Cosworth-Norton Technical Analysis

The P86 project, which was to become the Cosworth-Norton engine, was a hugely ambitious undertaking. The new engine had to be all things to all men. How could one engine do it? Successfully? Or not at all?

By Kevin Cameron

● THE 1960S WERE YEARS WHEN NORTON had little unique to offer while the competition went from strength to strength. After feeble efforts at innovation such as the ill-fated Electra (can you build a British Honda?) the company collapsed and was reorganized as Norton-Villiers, Ltd. Now the old Norton technique of felicitously marrying tradition with something quite new again offered hope. The 500cc Dominator twin had been successively enlarged and redesigned; it was now a 750. Since both its pistons went up and down together (like all British vertical twins), its vibration was all in a single plane. If an engine mounting could be devised that was soft and compliant in this plane, yet stiff in all others, an acceptably smooth machine should result. And it did. The Norton Commando with its Isolastic engine suspension was a considerable success for a time.

Even the old Norton racing tradition began to revive a bit. A hotted-up Commando finished second in the 1970 750 Isle of Man TT, ridden by Peter Williams, who was now an important man in the development shop at NV. Little time passed before special racing Norton 750s were being built at a new Norton race shop, located appropriately at Thruxton race circuit. The men involved had no way of knowing that this would be the last try, that the trick of blending brilliant innovation with tradition would not see them through again.

For the 1972 Daytona race Peter Williams created a special F750 racing Norton powered by the venerable pushrod twin, which gave slightly over 65 bhp with acceptable reliability. In a world of 85 bhp Triumphs and 100 bhp Kawasakis and Suzukis, it was hopeless but would have to do. Wind tunnel tests showed the way to a shape that should run 150 mph on the Daytona banking. Williams rolled through the big tri-oval at 149. Pretty good engineering, though of course the two-stroke giants weren't exactly shaking in their boots over this performance.

These people were clearly doing some things right. When I asked Peter Williams at Daytona what he could do with another 35 bhp he just grinned. Here is why.

As development of Norton's 1973 stainless sheet monocoque frame went forward, a radical new engine was discussed. Ford of Britain had in 1966 commissioned Cosworth, Ltd., to build a winning Formula One car engine and they had done just that. The Cosworth DFV had by 1973 won over 100 F1 events. It was a short-stroke water-cooled V-8. Two cylinders from that engine would total just 750cc. Two of those eight cylinders would also total 115 bhp!

Meanwhile the monocoque Norton went off to Daytona with its ancient engine and talented development rider, Peter Williams. Under his arm were more tunnel data which now predicted that the monocoque should reach 175 mph at the speedway.

The Norton ran only 142 mph and the cause (choked flow to the carburetors) was not discovered until later. It was a setback.

Now Norton and Cosworth agreed to jointly design and build a new twin for motorcycles, based on the thoroughly proven moving parts and internal gas flow of the race car engine. A hugely ambitious plan, designated P86, required that the new engine be all things to all men. It had to meet an 86 db(A) noise criterion while making 75 street horsepower and running virtually without vibration. It must have a life before overhaul of 50,000 miles. It must meet any foreseeable air pollution standard without major redesign. Finally, it must also win international Formula 750 road racing events.

How did they plan to do it? Why did they think it was all possible? A lot of noise would be killed by the water-cooling. More would disappear if a toothed rubber timing belt were used to drive the cams. The goal of 75 street horsepower was formidable, but remember, Cosworth, Ltd., was already the world leader in high performance four-stroke design. Vibration? Counter-rotating balancer shafts could be incorporated in the design to take care of that. A 50,000-mile life? There were already plenty of street machines that old, and this one would have super-ample bearings with a modern, fully filtered oil supply. No problem. Emissions control would be simplified if the fuel were metered at a single point, so the new machine must be capable of running on one carburetor. That meant both pistons would have to go up and down together, just like all the vibrating Dominators, Atlases, and Commandos of the past. This is because a 180-degree twin has irregular firing intervals of 180 and 540 degrees, while the traditional big twins used the 360-degree crank. The 180-540 intake phasing would always make one cylinder rich and the other lean, an air pollution nightmare.

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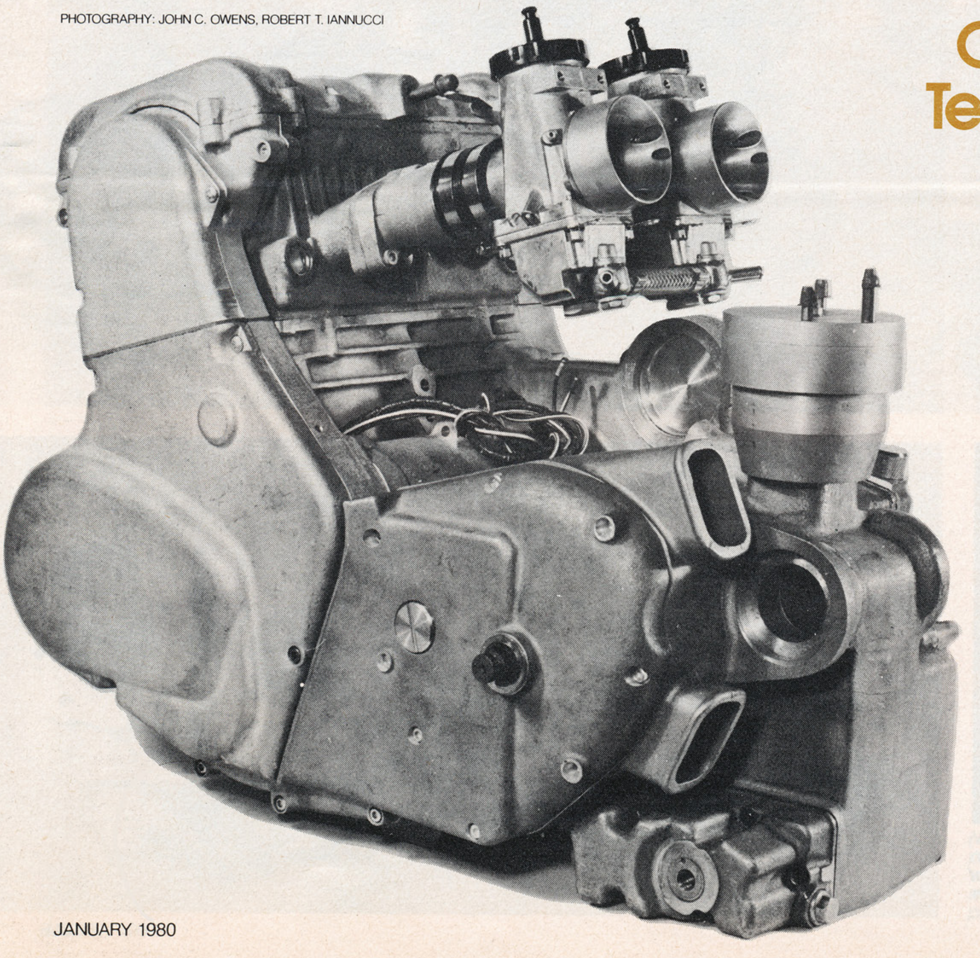


How, finally, did they think they could win F750 with the P86? Consider the opposition. Yamaha was running a 70 bhp 350, which was maneuverable but not blazingly fast. The TZ750 still lay in the future. Suzuki's entries were 400-pound triples with 110 bhp, real lumberwagons but very fast. The Kawasaki H2R was quick but brittle in the extreme. If everyone held still while Norton took aim with P86, they just might hit it right. The design went ahead.

And so the P86 emerged with both its 85.6mm pistons going up and down together. How do you make a big twin idle? With a flywheel. Where do you put it? If it isn't to go outdoors it has to go between the cylinders. You say you'd like to put a center main bearing there? Forget it. Besides, look what happened when Matchless tried that back in '52. The P86 began to look a lot like a traditional British big twin, and we have to suspect that people from Norton twisted Cosworth's collective arm a bit to achieve that conservative result.

Two balancer shafts, turning at crank speed, but in opposite directions, would generate an up-and-down imbalance equal to but opposite that of the pistons and rods. Instant smoothness, but complicated.

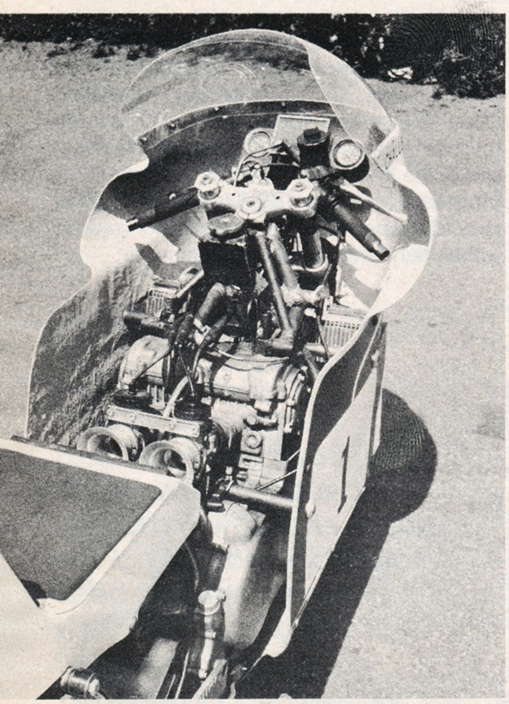
While P86 plans were being made, the actual racing program went ahead slowly. Money was not coming in, so it was hard to spend. The 1974 chassis was light and clever, but the engine was the same old pushrod dinosaur. A test P86 chassis was also built—different but hardly revolutionary. The engine-gearbox would be a stressed member, with vestigial tube structures attaching the front and rear suspensions to it, rather like F1 car practice. The rear wheel would be braked by a disc *outboard* of the swing arm, on a common carrier with the drive sprocket. This allowed the rear wheel to be changed in less than a minute by withdrawing the axle, leaving chain line and brake caliper undisturbed. The axle would be live, turning in bearings pressed into the ends of the swing arm itself.

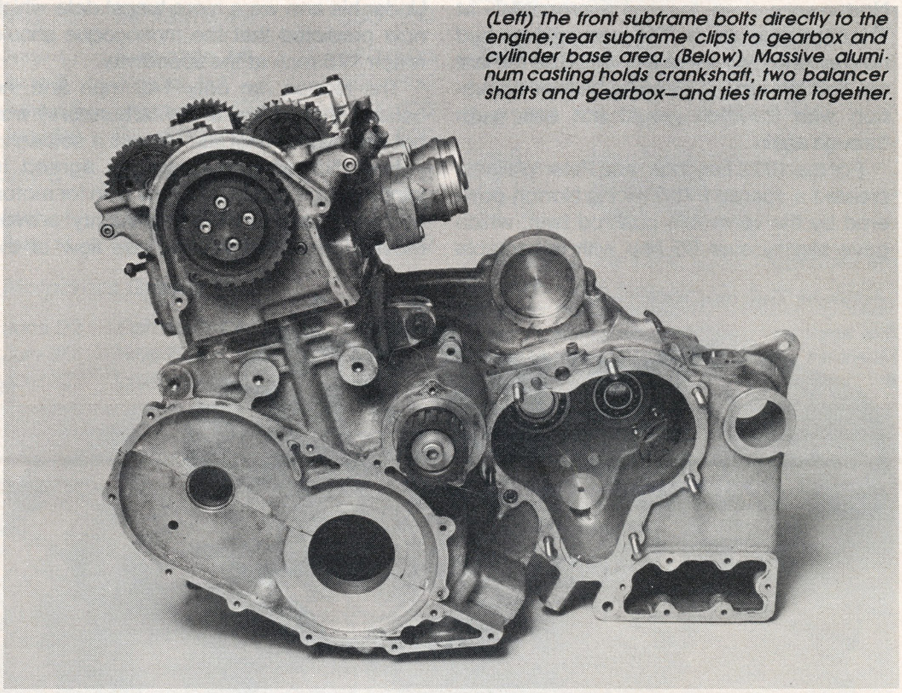
Money, money, money. The traditional design of the Norton Commando could not hold its own forever in the rapidly changing world of the Japanese mass-produced motorcycle. Norton's antique production equipment required hand labor and was expensive to operate, while the Japanese companies were using versatile automated factories that kept production costs low. Little by little, whatever Norton had had to offer in world markets was whittled away.

Every week in the British motoring press the controversy raged over whether it were nobler in the mind and pocketbook to buy British and endure the traditional deficiencies, or to yield to the seductions of a Japanese machine, as predictably efficient as a toaster. Stick in bread, get out toast.

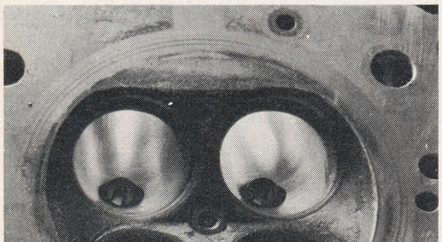
By the end of 1974 Norton's race program had all but stopped. The plan now was to prove the P86 in racing first, then promote it to production as a roadster. As 1975 be-

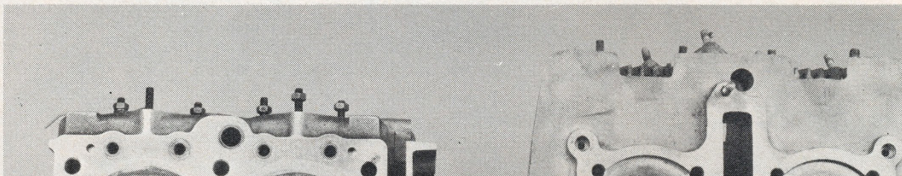
Norton had no money and Cosworth had no time. That made it an alliance for misery.





(Left) The front subframe bolts directly to the engine; rear subframe clips to gearbox and cylinder base area. (Below) Massive aluminum casting holds crankshaft, two balancer shafts and gearbox—and ties frame together.





(Above) Combustion chamber is shallow V-trough; included valve angle is 32 degrees. With flat-top piston there's excellent concentration of charge. (Right) Honda CR-72 combustion chambers are much deeper than the Cosworth's.

gan Cosworth predicted that horsepower goals would be reached and that 100 bhp was enough to deal with racing opposition. But there was no money!

Norton-Villiers-Triumph was petitioning the British Government for forty million pounds to revitalize the industry. A special team was researching world markets to determine the sales appeal of new Norton models. Together with the P86, Norton displayed an array of prototypes being readied for production. If the money were forthcoming, it would buy new production tooling that would cut costs and make the new line competitive.

In March the Commando-engined P86 test chassis weighed 325 pounds, no mean achievement. The real thing, complete with Norton-Cosworth engine, was to debut at Silverstone in August. A success would have enormous influence on the government's decision. The press vibrated with expectancy. August 30th came and went. They would try for Thruxton on September 28th. That date, too, passed with no Norton entry. Now the big moment would come at the Race of the South at Brands Hatch.

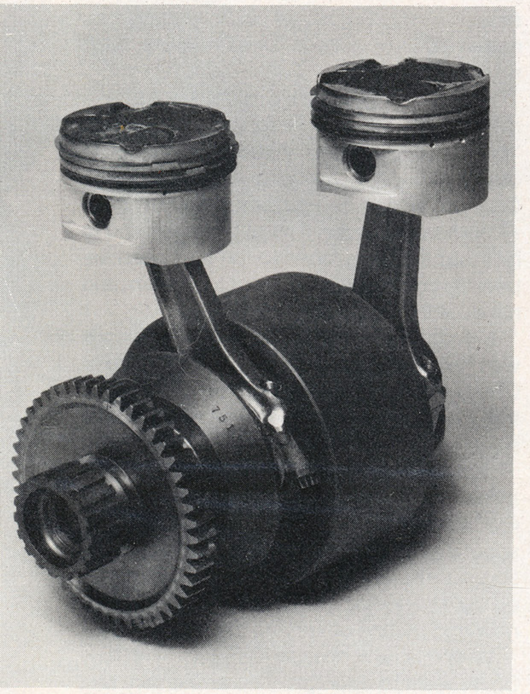
The bellowing P86 prototype came to the line at Brands, as promised. The flag dropped; machines streamed away toward Paddock Bend, 300 yards off. A Yamaha rider fell, bringing down eight others—including Dave Croxford on the prototype. It was a considerable blow to the project. Even though the Brands Superprang was a true accident, it damaged Norton; the company's financial condition was now very serious.

In December Phil Read announced his willingness to test the new machine. Many times a world champion, Read had the prestige to carry the project ahead. In January he made a bid to take over the race effort, top to bottom, and required that everything be placed under his direct control. This was a sound move; only dictatorial powers could sort the good from the bad in P86, and only a real racer, as opposed to a bureaucrat, could do it.

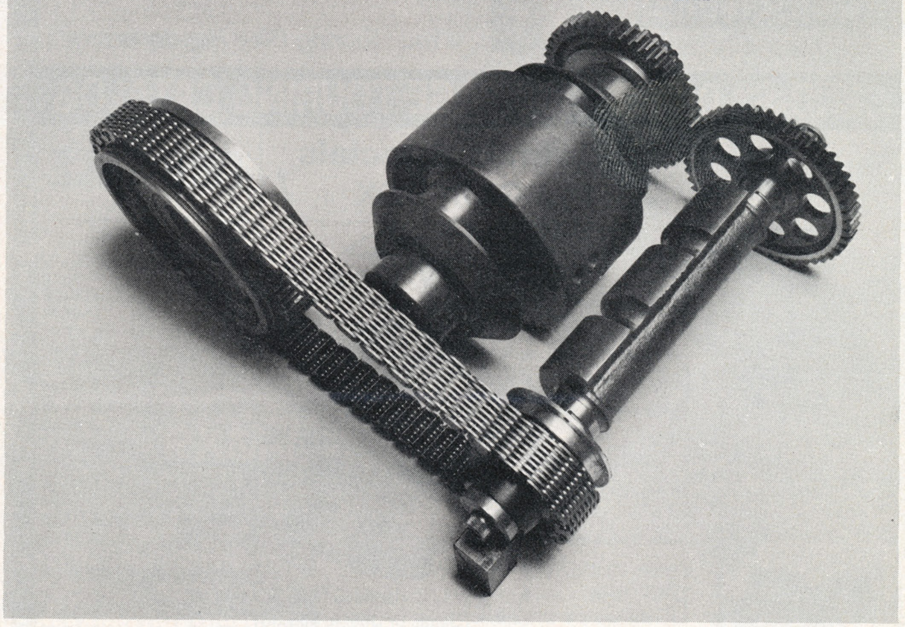
By February Read had withdrawn his offer after consultations with the makers. His reasons were that the device could not win as it was, that Cosworth was too busy with F1 commitments to make the needed changes, and that it was not fair to the public to continue raising their hopes for a British renaissance. Read was out.

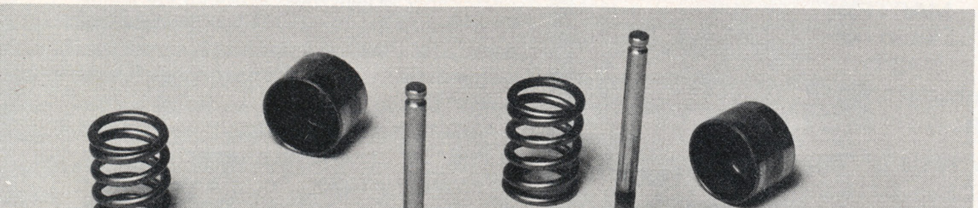
What had he discovered? What had he wanted? Right on the Cosworth drawings the weight of the race engine is given as 195 pounds. Of this large total, more than 75 pounds is rotating weight. This is doubly important, for during vehicle acceleration its mass must be accelerated not only in a straight line but also around its own axis. Competing brands' engines then weighed around 140 pounds, of which some 40 were rotating, and gave close to 125 bhp.

The power of the P86? The most the factory ever got was just over 100 bhp, achieved with an experimental fuel injection setup. With the standard Amal Concentric Mk II carbs, power fell into the mid-90s. And it was sluggish power because of the inertia



(Left) Pistons and rods from Cosworth F1 engine are used with a crankshaft supported only by two outboard plain bearings. (Below) Hy-Vo chain drives clutch from quill shaft inside front balancer shaft that's driven off the crank.





(Above) Amal carburetors did not produce power of fuel injection, though these carb bells were worth five hp. (Left) Valves are relatively short and intake's stem necks down in port. Tappets ride directly in head material.

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of the heavy crank and balancers. This power, such as it was, was all on top.

What do you suppose Read asked Cosworth to do for him? Surely he asked that the engine be relieved of the 20 extra pounds of balancer shafts. Not so easy with the power passing through the front balancer. Surely, too, he asked that the huge center flywheel be dropped and a center bearing be substituted. With its support, Formula-car rpm would be no problem. He would also have insisted on a redesign of the gearbox, a constant source of trouble; insisted on fuel injection instead of money-saving carburetors; insisted on light metals where iron and steel had been used in the prototype.

Such a revised engine could have weighed under 150 pounds and might have given 110 bhp. That power peak combined with a four-stroke powerband and light vehicle weight might have been a good tool against the two-strokes with their bill-spike powerbands. Might have been worth a man's time.

But Cosworth could not do the impossible. Norton had no money and Cosworth had no time. A hastily organized public subscription netted 1600 pounds to keep P86 alive, but it was only a gesture.

In April of 1976 Dave Croxford quit after a rash of mechanical failures. The project "cried out" for Peter Williams, now out of racing altogether owing to a bad accident. Croxford was a competition rider not a development engineer. It must have seemed to him that the Cosworth-Norton had been especially concocted to make a fool of him and his excellent reputation.

In August a major redesign of the chassis was begun, supposedly on the insistence of Cosworth's chief, Keith Duckworth, who felt that the machine's problems must stem from poor handling. The engine was relocated where he had wanted it in the first place, two inches lower and inclined forward. The live rear-axle scheme and forward-mounted Koni shocks were abandoned for more conventional parts. The machine was further lowered by shortening the steering head, which now had means of varying the wheelbase.

With this new chassis Croxford and Tony Smith went to open practice at the very fast Silverstone circuit. Mick Grant on the works Kawasaki lapped at 1:38 with apparent ease. The best the Norton riders could do was a 1:46.8. It was a catastrophe. Horsepower, please.

Cosworth and Norton had been partners in P86, but the division of labor was often paralyzingly complete. NVT people were under strict orders to touch nothing but the spark plugs. Any engine trouble required return of the complete unit to the makers (per Cosworth's F1 policy). Each party tended to see in the other's work the source of all current troubles. Norton had insisted on many traditional engine design features, and Cosworth had put its fingers into chassis matters. As money ran out, there was a constant speed-up of the schedule, and things

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done in haste are seldom right.

Everything had run out. The government rescue of NVT had fallen through. The skilled crew at Thruxton race shop were ordered to earn their keep by modifying batches of Russian sidecars, and many of them quit. That was that.

The prototype P86, numbered 002, made its way to NVT's California operations center just as the company's imminent demise made the whole thing into so much surplus property. And as such it came to the attention of a certain Robert Iannucci, a man who makes it his business to collect the unobtainable. Beginning years ago with an interest in the big racing singles, this extraordinary connoisseur has branched his interests in a number of directions. Time, the telephone, and stacks of correspondence summoned the P86 to him.

At the Bridgehampton fall AAMRR race in 1978 we were to hear it start and run with a blast of noise that nearly got us all jailed. The mechanical marvel was later ridden several laps in demonstration, retiring with a cracked waterpipe. Because of its unique place in British motorcycle history, there could be no real track test. Rider David Roper pronounced the machine "a blast," termed the brakes "good" and the power "OK—pretty good," and that was that. But we could disassemble, measure, and inspect.

The motorcycle is compact, incredibly dense. Even though it is low it gives an impression of ponderous weight. It has that indescribable development-department finish that says that the way it works is much, much more interesting than the way it looks.

The nice features abound, of course, as they always do on hand-built prototypes. The fork is a forward-axle design, allowing larger overlap of tube and slider for smoother action under braking. Five-spoke mags carry the weight; Lockheed aluminum calipers grip modest-sized iron discs floating on splined carriers. The swing arm is a bolted up fabrication of aluminum beams milled from solid into a complex pattern of reinforcing ribs and flanges. The section of the arm increases from front to back, the reverse of usual practice. By the old grab-the-tire-and-seat-and-pull test, this arm is not very stiff.

Flanking the engine at the front are the small water radiators. Below, in the center, are the oil radiator and filter. The power unit itself, squat, bulky, and complex, sits very low and forward. This is the modified frame, incorporating Duckworth's ideas. The left side of the engine is a maze of cam drive belt and pulleys; the ignition generator and trigger units. On the other side is only a vast featureless expanse of high-quality sandcast primary drive cover.

The fuel tank, truncated at the front by the steering head subframe, sits tall and carries back to the very angular low seat. The two generously dimensioned header pipes emerge from the front of the near-vertical pillar of cylinder and head. The tubes join the collector at the back of the gearbox, and this large-bore pipe ends at the axle.

This engine cannot be removed from the frame. Rather, the frame must be removed from it—in pieces. The front subframe with fork and front wheel, once unbolted from the cylinder head and front of the main casting, can be wheeled away like some Buck Rogers shopping cart. The rear subframe, carrying rider and suspension loads, is clipped on at the gearbox and cylinder base areas. Footpeg plates originate at the back and bottom of the gearbox, jutting rearward to the rider's feet.

Really, the power unit is nearly all there is. A single 40-pound aluminum casting houses the crank and balancer shafts, the gearbox, the integral oil tank and the swing-arm pivot bearings. The parts that fill all these spaces are not light. I knew as I helped load the engine in my van that I would need help to get it out again. I can lift and install a TZ750 engine as easily as the next fellow but this model was beyond my strength.

There was plenty of reason to be fascinated by this engine, success or failure. This monster twin was the little brother of the Cosworth DFV, the winningest four-stroke in recent F1 history. Right on my bench.

When the Cosworth F1 engine first appeared in 1967 its winning performance was a bit baffling to traditional analysts, but what Duckworth had done was to unify several concepts then current into a single workable engine. There had been plenty of oversquare engines before and there had been engines with four valves per cylinder. Duckworth, however, concentrated on the problem of getting rapid, efficient combustion.

In an ordinary two-valve engine with a so-called hemi chamber it could take a long time for the combustion flame to burn the whole charge. Hemi chambers had stopped being hemispherical as soon as compression ratios went over five or six to one; when that happened, the formerly flat piston top had to begin protruding up into the combustion chamber. It had become a dome. In modern two-valve designs, such as the Suzuki GS1000, if an 11:1 compression ratio is desired, the piston dome is so tall that the combustion space becomes very thin and arched, rather like the rind of half a cantaloupe. It is hard for hot, efficient combustion to occur in such a space—too much heat is constantly being lost to the nearby metal surfaces. In addition, the only place for the spark plug is over on one side, making the flame path long as well as narrow.

The early work with four valves, such as Honda's in the early '60s, had concentrated on the rpm advantages of the layout. Piston domes remained tall and combustion thin.

All right then. I removed the huge allen bolts retaining the head and lifted it off. There were no big surprises, no shocking innovations. There were the pistons, completely flat on top except for small valve clearance cutouts. The combustion chambers in the head were like shallow V-shaped troughs, with the two sides and the valves in each of them at 32 degrees to each other. Because of this small included angle the chambers are not very deep—10mm along their centerlines—but this is deceptive. Since the piston crowns are flat, the 10mm depth actually constitutes a strong concentration of mixture very near the spark plug, right in the center. This concentration of charge is the main feature of Duckworth's rapid-burn chamber. In the P86 there are two 34mm intakes and two 29mm exhausts per cylinder. These are equivalent in area to one 48mm intake and one 41mm exhaust, almost exactly the sizes used in the old 500 singles. Yet these cylinders are only 375cc each. The large valve area is needed for flow at the rpm peak of 10,500, whereas the old Manx pulled only to 6800–7200.

But how about this design? Could it have rescued the company, either on the track or on the sales floor?

The actual power of the race engine, some 95 bhp, was 20 per cent down from the target 115 bhp figure. Where did the power go? Very likely several things account for this. First, the GP car was a fuel injection design while the P86 has 40mm Amal Concentric Mk II carburetors. Fuel vaporization in a fuel-injected engine is assisted by the fairly high pressure forcing the fuel out of the spray nozzle. This is at least 500 times greater than the pressure difference which forces fuel out of a carburetor's needle jet.

It is customary when using carburetors to make the carburetor the largest part of the intake tract, then to progressively narrow the bore as it goes deeper towards the valve. This accelerates the flow. Carbureted mixture always includes a fair proportion of fuel in the form of large droplets, and the charge acceleration helps to keep them in the flow rather than on the walls of the duct.

The P86, which has the port dimensions of a fuel-injected car engine, has a constant cross-section through the carburetor and manifold right into the head. Once there, the section actually increases somewhat, finally necking a bit to approach the valve ports themselves. If the mixture flowing through this pipe has been mechanically produced by fuel injection, droplet size will be well controlled. However, anyone who has watched fuel streaming from the needle jet of a carburetor during an engine test has seen the big globs of fuel which depart along with the mist. Without a port designed for this kind of mixture, the carburetion would have to be set very rich; many of these globs are not going to burn at all, simply getting hot, drawing valuable heat out of the combustion flame, contributing nothing.

In addition, the race car engine has a steep downdraft angle of 35 degrees where the intake pipe enters the head. In P86 this angle is zero, to allow the carburetor float bowls to work without an abnormal tilt. This means that the intake pipe and the mixture have to make that 35-degree turn inside the head in order to approach the valve ports as in the car engine. This turning is a further invitation to the fuel droplets: "Here, let us centrifuge you right out here on the wall. Drop out, droplets."

Another troublesome aspect is the cam drive system. Told that the engine had to be

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dead quiet, the designer knew that rigid drive by gears, as in the car engine, was out. To have the correct tooth spacing when hot, gears often have to be loose and rattly when cold. They require lots of precision machining and nice ball-bearing support. Good for the race car but not for P86. Chains were a possibility but still noisy and troublesome, always spitting their connecting links. They could be a development headache, too, requiring rubber-covered dampers to prevent vibration and irregular cam action. And they had to be in an oil bath. And they wore out and had to be adjusted. No good.

In the early 1970s toothed rubber timing belts were solving lots of automotive problems. They are quiet, need no lubrication, give a positive drive, and don't wear or require adjustment. These qualities made a timing belt the choice for P86. The 3/4-inch-wide, 3/8-inch-pitch belt chosen might have made a fine drive for the street bike's camshafts. The 75 bhp version was to have smaller valves and lighter springs than the racer, and to turn fewer rpm. On the racer, however, the little belt didn't do well. It had to be replaced constantly. Better and better belts were tried. The belt on 002 bears the word "prototype." There was a bad torsional vibration at 4000 rpm. Just tell the riders not to run the engine at 4000 anymore—the power range is 7000–10,000 anyway.

Even in development of the original Cosworth V-8 the cam drive had been a problem, giving rise to torque transients 10 times greater than expected. If this was a problem in an eight, with its overlapping valve events, wouldn't it be much worse in a twin? It was. The belt cannot have been a rigid drive. Valve events would occur according to the accident of belt action rather than designer's intent. Horsepower down, down, down.

Belt life was also limited by having to drive the rear balancer shaft, a nearly eight-pound item which had to turn in exact lock step with the crankshaft. At a steady speed, there would be no problem, but in a clutchless upshift, the heavy balancer would produce a violent torque transient.

Then there is crankcase pumping. The two pistons moving together produce a big change in crankcase volume every revolution. The pressure generated in this way is forced back and forth through the engine's internal passages much as oil is forced through the orifices of a shock absorber—absorbing power. Udo Guitl discovered how much power in his work with the BMW twin, and went to great lengths to eliminate it. On P86 there is only a 3/16-inch line with a check valve—not enough to make much difference.

Finally there is crank flexibility. Many are the engines which have gained power through stiffening of their bearing supports or rotating parts. Here in the Cosworth-Norton crank are two main bearings, one at each end, and suspended between them are the two rod journals and the huge flywheel. No center bearing. (After all, the 1952 Matchless twin had a center main bearing and it was a failure. We don't want that!)

Racing on short tracks is largely a matter of handling and acceleration. Here is the Cosworth-Norton with its 35-pound crank and 20 pounds of balancer shafts, a 12-pound steel clutch and an eight-pound gearbox, all rotating mass waiting to oppose vigorously any attempt to accelerate them.

Here is the basic layout, with facts and figures. The crank is carried in two 62mm plain bearing journals, copiously cooled and lubricated by pumped oil at 35 psi. The forged steel, shot-peened rods are Formula One car parts and ride on 49mm diameter plain bearing journals. The pistons are also from the car engine, beautifully made three-ring forgings made in Cosworth's own piston forge plant. The company was forced to buy their own to guarantee quality. The bore and stroke are 85.68 x 64.77mm for a bore/stroke ratio of 1.32.

A big gear pair takes the power from the left crank end to the front balancer shaft, which is a big iron bar of D-shaped cross-section, turning in plain bearings. Down its hollow center passes a quill shaft, taking the drive to the primary sprocket on the right side of the engine. This quill shaft is a torsion spring. Its job is to protect the primary drive and transmission from the whacking they would otherwise get from the big twin's power impulses. The rear balancer shaft, turning in ball bearings, is driven from the cam belt.

The primary drive is a 1⅛-inch-wide Morse Hy-Vo silent chain at a ratio of 25/56 from the front sprocket on the balancer to the rear one cut on the outside of the clutch drum. No wear was expected from this drive, so there is no provision for adjustment.

The clutch is heavy but beautifully made. Four 140mm O.D. friction discs coated with sintered copper are confined with steel discs and top and bottom pressure plates, all compressed by a single diaphragm spring.

The gearbox is all indirect. Power from the clutch enters on the front shaft, then passes through one of the five gear pairs to the countershaft, whose left end bears the 5/8 x 3/8-inch final drive sprocket. The ratios are very wide by modern standards, with the minimum rev drop in an upshift being the 1900 rpm between fourth and fifth. This is what four-stroke powerbands are all about. The gears are selected by conventional C-shaped shifter forks, actuated by a nicely finished drum cam and ratchet mechanism. The gears are also well-finished, and large enough for a medium-sized automobile.

Back to the crank. Outboard of the drive gear on the left end, isolated from lubricating oil by an intervening seal and case cover, is the cam belt drive pulley, and on top of that is the ignition trigger blade—a little tab of steel projecting from the rim. As the leading edge of this blade passes a magnetic pick-up, a positive signal is produced. As the trailing edge passes the pick-up, a negative signal results. For running, the leading edge signal is used to trigger the ignition sparks, but for starting, when a retarded spark would be nice, the rider thumbs a handlebar-mounted

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button and the ignition begins to trigger off the trailing edge signal. Instant retard. Clever. The ignition is the Lucas RITA CDI system. Running current is supplied from a small alternator mounted on the front balancer shaft, supplemented for starting only by a small NiCad battery. This battery, the output coils and the ignition control box are all mounted in a box under the seat.

The hard-working timing belt finally arrives at the cam-drive pulley, which rides on a hardened-steel pin pressed into the head. The back of the pulley is a gear which engages the two camshaft's drive gears.

The short cams, each with four lobes, ride in pressure-fed split shell plain bearings in the head. Because of the narrow valve angle, a single cover spans both cams. Short, bucket-style tappets ride in the head material itself—there are no separate tappet guide blocks. Valve clearance is set with selective fit lash caps which socket down over the valve stems before the tappets are installed. There are thus no shims to be spit out. Reliable, strong, trouble-free.

The valves are rather short at 98.3mm and have 7mm stems. That part of the intake valves' stems which is in the port is necked down to 5.4mm to reduce airflow disturbance. There is no loss of tensile strength for this diameter is already present in the retainer collet grooves. Steel retainers transmit force from double coil springs.

The valves are opened to a lift of 10mm using a moderate (by the outlandish standards of United States drag racing) acceleration of some 1600G at 10,000 rpm. The effective valve timing, measured at one millimeter lift, totals 274 degrees, with the exhaust opening at 60 degrees BBDC and closing at 34 degrees ATDC. At the running clearance, these timings approximately increase seven degrees per side, becoming exhaust opening at 66 degrees BBDC and exhaust closing at 41 degrees ATDC, total duration 287 degrees.

The water pump is driven from the right-hand end of the head and circulates coolant through the head, the radiators, and around the wet cylinder liners in the main casting.

The oil pumps are driven from the back of the clutch. There is a scavenge section, whose pump volume is five times that of the pressure, or delivery side. This is done, as in formula car practice, to ensure that only a minimum of oil is ever present in the crankcase, where it can wrap around the crank at high speed to consume amazing amounts of power. The oil is sent to a separator, then to the integral holding tank behind the gearbox.

The engine is of dry deck construction, rather than a single head gasket which tries (often unsuccessfully) to seal everything. The cylinder head seals to each of the liners with a special metal ring and all oil and water passages are sealed by o-rings resting in counterbores.

The two Amal Concentric Mk II carburetors are flexibly mounted to short intake stubs and each is fitted with a lovely spun aluminum intake bell with a generous flaring shape. These are said to have added five horsepower in themselves.

In sum, here is a tool-room special—an engine clearly very expensive to make—which combines features proven in GP car racing with traditional design quirks taken from the most uninspired of street bikes. Although parts quality is high, and Duckworth's original design beyond reproach in its own field, the combining of features was done in such a way as to make this apparent: the designers ignored useful techniques current in Japanese design. Steeped in their years of tradition, they felt no need to look elsewhere. They had practically invented the motorcycle, after all, so why consult with anyone else? (Of course our frames handle—we're English.) NVT did not accept that the world had already turned.

Had the company readied this design in the late 1960s, when there was still a large following for English machines, things might have been different, at least in limited respects. As a racer, the P86 might well have done in the Triumphs and BSAs of the time, and through development it might have fended off the early, immature two-stroke racers as well. It could have had an honorable and successful career in racing and then faded quietly away, like Norton itself. ◉