MOTORCYCLE SPORT

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"FUNNY ENGINES"

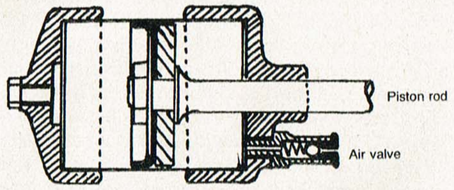
. . . which is how Michael Cross refers to the rotary-valve engines so long associated with his father's name

ENGINEERS among readers may know of the Cross Manufacturing Company (1938) Ltd as manufacturers of many wire-formed items, such as circlips, spring washers, retaining rings (the circlip-like devices favoured by the Japanese for locating bearings), and wire-threaded inserts (which we all call helicoils, although in fact this is a trade name, in the same way as Barbour and Hoover). A little nearer to our chosen subject are the piston rings the company makes — high-performance rings advertised as being used in Cosworth DFV and DFX racing engines.

The firm was started by Roland C. Cross in the 1920s to take on experimental and development work. Roland Cross had been apprenticed at the Arrol Johnson Motor Company, had worked at the Bristol Aeroplane Co and Vickers Ltd, and was an inveterate experimenter, having greatly modified a 1907 Triumph motorcycle and built the first of his rotary-valve engines in 1922. In the late 30s and through the war years the company began to specialize in manufacture of items which required forming or rolling from high-quality wire or rod. However, the development side has continued and the interest in engines has been inherited by Roland's son, Michael E. Cross, FIMechE, who is the current managing director. When a little time and money can be spared, the Cross company continues to dabble with what Michael describes as "funny engines" and particularly with their speciality — the rotary valve.

Although this article is primarily about the rotary-valved engines, that '07 Triumph is too interesting to be passed over without description. In later years Roland Cross recalled that his attentions might have been better directed towards the stirrup front and belt rim rear brakes, but in the enthusiasm of youth performance and fashion took precedence. Thus the Triumph grew a dropped frame, for low seat height, air suspension (yes, air suspension, decades ago), a home-made carburettor to replace the double-barrelled Triumph item, and a "supercharged" engine.

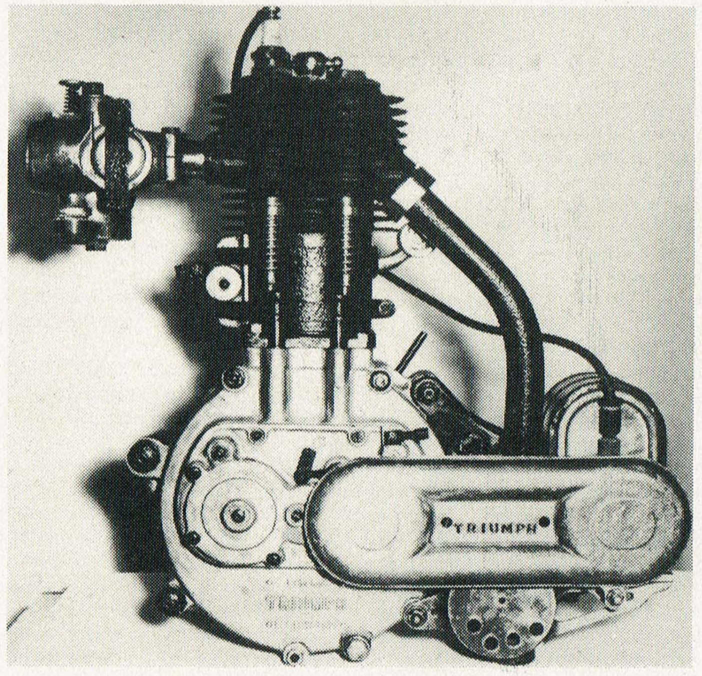
People familiar with veteran and vintage Triumphs will know that the fork has an unusual fore and aft action, being pivoted at the bottom yoke and with a barrel spring at the top yoke to control movement. (There were separate bump and return springs on earlier models.) With the

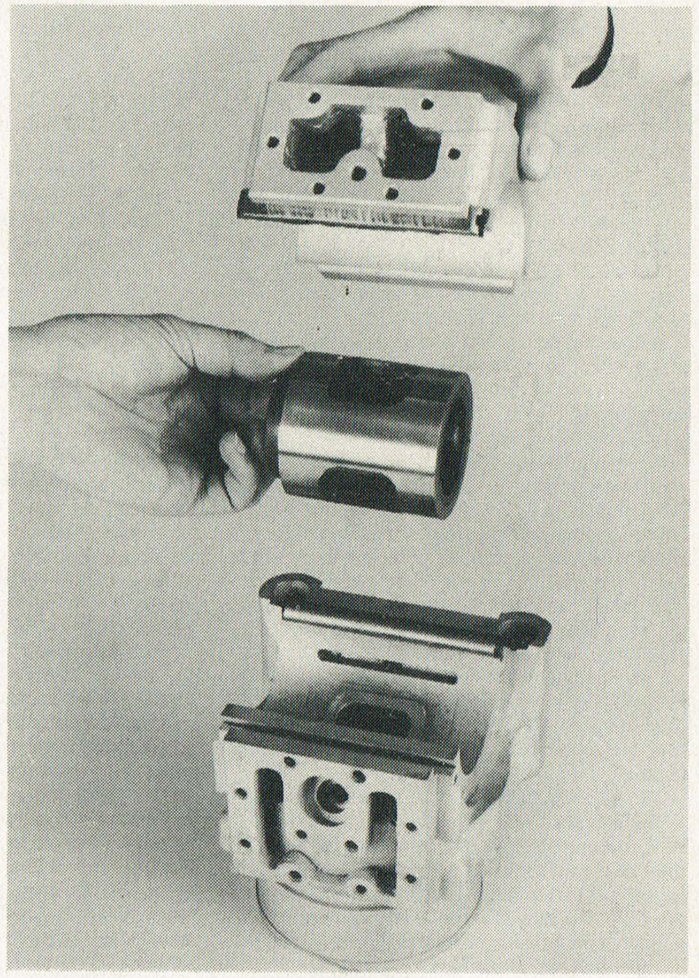


rigid rear end of the period, comfort was somewhat limited. Roland Cross was aware of the progressive nature of an air spring, which gets stiffer as the air is compressed into a smaller and smaller space. Since this permits a soft initial rate for comfort, yet firms to provide a harder one on big bumps, to prevent bottoming (the same trick as with modern rocker arm systems), he made a spring unit of this sort for his Triumph. As illustrated, it is in principle a short, fat bicycle pump without an outlet — even to the use of a leather sealing washer on the piston. On its own such a seal would have been inadequate, so the space behind the piston was fitted with ball-valve controlled ports. As the unit bounced the first few times, the predetermined space behind the piston drew air in past the valves and then pressurized the unit. A clever idea which modern manufacturers might do well to ponder. Why shouldn't our suspensions pump themselves up to a predetermined ride height, irrespective of load? After all, how many riders do you know who actually readjust their units each time they carry a different load?

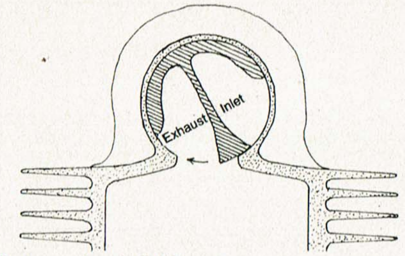
The supercharging scheme was very ingenious — yet simple. A transfer port was fitted from cylinder to crankcase, as per two-stroke practice save that this one was fitted with a valve so that it could be used, or not, at will, and a crankcase air inlet valve port was added to replenish crankcase air. On an engine of this date, the oil supply was so meagre that oil contamination of crankcase air would have been slight. At the bottom of the inlet stroke, crankcase pressure would push more air into the cylinder and sufficient extra power was thus made available for the pedals to be dispensed with. Of course, a similar puff of air was also pushed "upstairs" as the exhaust valve opened, and improved scavenging may have been as much a contributory factor in increasing power output as was the supercharge. Such use of the underside of the piston, in exactly the same way as with a two-stroke, would appear to be permissible under FIM racing rules. A pair of side-by-side cylinders could be arranged to utilize fully this effect by permitting each piston underside to assist in charging the paired cylinder when its own is on the exhaust cycle. A straight-line crank mechanism would be called for to obtain a worthwhile compression ratio in the charging cylinders (maximum theoretical supercharge 14 lb/in^2), and the author has been sufficiently intrigued to sketch such an arrangement. Alternatively, the same arrangement could be used for a "compound" engine, where the exhaust, which is never actually exhausted of energy, is made to give up more energy by expanding further in larger cylinders (a "steam" practice you see on most traction engines, with one small high-pressure cylinder, and one big low-pressure cylinder); or, with slightly more complex arrangements and stepped pistons, both facilities could be had together.

Photographs show (left) 1907 Triumph engine with crankcase supercharging and home-built carburettor, and (right) cylinder, valve and valve cap of Abingdon-Cross engine. Drawing (above) shows air spring for the 1907 Triumph.





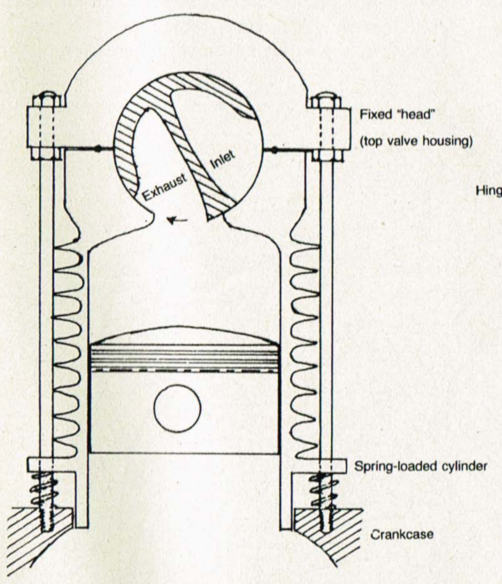
However, to return to the subject of rotary-valve engines, of which there are two particularly well-known forms: the Aspin which uses a conical valve spinning in the combustion chamber, and the Cross with a cylindrical valve above the combustion chamber and controlling a port into it. R. C. Cross, in common with many other engineers, always felt that poppet valves bouncing up and down could not be the best way of controlling inlet and exhaust passages — especially the exhaust where the valve is poorly cooled and may work at red heat in sealing combustible mixtures. A rotary valving device eliminates the inordinate accelerations and decelerations of reciprocating valves and may give faster opening and closing as well. In fact in the last century gas engines, with their big cylinders, small valve area, low speeds, and exposed cast-iron mechanisms, used rotating devices as valves. Quoting R. C. Cross — "There was never a thing mechanical that had not its difficulties, but it was not until I made my first rotary-valve engine, in 1922, that I discovered the 'flies in the ointment'".



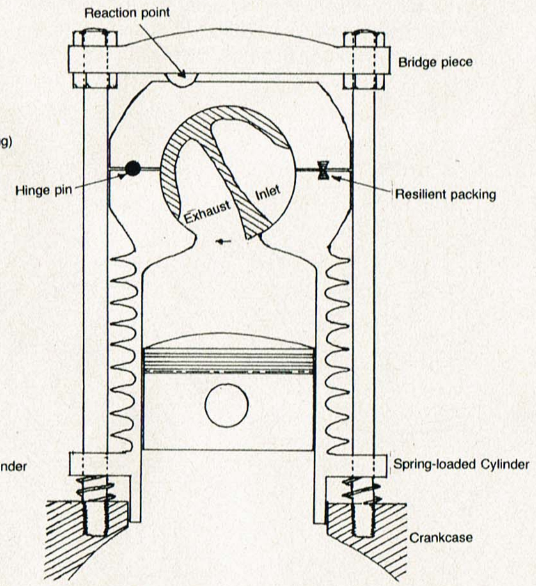
Rotary valve (solid housing)

This 1922 effort was the first of a long series of engines in which difficulties were discovered and ironed out. Prime among these are sealing and friction. An ordinary (poppet) valve is held tight against its seat more by gas pressure than by its spring during the power stroke, but at this time it is stationary. Most of its motion takes place during low-pressure parts of the four-stroke cycle, so friction is low. The simple rotary valve is blown off its seating by gas pressure on the firing stroke, which calls for very tight clearances; this tends to increase friction, as does the fact that the valve motion continues during a period in which the valve is subject to high pressures on its seating.

The next Cross engine had piston ring type seals at the ends and vanes either side of the port, reducing the sealing problems responsible for poor starting, poor low-speed output and high oil consumption. Nevertheless performance at higher speed was good. Engine number two (adapted from a 1923 TT Sunbeam, ohc of course, as this conveniently supplied the drive up to the head) lapped Brooklands at 80 mph.

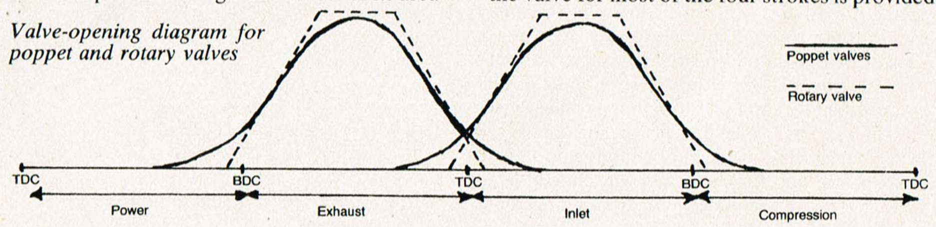


Rotary valve with split valve housing



Rotary valve with controlled valve loading

The next evolutionary step was to bush the valve hole with a bronze sleeve, with the port cut into this sleeve forming the top of the combustion space. The valve was in cast-iron . . . this was the normal material for Cross engines since the valves do not run hot. Unlike a poppet exhaust, which is exposed to hot gas over most of its area

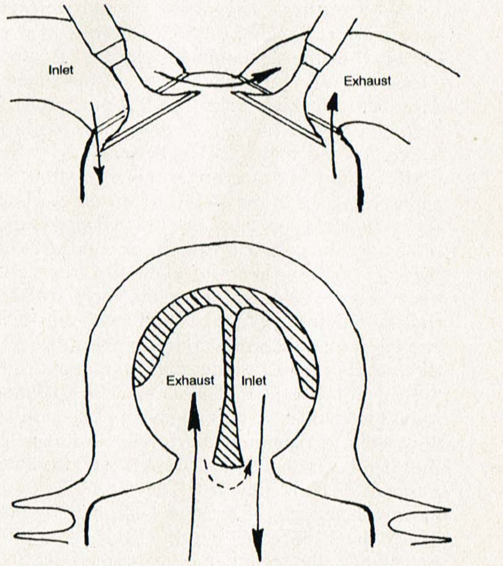


Valve-opening diagram for poppet and rotary valves

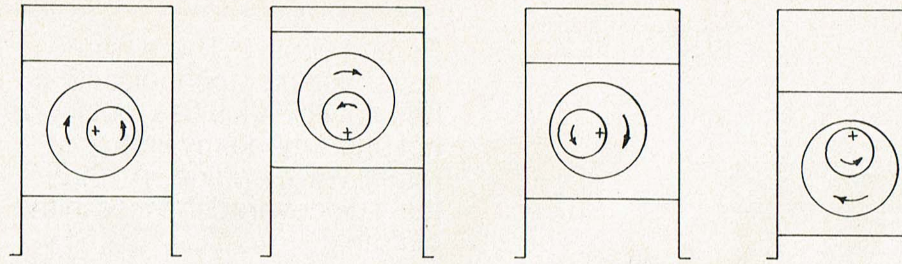
Roland Cross: "There was never a thing mechanical that had not its difficulties, but it was not until I made my first rotary-valve engine, in 1922, that I discovered the flies in the ointment."

and has cooling contact with the head over very little area, the rotary valve maintains intimate contact, for cooling, over most of its area at all times. The bronze sleeve had its lip sprung to contact the valve, and was aided, no doubt, by combustion pressure at critical times and able to accommodate some differential expansion between valve and head. Oil consumption was dramatically reduced, so that a recirculating system supplying 10 times as much oil as on previous engines could be used. This springy lip design was employed until 1935.

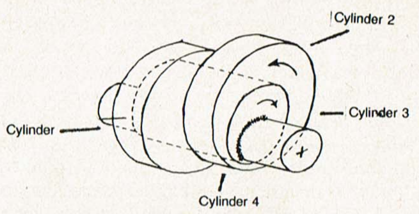
The major step forward, and the one which distinguishes the Cross valve from others, was taken in late 1935 when the valve housing was split and the cylinder allowed to "float", as shown in the illustration; the purpose of this floating will be explained shortly. The valve housing split was the only "head joint", because no such joint was necessary at the top of the bore since there were no valve seats to cut, grind, and so on. Furthermore, the "head" bolts were a little unusual as their job was to space the "head" precisely from the crankcase and not simply to pull it down on to the cylinder. Instead, the cylinder was a fraction short for the space provided. A spigot into the crankcase provided the seal there, and springs or resilient gasketing pushed the cylinder against the fixed "head". In operation, therefore, the pressure on the valve for most of the four strokes is provided



Unburned gas leakage with poppet and rotary valves



Contra-rotating crank mechanism



Four-cylinder crank assembly

by these springs, or the resilient device, and can be modest, with the benefit of low friction. Indeed, it would be far *too* modest to provide a seal against combustion pressures were it not that when these high pressures occur the floating cylinder is pushed upward by them and squeezes the valve. The higher the pressure to be sealed, the more squeeze!

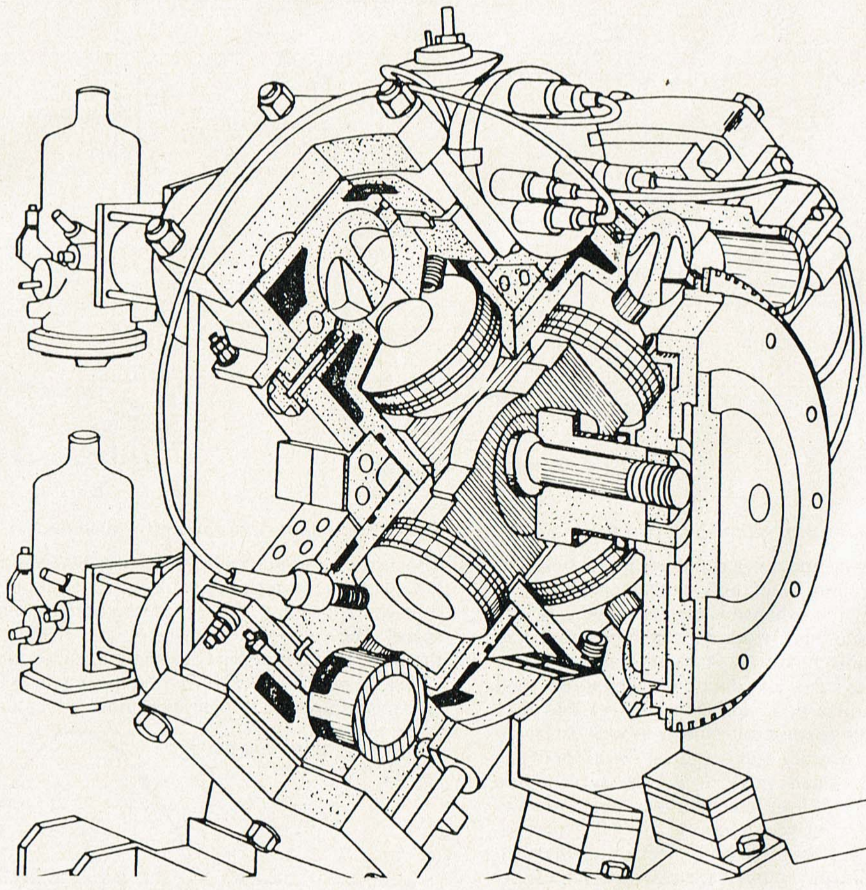
Thus a good seal was achieved, but with much reduced friction because it was only high in that part of the cycle where high pressure sealing was required, and then it was proportionate to the pressure. This modification transformed the engine characteristics. Gas sealing was excellent and slow pulling "rivalled that of a steam engine" (the reasons why it should be better than a poppet valve we will come to later). Seizures were eliminated, and the bearing metal for the valve was the same as that of the cylinder. A 750 cc Austin engine was converted with this type of split-valve housing and could produce a continuous 30 bhp on 65 octane fuel, while a 500 cc single based on a Rudge bottom end did a 10 hour full power test at 6,000 rpm.

One further significant improvement remained to be made, that of "controlled valve loading," in the development work of Roland Cross. With the split-valve arrangement described thus far, and a practical port area of perhaps one-fifth of the bore area, valve loading is actually too high. This is because the valve itself is subject to cylinder pressure on the exposed surface of the one-fifth bore area, while the cylinder is pushed on the valve by the remainder, ie, cylinder pressure on four-fifths of the bore area — something like four times more than is necessary. If the excess force can be transmitted directly to the "head", and only just enough to maintain sealing transmitted through the rotating valve, friction may be reduced and more power liberated. This can indeed be done, using the standard Cross engine construction as illustrated in diagrammatic form. No longer is the "head" rigidly tied to the crankcase; Instead, a bridge piece is attached. The top part of the valve housing (the "head") is restrained by this bridge piece through a self aligning reaction point, and the cylinder is restrained by the "head" through the valve itself and a solid hinge pin to one side. On the opposite side from the hinge pin is a resilient pin which opens up the valve clearance on light load but is incapable of transmitting any large forces. Thus if the reaction point is situated directly over the valve, all the forces are taken through the valve and none through hinge pin or resilient packing. However, if the reaction point is placed over the hinge pin this transmits the force, with virtually none going through the valve. By choosing a position between these two the designer can split the loading as he wishes between the direct route via hinge pin and through the rotary valve. In fact, other mechanical arrangements to achieve the same ends can be made and indeed were made (eg, fixed cylinder and hinged head with valve at the side) but the arrangement

Let us examine why a rotary-valve engine might be expected to have different, probably better, power characteristics than a poppet-valve unit.

described was the preferred one in most engines.

It is quite fair to refer in this way to "most engines", because the Cross rotary-valve engine was, and is, no one-off special for which the builder makes extraordinary claims but which never appears. There have been many Cross engines, in many forms, including a range of singles based on Rudge bottom ends, fours, radials and vees. Some have been made to Government order and rigorously "type tested" (as aircraft generating engines in the early war years). A very interesting version of the single appeared in a Rudge frame at the 1935 TT with L. G. Martin as the rider. It had an outsize "cylinder", which was actually an oil-cooled cylinder surrounded by its own radiator; this arrangement avoided pipes, increased fin area



Abingdon-Cross BX engine of 1621 cc

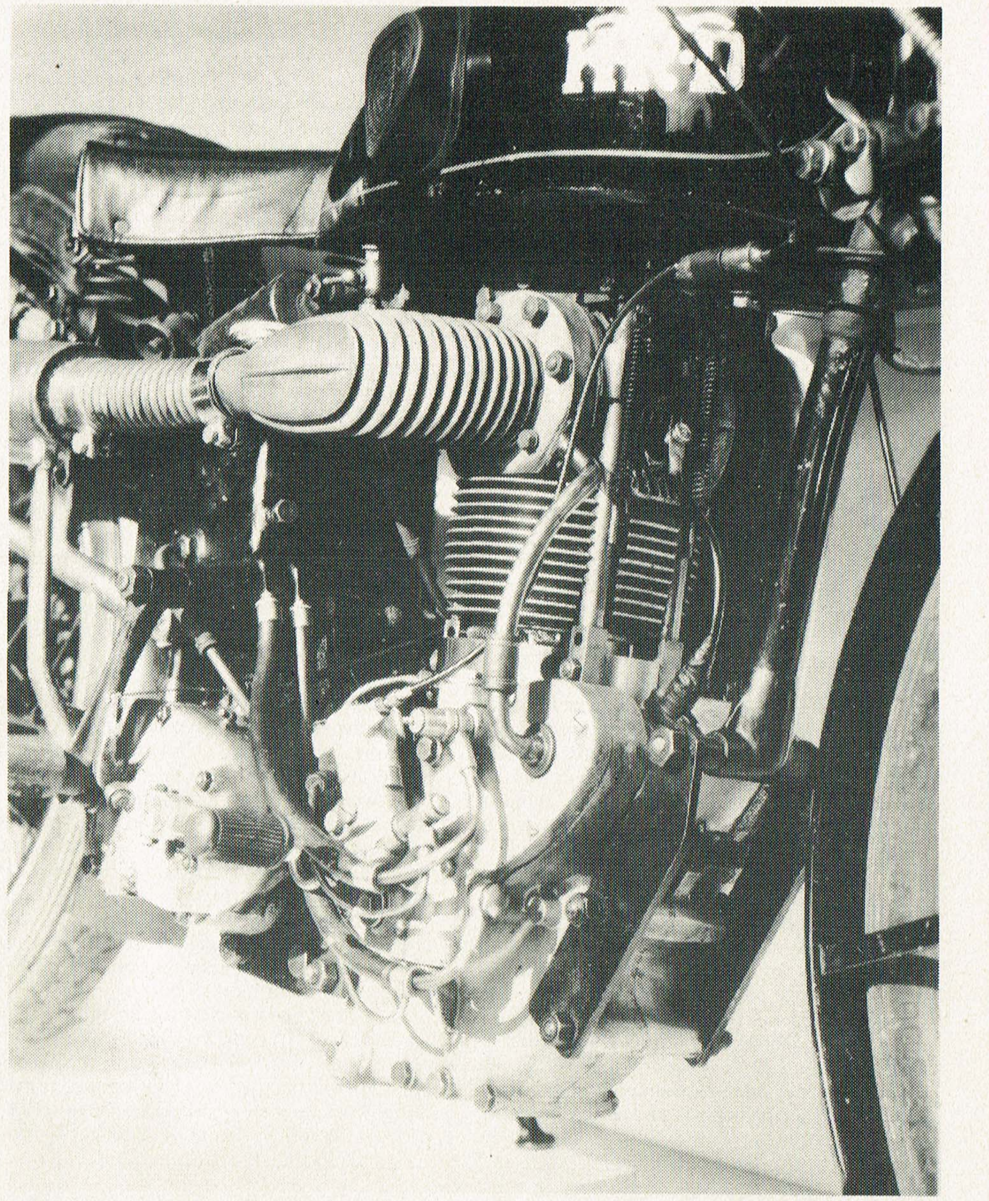
over that of a normal cylinder, and improved the cooling of hot spots (which in any case are less on a Cross engine). The author has no information on how the machine fared but he and no doubt *MCS* readers would be pleased to learn. . . .)

Performance of these engines was always good; bmep was up to 195 lb/sq in . . . it was possible to run with a ratio higher compression than on a comparable poppet-valve engine . . . or on very low octane fuels . . . and yet they were flexible, a typical torque curve dropping no more than 10 per cent below peak over the 2,500-to-5,500 rpm range. But Cross were a small development organisation, not a large engine manufacturer. Someone else would have to be convinced of their engine's value. The Government, who were interested during the war years, were more concerned with Cross's skills in wire-forming techniques which were at that time desperately needed — hence the line Cross manufacturing has taken.

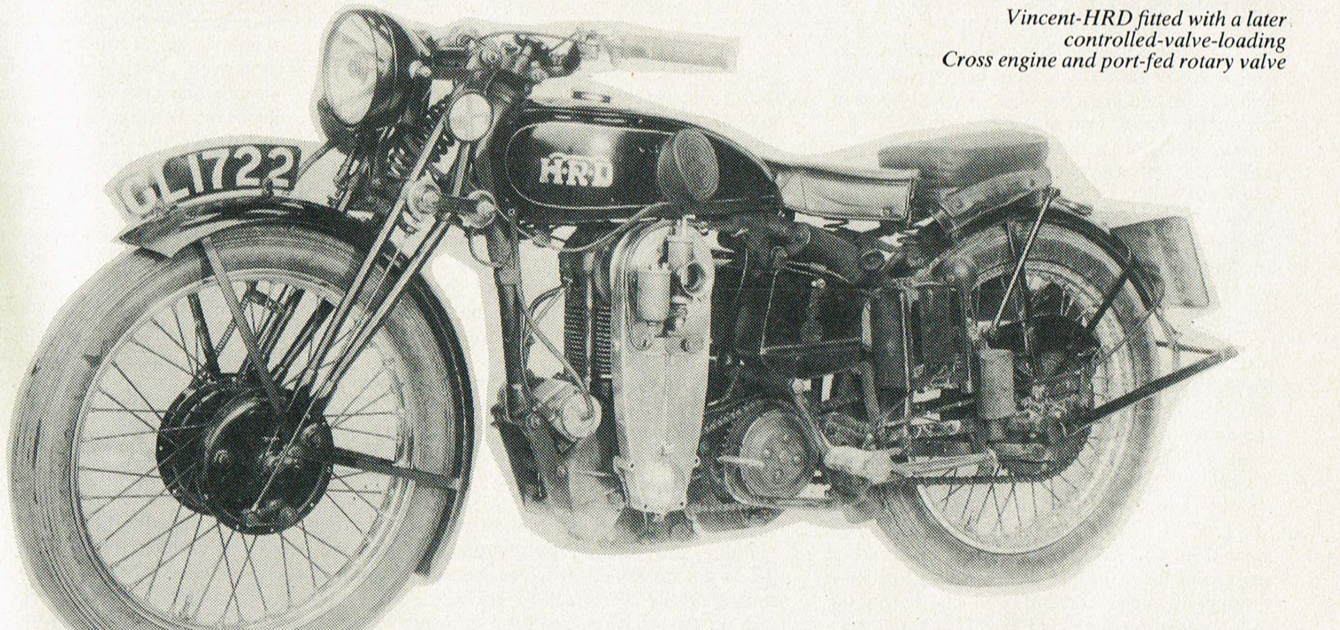
For the car industry the engine type does have some disadvantages. In particular, the need for floating cylinders and / or heads does not permit the cheap, one-piece casting for four or more cylinders on which conventional design is based. Sadly, then the idea has never been taken up on a large scale. That is not the end of the story. But before pressing on, let us examine why a rotary-valve engine might be expected to have different, probably better, characteristics than a poppet-valve engine.

Most readers will be familiar with the first of the valve timing diagrams. Each valve has to accelerate from a standstill and, hence, has to begin moving well before top or bottom dead centre and, even so, only approaches full lift (passage unobstructed) well afterwards, when the valve has to be gently slowed again. Closing is a reverse sequence and is equally restricted by valve inertia. If an engine is expected to be economical at modest speeds, overlap when both valves are open together is small, so that gas blown back or out of the exhaust is small, but at high speed opening time is too short for proper cylinder filling. Alternatively, a large overlap may be used. Opening time is adequate, especially when high-speed gas inertia can keep gas flowing in an inlet passage for a while after the piston commences the compression phase. But at low speed the valves are effectively opening and shutting too early and too late, to the detriment of performance and economy.

Now consider the rotary valve. Only one hole in the combustion chamber is required, so it is not dificult to make it adequately large at maximum opening. The valve motion is continuous, so opening and closing can be rapid since no acceleration time is needed. The resulting valve timing is shown in the second graph, in which it can be seen that opening areas can exceed a highly tuned poppet arrangement, and yet valve overlap can be very small, as in much more softly tuned engines. Combustion-chamber design is not dictated by the need to accommodate large valve heads and no red hot exhaust valve head intrudes, so problems of detonation are reduced and higher compression ratios or lower octane fuels are permissible. A tractable and efficient high-performance engine is the result. With up-to-date problems in mind, it may be noticed that there is no critical exhaust valve to suffer should the lead content of fuel be reduced. As it happens, this is not the only advantage which the Cross engines might have in our modern world of fuel shortage and emission problems.



Vincent-HRD fitted with a later controlled-valve-loading Cross engine and port-fed rotary valve



Vincent-HRD of 1934 with split-valve housing engine and end-fed rotary valve.

Since inlet and exhaust use the same hole, it is not too easy for unburned mixtures to escape without completing the whole cycle of events, as may happen with ordinary valves, particularly when arranged in the hemispherical head traditionally used for high performance. Noise, too, is potentially lower without all those cams, followers, and valves banging up and down. As a result, Michael Cross and others are still interested, and developing, the Cross rotary-valved engine, even if it remains an uphill struggle for a small enterprise to keep pace with, let alone beat, wealthier rivals in a large industry.

One such modern development is the Abingdon Cross engine built at the Esso Research Centre in conjunction with Cross Manufacturing Co. (1938) Ltd, and described in detail by A. J. S. Baker and M. E. Cross in the Proceedings of the Institution of Mechanical Engineers, Vol. 188, pp 38-74. As mentioned previously, the Cross valve arrangement does not favour single block and head castings; thus an adaptation of a conventional layout falls far short of optimum. Other more suitable layouts were considered. One poor feature of a conventional engine is the large and more or less empty space which has to be provided, in which crankshaft and connecting rods will flail about in . . . and indeed the long and whippy crankshaft itself which for many years was a troublesome part of six-cylinder design. The long, whippy crankshaft, and excessive engine length, can be improved on adoption of a radial layout suitable for separate cylinders. The large diameter and funny angles of a normal radial (with its "odd" number of cylinders) would be a nuisance in most applications. A novel alternative has been designed. A pair of contra-rotating eccentrics is one standard mechanical way of generating reciprocating motion from rotary motion, as indicated by the series of sketches. Unlike the crank and connecting rod, this mechanism generates straight-line motion and does not rely on cylinder and piston to define the axis, so the piston may bear directly on the outer eccentric. This eliminates the con rod and all the space the con rod requires. Both ends of the piston assembly may be closed and fitted with rings, working in opposed cylinders, with the advantage that there will be no need for piston skirts to hold the piston square in the bore (if cooling permits). This two-cylinder setup would require the contra-rotating eccentrics to be geared together with quite hard-working components (there may be no flywheel between them and the pistons), but further improvement is possible. Another identical pair of cylinders, sharing the same inner eccentric, can be mounted at 90 degrees to the first pair, much closer than a cylinder diameter with the right piston design. The outer eccentric for this pair rotates with the other outer one, but 180 degrees apart in timing. When they are rigidly attached together, it turns out that the pair always know which way to go on their own with no geared drive. Balancing is similar to that of a 90 degree vee-twin. With one piston assembly 100 per cent balanced by a rotating balance weight on the crank mechanism, the second cylinder is automatically balanced too, as far as "primaries" are concerned. Unlike normal crank and rod assemblies, this "Baker crank" does not generate any "secondaries" because piston accelerations are identical at TDC and BDC; thus balance is almost perfect with only a small residual rocking couple, due to the small offset between cylinder axes. This could be eliminated by making an eight, with a second four cylinders having a mirror image offset; this arrangement would also cure the one real peculiarity of the four, which is its very odd firing intervals (the reason why radials normally have odd cylinder numbers) and rather difficult carburettor requirements. As can be seen from a drawing of the engine (which is to scale, including the SU carburettors), the whole assembly is quite compact, especially as the four vees can conveniently accommodate ancillaries such as starter, alternator, and so on.

The test engine was constructed quickly and at modest cost. How did it perform? Very useful results were obtained, performance being comparable to that of a high-power conventionally constructed engine. This, however, was not considered to be good enough — quite correctly as no manufacturer is likely to trade a well-known technique, where he is already tooled up, for a new and different technique unless it promises distinct advantages. Investigation showed that friction losses were rather high, compared with those of an ordinary unit. This had not been the case in the past. However, over the years engines have taken advantage of better materials and lower-viscosity oils, and generally have improved quite a bit. With very little development in recent years, the Cross has some catching up to do, but more ideas and developments are being tried out as and when normal business permits.

As a parting thought — consider that Cross have a long history of association with motorcycles, that they still maintain a much modified Royal Enfield as a piston-ring testbed, and that one of the remaining Cross engines is in a 1934 Vincent-HRD. Surely the vehicle in which the engine is a focal point, where something a little different — as long as it is not *too* revolutionary — can command a premium, is a motorcycle. Design life expectancy can be shorter than in the car market . . . rather a sad state of affairs. There is a resurgence of interest in singles and, particularly, vee-twins with their reputation for torque and performance. These legendary characteristics are remembered from the days of singles, when the vee-twin had more frequent power impulses, and usually more ccs, than the opposition, but now the fours have this advantage over the twins. Attempts to keep up, using fashionable dohc arrangements, rapidly escalate manufacturing costs on the Vee, which cannot share its camshafts and drives across the cylinders.

Really, a single camshaft in the vee, with pushrods, is the sensible but unglamorous way to go (even Honda, with the CX500 agree on this). A Cross rotary valve atop each cylinder would be ideal, with a simple drive by chain to each, the layout suiting the separate floating cylinders required much better than a four, and restoring the characteristics we all want from a vee-twin — flexibility with high performance. Would that we had a motorcycle manufacturer in Britain who'd consider the prospect! P.(U).B.

TEAM SPORT

Continued from page 418

I'll lose the front end. The bike gradually works its way across the road, no matter how you strive to hold it in and keep the throttle on. It bounces nearer the bank, and you heave mightily. It's inching into the gutter and again I'm going up and down that I can't really see properly. And I scare too easily. If I can't see, my right hand creeps back, and I just make the second lefthander. And that corner's beaten me again. So does the following right. And I've watched Mr Hailwood go through there under the shed. Ah, well!

The second lap was 103 mph and the sweat was pouring down inside my leathers. And on the third lap only two riders have actually come by. It's all but 104 mph. And it's the slowing-into-the-pits lap for fuel at the halfway stage. There are bikes all over the pit road. There's just been the makings of a fire with gallons of fuel spilt from one of the works-style quick fillers. Why the hell can't we all use the same tried and trusted slow fillers? It would be safer, and the same for all of us. I thread Rose through the mêlée and Bill is waving me into the pit as precious seconds are lost. The twin Monza fillers are sprung by Ron and in goes the gun — or pea shooter, if you follow the analogy. And the interminable wait commences as the fuel trickles in.

The pitstop costs a minute if you compare the third and fourth lap times at 99 mph. This time I didn't juice up the plugs, and set off with a full load of fuel. Carefully does it at Quarter Bridge and brake really early. Five gallons is a lot of top weight and so many come to grief by not allowing for it. Braddan Bridge likewise . . . fell off there once. Boot it down to Union Mills. Clip-on broke here once, under heavy braking. Funny how you remember these things when you ought to be at 101 per cent concentration. But I suppose you can't maintain that for over two hours, anyway, unless you're Joe Dunlop or some other superstar.

The fifth lap was 103 again, which was a surprise as I had consciously told myself to relax as muscles were begining to knot up and I'd started to feel ragged. Better to let it flow, it seemed, and stay on the island. I was beginning to get punchy on the sixth lap. Now I knew why some of the blokes went on weight training and running programmes before the TT. I got mixed up with one lunatic without a fairing on his 500 Suzuki. I could actually pass him on the straights. But then he'd stuff a front wheel under me going into Ginger Hall or somewhere else quite stupid, and several times I thought we'd tangle. But I made Rose really work at 9,000 for a while and gradually dropped him over the Mountain. I'm beginning to feel very tired. Even so, that lap was just four seconds short of 104 mph and that chequered flag is so welcome and there are not so many bikes in the finishing enclosure this time. George says, "All right, then?" "Magic", I reply. "Never missed a beat. What did you put into it, nitro?" Bill says placing is somewhere around 20th. Average well over the ton.

It's over. Three races — three finishes. And this time I was more than a little knackered. Race average was 102.55; placing 22nd. But best of all, another Bronze replica for the collection; in fact, the very last one in that race.

Day 13

As I watched Mona disappearing into the west from the deck of the Steam Packet ferry, the "buzz" was still there. I still remember finishing 56th in the 1962 Manx Grand Prix and lapping at 75 mph. Now if they hold the Senior / Classic race at 1,000 cc for 1984, maybe 105 mph?

Now that really would be some sort of progress after 21 years — a 30 mph lap speed improvement. Just shows you; it's never too late. And you always have to have targets and ambitions anew . . . or it is too late. R.K.