which are then further lowered by another distinctive feature — namely that the cam has only two lobes per cylinder, just like a two-valve design. But here you haven't got one lobe operating the inlet side and the other the exhaust. Each lobe actuates its adjacent inlet valve and the opposite exhaust valve. The idea of using one lobe for both valves is rare though not unique. But the Sprint's the first engine to use the low-cost lobe-sharing design in an efficient four-valve arrangement. It may not be the last.

Not the least of the four-valve head's attractions is that it allows an excellent pent-roof (inverted V) chamber shape with the spark plug located in the middle, not offset as it must be in two-valve chambers. There are several advantages to using two small valves rather than a big one. Though their individual diameters are smaller the paired valves combine to have a lot more port area than a single valve of larger diameter. And because they each weigh less than a bigger valve they can use lighter springs while operating more accurately.

So for those seeking optimum efficiency — maximum performance and economy consistent with minimised pollution — the four-stroke engine clearly offers the brightest prospects for the future. It isn't perfect, of course, but until something better comes along it's the best we've got! *