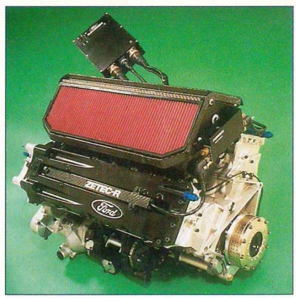
COSWORTH

THE SEARCH FOR POWER



GRAHAM ROBSON

Foreword by Mario Andretti

3rd edition

COSWORTH

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COSWORTH
THE SEARCH FOR POWER

Foreword by Mario Andretti

Third edition

GRAHAM ROBSON

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Guild of Motoring Writers' Pierre Dreyfus Award

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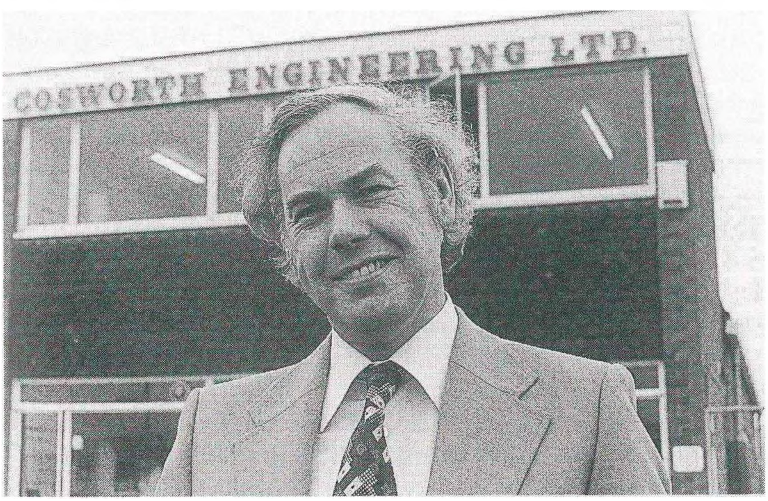
My grateful thanks to everyone.

Introduction

This book, I hope, is as close to the full story of Cosworth's thirty years as anyone will be able to write. I have been looking forward to tackling the job for years but it took a great deal of time to persuade Keith Duckworth to get involved for there always seemed to be something more pressing to occupy his amazing intellect.

Cosworth's co-operation as a company was assured, I think, when it realized that a book written without its help would have to rely on recycled information, might be missing great chunks of history, and might be inaccurate in so many ways. The breakthrough came, I am sure, when Keith decided to retire from the business which he had founded, and could actually give me time to discuss the earlier days. Not only did I spend many hours persuading Keith to stop lecturing me about my own (and the journalists' profession's) technical shortcomings and to talk into my tape recorder, but I also managed to corner most of the important personalities who had contributed to the growth of Cosworth since 1958.

I first met Keith Duckworth and Mike Costin in 1965. The occasion was social – one of those fascinating *Autocar* 'Thursday Club' dinners in Warwickshire, where top



The co-founder, Keith Duckworth, smiling as always, poses in front of the Northampton factory which has been Cosworth's headquarters since 1964 (*Phipps Photographic*).

engineers got together, secrets were swopped, and everything said was *strictly* off the record – and both were in their element.

Here was a stage on which Keith, in particular, could give a performance. Here was the place where everyone could polish his aphorisms, savour the latest industry scandal, and float often outrageous engineering theories.

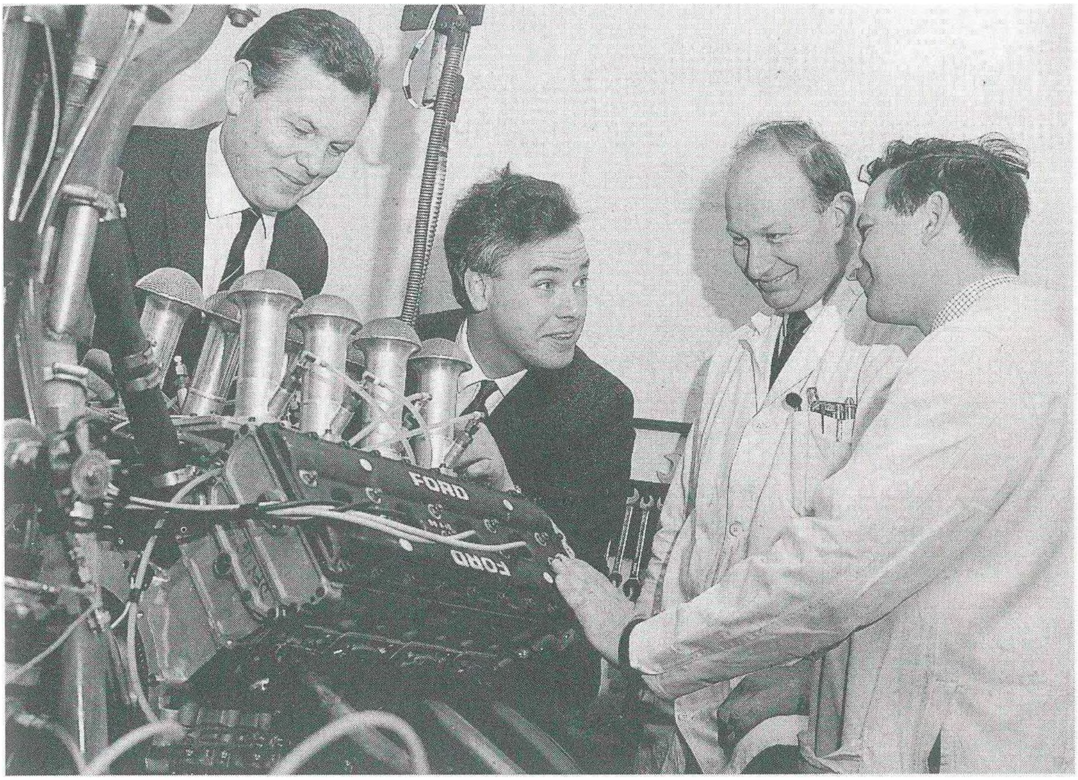
I noticed, right away, that Keith and Mike clearly liked each other, and enjoyed these occasions, but that they had different characters. Both were relaxed and affable with their peers, and both were delighted to gossip about cars, engines, and motor sport in general. Mike, on the one hand, would ease his way out of any conversations, or controversies, which he didn't enjoy. Keith, however, used to fasten on them, and pursue them – like a dog after a rabbit – and follow an argument to the end. It was on occasions like this that the wagging finger would come into play, the facial expression would become belligerent, and the voice volume would gradually increase.

Over the years I realized that Keith simply would not put up with those he succinctly called 'bloody idiots' and I was flattered that he never cast me off as one of them. Two of Keith's most chilling remarks were to call something 'fundamentally unsound', and to be heard to say of unlikeable people: 'Well, he's not one of us, is he?'

I shall never forget the expressions which flashed across his face when, at a VIP's lunch at Silverstone one day in about 1970, a so-called eminent technical director of one of Britain's largest car-making concerns expressed the opinion that overhead-camshaft valve gear was not justified on a road car, but invited Keith to convince him otherwise. That man, whose products were always boring, may never know how close he was to being bawled out . . .

There was also an occasion, some years later, when Keith and I ducked out of a particularly boring new-product launch, and made for the hotel coffee-shop instead. But Keith was never very good at killing time. Having settled down placidly behind a large pot of tea, he beamed at me, came to the alert, pointed like a gun dog, and said: 'Right, let's have an argument, I'm just in the mood for a good argument!' The subject, that afternoon, was the technical consultancy business, why he didn't think the time was ripe for Cosworth to 'do a Porsche', and his own thoughts about the future of his business. There have been several such arguments since.

All this, and much more, made me realize that Keith,



Four people who changed the face of British motor racing — (left to right) Bill Brown, Keith Duckworth, Mike Costin, and Ben Rood. The engine, of course, is the famous DFV V-8, the date is 1967.

Mike, and Cosworth, which they had founded, were quite exceptional, and one day I vowed to write a complete story of the company. When the time came Keith, Mike and their Cosworth colleagues, could not have been more helpful.

Right away, I decided that this book should not be a number-crunching, nuts-and-bolts, power-outputs and average-speeds product. After thirty years, I thought, there must be many personal stories to be told, many secret files to be prised open, with successes to be balanced against failures, policies to be weighed against practicalities, and people to be matched to machinery.

This book, I hope, is as much about 'why' as about 'what'. Why did Keith discard aero-engine work for motor sport? Why did he link up with Mike? Why did he move from London to Northampton? Why did he dabble with transmissions, helicopters and motorcycle engines? Why did he sell out in 1980? Why did he walk away from the business in 1988?

I *think* I have asked all the questions, and I *hope* I got all the honest answers. It is a fascinating story . . .

Graham Robson

Introduction to the third edition

Cosworth never marks time. In the years since this book was originally written, Keith Duckworth and Mike Costin have retired, the company has expanded, and other personalities have changed, while more and yet more new engines have appeared. World-wide success in Formula One and Indycar racing has been matched by the launch of new and exciting road-car engines.

Will there never be an end to the Cosworth success story ?

Graham Robson
1995

Foreword to the first and second editions

by Walter Hayes, CBE

This is one of those special books that one feels should begin: 'Once upon a time . . .' It has so many ingredients of the classic fairy tale. Its hero was born into little money, didn't get his Royal Air Force wings, did not manage a good university degree and knew nothing very much about anything in particular. He certainly knew next to nothing about engines, but he went on to become perhaps the most remarkable British engineer of his time.

If this seems – as it may to some – too large a claim to make, all that is necessary to turn doubt into conviction is to read this book and get to know Keith Duckworth.

At a time many people still regard as the beginning of the Golden Age of motor racing, he determined to produce the best Grand Prix engine in the world. And he did it; essentially by himself. It dominated Formula 1 for sixteen years, won 155 Grands Prix and became the dependable power behind the throne for a dozen or so World Champions. If the rules of the Formula had not been changed, I think it would still be winning today. In a different form, it was also victorious at the Indianapolis 500 for the best part of a decade.

Inventiveness is the true measure of genius but engineers have never been seen or represented as heroic figures. The trophies are held high by other hands. Sometimes it's their fault for – like the Hobbit – they often seem to inhabit a different world from the rest of us and keep their thoughts to themselves.

But Graham Robson was brave and persistent enough to persuade Keith Duckworth into a confessional of sorts and to draw reminiscences from the other equally unlikely characters who formed the Cosworth brotherhood, in particular that talented and perceptive catalyst, Mike Costin – the front legs, as it were, of the Cosworth founding partnership. So this is a great deal more than a book about motor racing.

It was my good fortune to be something like a godfather – sometimes more nearly Devil's Advocate – of this unruly, opinionated, self-dedicated, and sensitive tribe and to enjoy the vicarious pleasure of their creations (for Cosworth has had more than one triumph to its name). It was no less pleasurable to watch and encourage their progress from what was little more than a shed to the creation of a major industrial enterprise whose pioneering technology won them a very special kind of respect among their peers.

History is best when it is biography and Graham Robson has chosen to let Keith Duckworth and his colleagues and allies speak for themselves. It seems a very appropriate thing to do. For their achievements have already done that.

Foreword to the third edition

by Mario Andretti

Although there have been many rewarding events in my motor racing career, I am delighted to recall how many victories and milestones have been achieved with cars powered by Cosworth, or Ford-Cosworth engines. It has long been a pleasure for me to work with the team at Cosworth, whose engines always seem to have plenty of race-winning power, lots of torque – and great reliability.

I first raced Ford-Cosworth engined cars for Lotus in 1968, when I won the pole position in my Formula 1 debut at the US Grand Prix at Watkins Glen, and continued to race with a March-Cosworth in 1970. But it was in 1976, when I rejoined Lotus, that the Lotus/Ford-Cosworth combination began to pay off, ultimately helping me win the 1978 F1 World Championship. Eleven of my 12 F1 victories were with Cosworth power, including six in the Lotus 79.

That was just the start, for I went on to win many Indycar races with Ford-Cosworth, including winning the PPG World Series title in 1984. Of my 19 victories in the 1980s and 1990s, most were in Cosworth and Ford-Cosworth powered cars.

In Indycars and Formula 1, my son Michael and I have always had a superb relationship with Cosworth. Dick Scammell's team, which later included Steve Miller and Malcolm Tyrrell – all among my favourite people – has consistently backed up the engines with excellent technical expertise and support, and every year the engines seem to get better, more powerful, yet stay just as reliable. In fact, the quality of the product is exceeded only by the quality of the people involved over the years in designing, building and servicing the engines!

It was Cosworth's record, expertise, and infectious enthusiasm which convinced Michael and me that Newman/Haas should adopt the fabulous new XB engines for 1992. We both have had our share of success with the engine since then, including my record-setting pole position at Michigan International Speedway in 1993, with a speed of 234.275 mph.

As I reflect back on my 30-year Indycar career, I recognize the contribution that Cosworth in Northampton and the USA has made to the sport. I'm convinced that they must now be the world's most successful designer, builder and operator of racing engines, and I certainly am proud to have been associated with them.

As we look ahead, I feel good knowing that Michael will continue to rely heavily on the performance and reliability of the Cosworth engine in the foreseeable future. I want to wish the entire Cosworth clan continued success in every category they tackle.

CHAPTER 1

Keith Duckworth and Mike Costin – the founders

'It is a fundamental that I should understand what I am doing, and that is what turns me on . . .'

Genius may be born, and develop, in unexpected places. Would any motoring enthusiast really have expected the founders of Cosworth to be, respectively the second son of a Lancashire weaving shed owner, and the third son of a fashionable marbler and grainer who lived in North Harrow?

Real life, however, is often much more complicated than fiction – and never as romantic. Although Keith Duckworth is probably the world's most famous racing engine designer, and Mike Costin is renowned as the practical and resourceful engineer who always underpinned the growth of Cosworth, neither had an engineering background in the family. So much for heredity . . .

This, at least, is not a story of rags to riches, for both families were comfortably off, if not actually well-to-do. In neither case is there a story of 'how I rose above the bare-foot holes-in-trousers stage, and look how well I have done today.' Even so, it is fascinating to listen to Keith and Mike talking about their early days, in the 1930s:

'I was born in August 1933, at Blackburn, in Lancashire,' Keith recalls, 'the second of two sons. My father, Frank Duckworth, was the owner of a weaving shed, who also sold cloth on the Manchester Cotton Exchange. My mother was the daughter of a blacksmith, and she then took a diploma in domestic science. She was the very first lady demonstrator of cookers in the Blackburn electricity showrooms.

'My father was an enthusiastic wood-worker, and a rebuilder of cars in his spare time. *His* father had died when he was only twelve, so he'd had a fairly hard, and a fairly poor, upbringing. But he managed to go to night school, and he also traded in motorcycles. Fairly early on, then, he was running a motorcycle, and my mother even managed to do some racing across Southport sands on a motorcycle and sidecar.'

Mike Costin, on the other hand, was a Londoner – not an East Ender, though that was where his father and mother met each other:

'Father and mother nominally came from East London, where they met.' Mike recalls, 'They got married at the end of the 1914–1918 war, and moved to a house in North Harrow.'

Henry John Costin had been born in Hammersmith, and was always the dominant figure in the marriage.

'He was a very straightforward character, with very strong views, and his educational background was utterly straightforward – he had no higher education of any sort.

'Very quickly, I think, he decided he'd like to join the Army for an interesting life. He went on to do all sorts of things in the services – he was a rifleman in the Rifle Brigade, then a Corporal PT instructor, he was in the Army right up to the end of the 1914–18 War (he was one of the lucky ones), ending up as a Battery Sergeant Major in the Artillery.

'After the war, he still didn't have a trade of any sort, so he set himself up in business, from nothing, as a marbler and grainer. He just found that he'd got a bit of a bent for it. From about 1920, to 1939, he built up a very distinguished clientele.

'There were four children by the marriage – Frank, Eric, myself, and Mary. Frank was born in 1920, while I was born in 1929.'

Mike's eldest brother, Frank Costin, would later go on to make his own distinguished career as an aerodynamicist (his shapes for various Lotus sports cars, and for the Vanwall F1 car made him famous), and later as an idiosyncratic designer of sports cars, including the early Marcos models. At this stage there was no more than a hint at future links with motor cars, and engines for either future partner:

'My father became a Riley fan,' Keith Duckworth says, 'and we had a succession of Rileys. By the beginning of the war we had gone to live in Wilpshire, just north of Blackburn. Going out through our back gate, I found myself on the first fairway of Wilpshire golf course.

'My elder brother is Brian. There's absolutely no connection between his career and the kind of things I've done. He went to Leeds University after doing his National Service, where he became an officer in the Gunners, then he got a degree in Textile Engineering. After spending time selling papermakers' felts, as a technical representative, all round the world, he ended up running a string of launderettes in and around Blackburn.'

'There was no engineering in the Costin family, as such,' says Mike. 'However, I was interested in engines and engineering from the time I had my first bike – a push-bike, that is. I was always taking that bike to bits, then putting it back together. Even when I was about three, they tell me, my little two-wheeler bike (I never had a three-wheeler) had an old sparking plug wired on to the front tube. I got my leg pulled a lot about this.'

When Keith was born, the Duckworth business was very successful, not only for weaving and selling the cotton, but for trading on the Manchester Cotton Exchange. By the time Keith Duckworth's father died, in 1944, his business, Oak Street Manufacturing, was well set, and the Duckworth family was comfortably off. Keith not only insisted that his father was 'very competent' (close acquaintances of the dynamic Duckworth realize

Mike Costin's official biography looks like this:

COSTIN, Michael Charles. Chairman and Co-Founder, Cosworth Engineering Ltd, St James Mill Road, Northampton NN5 5JJ. *Born*: July 10 1929. *Education*: Salvatorian College, Harrow Weald; engineering apprenticeship, de Havilland Aircraft Co, Hatfield; licensed aircraft engineer 1950. *Career*: 1953–1955 Design Draughtsman, de Havilland. 1953–1956 Lotus Engineering, part-time and full-time. 1956–1962 Technical Director, Lotus Cars. 1962 took up appointment with Cosworth. Became Chairman in 1988. Retired in 1990.

But that isn't enough. I also ought to add:

Long-time 'king' mechanic, talented racing car driver, practical design and development genius, flying enthusiast (gliders and light aircraft), and irreplaceable 'sheet anchor' to every Cosworth project conceived in the first thirty years.

Not even this summary, however, can catch the sheer down-to-earth, practical, engineering ability which superbly matched and balanced everything produced by Keith Duckworth's design talents all along the way.

that, to him, 'competence' – along with 'brightness' – is a real virtue, and a term of professional recognition), but gleefully points out that '. . . he wasn't a Mason, either!'.

When war broke out, the Duckworth family had a Riley Kestrel 16 hp, complete with hemi-headed 2½-litre engine, and a Riley Adelphi 1½-litre as well:

'Father liked his Rileys, they had fine engines. He once tried an Alvis, but it required too much warming up. He went about a mile down the road with the engine coughing and fighting.' (I *think* he said 'fighting' . . .), came home, said "This is no good, I'm taking it back", and that was the end of the Alvis, so we stayed faithful to the Riley.'

At first, Keith attended a convent in Blackburn (there were only about seven boys there at the time), but soon his brother went off to Giggleswick School. Keith later went to a small private school in Blackburn, with about seventy pupils, but from 1942 he joined his brother at Giggleswick, as a boarder.

Giggleswick was, and still is, a much-respected public school, set in the folds of hills close to Settle in Yorkshire. Later made more famous to TV addicts as being the school where Russell Harty taught before becoming a show business personality, it was a very happy location for a growing boy to move towards manhood:

'I boarded at Giggleswick from 1942 to 1950. I played a lot of rugger, but couldn't stand cricket.'

[Perhaps that explains why, when in later life Keith was invited to visit his old school he travelled by helicopter, landed it on the cricket pitch and was politely asked to remove it so that the Old Boy's match could take place!]

'By the time I was eighteen years old I was quite good at drinking beer. I was a fat sod, a prop, second row, or hooker. I hooked for the school for a time.

[At this point in an interview, Keith exploded into typical rumbustious gales of laughter: 'A *hooker*, yes a *hooker*! You'll have to be careful if you're going to sell this book in America . . .!']

Even when he was a schoolboy the reputation for independence, deep thought, and – at times – sheer chin-jutting stubbornness, was developing fast.

'I trace my first demonstration of independence of thought to Giggleswick, when I was fourteen. Everyone else was to be confirmed, into the Church of England. This meant that you had to say The Creed – "I believe", and all that. I read this through, and said that I was sorry, but it would be grossly hypocritical for me to say that I believed, at my age. It all sounded grossly unlikely.

'Pandemonium. I had to go to see the Padre, the housemaster, then the headmaster, to explain myself, and I *never* was confirmed.

'It was the first time that I actually went on my own analysis of a situation, and came to my own conclusions.'

This approach to life led to all sorts of difficulties for the growing boy, especially where discipline was expected:

'When I was at school, I always held out, and tried to get an explanation of things. I used to get my arse tanned [which, in Lancashire dialect means 'backside spanked'!] – now I know there was a war on, but I thought that to try to produce leather while it was still on the living animal was a bit unfair!

'I had similar problems in the RAF, but compared with school the discipline *and* the food was so much better that I almost found it to be a holiday.'

From an early age Keith had been a keen model builder. Even though there was a war on, he remembers building the odd Frog kit, and making model aeroplanes from 'spills and bog paper, rubber bands and all sorts of odds and ends'. He also had a Bassett-Lowke stationary steam engine and boiler, which used meths burners to raise the steam.

Keith Duckworth's official biography looks like this:

DUCKWORTH, David Keith. Honorary Life President, Co-Founder and past-Chairman, Cosworth Engineering Ltd, St James Mill Road, Northampton NN5 5JJ. *Born*: 1933. *Education*: Giggleswick School, Yorkshire, and Imperial College, London. *Career*: 1957–1958, transmission development engineer with Lotus. Founded Cosworth Engineering in 1958, with Mike Costin. Chairman and chief engineer until 1988. Member of main board of UEI plc. Retired from executive management of Cosworth in 1989.

But that isn't enough, not by any means. This must also be added:

Engineering design genius, inventing the world's most successful Formula 1 engine. Workaholic, frustrated helicopter pilot, successful businessman, the inspiration behind every Cosworth project until mid-1980s. Multi-talented, super-confident, deep-thinking, forthright, stubborn, often combative, dismissive of fools, gregarious in company, but dangerous in argument, unbeatable in analysis of engineering problems and possibilities, a one-off in every respect.

The Duckworth family home was a solid, but unpretentious 1930s-style three-bedroom type, 'nothing special', but at least it had a workshop of a most unusual type. Just before he died, Duckworth senior saw that his younger son was keen on engineering and model making, so he bought up an old Myford lathe, a vertical drill, and a grinder, and set up the workshop in the old air-raid shelter, which had been added to the back of the house.

'We'd had a window knocked into it, he had just wired it up, and he had just put the machines into the workshop when he died,' Keith remembers.

After that, with Keith and his elder brother still at boarding school, and the war still on, the cotton exchange business stopped immediately, while the weaving shed had to be run by a manager.

'Eventually we sold off that business. I wasn't interested in running it, neither was my brother Brian. Father had already decided that cotton wasn't going to be a go-er in England after the war, because of cheap imports from India and elsewhere . . . he was right, wasn't he?'

Keith rapidly built up his modelling and engineering expertise. Having inherited his workshop at the age of eleven, where no-one in the family knew how to work the machine tools, he became a self-taught operator, made bits and pieces for model steam engines, then after the war he began flying powered model aircraft.

'I had a great stack of miniature engines, petrol *and* diesel, and when I was sixteen I built my first radio-controlled equipment, from plans in *Aeromodeller*.'

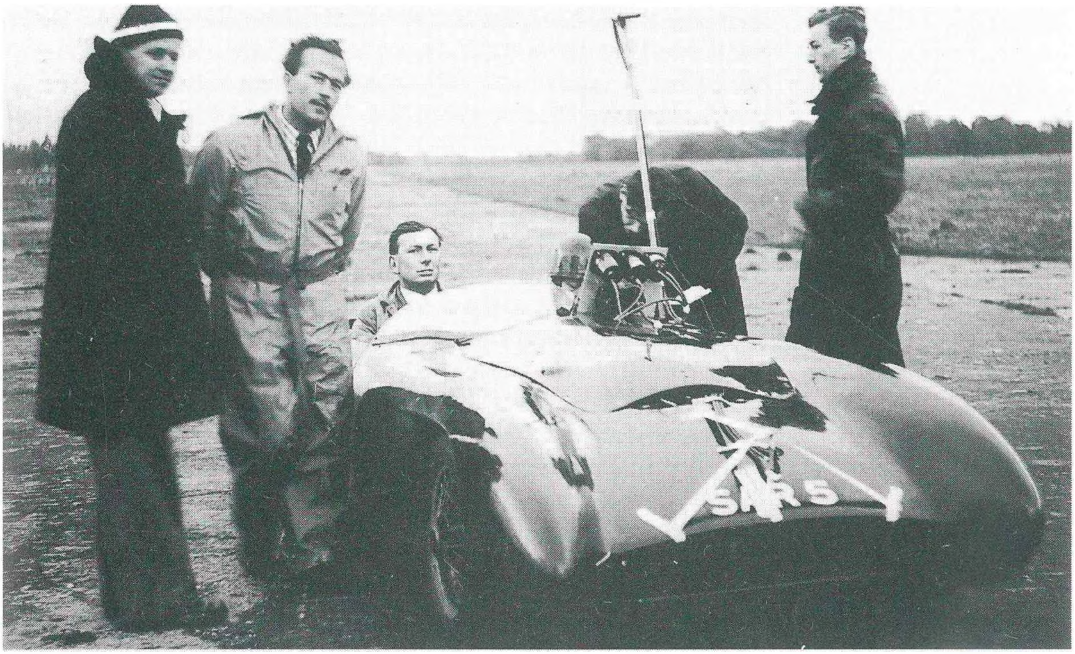
Already, therefore, he was on his way to becoming the 'whiz-kid from Wilpshire'. He got a name for sorting out electrical wiring problems, for repairing electric sewing machines, and other mechanisms:

'I once won a bet with my uncle by being able to switch on an electric blanket at two miles range, by radio-controlled equipment.'

All the time, the teenage Duckworth was teaching himself about engineering, for he had started making parts for his engines and team boilers, had bought many measuring intruments and tools, and reckoned he had done all the 'compulsory filing and graunching' by the time he left school.

As soon as he was sixteen years old, he bought a motorcycle, paying out £25 for a side-valve 250 cc BSA, so old that it still had a hand, rather than a floor gear change:

'It wasn't a runner at the time, but I refurbished the engine, putting in new valves and guides. We weren't



Test equipment was less sophisticated in the 1950s! This shows Mike Costin at the wheel of a Lotus Mk 8 on a disused airfield near Chester. Colin Chapman — 'Chunky' to his friends — stands to the right of the car. Mike's brother Frank is hidden behind the test gauges. Extreme left is Sqn Ldr Fifield of Martin Baker Ltd. He was the first man ever to eject himself from an aircraft while accelerating along a runway for take-off.

allowed to ride motorbikes at school, but as I had fairly long holidays from Giggleswick, I could have the bike at home, and play with it then.'

By 1950, School Certificate and A-Level examinations were over, and National Service was looming over the horizon:

'I had done reasonably well in exams, ['reasonably' is another well-known Duckworth buzz-word which, being roughly translated, means 'very good, but maybe I'd better not boast too much about this' . . .], taking A-Levels in Maths, Physics and Chemistry, while I did extra Latin, in case I wanted to go on to Oxford or Cambridge.

'I decided I was keen on flying, and there was a chance to do this in National Service. Just before I left Giggleswick I went down to Hornchurch, by train, to be graded as suitable, or not, for National Service aircrew. I did a whole series of aptitude tests in those two days, and though I wanted to be a pilot, they were doubtful about this, and wanted to put me down as a navigator . . .

'They didn't think my aptitude was right, but they decided to allow me to try as a pilot. As I wanted to go to University in two years I decided to try for an early call-up, and I was in, on a flying course, on the day that I was eighteen.'

Mike Costin, too, had the sort of childhood where engines, machines, and all mechanical things, never seemed to be very far away. Mike, like Keith, was never overawed by personalities, or reputations. He recalls how his father's business – an artistic form of interior decoration – rapidly built up in the London of the 1920s and 1930s:

'Father used to say "I paint houses. The only difference between the other painters and me is that I carry my brushes in my top pocket."

'All the top people in London had to come to him to get their jobs done. Lord so-and-so, or Lady so-and-so, had seen a room done somewhere, wanted their room done like that, an oak-panelled room, a pine-panelled room, marble or whatever. He was actually a terror in the "Establishment" because they couldn't do without him. There wasn't always a lot of money, though. I remember that he did a deal with the professions in North Harrow – in exchange for a bit of decorating, we would get some free medical or dental treatment . . .'

All three Costin boys went to the Salvatorian college in Harrow Weald, which was run by the Catholic Salvatorian order. Mike was ten when war broke out, and sixteen when peace returned in 1945.

'I was influenced by Frank's activities,' Mike now remembers. 'From a very early age he had been totally involved in aeroplanes – there used to be copies of *Flight* and *Aeroplane* all around the house. I left school at 15½, and I decided to apply for an apprenticeship at de Havillands. It wasn't local, of course – it was quite a way from Harrow to Hatfield – and it wasn't Frank's influence, for he was already away from home, with Percival Aircraft, where he was Project Design Engineer. He didn't actually move to de Havilland, as Aerodynamic Flight Test Engineer, until 1951.

'I thought de Havillands would be an excellent place to be – they had no fewer than 1,200 people in the technical school. I wrote to them, got an interview, and was accepted as a trade apprentice, as a fitter, and that was a 4½-year apprenticeship.

'I left school in July, but the de Havilland entry in those days started in early January, so I had time to spare. In the meantime a school friend of mine had a father who owned a string of bicycle shops – I worked at one of them, repairing and rebuilding cycles, wheels, three-speed gears, and everything.

'When the time came to start work, I went into digs in Hatfield. I was earning 26s (£1.30) a week, but my digs cost 35s (£1.75) a week, so I needed help from my parents.

They weren't very well off, but somehow they survived, and they helped me.

'De Havilland gave me fantastic training. I had nine months of basic training, for instance, at Salisbury Hall, near London Colney. The academic side of training was all at Hatfield, just inside the gates where there was a collection of wartime huts.

'At that time I didn't have a thought about cars, or anything else. I was totally bound up with aircraft, that was my horizon. I didn't have any great ideas. I didn't see that I could have any great qualifications to do any more, but I was always in there, trying . . . After two years, though, I must have been doing fairly well, at the academic level, because I was upgraded into an engineering apprenticeship, which put me on a different level.

'When you start out as a fitter you have basic training, then you go through the fitting shops and you are trained as a fitter – but as an engineering apprentice the training was wider – into foundries, press shops, laboratories: I went to fourteen different departments and it was an ideal grounding.'

When he was sixteen years old, Mike had got his first mechanized transport, a 250 cc unit-construction New Imperial motorcycle. Like the BSA which Keith had bought:

'It wasn't serviceable at the time, it had a gearbox

Sweet success, at Le Mans in 1957, where this Lotus 11 won the Index of Performance category. Mike Costin is to the right of the car, Colin Chapman to the left, with drivers Cliff Allison and Keith Hall on board.

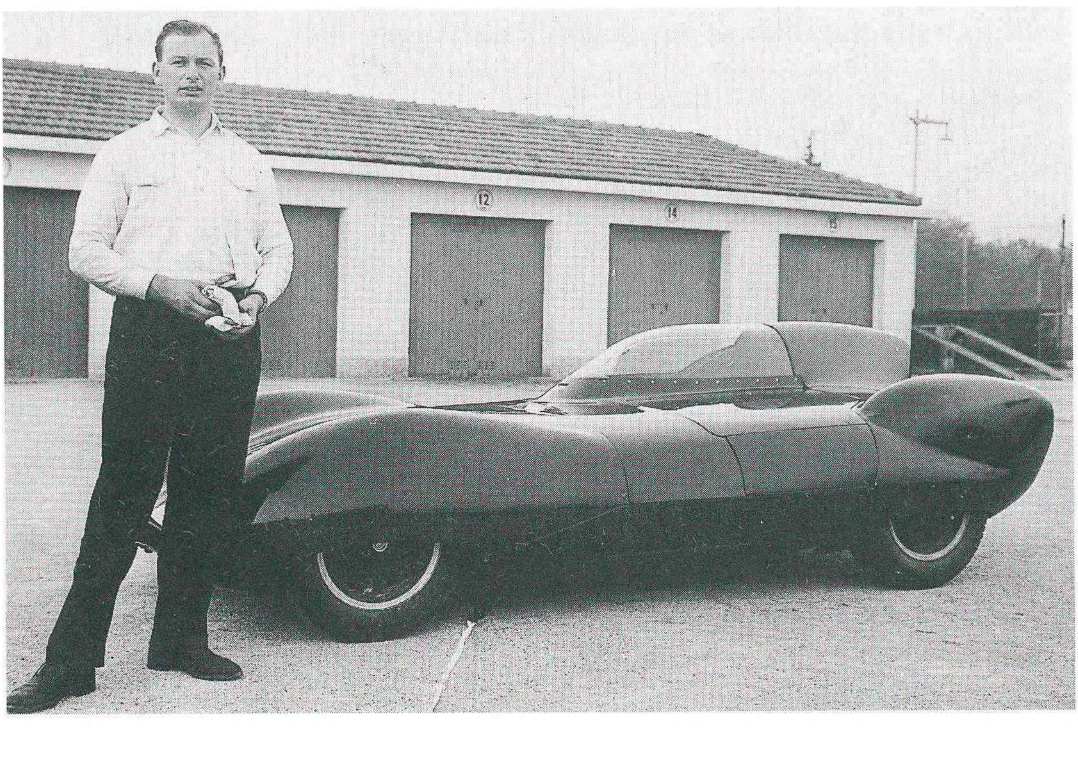
layshaft which was worn out. I saved up, and bought a new layshaft from Colliers of Birmingham. They screwed me, I know that now – and these days I would have the buggers for breakfast – because the shaft hadn't been hardened, and in about five minutes it ruined itself. At that point I sold the bike, because I couldn't afford to keep running it, so I went back to a pushbike for a time.

'I then had another motorbike, an old BSA 250 cc, then ended up with a 1934 BSA Blue Star 500 cc single. I had gone back to live at home for the last year of my apprenticeship, and as I was at Panshanger, qualifying for my maintenance licence, I used the plonking old BSA for transport.

'I used to ride 26 miles each way, starting at Panshanger at 7.30 am every morning. In that year, too, I was doing four evenings a week at night school. We used to have one full day off work to go to college, and four nights at night school. That was a fair old flog . . .'

At the conclusion of his apprenticeship, and having won two deferments to successfully sit his ARB examinations, Mike then went into the RAF for two years of National Service. Back from a routine stay in the forces, he returned to de Havilland, moving straight into an office designing test rigs on systems, mainly for the jet-

Mike Costin, with the bubble-canopied Lotus 11, as used to break records at Monza in 1956. Mike is tall, but he could *just* squeeze in under the bubble.



propelled Comet, but also including Vampire work and 'whatever was going – it was very interesting . . .' There was also another side to the work, that of accident investigation of components and systems on military aircraft.

'The first car I used wasn't actually my own. Peter Ross had started his apprenticeship when I did. He had a nice, pristine, 1928 Austin Seven Chummy, but it didn't stay that way, it got modified. Through Peter I met Derek Wootton, the famous bloke who Colin Chapman got to follow back to his workshop after a 750 Club race meeting. Colin was in his Mark III race car, Wooty in his clapped-out old Austin Chummy with the Ford 10 engine. Chapman was having great difficulty in keeping up with him, but when they got to the end of the trip he saw that Wooty was wearing dark glasses. Chapman then said, "What the bloody hell are you doing with them on, at this time of night?", to which Wooty replied, "Well, if I don't wear them, my eyes water . . ."

'Now, Wooty was a mad-man, a great enthusiast, and he had a barn full of Austin Seven and Ford 10 pieces. I started to use a car which belonged to Derek Wootton – he had two cars and I used to borrow one.

'There was one amazing occasion, when I was driving along with my wife-to-be in one of them, a 1937 Austin Seven Ruby, when suddenly, whoosh, a wheel came off the car. I rescued the wheel, and had a look round the car, and found that *all* the wheel nuts were loose.

'Wooty had come round to the garage during the day, and because he'd wanted the wheels and tyres from one car, put on the other car, he'd swopped them over. He'd just put the other wheels back on "my" car, but he hadn't bothered to tighten up the wheel nuts, and he hadn't told me! I haven't been able to live it down, with my wife, ever since.'

At this point, we might reflect that one of the most important early influences on the founders of Cosworth was aircraft engineering, and the aircraft themselves. *If* Keith had not gone on to fail his pilot's training course, and *if* Mike had not met Colin Chapman by a series of coincidences, the first meeting, the formation of a friendship, and the foundation of Cosworth might never have occurred.

In the meantime, Keith was also enjoying himself, and eventually moved up to running his first car. His National Service experiences, as you might guess, were both flamboyant, and eventful. After twelve weeks of squarebashing at Kirton-in-Lindsey, and initial Tiger Moth flying experience at Digby (not far from Sleaford):

'My flying of Tiger Moths suitably impressed the RAF, so I was re-graded as a pilot. I went on to do sixty hours in Chipmunks at Booker [the airfield near High Wycombe], then went on to Holme-on-Spalding-Moor [near Market Weighton] and did about seventy hours on twin-engined Oxfords.'

At that stage disaster struck for the prospective pilot for:

'I was then flung out for "dangerous and incompetent night flying" – I actually went to sleep in the circuit. I'd had some medical troubles – I had been chasing model airplanes round in a field, tripped over and sprained my ankle, they'd taped me up, and I *now* know I'm allergic to Elastoplast . . . I was trying to catch up on the course, having been off for a time. Anyway, I was within ten hours of getting my wings, but I never got them.

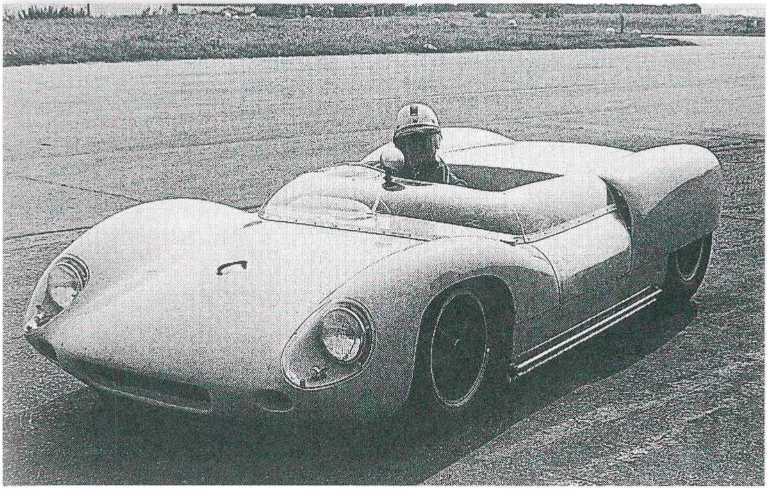
'When I was thrown out as a pilot, I was immediately sent to do navigation, and I went down to RAF Thorney Island, near Portsmouth. I studied navigation, found that I could do this without any trouble, and I also proved that I had a strong stomach. We went on many bumpy flights in Ansons, four or five of us, and occasionally I was the only one to put in a chart for an exercise because everyone else had been green, and sick.

'Now I don't compromise easily – a lot of people will tell you that [They did – AAGR] – and my lecturer in astro-navigation was a blithering idiot: we used to have big arguments about his theories about star shots.

'I simply won't accept anything that is wrong, theories that are wrong. I can spot the bullshit factor at a 100 yards range! If anyone makes a statement about a physical or mechanical phenomenon, which is actually suspect, I have a little automatic mental mechanism which says "Hang on, is that right?", then it starts another mechanism to work out what *is* right.

'Because I'd started the course late, I was very tight for time. Then I had cartilage trouble in my knee – a rugger injury – was carted off to Halton hospital for it to be removed, and got water on my knee, then I spent time at the rehabilitation centre at Headley Court. In the end I couldn't complete my navigation training before I left after two years, though I was still top of the course. Actually I was allowed out early, still as an Acting Pilot Officer/trainee Navigator, and went straight to Imperial College, London in 1952.

Even before he joined the RAF, Keith developed a



Mike in 'the office' — testing racing cars, as he so often did. This was Stirling Moss's Lotus 19, at Goodwood, in 1960.

passion for Scott motorcycles:

'The Flying Squirrel, which had a water-cooled, parallel-twin, two-stroke engine with deflector pistons, well angled forward in the frame, made a very interesting noise when it was actually firing on both cylinders [here the famous Duckworth cynicism for other designers' work, well-developed in later years, was being honed]. I was still playing with Squirrels, whenever I had the time, when I got to university.

'In the RAF, three of us who all came from the Leeds and Blackburn areas clubbed together to buy a car, an old Singer 12 saloon, the one with the overhead cam engine. It did a few trips from Kirton-in-Lindsey, and from Digby, but it was a real heap, and eventually I think we just abandoned it.'

Keith, as you might expect, had trenchant views about the right, and wrong, universities to learn all about engineering:

'Most people told me "If you *really* want to be an engineer, don't go to Oxford or Cambridge, but go to where engineering is actually taught as an intended subject", and that Imperial College was the place.

'So that is where I went, to take a mechanical engineering course. I knew that if I wanted to get anywhere in life, I needed a degree. But there was never a Duckworth "Master Plan" – there never has been one. I think that people who plan like that have a mental deficiency, and a *very* high opinion of themselves. Later on, at Cosworth, nothing upset me more than interviewing graduates who wanted to see how their life could be planned for the next few years – if they had wanted planning, they should have joined the Forces, or the Civil Service!

People like that have no sense – they should realize that their progress in life is dependent on the competence that they demonstrate – it's nothing to do with the passage of years, or of seniority. One of my principles is that young fools go on to become old fools . . .

[Interviewing Keith while preparing this book usually resulted in at least one major philosophical 'lecture' like this, every hour, if not more frequently. His colleagues assure me that business life used to be like that too . . .]

It was in his first year at Imperial College that Keith began to get interested in motorsport. Some of his new-found friends were interested in motor racing, and visits to the circuits – mainly Goodwood, Brands Hatch, and Silverstone in the early 1950s – all followed. At first he was still running a Scott motorcycle, but eventually graduated to an Austin Seven Ruby saloon.

The Ruby, like all such ageing Austin Sevens, had very erratic brakes, and on one notable occasion Keith was driving down Regent Street with his future wife, Ursula, by his side, when hard braking ahead of red traffic lights resulted in the car swopping ends and going through the (still red) traffic lights backwards! No-one was hurt, but Ursula was not best pleased.

'I also rose to the delights of riding a Triumph Speed Twin motorbike, which had a sidecar on it, so I did my share of sidecar driving. That included the novice's obligatory visit over a kerb! The owner, Noel Davis, who is now Chief Executive of VSEL (which is a large shipbuilding and engineering concern), was very nice about that . . .'

At the end of that academic year he took a vacation job, one as far removed from high-tech as could be imagined, even by the standards of the day:

'I went to the National Oil and Gas Engine Co in Ashton-under-Lyne, one of the groups making middle-size (not full ships' size) stationary engines.

'I can well remember helping someone tap out a 2½ inch Whitworth head bolt in the bottom of a cylinder liner – and those engines could have 12 in bores.

'When I arrived they'd just had a very jolly explosion, where a turbocharged gas engine had mixed gas into its crankcase, which had gone up, blown the inspection doors right off and gone out through the rear corrugated iron wall of the building.'

In that same summer, though, Keith convinced his mother that he should be allowed to buy a Lotus Six in kit form and that some of the money his father had left him should be invested in the kit. Keith admits that his mother didn't even know what a Lotus Six was, or looked like. Right from the start, he decided that his Six had to be properly built, with the best components. It was not about to be a scrap-yard special:

'So off I went up to Lotus, which was in the pub yard in Hornsey, got hold of the specifications, the price list, and I looked at all the options that I could have, and paid my deposit. I made the bold decision to use a Coventry-Climax engine, and an MG gearbox – that was *very* bold, because the Climax was the most expensive of the engine options, about £250 at the time, I seem to remember.

'I saw that I needed Ford axles, which needed to be sent off to be modified. They were E93A parts, available from my local Ford dealer, so as there didn't seem to be much price difference between new and secondhand prices, I managed to buy a new rear axle, and other new Ford bits.

'At the beginning of the summer holidays, I borrowed a trailer, went down to Hornsey, and collected the kit.'

Perhaps Keith met Mike Costin for the first time during those visits, but neither now recalls an occasion. Even though he was then struck down with glandular fever during his second year ('I was too ill to take second year exams, I had to take a second second year, so my three year course actually took four years'), Keith installed the Lotus kit in the workshop in Wilpshire, and got on with building it. At the time he rather fancied himself as a budding racing driver, and thought the Six was the ideal way to prove his point. The problem, however, was that his ambition was way ahead of his abilities:

'I did, in fact, race three times. I finally decided to give up because I shunted the chicane at Goodwood, when the VG95 linings picked up in the drums and the wheels didn't unlock when I took my foot off the brakes. I went straight into the chicane, which was a solid bank with a row of geranium pots on the top. I ended up against the bank with a geranium in my lap.

'Earlier on, that day, I'd actually gone through Fordwater, that's the very fast kink, where there's a change of surface, and the car had leapt up and gone sideways for a way before I straightened it up.

'I remember thinking, "Jesus, you're not with that, not even vaguely with that, are you?". There was a great deal of luck that it covered the next piece of road without going off. I'm hopeless, my hand/eye co-ordination is poor. It upsets me. Full stop. It upsets me that I could never be competent in the Uhlenhaut mode, that I'm not blessed by being able to drive properly.

'Now Mike, on the other hand, I've never seen him over-correct a car. When the back end goes he just puts on the right amount of opposite lock at the right time, the car carries on sliding, and mysteriously as the kerb approaches it stops sliding and carries on in the right direction. That is totally beyond my imagination.

'Later I decided that there seemed to be two categories of racing driver – those who could drive by natural ability, and those who actually gained competence by experience. I thought that those who had the natural ability were most likely to win the races, and that I was firmly in the other category. I decided that I never did the right thing, the right amount, at the right time. I soon learned what proper driving was about, when I went out with Mike.'

Mike Costin, in the meantime, who had rejoined de Havilland after National Service in November 1951, had also started to work at Lotus while keeping his job with the aircraft company. The Lotus connection all started with Peter Ross, and his cousin Adam Currie, who had bought Colin Chapman's Lotus Mk 3B. At the time Colin Chapman's business partners were the Allen brothers, Michael and Nigel, who finally walked out on an unsatisfactory working arrangement, leaving Chapman on his own.

'Towards the end of 1952,' Mike recalled, 'Peter told me about Colin Chapman – I hadn't met him then – about his cars and his big ideas, and that he wanted help. Through Peter, I met Colin, and eventually we struck up a deal. I would work there part-time (in the evenings) but I would keep my job at de Havillands, which I did for the next two years or so.

'The object was to build Mk 6s at a profit, to subsidize Colin in racing. I actually built Colin's racing engine, but I also did the production engineering for the Six, I did all the thinking behind that. Colin didn't actually pay me any money – Oh no, not Colin! – but I got gallons and gallons of petrol instead.

'It was a busy life. I used to finish work (we were living in Hatfield) and I used to get away from work at about 6.00 pm, start again in Hornsey at 7.15 pm, and work through until one or two in the morning. Then it was back home, and back to work the following morning. I was already married and my wife didn't see much of me at the time. She was *very* understanding.

'I used to get back into Hatfield every morning, with packets of fags to use as bribes, drawings, pieces to be treated and welded, bits of material to be scrounged – it was a bit naughty, the "foreigner" syndrome, but as Colin and Lotus were already winning, and we were getting famous, I managed to enthuse a few people.

'That year we did a deal, that I would do the 1,172 cc races, and Colin would do the 1,100 cc races. I hadn't done any racing before that time, in fact I'd hardly been to any events as a spectator. In 1953 there was Colin and myself at Hornsey, nobody else at all, then one or two other people joined us in 1954.

'That was the year when Chapman designed our first so-called aerodynamic car, but I wasn't very impressed at first. Fortunately, my brother Frank had joined de Havilland by this time – he was in charge of flight test aerodynamics at Chester. So I shipped the balsa model which Dave Kelsey of Progress Chassis had made for us, up to Frank, by the inter-factory airlift, and asked him what he thought, and could he improve it? He could – he totally changed it, into the familiar shape of the Mk 8.

'Up to that stage Frank had been totally uninterested in cars – he only thought of aeroplanes. But I kept on at him, and said "It's great sport, and you could do some interesting aerodynamics". He made a good job of the Lotus Mk 8, and that's how he got drawn into automobile engineering.'

By the late 1950s, therefore, Mike Costin was Colin Chapman's right-hand-man in every way, and had taken on the grand title of 'Technical Director'. Throughout the period when Chapman's methods – and Lotus – was all about advanced design, exhortation, and close-to-the-wind wheels and deals, Mike was his sheet anchor, the best car and engine builder at Hornsey, the most practical personality on the ground.

Keith Duckworth, on the other hand, was enjoying himself at Imperial College – rather too much to get a lot of work done. Returning to start his second academic year, he moved into digs in Lavender Hill Gardens, Clapham, to find a young man called Bill Brown installed on the other bed in his room.

Keith's friend Brian Bannister, who had provided the lift down from Blackburn to London in a Triumph Roadster, expressed the opinion that Bill Brown was going to be a very boring room mate, but after an evening spent together at the local pub, Keith was staggered to find himself: 'drunk under the table by this nineteen-year-old who had already spent a year on the buses. I thought this was a very reasonable start!'

Lotus – the 'midwife' for Cosworth

Without Lotus, and Colin Chapman, Cosworth Engineering might never have been born. Although Keith Duckworth and Mike Costin both lived in London in the 1950s, and both were interested in motor racing, they might never have got together if it had not been for Colin Chapman, his exciting sports cars, and the cramped Hornsey premises of the Lotus Engineering Co Ltd.

Keith Duckworth's first Lotus connection was the purchase of a Six, in kit form, which was followed by visits to Hornsey to buy bits and pieces. From there, it was only a short step to 'lending a hand' at Lotus, in the evenings.

Mike Costin first learned about Lotus cars from his friend Peter Ross, and a friend of Peter who had bought the Lotus Mk 3B, and it was not long before he was attracted to Hornsey as well, first of all to work on the cars in the evenings. By 1956 Mike was working full-time at Lotus, Keith met him on one of his irregular visits and the rest, as they say, is history . . .

From that moment, the two undergraduates became firm friends. Bill hailed from Hartlepool in County Durham and eventually bought Keith's Austin Seven Ruby, at one time suffering from police attention over its roadworthiness failings, and eventually turning it into a special.

Keith now admits that the two worked very hard on their social life in London, but that neither of them actually worked very hard at their studies. The tutors eventually suggested that Bill Brown should leave when he failed a set of examinations, and though he later returned to try again, he never achieved those coveted initials 'B.Sc'. By the time Keith set up in business, Bill Brown had joined the RAF, to complete his National Service. Keith, on the other hand, had scraped through. Many people, including the author, are surprised to learn that he did not get a toweringly successful First Class degree:

'I passed, just passed. No way was I going to get honours. In those days the people who got honours were the ones who talked to walls. I just scraped through with a pass, and I think I was quite lucky to qualify. I made quite a few mistakes. One was that we had to write reports of the work we had done on the various gas engines and oil engines. Most people just copied the previous year's reports, but not me. I actually wrote a critical analysis of whether we had learned anything, and in most cases I came to the conclusion that the measuring equipment, and the way that the experiments were done, didn't prove *anything*. I wrote this down at great length, and my conclusions were that it was not a worthwhile exercise.

'As this was totally new to the examiners, I got very poor marks for my course work. But I reckon that that is the foundation of why I am a good development engineer.

'I was always in trouble in passing exams, because I didn't like learning everything as a parrot. While I have a good memory, I wouldn't spend the effort to programme it. I really only learned the things I could understand. In exams, where I hadn't learned the equations, I just had to sit down and work everything out from first principles, so I never did sufficient in the time available, I didn't answer enough questions.

'But there was no way that I was going to adjust my principles for the sake of passing exams. It is a fundamental that I have to understand what I am doing, and that is what turns me on.'

Keith and Mike, looking impressively smooth, and ready to go off to their friend Howard Panton's wedding.

Before examination time, however, Keith had visited Lotus several times, always in search of bits and pieces for his Six, and spent the whole of one summer vacation at Hornsey:

'I decided that working on sports cars was a more congenial way of vacation training than tapping vast threads for gas engines. I wasn't paid much, but I did at least get a nominal sum. During that time I worked in all the shops, and this would be the time that I met Mike. I was given astonishing responsibilities really. I was working for Graham Hill in the gearbox shop – he wasn't a full-time racing driver at that stage – and he liked to give the impression that he was the only bloke who could assemble racing A30 gearboxes. One time, when he was away somewhere, racing, I was asked if I could assemble boxes. I could, and I did. It wasn't as difficult as Graham had tried to make out. After all, I had a collection of bits, there were instructions for building standard boxes, and a picture, so I thought that was enough.

'There were a few bits to shim, here and there, but since they all had to go together in some sort of logical order I soon worked things out.

Then, in 1957, Keith's final examinations were upon him, and it was time for him to start looking for a job:

'I went on the usual university "milk-round", looking for a post-graduate apprenticeship. I certainly hadn't decided to start my own business, and I hadn't considered working for Lotus full-time. I went for interviews to Rolls-Royce Aero Engines, and to Napiers. I was offered graduate apprenticeships by both firms, but I was *very* attracted by Napier. They were still making Deltic engines, and Nomads – both great , crazy, engines, it would have been interesting work.

'I was very tempted by Napier, because they seemed to be doing even more daft things than Rolls-Royce. I must say, there was the prospect of working with Nomads – an H24 two-stroke diesel compounded with an exhaust driven turbine through an infinitely variable drive. In fact I'd already accepted Napier's offer, but then I sat back and considered that all such apprenticeships would probably have to start by filing blocks of metal for weeks, and I didn't really think I needed that.

'Now what was really fascinating was the insight offered by the report which I got from Rolls-Royce after my application that: "They would take me on for a graduate apprenticeship, but that they had severe doubts as to whether I was suitable to be a member of a

Keith Duckworth, born in Lancashire in 1933, was always interested in engineering. Already renowned in the motor racing business, he sprang to world-wide fame in 1967 when the DFV V-8 engine was launched; it was an amazing design achievement by a man who was only 34 years old.

team . . ." They'd actually picked up my personality, even though I was quite shy at that time, and I would have thought that I was introverted, so I think that was quite the brightest thing that an interviewer ever worked out about me. His conclusion was exactly right, and I was still only 24.

There was also another opportunity:

'I was also asked if I would stay on at Imperial College, and do research into the tribology, the science of lubrication, which was still relatively new. That didn't interest me though . . .'

Then came the breakthrough, the event which was to start Keith along the path to fame and fortune in the motor racing industry:

'Graham Hill was about to leave Lotus, to become a full-time racing driver. I went along to Lotus, to see Colin Chapman, and he offered me a job, straight out of college, as a gearbox development engineer. Rather unkindly, therefore, having already accepted Napier's offer, I turned them down, and went to work for Lotus, at a salary of £600 a year.'

Keith admits that there was some concern at home, in that he wasn't joining a large company. However, since his father had always been something of a rebel – 'They said he'd never become a member of the Cotton Exchange unless he was a Mason, but he just retorted "Well, we'll see about that . . ."' – there was no real resistance. For Keith, it was a great opportunity.

Early days in North London

'It must be possible to make an interesting living, messing about with racing cars and engines . . .'

When Keith Duckworth joined Lotus in the autumn of 1957, he was embarking on 'Mission Impossible'. His job, quite simply spelled out by Colin Chapman, was to turn the troublesome new five-speed gearbox – already nicknamed the 'Queerbox' – into a reliable proposition. It didn't help that he was the first graduate to start working at Hornsey, and was greeted with a notice on his locker stating: 'Who needs experience, I'm a college graduate'.

'When I arrived,' Keith says, 'the "Queerbox" had never managed more than fifty miles before the crown-wheel-and-pinion failed. The previous incumbent in the job was Graham Hill, but he was doing more and more racing driving.

'At the time Lotus had sent a 'box down to a big company on the North Circular Road, who were doing tests on a 4-square rig, putting torque on the box and measuring deflections – quite a lot of intense effort was going on.

'The "Queerbox" had its selector mechanism running through the middle of the gears themselves, with a quadrant gearchange. It was an all-indirect gearbox. Drive came in through the cluster of gears, the input shaft was the bottom one, while the crown wheel and pinion, which had a ZF limited slip differential, was at the back. It was a very short gear cluster indeed.'

This was the gearbox which had been designed for Chapman by Richard Ansdale. Later, Ansdale, a very experienced designer, was to be involved with the marketing of Wankel engines in the UK, and with the birth and concept of the Lotus-Ford twin-cam engine. The box was first shown, in public, in June 1957, as an integral part of the design of Lotus's first single-seater racing car, the 12. A year later, while Keith was still working on the development of the design, it also made an appearance in the 15 sports racing car.

Anyone with half an hour to spare, and the sort of engineering insight which is not overloaded by talk of tolerances, mechanisms, lubrication levels, and assembly methods, should encourage Keith to talk about his struggle to make the 'Queerbox' work, and work well. It is a riveting story of enterprise and first principles (on Keith's side), fighting against expediency and a reluctance to invest in change (by Colin Chapman). Mike Costin, wisely, kept well away from it all.

'The two main problems with the 'box', says Keith, 'were that the gears had very short internal splines to locate the selector linkage, and that was the crown-wheel-and-pinion was not getting enough lubrication. I looked at all this, and the failed crown wheel and pinion gears, and reckoned that the oil wasn't getting where it should. I made up some shields and tinware inside the housing, then some jets, convinced myself that oil would now get up to the gears, and that if we assembled it properly, with the right offset, that there was a fair chance that it would work.'

Placidly, and somewhat complacently, he then summarized:

'The first crown wheel and pinion that *I* assembled, with all these bits and pieces, went on for ever. *That* ceased to be a problem.'

Meantime, ZF was building a new batch of gearboxes. Keith then had to travel to West Germany ('It was the first time, the *very* first time, that I'd ever been out of the country!), to show them how to add all those shields and jets.

'There was an oil force-feed to the gears, but I had to reposition the jet. Even so, although we could make the crown wheel and pinion work, the gear change was hopeless. It seemed easy to arrange the change through the centre of the gears, but there was so little space.

'Certain people didn't seem to *understand* anything. It was no good doing all the sums, and the drawings, if there was no understanding. There's a lot of difference between regurgitating knowledge, and actually being able to understand how things work.'

[Time, now, for another commercial for the Cosworth philosophy . . .]

'There is a fundamental thing about Mike and me which is different. We are understanders, we think out how things actually work. It really is me who has taught Mike to do this. What is quite remarkable about Mike, and Ben [Rood] is that I found them early on, and they are still the only two who *really* understand what I'm about, and what everything is about. They are the only two who have been good disciples.

'By the way, I think that Colin Chapman was the brightest and quickest bloke I have ever met. Technically he was the brightest I ever met in conceptual thinking – the amount he could do in a short time was prodigious. He'd go away one day, having decided on something, and come back the following morning with a complete drawing, having done it overnight. But he wasn't that good at detail design because he didn't have enough grasp of limits, fits and running clearances.'

Even so, Keith could not persuade Chapman that the 'Queerbox' was a hopeless case:

'All kinds of people tried to design a positive stop system; Len Terry was at Lotus by then, he actually drew up the parts. I used to say that this wouldn't work, and that wouldn't work. Eventually Colin said I should design the stops myself.

'It was incredibly difficult, requiring incredibly precise positioning, but I actually managed to make a positive stop change that worked. The problem was that we really needed to lengthen all the gears, only by about 1/10th in, so that wear and radiusing on the gears and the shaft wouldn't be critical. *That*, though, would have meant a new casing, but Colin said he couldn't afford that, it would have meant machining new gears and a new casing: "You've got to make do with what you've got."

'I was very weak, very feeble, I shouldn't have allowed this to go on for so long. Richard Ansdale was continually proposing modifications, such as a synchromesh proposal – but although that would have helped in down changes, it would have hindered as you went up through the 'box. There was also his proposal to use the first-gear pair of gears as an oil pump, but I did a few quick sums and worked out that this was going to pass 3,000 gallons every hour, so the mechanical losses were out of this world . . .'

'In the end, I said, "Well, Colin, if that's the case, I'm not prepared to waste my life developing something that will never work." I was working morning, noon and night anyway, for my £600 a year. By that time I knew it was never going to work as it was designed. I could see that it was still unsound . . .'

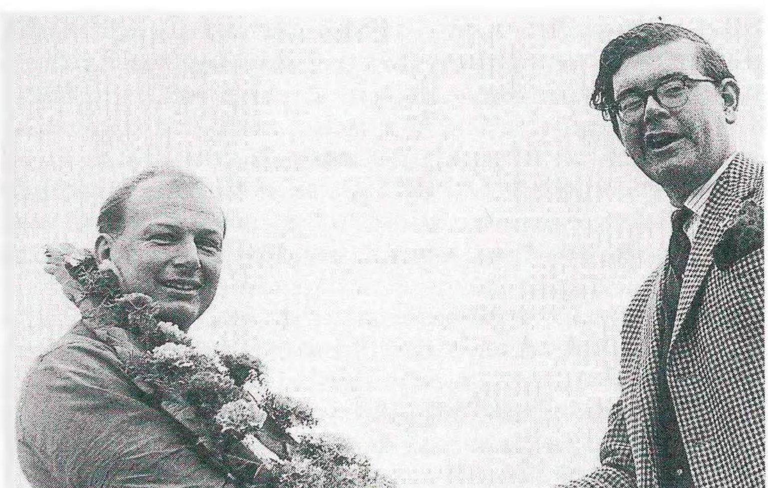
After ten months of frustration with the awful 'Queerbox', Keith was ready to leave Lotus. (Once he had left, Chapman handed over 'Queerbox' development work to Steve Sanville – but Steve was no more successful than Keith had been). Before this, however, Keith had struck up a friendly working relationship with Mike Costin. As Mike recalls:

'I used to build all the racing cars in those days, and Nobby Clarke was production manager. I was really in charge of building all the prototypes. Jack Field was in charge of the stores, upstairs in the loft.

'Straight away I could see that Keith was a bright bugger, even in that vacation job. I got to know him better when he came to Lotus, straight from college. My regard for his ability was enhanced as soon as he started working – the sort of jobs he was doing, his approach, his handling of mechanisms, of understanding how they worked, and his judgement of what would work and what would not.

'He could take anything from start to finish, from concept, to layout, to the design details, to making the prototype bits, to assembling it himself, to showing how it would work *and* understanding the principles involved – I was totally sold. He was the brightest thing I had ever come across.'

'I always had a very high regard too for his academic knowledge, it was far higher than mine. The bloke who can *really* understand the law of physics – the world goes round on the laws of physics – had an advantage. The whole thing is common sense, and Keith had a lot of that.



Even though he was a hard-working engineer, Mike Costin was also a successful racing driver. Here he receives yet another laurel wreath from Nick Syrett of the BRSCC.

'Colin couldn't stand that this bloke was so bright. He was very forthright, and he wanted an explanation of everything, he wanted to discuss everything. Colin didn't want to know: he wanted to do it *that* way, even if proved to be wrong – and, by the way, he wanted it done yesterday.'

The idea of setting up in business took time to germinate, but both Keith and Mike can really thank Colin Chapman for forcing them to think about it.

'While I was at Lotus,' Keith told me, 'we discussed setting up in business, because Mike had decided he didn't like Colin Chapman's business ethics.

'Colin was a stranger to the truth in many ways – he used to lie for no reason! I think he did that to make life complicated, to keep his mind agile. He always needed a lot of things to consider. If he told different things to different people he was going to have some explaining to do, so he kept his mind sharp in digging himself out of the holes that he had himself created . . .

'While I worked there I lost engineering arguments that I should have won, because he marshalled his thoughts and his facts so much quicker than I could, so I would find myself agreeing with something that was wrong. He would get his way by throwing in red herrings. I am so undisciplined, and such a persistent thinker, that I would chase the red herring and lose the drift of the argument.

'Eventually I could counter this by saying: "Yes, Colin, I've heard everything you have said, I've still got the odd doubt in my mind, I'll let you know in the morning", then I would manage to avoid agreeing to things that I thought were daft.'

Keith, in any case, was completely convinced that he wanted to enter a partnership with Mike Costin:

'I thought Mike was supremely capable. We actually are a brilliant pair – he is still a racing mechanic by nature, whereas I tend to think too long. If you are a racing mechanic you do the things you can in the time available. I'm a bit too slow, I try to do the right thing. Mine is the right way to go if you want to go away and win a lot of races.'

Mike's reasons were more basic. He was chief mechanic in charge of the racing team, did some of the test driving, and had his share of the 'all-nighters' that seem inevitable in such organization. He didn't seem to be getting anywhere in life, he wasn't seeing enough of his family, and he was wearing himself out:

'I used to have my seasonable ups and downs. At the beginning of a year I'd be reasonably rested, but at the end of the season, by October time, I was finished. I was very unhappy [the words, and adjectives, were much stronger in the original interview!], because we would still be in all sorts of panics and disasters. Life was bloody difficult. Regularly I used to talk about leaving – I was sure that life shouldn't be like that.

'Colin was really an impossible person to deal with, but he and I had a relationship which was extremely good. We only had two or maybe three major rows. He knew he could push me a hell of a long way – he was a very fine judge of that limit.'

The fact was that by the summer of 1958, Mike had taken to Keith, and Keith to Mike. Both thought the other was a 'useful bloke' [that's another standard form of professional recognition at Cosworth, even in the late 1980s], and that they should go into business together.

Choosing a name for the projected new company – Cosworth – was easy enough, for it meant using parts of each other's name. COStin and DuckWORTH worked quite well; would anyone have been as impressed by a company called 'Ductin' instead?

Aims and ambitions? This was simple enough. Keith says:

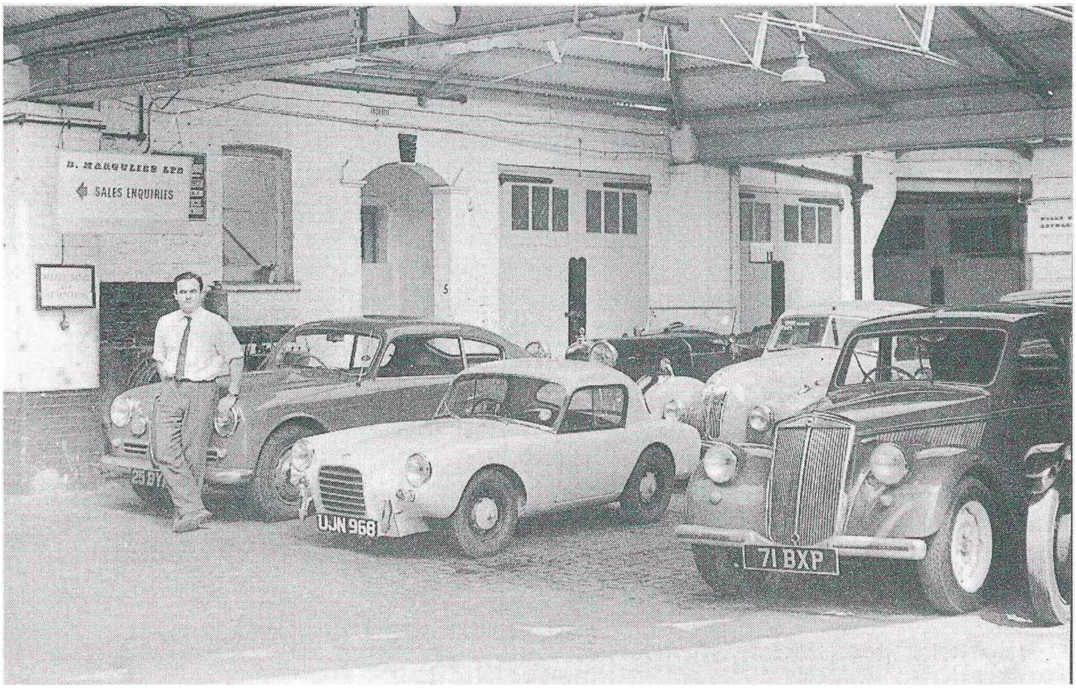
'We thought it must be possible to make an interesting living, messing about with racing cars and engines. That was the total objective behind the formation of Cosworth Engineering – the *total* objective.'

'Mike's view was similar:

'We thought we would set up a company in motor racing, and get work. It was as general as that. Lots of people wanted work doing – they wanted things designed, developed, engineered, manufactured, modified, raced, maintained – and there was plenty of work around.'

When the decision was made, Keith buttonholed Colin Chapman, spent two-and-a-half hours telling him what he had come to think of his organization, his gearbox, his unwillingness to invest in change, and of his methods.

He then told him of his proposal that Mike and he would be starting their own business. The crafty Colin Chapman, however, might have picked up advance vibrations about all this, and had just persuaded Mike Costin to sign a new three-year service agreement. Immediately, therefore, he insisted that Costin could not leave Lotus, and that furthermore he forebade extra-mural activities, he would not allow him even to contribute to Cosworth's



Dan Margulies posing in front of various cars at the Shaftesbury Mews garage, which was Cosworth's very first home at the end of the 1950s. At the time Keith shared facilities with John Campbell-Jones and Dan Margulies. Cosworth has changed considerably since then! (*Dan Margulies*).

activities until that agreement expired.

This was a serious blow to a project which was still unborn, but the miracle of it all was that Keith decided to go ahead in any case, Mike decided to stay on at Lotus, and a relationship between Cosworth and Lotus was forged, and expanded, in the years which followed.

'I had no choice', Mike recalls, 'for I was totally impecunious, with a wife and three kids to support. I'd been earning £12 a week at Hatfield, which rose to £15 a week when I joined Lotus in 1956, and now I was on about £1,000 a year. It could have been worse, but I didn't even own my own house – I didn't own a house of my own until I moved to Northamptonshire.'

Keith, on the other hand, could afford to take a bit more risk, for he had a little family money behind him: 'I had enough money to buy a dynamometer. As far as I could see, none of the other tuning firms were even using a dyno, which I thought was incredible. At least if we used a dyno, we could prove that we were getting somewhere.

'I had £1,000 of my own earmarked for a dyno, but it only cost £600. The wonderful situation is that the supplier was worried about my creditworthiness; I'd put in the order from Cosworth Engineering on something very similar to bog paper. They put some credit inspectors on to the job to find out if I was credit worthy – and then they went and asked Mike, and Mike kindly said that I was!

'I could still afford to get started on my own. Mike and I decided that there was a reasonable chance that the other people who were fooling around with racing cars and engines weren't all that bright.'

At this point, please note, Keith had never tuned or modified a single engine, but thought 'he was sufficiently numerate, and practical' to be able to tackle that sort of thing.

And so it was that a new company, Cosworth Engineering Ltd, was set up, and incorporated on 30 September 1958. The company's authorized capital was £100, of which precisely £2 – one share each for Keith and Mike – was actually issued at the time. It was not until June 1963 that the remaining £98 was issued, all of which was taken up by Keith himself. Then, as at all stages until the sale to UEI in 1980, Keith was by far the largest shareholder in the company. The share capital was not to be increased until 1966. But where was Cosworth to operate?

'Even before Cosworth was set up, in 1958', Keith relates, 'I was living at John Campbell-Jones's house in North Kensington – a very posh house, because his father was a very great architect. I had met John on one of his visits to Lotus.

'My own first premises – working on my own – were in John Campbell-Jones's garage in Shaftesbury Mews, London W8 – not far from Kensington High Street – which also had Dan Margulies in it.'

This historic site (for Cosworth fans) no longer exists as a garage, for it has been converted into stylish neo-Georgian houses.

'The very first work we did was to build a jig for the Vanwall F1 cockpit bubble canopy, then I started work preparing Dennis Taylor's F2 car.'

This, of course, was only the beginning, for Keith needed a more permanent home, somewhere to instal his dynamometer, and to get on with the developing, tuning, and building of engines. At around the same time Keith also married Ursula, whom he had met at Imperial where she had been studying French and Geography.

'All the time I was looking for premises. Eventually I answered an advert for buildings occupied by Hubbard and Wink, who were firewood merchants, and took over from them. They were using some old coaching stables adjacent to the Railway Tavern, at 43 Friern Barnet Road, Friern Barnet, in North London. They used to bring in trees, and chop them up for firewood!'

This site, which was about eight miles north of London's West End, was by no means 'des res'. Early employee Bill Pratt's memories include the fact these stables were in a total state of disrepair, still had the hayfeed baskets on the walls, and had an upstairs section which was completely unsafe. Regular hunts had to be mounted to keep down the rat population:

'Keith used to use the bit under the stairs as an office. His wife, Ursula, used to come in at 6.00 pm, make him a meal, and catch up with the paperwork. She was also the cashier, and used to take the money across the road, to the bank. There were no toilets on the premises, so we had to walk up to the local railway station if we wanted to go.'

The Railway Hotel, by the way, has now been refurbished, and renamed as the Turrets Hotel.

It wasn't a palace, but it was available, so while Keith installed his precious dynamometer in the bottom booth ('I didn't apply for planning permission, nothing *formal* like that, we just got on and did it. The exhaust pipe went straight up through the roof.'). Ursula went house hunting. Before long Keith had moved in to Northwood Gardens, also in Friern Barnet, close by the disreputable Cosworth premises.

In the beginning, Keith worked at Friern Barnet by himself, for Mike Costin was securely tied to Lotus, becoming more and more of an executive, less and less of a designer, as Lotus entered Formula 1 racing, and as the Elite road car staggered into production. Apart from the important Costin-Duckworth link, however, there was one further link which would eventually become important to Cosworth – that Lotus built the first few Elites at a scruffy old building in Kenningdale Road, Edmonton. This building, which was four miles east of Friern Barnet, along the North Circular Road, would eventually become Cosworth's second home.

Keith has very clear memories of Cosworth's first trading year, and the work he was doing to establish the business:

'I was working there on my own, looking after Coventry-Climax engines for Lotus Elites, for Graham Warner of the Chequered Flag, and for Ian Walker, and I was still looking after Dennis Taylor's F2 car. I then started doing engines for John Brown's Elvas, plus making new wishbones, and a different front suspension.

'The first bloke I ever employed was Les Spilsbury, an Australian who was over here as a dirt track rider. For the best part of a year he helped me to rebuild Climax engines.

One of Cosworth's earliest employees, Bill Pratt, retired in 1989. Here he is seen building a 1,220 cc Coventry-Climax engine, the unit which occupied much of Cosworth's maintenance time before the Formula Junior engines came along.

I spent most of the day chasing spares, and rebuilding engines at night. The next to arrive was Bill Pratt – he came from JAP engines, who were just around the corner – who finally retired from Cosworth in 1989, and then we got George Duckett, who was still building F1 engines at the end of the 1980s. Bill Brown, too, although he was still in the RAF, he'd got himself a posting somewhere up the Great North Road, and he used to come down at weekends to help out.

'Ursula was keeping my books for me during the evenings. It has been observed that I always employed the "Jewish Accountancy System". You extract your money promptly from customers, ensure that you pay up promptly, so that at any time the money in the bank represents your position, and you don't have to do much paperwork.

'I used to like the "three nail" system on the office wall – paid, unpaid, and pending – and I *always* made sure I was paid promptly. Fortunately, I always seemed to have enough sense to realize that unless my regular income exceeded my outgoings, then bankruptcy was certain.'

Then, as later, Keith, a paid-up member of the hard-headed North country fraternity who sees great merit in making money, was determined to stay afloat. In the meantime, he had met a resourceful machine shop owner from Walthamstow, Ben Rood, who seemed to be able to make anything, from any metal, to any specification.

Furthermore, he was remarkably quick, accurate, and possessed of the same mind as Keith himself. Ben Rood originally met Keith at a Brands Hatch race meeting, when he was still working for Lotus. Once Cosworth was formed, and various parts had to be machined, Ben's business, Rood's Engineering, got the work, as Ben recalls:

'I only had three or four people working for me at the time. I went to see Keith to see what he needed, and started making pieces for Cosworth, more or less on a daily business. The important thing, the unbelievable thing, is that he used to pay me – without being asked. Everyone else was hanging fire, and taking as long to pay as possible, but Keith would actually corner me and say "We owe you some money", and write out a cheque.'

By mid-1959, however, the Formula Junior phenomenon was beginning to spread across Europe. It was inspired, in the first place, by the Italian, Count 'Johnny' Lurani, as a nursery for budding drivers, with the intention of using modified mass-production engines. The engine size limit was to be 1,000 cc at a particular weight limit, or 1,100 cc if the cars weighed somewhat more.

At first the long stroke Fiat 1100's *Millecento* engine looked like being the most tuneable unit, so Keith began a development programme on this design. Fortunately, however, one of Keith's college friends, Howard Panton, had asked Keith to make him a junior car, which was already part built, and to be powered by a Fiat engine. Howard, who had gone on to work for Ford, then told him about the imminent arrival of the ultra short-stroke 105E design. Ford's Walter Hayes, who later did so much to bring Cosworth into Grand Prix racing, described FJ as: 'eventually a Ford formula, because we had a modern engine with an unburstable bottom end'. In Keith's own words:

'To me the 105E sounded like a reasonable proposition because of its design, so as soon as possible I got hold of a couple of engines and started work on them.'

Not only that, but through his continuing relationship with Mike Costin, Keith landed the order for providing engines for the first mid-engined, Lotus 18, Formula Junior cars. But there was an alternative, as Mike Costin pointed out:

'When Lotus came to build the FJ 18 in 1959/1960, there was somebody around called Graham Hill, who was a director of Speedwell. The natural engine to choose was the Speedwell A35 BMC unit instead of the Ford. There

Ben Rood

Ben Rood, technically speaking, is a Cockney, for he was born in Bethnal Green, within the sound of Bow Bells, in 1926. He was born above a shop where his father was running a confectionery business, and also made ice cream. Shortly afterwards, the family Rood moved out to Essex, to the Bucks Hill and Loughton areas.

Soon after leaving school, for the war had broken out, Ben began to work in a local engineering factory. Not only did he make models, but he soon had a lathe of his own, and bought his first motorcycle. After serving in the Army, in REME, he joined Browns Engineering in Loughton, and soon committed himself to a life in engineering:

'I never really thought about doing anything else. I always thought about engineering, and engineering problems. I used to go and lie in the bath reading *Machinery Handbook*.

'Later on, after the Army, I got involved in motorcycle racing. I went off and built myself a grass-track racer, and began to win about one in four of the races I entered. Then I got interested in road racing.

'Then I bought an Excelsior Manxman which had a split cylinder head. This didn't respond to any form of repair so I thought "I know, I'll make a head and a cylinder barrel" – which I machined up from solid, believe or not.'

Later Ben moved up to a Mark VIII Velocette, a genuine 250 cc racer, which he drastically lightened, raced for the Velocette 'works' team in the Isle of Man, and for which he eventually designed a twin overhead cam engine:

'One day I decided to do a twin-cam head. It didn't *look* too difficult, so I kept the original shaft drive, operated the valves through a train of gears, and built it all myself.'

This, mind you, with no formal engineering training, and very simple machinery! Later an enthusiast called Gerald Smith, who raced a 500 cc F3 car, asked Ben to produce a twin-cam head for his 500 cc Norton – which he did by using the same basic casting, but many different machining details. In the same period Ben also started making complete engines – the Hogan-Rood engines – for hydroplane racing. These were very successful, for instance, in the hands of the Stacey brothers (who were brothers of Lotus F1 driver Alan Stacey).

One thing led to another: Ben started maintaining Gerald Smith's car at race meetings, and before long he came across Keith Duckworth, also visiting to see how his Lotus 'Queer-box' parts were performing.

Rood's Engineering, a small machine shop concern, was founded in 1954/55, and it was while searching for business that Ben started to make engine pieces for Cosworth. Once the Formula Junior business took off, that rapidly grew to the point where Ben was working almost entirely for Cosworth – and the rest of the story belongs to the main text of this book.

were great battles, and in the end we built up two prototypes, put one engine in each, and ran one against the other. Fortunately Lotus decided – with no bias of course – to go the Cosworth way.'

But this is no fairy story, and Keith makes no secret of his problems in that fraught period late in 1959. Keith's target was to have two engines ready for use at Boxing Day Brands Hatch in 1959 – one for Lotus, and one for Graham Warner's Chequered Flag Gemini – and with a delivery deadline looming up, he couldn't get the 105E engine to work. The memory lingers on:

'There were two snags, which went in parallel. One was that we couldn't get camshafts which would run through surge periods at about 6,000 rpm, and at 7,400 rpm. The other was that we got inconsistency of performance from day to day. The same engine performed differently on a Monday, from the previous Friday. We would get 75 bhp on one day, and more than 80 bhp on the next.

'In the end I concluded that it was all due to humidity. We were using so much combustion chamber squish that I decided that the only possibility was that under certain conditions the squish was actually trying to blow the combustion flame out: somehow or other it was quenching the fire. We cured that by removing the squish, by carving great lumps out of the cylinder head, then milling some more off the head to restore the compression ratio. That worked well, and we left things the same way for the whole of the life of the 105E-based engines.

'But there was still the problem of the Ford valve gear. At that time I hadn't designed many cams – I'd designed a special profile for the 1100 Climax which didn't seem to be much different from the standard one. My problem was that I had read the books on cam design and I had believed them. That was fatal. Even so, those people seemed to be fairly knowledgeable about the various types of profile, and acceleration diagrams.'

[Another pause, here, to eliminate the long Duckworth lecture on camshaft design, valve springs, surging, and accelerations, which followed . . .]

'. . . At first we used a cam profile that was very mild by comparison with my later efforts, and especially compared with BMC racing cams of the day. But this caused quite catastrophic spring surge at just below 6,000 rpm, and the engine wouldn't go through it at full load. We were wearing out cams and tappets as well. If we offloaded the test bed, then took a run at it, we'd get there, and it would work reasonably well at up to 7,500 or even 8,000 rpm.

COSWORTH ENGINEERING LTD.

MARK IV 1100 c.c. FORMULA JUNIOR COSWORTH-FORD ENGINE

GENERAL INFORMATION

Capacity 1098 c.c. Bore 85 m.m. Stroke 48.4 m.m. 4 Cylinder

Compression ratio 10.5 - 11/1

Gross horsepower rating 96 b.h.p. @ 7,600 r.p.m. minimum.

" torque " 73 lb.ft. @ 6,000 r.p.m.

SPECIFICATION

Cylinder head	C.I. Modified to 'Cosworth' specification.
Cylinders	C.I. - bored in block Bore dia. 85 m.m. +.001" -.000"
Crankcase	C.I. Monobloc type
Crankshaft	Hollow web nodular iron. End play .002" - .011" thrust taken by 2 half thrust washers. Main journal dia. 2.1255"/2.1260". Conn-rod journal dia. 1.9370/1.9375. Stroke 1.902"/1.910".
Main bearings	Shells - 'Vandervell' lead indium-copper, steel backed. Part No. VP 4478. Main bearing caps are special steel, housing bored .015" o/s.
Camshaft	1% chromium alloy iron. Driven by simplex chain. Crankshaft sprocket-steel. Camshaft sprocket C.I Bearings - white metal press-in, pre-finished.
Valve mechanism	Push-rod O.H.V. Special push-rods, rocker shaft and pillars. Tappets - chill cast iron mushroom type, 80" spherical radius on face. Rocker arm ratio 1.54/1.

Even in the very early days, Cosworth was meticulous in detailing the work done on its engines. This was a Specification Sheet for the Ford-based Mk IV Formula Junior engine of 1961. It was no wonder that Cosworth's reputation already stood so high in the world of motor racing.

'We looked at everything in the valve gear, we had different frequency springs, stiff pushrods, stiffened rocker assemblies, steel camshafts, but we could never get through that period. Much later I finally concluded that the problem was in the support of the rocker pillar on top of the cylinder head. At this stage we were about to go broke, because we couldn't deliver engines, and get paid for them. If we couldn't get a commercially viable racing camshaft, we would go broke. I had just been refused a £30 bank overdraft – I thought the bank manager was a dreadful judge of character! It was the one and only time that we nearly went under. There's no doubt – we were in a bit of bother . . .'

Did he ever consider abandoning the project, I wondered?

'No, I don't think so. I've got a fierce determination. The more I can't understand something, the more I worry it out – I believe that in engineering there is *always* an answer, it's just that we are often too dim to see it. Even if the solution was quite expensive, it was better than going broke. A solution was suddenly going to be worth quite a lot of money – and I didn't think *any* other tuner had solved the problem at that time.

'I do think the prospect of bankruptcy at Christmas 1959 sharpened up my thinking process. I just wasn't prepared to have to go out and get a job, with my tail between my legs, having failed to manage on my own.'

Keith couldn't consult Mike about this problem ('Once he gets on to something as mathematical as that, Mike is in a great deal of trouble . . .'), but fortunately he could consult Ben Rood, who had already progressed to making camshafts for his own racing motorcycles:

'Ben almost has Newton's Laws programmed into him, I think they've been there from birth, but he'd had no mathematical training, or theoretical training at all. He could work from incremental tables, and use lift figures to give a smooth acceleration diagram, even though he didn't know the theory behind it.

'We'd tried everything by then, and decided we'd have to change the cam. I think I probably spent most of my time, for a week, trying to *think* as to what mattered, on cams.

'I'm fairly difficult to live with when I'm in that sort of situation. By the time you've got a great picture going, to get a multi-parameter problem assembled in your mind, it's a bit difficult to keep it there. If the 'phone rings, or somebody asks me something, I can be put back about three hours of mental model construction – in such cases

1958 to 1961, the struggle to make money

Building a reputation in the motor racing business is often easier than building a bank balance. Even though Keith Duckworth's early business philosophy ('It must be possible to make an interesting living') was justified, it was hard work. At least, as he so gleefully pointed out in later years, no-one could accuse him of profiteering! Here is Cosworth's basic financial record for the first three ('Friern Barnet') years:

Financial Year	*Turnover*	*Profit (Loss) after tax*
Year ending 30 September 1959	£ 3,666	(£744) Loss
Year ending 30 September 1960	£21,591	£2,215
Year ending 30 September 1961	£68,507	£2,525

In the first year, the loss was caused by 'start-up' costs, not least the purchase of the dynomometer, and in that stage Keith Duckworth *was* Cosworth, preparing, rather than manufacturing, engines. The second year included the crisis period when Keith was even refused a £30 bank overdraft to pay his telephone bill, but it was also the period which saw mass deliveries of Formula Junior engines get under way. In the third year Friern Barnet was already bursting at the seams, for Cosworth had become the prime supplier in the Formula Junior engine business.

I'm not very keen to be disturbed.'

The result was that Keith and Ben completely revised their views on camshaft design, went for constant acceleration curves ('I reasoned that I didn't know what "jerk" was all about, and so I was fairly sure that the valve gear didn't know it either. I thought that all the arguments about "jerk" were grossly over-rated'), and produced a completely new profile:

'We ran it, the surge had miraculously disappeared, it went straight through 5,800 rpm, and we were clear, right up to 9,000 rpm and beyond. We had an engine that could race, that would produce 75 to 80 bhp.

'That was when I decided to stop reading books, which only tended to mislead me. I decided that it was always better to work things out from first principles. One of my most important sayings, as a result, is that; "It is better to be un-informed, than ill-informed". After all, if you are *un-informed* your only option is to sit down and think about a solution. If you think hard enough, it is even conceivable that you might get to the right answer.

'Unfortunately, for Boxing Day Brands we only had a single cam and one engine together, complete with Ben's tappets and a steel camshaft. That was for Gemini. We built it on Christmas Eve, we did a test bed run, it went straight to Gemini, and they took it to Brands.

'Except for the twin carbs and a special exhaust manifold, Lotus, for that race, had to turn up with a standard engine! Their car was brand new, not even tested, so the suspension was set too soft.'

What followed, in retrospect, was hilarious, but at the time it was another major set-back, as Keith remembered:

'Gemini obviously didn't tighten up their flywheel bolts, so in practice the damned thing fell off, going out through the bell housing, and knackering the crankshaft. That put Gemini out of the race.

'Well, Mike and I then took Lotus's standard engine, and the broken Gemini engine, rebuilt the Lotus engine using the standard crank and most of the racing bits from the Gemini, and cobbled up half a racing engine for the Lotus. He finished, he didn't win, but at least it was a good start.'

This is where the fairy story clicks back into gear. The next appearance for the Lotus 18, complete with Cosworth Ford 105E engine and A2 camshaft, was at Easter Goodwood:

'Lotus wouldn't run a dry sump at the time, they kept to a wet sump, which surged very badly, so when Jim Clark set the tail out, and held it out, the bearings ran. We had to get a new set of crank bearings, from the Ford dealer in Chichester – they sent them up the road by bus! – and there are pictures in Lotus books of Mike and I working on the car, tipped on its side, so that we could change the bearings *in situ*, and modify the baffling to the sump.

'It raced like that, with Jim Clark going out, and winning' – it was the very first outright victory by a Cosworth-tuned Formula Junior engine. Suddenly, the fledgling Cosworth company was submerged in orders. Mike Costin recalls that in February 1960 Lotus had only three orders for its first 25 FJ cars but that:

'. . . by October, we had made 125 cars, which means that Cosworth had supplied that many engines to Lotus alone, never mind Gemini, Elva and others.

'We would buy engines in batches of ten, send them down to Friern Barnet, where Cosworth would strip down, machine everything, modify everything, build it up, test it and send it back. The cost was £145, and Cosworth would keep the standard pieces. That was the deal.

Very soon the place was cluttered up with unwanted standard parts, but no-one had the heart to throw them away. Not only that, but Cosworth had also started to supply special 105E parts, particularly camshafts, to other tuners and engine builders. Keith was quite happy to do this:

'Everyone was trying to tune 105Es at the time, but our A2 was the first cam that actually worked, and it remained the only one that would work for years afterwards. We used to sell it to our rivals for the outrageous sum of £17.10s (£17.50), to allow them to keep going.

'We made our own master profiles, but Leonard Reece

One of Cosworth's earliest contracts with Ford was to develop the inlet manifold and camshaft profile for the Cortina GT of the early/mid 1960s. This was the revised-shape Cortina Mk 2, introduced in 1966, which retained the same engine in GT and (this car) 1600E form.

Autosport: 25 March 1960

'The 1960 European racing season got under way with the 39th B.A.R.C. meeting at Goodwood . . .

'A 10-lap Formula Junior race followed and proved to be the race of the day. Among other reasons for this distinction it marked the car racing debut of world motor-cycling champion John Surtees . . .

'Surtees, driving Ken Tyrrell's Cooper Junior, and Jim Clark in a works-entered Lotus, accelerated neck-and-neck from the flag and went into Madgwick very close together. The rest of the field were in a close-packed bunch some way behind the two leaders, with Trevor Taylor's Lotus leading. D. Mason (Elva) spun off at St Mary's and retired and at the end of the first lap Surtees was in the lead, mere inches ahead of Clark's Lotus, Clark paying him the compliment of slipstreaming him on his first outing. On the second lap Clark and Surtees went into Woodcote side by side and the popular Scot came through in the lead; Trevor Taylor had outstripped the rest of the field and was moving up to challenge the leaders, while Chris Lawrence's Deep Sanderson was far behind and sounding very sick. From the third lap the first three cars were out on their own; Surtees momentarily passed Clark on Woodcote on the fifth but was soon retaken. On the sixth lap Taylor slipped past Surtees coming out of Madgwick and from then until the last lap the order remained unchanged. All three were driving on the limit and were only a few yards apart until, on the last lap, Surtees took Taylor on acceleration out of Woodcote to finish three seconds behind Jim Clark and 1.4 seconds in front of Taylor . . .

'The fastest lap, achieved by Clark at 1min 35.6sec, constitutes the first lap record for Formula Junior cars at Goodwood . . .'

This, then, was a famous occasion – for the two Lotus cars were using Cosworth-prepared Ford engines; it was the first race ever to be won by such an engine, and one which established the Lotus 18 as a dominant Formula Junior car.

used to make the cams for us. Later we made a simple modification – we added 1/32 in of lift and extended the opening period. That was the A3.'

In the meantime, the de Havilland/Mike Costin connection struck again. When Mike had been training at Hatfield, one of his colleagues was a young man called Brian Hart. Brian stayed behind to do a further two years, in Flight Test and experimental work, doing airframe and engine design. Then, one day:

'I'd started racing. I went along to Friern Barnet to buy a camshaft to go in my Formula Junior car, then one thing led to another. Before long I started working there in the

To idealise the flow from a down draught Weber carburettor to a four-cylinder engine, Cosworth developed this 'semi-circular' inlet manifold for Ford 'Kent' engines of the 1960s. Like many other contracts, this was a job done efficiently, without fuss, and without publicity.

This Ford-based Cosworth Formula Junior engine installation, in a Lotus 22, was typical of the hundreds of cars built around such engines in the early 1960s. Cosworth, quite simply, could produce more power than any other competitor in this class of motor racing.

evenings, then I finished up working there full time. It was the "thin edge of the wedge" business – I caught the feeling, and the exciting atmosphere in the place.

'Eventually I was building engines, doing detail drawings, and some development work. I was racing a lot at weekends, too – it was a busy old life.'

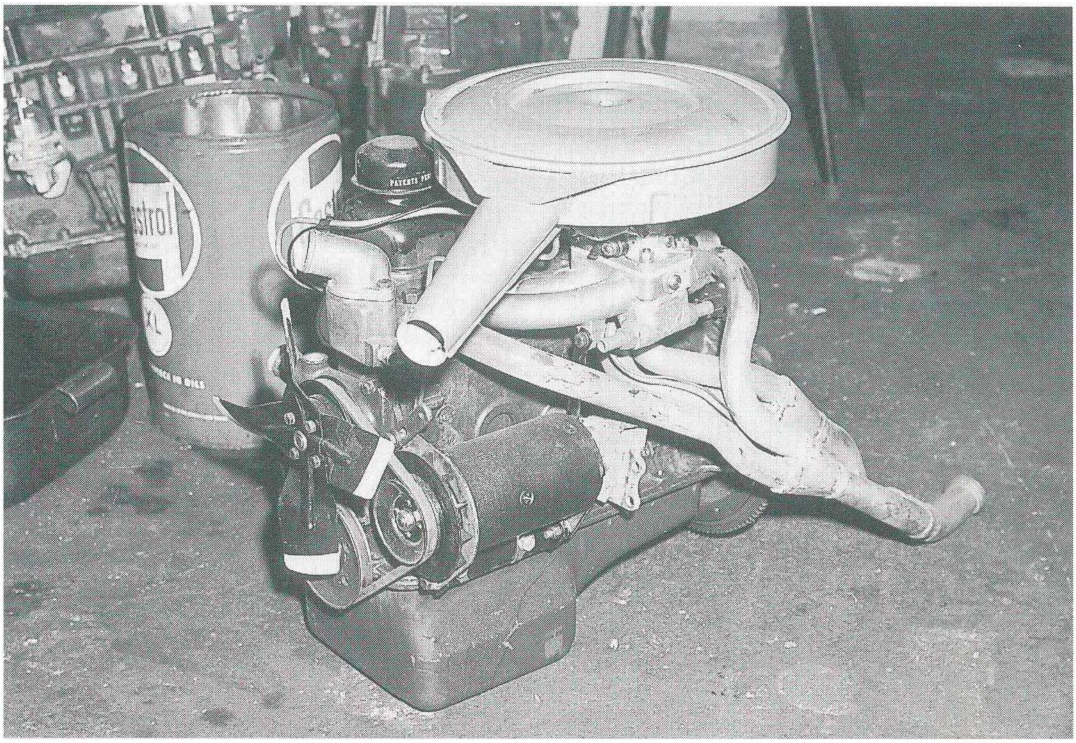
Business was booming, Keith was having to spend too much of his time managing the business, and could not get back to his favourite occupation, which was designing new parts, and tuning engines. Except for Mike Costin who was still not free to join Cosworth as a working director – that move did not take place until August 1962 – the other important partners all arrived at around the same time. Ben Rood recalls that his machine shop business was working so much for Cosworth that he was in and out of the business constantly:

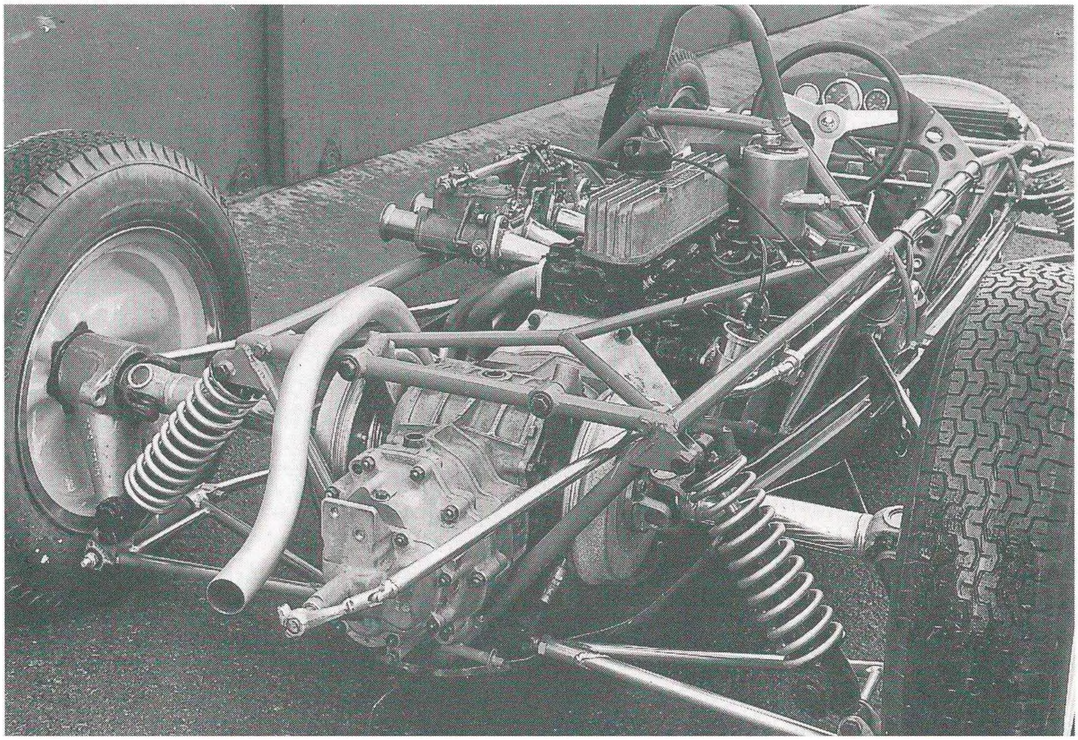
'One day I said to Keith, "What about me working with you all the time?", and almost simultaneously Keith said, "What about joining me at Cosworth?", so we did that. I was more or less the "Self-Employed Director" for a time, since I kept Rood's Engineering going, more or less independently, for the next few years.

'I now see myself as a sort of uneducated Keith. Like him, I have an interest in mechanisms, but he's had the advantage of a university education. We've always got on very well, in business and out of it. We used to drink a lot of beer together. In the early days we used to finish up in the pub two or three nights a week, not to booze, but to talk. We'd spend our evenings talking until 1.00 am, in the car, in the car park, outside. I was a great "shop-talker", and I always wondered if Keith got fed up with me always talking shop. Little did I know at that time that he could *never* get fed up with that . . .'

Bill Brown, too, had been persuaded to join Cosworth at the end of 1960 after completing his stint in the RAF, to become the general business and sales manager. The work-load at Friern Barnet was so frantic, too, that Bill also produced some of the early detail drawings. Keith, at last, could get on with his designing and testing, leaving much of the administration to someone else, and Ursula could go back to becoming more of a housewife than a part-time book-keeper.

By 1961, and even though Cosworth (in Ben Rood's words) was 'producing Formula Junior engines like shelling peas', the dreadful old Friern Barnet premises were overcrowded, and quite unsuitable for further expansion. Up to fourteen people were now jostling for space in the





old stables, so Keith had to contract out quite a lot of the work:

'We had our manifolds, for the Weber carburettors, and our sumps, fabricated outside. We didn't provide exhaust systems at all, that was the responsibility of the car builder – we just supplied recommendations about lengths and pipe diameters.'

Even at this stage, too, there was the first 'works' contract from Ford. In 1963, not many Cortina GT customers realized that they were driving round behind pieces of Cosworth engineering. Keith recalls that:

'Ford obviously took notice of our winnings with the 105E engine. Quite early on, we were sent a Capri engine (the awful Classic Capri of the early 1960s, that is) in 1.3-litre form, to try to do something with it.

'We produced the camshaft for that, and an inlet manifold – the two-ring type of manifold which had a Weber carburettor sitting on top of it. This is why we were always so popular with Webers, because we introduced Ford to Weber carbs for the Classic Capri, and for the Cortina GTs. I can remember rushing around for a time in a car with that engine fitted.

'By the way, the surge problem was still there with the Cortina GT camshaft. I was very surprised that Ford cleared our cam to run up to 6,000 rpm, for I could hear it surging, quite clearly, at about 5,800 rpm. In the end I sold the design of the GT cam to Ford for £750, but I had to have a great argument with one of the buyers about that.

Fortunately, in 1961 Lotus had just vacated its old development workshops in Edmonton, where the prototype Elite road cars had been produced. Mike let Keith know of this move, and it was not long before Cosworth Engineering took over the lease, and found its larger (but still temporary) home.

CHAPTER 3

Big moves – to Northampton, and into F2

'Nobody else has been outstandingly successful, *and* made money, and managed to stay in business, by making racing engines . . .'

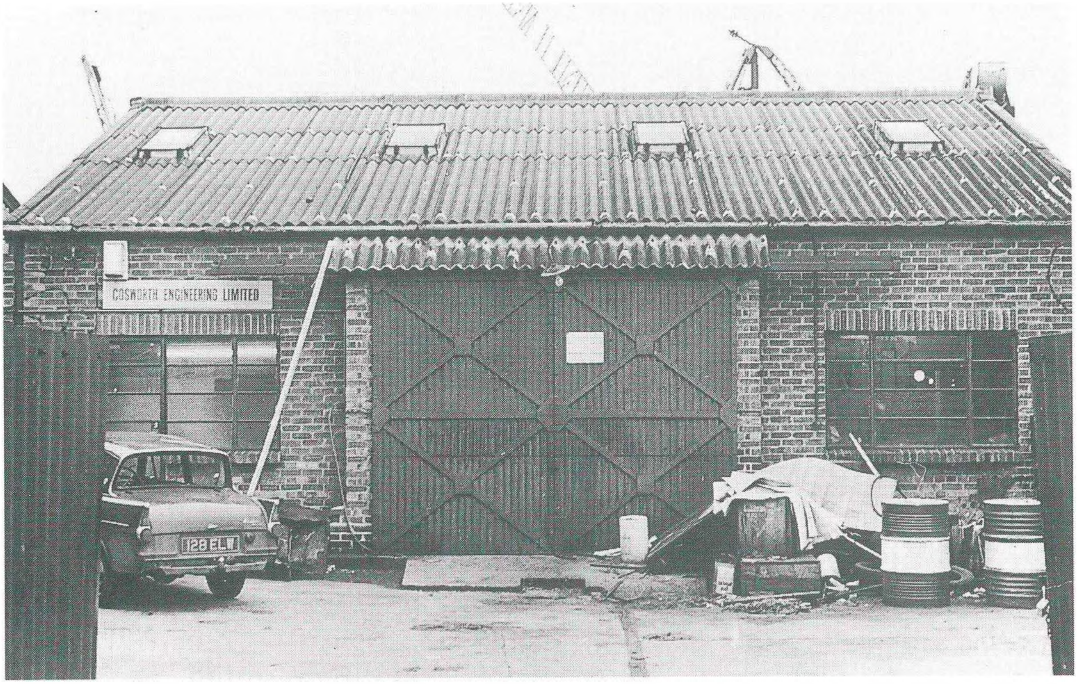
'We'll draw a line about 15 miles each side of the M1 motorway, and look anywhere in that band . . .'

Cosworth Engineering was still only three years old when it moved in to the ex-Lotus premises at 2 Kenninghall Road, Edmonton and there was still no place for glamour, and glitz. The Edmonton premises, to be frank, were only slightly less seedy than those vacated at Friern Barnet, for the factory roof was of corrugated iron, as were the big slide-away doors, and the yard was usually littered with oil drums, wood, and odd bits of building material.

In the meantime, Cosworth also installed some machinery in Ben Rood's workshops in Walthamstow, and before long Rood's Engineering was working full-time for Cosworth. As soon as Cosworth established a stores department at Edmonton, a young man called Jack Field moved in to run the operation:

'In the very early 1950s I got to know Lotus, when Colin Chapman had the sheds behind the pub in Hornsey, and it was there that I met Keith and Mike. I was actually working the sales counter in a Vauxhall/Bedford dealership across the road.

'Before he was even working full-time on his cars, Colin used to call in on his way to work with British Aluminium, leave me a list of bits and pieces, nuts, bolts, valve guides and what have you, then call back in the evening and



The original Friern Barnet buildings had been cramped in the extreme, so by comparison the move to this factory, at Edmonton, was a real step up for Cosworth. The building was taken over from Lotus, who had built the original Elite road cars on the site. Cosworth soon outgrew this facility, and moved to Northampton in 1964.

collect them, take them away and use them to build his cars.

'Then, when Lotus put up a stores, in the roof, he asked me to join him. It was the usual Chapman story: "We can't pay you a lot of money, but we're going to become one of the largest manufacturers in the UK, so you'll finish up as a rich man". I didn't believe him, but as I was a bit of an enthusiast, I joined him, and stayed for about three years. I left Lotus at about the time Keith left to set up Cosworth.

'I left because I couldn't afford to get married on the salary Colin was paying me. I went back to the dealership for a time, but because I was selling parts off the back of the garage's van, I used to call in at Friern Barnet, and kept showing an interest.

'Eventually, I went to work for Cosworth, at Edmonton, running the stores, acting as van driver, and if there was an engine to pack I'd make the packing case first! I was also doing the buying, and some of the selling, but eventually I released the buying, released the stores job, and I've been selling – or marketing – ever since.

'At Edmonton, though, everyone seemed to have a hand in sales. Bill Brown and Keith used to go to the races, Bill used to do all the deals with Lotus, everyone just got stuck in. I worked very long hours – we started late, but we finished late, and we also used to work at weekends.

Fortunately I stayed married – it helped that my wife had been the switchboard girl at Lotus, so she really knew what she was letting herself in for.

At this time Cosworth was selling a great variety of modified Ford 105E engines for Formula Junior cars, sports cars, and even as options for the Lotus Seven road car.

'We gradually changed over from 1-litre to 1,100 cc,' Keith says, 'by which time we were having special cranks made, mainly by Laystall, we had special pistons, in fact by the end of the programme we made so many special bits that there were really only the block and head castings that were not special – and that was because the rules didn't allow us to do those.'

At the same time, the company was financially sound – something which could not be said of many of its rivals. Keith Duckworth:

'We always used to pay our bills promptly, and tried to get paid promptly. The one thing that assures attention from suppliers is to be the one who pays his bills on time! I even managed to survive by not being paid regularly by Lotus. There was once a terrible drama, when there was £3,000 outstanding from them at the end of the first year. I don't know how we survived then.

'I can remember going to see Fred Bushell at Lotus, who said he'd have a cheque in the post. I remember looking at him doubtfully, and I can also remember that I got a significant lecture for looking at him quizzically as if I didn't believe him. He actually tore me off a strip for not believing him – but a couple of weeks later the cheque *still* hadn't arrived though it did arrive in the end.

'We never had an overdraft during the years that I owned Cosworth – or if we did it was purely for technical purposes, just for a week or so. I managed to buy all our equipment on a totally self-financing basis. We were a fairly high cash-generating business, right from the word "Go". Because I owned the company, I had a very personal view of what to do with profits. When we had enough money, I used to go out and buy some machinery. I wouldn't buy anything until we had the money to pay for it – that's a good North Country habit.

[Time, now, for another short Duckworth lecture . . .]

'I think that borrowing is one of the biggest immoralities there is. The more I think about life, and the credit society, the more irresponsible I think it is. I don't think that the moral fibre of most people makes it possible for them to be offered lots of credit.'

[Back to the growth of Cosworth . . .]

'I never had that feeling that I wanted to be a millionaire, not just for the self-esteem. Colin Chapman, though, he was definitely like that, but I could never understand him. Because of the tax regime of the day, we tried to invest almost all of our profits, and that's how we came to have so much capital equipment. In practice, that's why we were really forced into an expansion that neither Mike nor I really wanted, because we had a lot of capital machinery hanging round. But it was better to buy them, than to take the profits as salary, and pay 98 per cent income tax. It wasn't until years later that I realized how rare Cosworth actually was in this respect. There were lots of tuning firms, but nobody else has been outstandingly successful, *and* made money, and managed to stay in business, purely by making racing engines.

'When I totally owned the business, I always tried to hold enough money to see us through a bad period. When I was in total control of company finances, I never paid out any more than I wanted to do. I didn't pay myself much either, because I lived fairly simply. I seemed to work nearly all the time, so I didn't need much money to live on.'

Cometh the hour, cometh the man. Keith also acknowledges that Cosworth was founded, and grew up, at exactly the right time.

'Formula Junior happened at the right time for us, because it allowed me to design bits of engines progressively. The other factor was that we were always encouraged to think about engine design, and development. It was mainly our deep thinking, and our approach to life, which made us different.'

In 1962, with Cosworth's FJ engines used by as many teams as could reserve places in the queue, Keith had a chance to widen his reputation. He had already heard about the new Elan, and the Lotus-Ford twin-cam engine project, but until July 1962 (only three months before) he had not been invited to work on it. By this time, to quote a distinguished Twin-Cam restorer, Miles Wilkins, 'the whole project was in a bugger's muddle'.

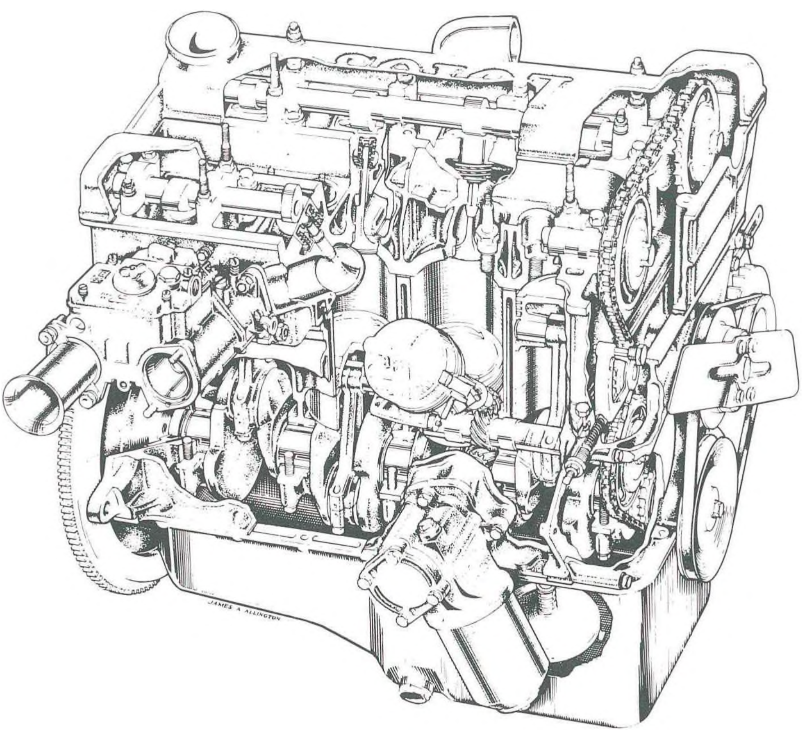
'The head had been designed by Harry Mundy,' Keith relates, 'then drawn up by Richard Ansdale. Colin approached us, not only to make a racing version of the engine, but to sort it out to go into a production car. It wasn't all bad, but at the time the head joint wasn't sound, the head structure wasn't any good, and its ports didn't look like ports ought to look. By that time we thought we knew a lot about ports – we tended to bore them as far as possible, to keep them straight, to make sure there were no valve guide bosses to get in the way, because we were trying to take air round the bend and through the valve with as little disturbance as possible.

'We had, after all, got more than 100 bhp/litre from the pushrod 105E engine, which was GP power of only five years previously, and were managing to run that pushrod engine up to 10,000 rpm, nearly 10,500 rpm. I didn't think the ports were as free-flowing, or as straight, as they should be. We did think we had a fair idea of how you should get air, at high velocity, through ports, and to work properly. So we straightened up the ports – we just arbitrarily redesigned them – then we added a bit of structure into the head too.

As Miles Wilkins noted, in his book *Lotus – the Twin-Cam Engine*:

'Therefore, the final shape of the head, including the oil breather arrangement, was produced by Keith Duckworth.'

Once Cosworth had sorted out the final specification of the Twin-Cam cylinder head, race-engine development went ahead smoothly, many engines were supplied to Lotus for fitment to Lotus-Cortinas used in saloon car



The Lotus-Ford twin-cam engine was conceived by Harry Mundy in 1961, but was still not yet properly developed when Cosworth was asked to finish the job in 1962. All the original race and rally engines used Cosworth expertise, and components, to make them powerful and durable.

The Ford Lotus-Cortina of 1963 was a fast and exciting sports saloon. It used a new twin-cam engine which, though not designed at Cosworth, was much developed and refined at Edmonton before it went on sale.

racing, along with units sent to Ford for use in rally cars. Not only was it Keith's air-flow development which made a difference, but the design of several new camshaft profiles.

Although Duckworth always insists that there was no 'master plan', and that he never actively wanted Cosworth to expand, the company did not run itself. Each new motor racing season brought new regulations, new challenges, and a new queue of customers who wanted engines to suit. Forward planning, according to Keith, only took place once a year:

'We used to spend the first week of our annual holiday shut-down, having a running board meeting to work out what the strategy should be for the next year. We'd already had to change our views about "making an interesting living, messing about . . .". Every year we'd have to sit down and think "What on earth are we going to do next?". We'd all been so busy running our various departments throughout the year, that the only time there was any peace and quiet was when everyone else went on holiday for two weeks.

'The four of us – Mike, Ben, Bill Brown and I – would meet, and try to discuss strategy. Originally we met for whole days, but then it became a question of mornings only. Three of us didn't mind thinking, and talking, until the late hours – but not Bill.

'There was one epic meeting where we asked Bill how many of such an engine he thought he could make. He said he didn't know, so I encouraged him to go away and have a think. At that moment Bill stood up, glared at all of us, and blurted out "It's all right for you, you don't mind thinking all the time. Me, I find it *bloody hard work*!".'

Even so, Mike Costin insists that the relationships were usually harmonious:

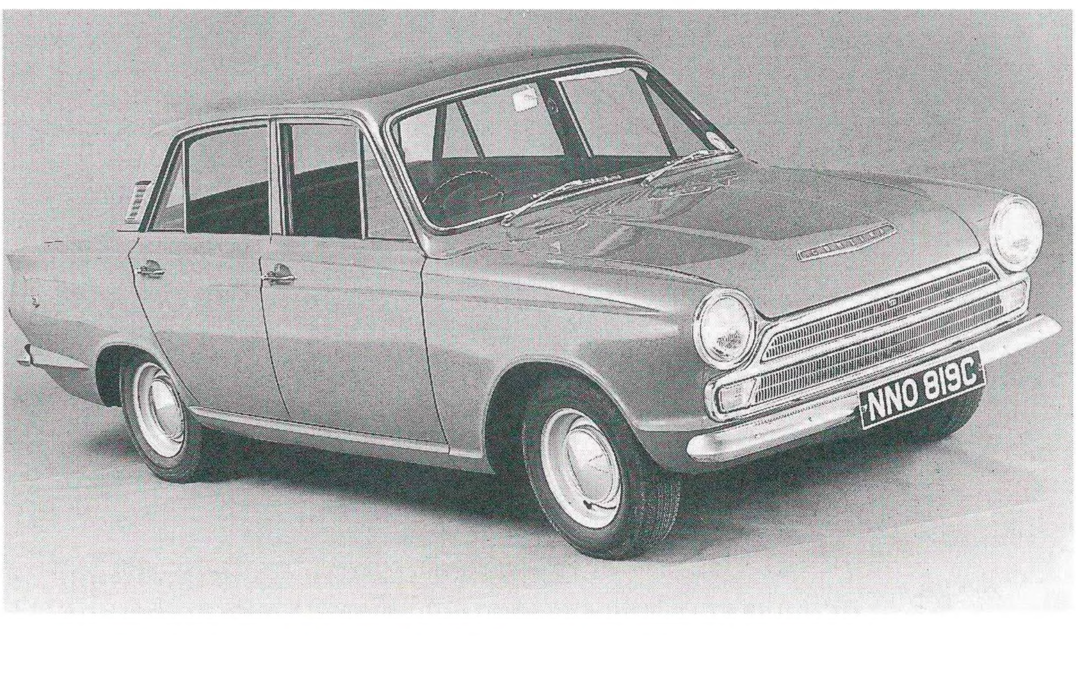
'The secret was that we always accepted Keith was ultimately the guv'nor. It was largely a case of personalities – he did, after all, own the bat, the ball and the pitch, but we all had, and still have, a high regard for his abilities. Some people say that he gets bees in his bonnet – I don't agree. Let's just say that sometimes he has particular topics of the day! If he has to go on and on about something, it usually means that other people haven't understood, that they haven't got far enough down the road.

'Keith, I've always said, should have been a teacher. My engineering education has been brought about by Keith, not by Colin Chapman, by always being totally involved with Keith. If there was ever *anything* I didn't understand, Keith has taken me back to square one, to discuss it. Keith doesn't have any books full of formulae – he develops every theory from scratch.

'It's simple really. I've never been overwhelmed, or threatened by this mountain of intelligence. I've never worried about an earthquake. I just accept that Everest is there.'

Keith sees it a little differently:

'Obviously, by thinking deeply, and by holding my own



This was the very first Ford model to have any Cosworth input — the Cortina GT of 1963, in which the inlet manifold and camshaft design originated at Edmonton.

views, whenever anyone says something with which I disagree, I will try to say "How do you come to that conclusion?". Because of questioning *everything*, I am more or less socially unacceptable.

'On the clock which I gave to Mike to commemorate his 25 years with Cosworth, the caption I had put on the side was: "From the idealist to the realist. Together, in Cosworth, we beat the world.".'

The fact was that, in spite of Keith's modest intentions, his fledgling company had taken on a momentum of its own, and it was expanding all the time. Not only that, but after four sometimes frustrating years, Mike Costin finally came to the end of his service contract with Lotus, and moved to Edmonton, to take up his directorship of Cosworth. Mike sums up the new relationship like this:

'Keith was the dictator, and the engineer. Bill was not a great engineer, but he was a good administrator. Me, well, I don't call myself anything, really. Apart from three years at de Havilland where I was on a drawing board most of the time, I wouldn't say that I was a draughtsman. I wouldn't say that I was proud of my drawing.

'My designing was always done as sketches, but the sketches had every radius, every limit, every finish, every heat treatment. I used to keep notebooks, stacks of the things. I used to spend quite a lot of time in the drawing office, commenting on things.

Bengt Soderstrom and Gunnar Palm, their 'works' Ford Lotus-Cortina in 'showroom' Group 1 tune, on the Monte Carlo rally of 1966. Cosworth always played a strong part in developing parts and building engines for these cars.

'I had, and still have, an input to design, through discussing for hours and hours with Keith how things have to be designed, but I'm not the designer. When it came to all the big engineering decisions, the big jobs, all three of us – Keith, Ben and me – could get together, and we could all talk about, say, how we were going to tool something, how we were going to design something. We could all talk about every aspect of the job, we were all relatively interchangeable, though we each had our own areas of responsibility.'

For the first time, since 1958, Keith could concentrate on design work, while Mike could get on with the development, the production engineering, and dealing with the customers. Within two years of moving to Edmonton, the workforce had doubled, and Keith began to mull over a new design project:

'I didn't mind that it was going to take a lot of thinking. For years I've been perfectly happy to sit down and think out a problem, I don't even find it hard work.'

By the beginning of 1963, the motor racing authorities had decided to bring Formula Junior to an end, not least because it had become dominated by Ford engines, almost all of them built by Cosworth! For 1964, and in place of Junior, it was decided, there would be two new formulae – a new 1-litre Formula 3, and a new Formula 2.

Formula 3 was really to be 'son of Formula Junior', and would still require homologated road car engines to be used, although one limitation was the use of just one, single-choke, carburettor. For Cosworth, this meant reworking the existing FJ design, and producing the new MAE ('Modified Anglia Engine') unit, a real screamer which could rev to 10,000 rpm and beyond, while producing 100 bhp/litre through a single carburettor choke.

The new Formula 2 sounded much more challenging – and much more interesting for Cosworth. Quite simply, the regulations allowed: '. . . racing vehicles of a capacity limitation of 1,000 cc. Maximum number of cylinders, 4. Minimum weight of car, 420 kg.'

Keith and Mike began planning a new engine immediately, and within weeks *The Autocar*'s Sport column rumoured that: 'Cosworth Engineering is developing a twin overhead cam head to suit the 1,000 cc 4-cyl, 5-bearing, Ford engine.'

That rumour, as it happened, was well wide of the mark, though it showed how far Cosworth had advanced in a few years. The motor racing 'establishment' (and there was nothing more 'establishment' than *The Autocar*'s Peter

Garnier and Harry Mundy) clearly believed, now, that Keith was capable of designing anything.

During 1963, Keith evolved his new engine, the first Cosworth unit to have its own purpose-built cylinder head. Called SCA ('Single Camshaft, Series A'), it was still based on the same 'bottom end' as ever – the successful 5-bearing Ford cylinder block, but this time it was topped by a new aluminium cylinder head, with the camshaft mounted above the valves.

'In a way, this was a logical step from the old Formula Junior engines of the past, for the head still featured a line of vertical valves, two per cylinder ('It was really an overhead cam version of the last of the Formula Juniors'). This time, though, the camshaft was upstairs, and there were no pushrods or rockers to add to the weight, the inertia, and the flexibility of the assembly.

Because the new SCA engine appeared soon after Rover had launched the 2000 model, some know-alls suggested that Keith had copied the layout of the Heron-headed Rover. The fact was that Keith's engine had already been designed months before the Rover made its public bow and, in any case, as Keith retorted:

'I *never* copy *anything*. My simple argument was that at the compression ratios we could use, and the valve sizes needed to ensure good breathing, then a bath-tub type of chamber ended up masking the valves. It was an awfully long way round their periphery. I argued, with myself, that if I put the combustion chamber in the piston, then for most of the time the valves would be out of the way, and that they wouldn't impede the flow. In fact, I'm not even sure I knew about Sam Heron, and his theories, when I started to design the SCA.'

The steeply aligned inlet port of the SCA owed much to the Mk XVII pushrod engine of the previous year, which was heavily modified by having tubular downdraught inlet ports brazed into the casting. It wasn't cheap, or easy, to make, but at least it proved that there was an improvement in gas flow. The SCA, in some ways, mirrored that approach.

'The SCA was the first cylinder head that I ever designed, and now I think there was quite a lot wrong with it. We had all sorts of trouble with the combustion – we couldn't make it burn – but it was still good enough to win a lot of F2 races. In the end, there was so much spark advance, that it wasn't reasonable. We ended up with 49 degrees. The SCA chamber suffered from a lack of circumferential swirl.

'It might not have been right, but we had to make it work. It won the Formula 2 Championships of 1964 and 1965, until the second Honda engine of 1966, with four valves and twin overhead camshafts, tungsten carbide rockers, torsion bar valve springs, appeared in Jack Brabham's cars. We'd run out of breathing at about 11,000 rpm so we obviously needed more valve area. That's what really started me thinking about 4-valve heads.

'Mike and I exercised great ingenuity – we had ports that curved round, we had the piston of the week, with every kind of shape, dint, and odd hole – but the combustion was not good, the mixture never burned properly. At that stage of development with the company so small, we had to make things work: we couldn't afford to spend a lot of time developing it.'

[Now comes the most famous Duckworth aphorism of all time . . .]

'Development, of course, is only really necessary to rectify the ignorance of the designers.'

Cosworth's, and Keith's standards, of course, have always been incredibly high. The fact that the original carburetted 1-litre SCA of 1964 produced 115 bhp, while the final Lucas fuel-injected type produced 143 bhp, is brushed aside:

'Frankly, with the SCA, I was sorry, the moment after I'd done it! I think that it was the "Heron" type of head that did it. I can later remember arguing like hell with Harry Mundy about this. I was staggered when he used a Heron head on the Jaguar V-12. Harry was very stubborn about things, but then so was I. I had some trouble in relating to him, but never to his boss at Jaguar, Walter Hassan.'

By 1963–1964, however, Cosworth had already begun to outgrow Edmonton. Even in two years, the place was bursting at the seams. Keith could not face the idea of expanding an old and unsuitable building that was not his, so he began to cast around for a new location:

'We were still leasing Edmonton, so now that we'd made a bit of money, we could afford to buy a place. I suppose I wanted to move a bit further north, to be a bit nearer home – I'm not that keen on London at the best of times – but we had to be within reasonable reach of airports, and people who were in racing, most of whom were in the south.

'Therefore we said "The M1 motorway's just been built, so we'll draw a line about fifteen miles each side of the M1 motorway, and look anywhere in that band.

Making money at Edmonton

Almost as soon as Cosworth was established at Edmonton, turnover and profits began to surge ahead. Never again would the company have to rely on its bankers for support, with the business expanding as a result of Lotus-Ford Twin-Cam, Formula 3 and SCA Formula 2 engine work.

The financial 'Year End' was soon moved from 30 September to 30 April, which explains the nineteen-month accounting figure for 1963. The move to Northampton took place at the end of 1964.

Financial Year	*Turnover*	*Profit (Loss) after tax*
19 months ending 30 April 1963	£156,696*	£5,885
Year ending 30 April 1964	£157,340	£11,973
Year ending 30 April 1965	£183,191	£23,775

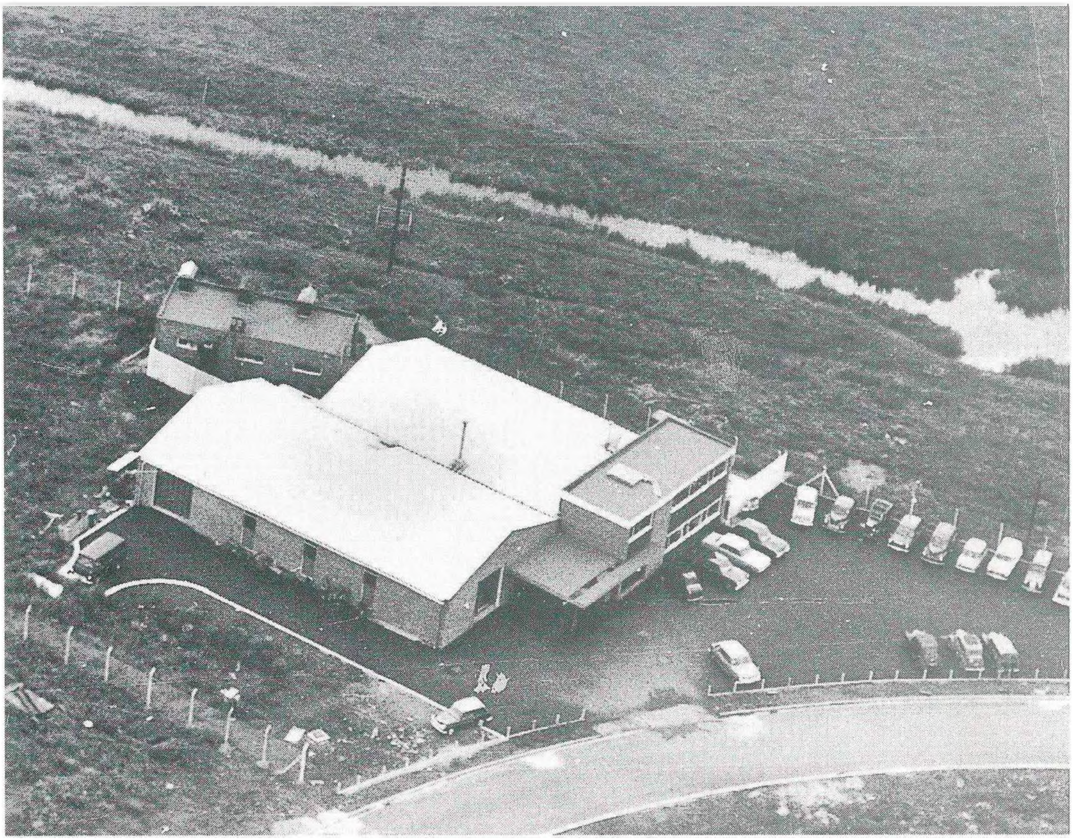
* This equates to £98,966 for a 12-month period.

The period ending 30 April 1963 was still bound up entirely with the manufacture of push-rod Ford-based engines, and the race-tuning of Lotus-Ford twin-cam engines.

In the next year the first single-overhead-cam SCA F2 engines were built, along with single-carburettor Ford-based F3 engines.

The year ending 30 April 1965 saw Cosworth concentrate on F3 and SCA engine manufacture.

Old hands at Cosworth now call this building at Northampton 'Factory 1', for it was the original block, completed in 1964. Incomplete when this picture was taken, it is now just one corner of an ever expanding complex, though it still houses some of the people involved in F1 engine design, development, and building.



You've heard of a 'green-field' site? The Cosworth factory at Northampton was built on just such a facility. It was in this modest building that the first 16-valve engines — FVA F2 and DFV F1 types — took shape.

'None of us had actually been to Northampton when it was first mentioned, but we knew an architect who knew about the place. I think it was Bill Brown who first suggested that we should go and look up there.'

Ben Rood remembers this rather differently:

'I never actually got round to looking at sites, but it just so happened that a friend of mine, for whom I was doing a hydroplane engine, had connections in Northampton. He told me about land being newly developed, and suggested we went to have a look. So, if I hadn't still been interested in hydroplane racing, we might have moved somewhere else.'

Keith now takes over the story:

'We thought about a site with development grants, and I think we were tempted by Wellingborough or Kettering, both of which were assisted areas, but we decided they were too far away from our customers. Northampton, simply, was the best bet. Anyway, we all went to look at Northampton, where we found a piece of land in what was to be St James Mill Road – it was still a field actually –

Time for a bit of socialising — Mike Costin and his wife greet Graham and Bette Hill at a British Racing Mechanics' Club dinner.

and I believe we paid about £8,000 for the site.

'There wasn't even a proper road there when we started building. We put up the first building on the estate, we occupied it before the road was complete.'

'Jimmy's End' was south-west of the town centre, close to the River Nene and the Grand Union canal, and almost overlooked by the main line railway, as it swept into Northampton's main station. It was a far cry from the hustle, bustle, noise and dirt of industrial north-east London, but this was where Cosworth was to make its permanent home.

Keith, prudent in all things commercial, took the trouble to buy more land than he originally needed, but the first Cosworth factory building at Northampton (now known as 'Factory 1'), occupied precisely 6,800 sq ft, plus 720 sq ft for dynamometer cells.

By comparison with Edmonton, it looked, and felt, palatial – yet another 3,000 sq ft was needed within two years, and another 12,000 sq ft had to be added eighteen months after that. At the beginning of 1971 another 22,000 sq ft was built on land across the other side of St James Mill Road:

Brian Hart, still combining a Cosworth job with a rising reputation as a racing driver, was one of the first employees to go up to Northampton, where he stayed until 1969:

'A few of us – Jack Field, Bill Pratt, George Duckett, and I went up to Northampton at an early stage, and actually helped to build the place. I was responsible for building some of the test cells, sometimes as bricklayer, then with pipework, in fact anything to get us going. Cosworth would always prefer to do something on its own, properly, than to pay for someone else to do the job.'

Although Cosworth was always deadly serious about its products, there was still time for some fun as well. Keith Duckworth told me that meetings were never formal — Keith, Mike, Bill and Ben 'in committee'.

Bill Pratt once boasted that the move really didn't cause any 'down time':

'We never stopped building or testing engines. We finished testing at Edmonton, then brought the next engine up to Northampton for testing. It was a very smooth change.'

Keith remembers the snags of sharing a newly-developed estate with other concerns:

'At first there was a factory across the road which boiled up rotten animal carcases to extract glue – that stank awfully on the days when the wind was in the wrong direction.

'This was the time when we regularized everything with Ben, for we'd originally bought half of the machinery that

was in his Walthamstow place. It was at this time that he closed down Rood's Engineering, and became a full-time Cosworth director.

Cosworth was employing no more than thirty people at Edmonton, but by no means all were attracted to the idea of living in Northamptonshire. One of the first tasks facing the four directors was to recruit more labour. The final moves took place towards the end of 1964, as *Autocar* noted:

'Mike Costin phoned last week to say that we shall shortly have to contact him at Northampton, instead of Edmonton. Instead of Edmonton 7694, it will be Northampton 51802/51803 after Christmas time . . .' [But don't try to ring those numbers today, they changed years ago!]

The company, newly-established in Northampton, was now set to get bigger and more important in the years which followed. Brian Hart recalls that the workforce rocketed to around fifty within three years, after which it continued to grow, inexorably.

Neither Keith Duckworth nor Mike Costin wanted to run a large business ('The one thing we both agreed on,' Mike Costin says, 'was that we didn't want to expand.'), but on the other hand they were not about to turn away business when it came knocking on the door. This, however, was only the start. The 4-valve revolution was just around the corner.

Fame in F1 – the DFV project

'I am responsible, by a completely original piece of thinking, for the modern narrow-angle 4-valve head.'

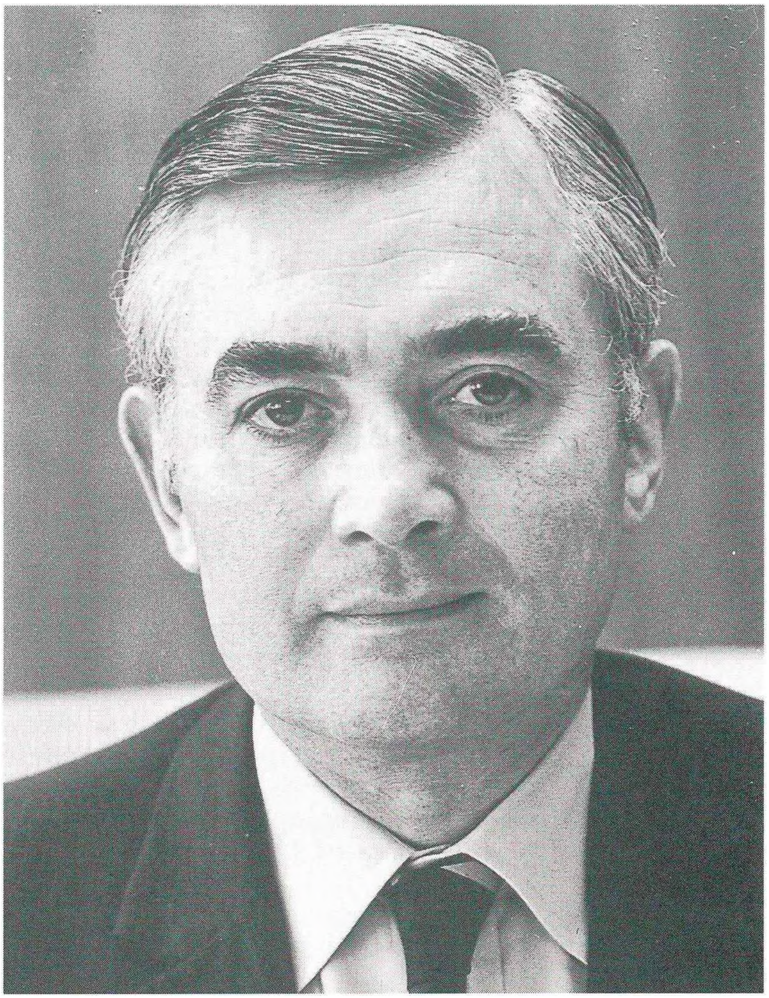
'I have a vast natural curiosity, so I'm always inventing things . . .'

Although the credit for the design of Cosworth's famous mid-1960s racing engines belongs to Keith Duckworth, their success was only guaranteed by the vision of two other men, Colin Chapman of Lotus, and Walter Hayes of Ford. Between the three of them, there was enough energy and vision to run *any* large project.

The inspiration, the driving force, behind it all was that Chapman, and Lotus, needed a new Grand Prix engine, Ford was persuaded to finance it, and both agreed that Keith Duckworth was the man to do the job for them. Even so, this was not a project which came together in a hurry. The basic timetable looked like this:

1961–65:	Grand Prix (F1) racing run to a 1½ litre engine formula. Like most British car constructors, Lotus relied on Coventry Climax engines.
Nov 1963:	FIA announced new GP formulas, to take effect from 1 January 1966. F1 engines to be normally aspirated 3 litre, or 1.5 litres with 'supercharging'. F2 engines to be 1.6 litre normally aspirated units.
Feb 1965:	Coventry Climax announced their withdrawal from F1 engine building at the close of 1965.

Spring/Summer 1965:	Colin Chapman persuaded Ford to back the design of a new 3 litre F1 engine.
Oct 1965:	Ford revealed F1 *and* F2 engine plans, with Keith Duckworth contracted to do the job.
Sept 1966:	First (prototype) appearance of 4 cyl F2 engine.
Mar 1967:	First F2 race held at Snetterton – Cosworth FVA-engined cars took all awards
Apr 1967:	Cosworth's first F1 engine, the DFV revealed.
June 1967:	DFV-engined Lotus 49 won Dutch GP in its first appearance.



Walter Hayes of Ford, the 'midwife' behind the FVA and DFV engines. Walter, in charge of public affairs and motorsport at Ford, brought Keith Duckworth, Colin Chapman, and Ford together in the mid-1960s.

Although Keith Duckworth already thought that he was capable of designing a complete racing engine, he was still too canny, still too much of the careful-with-his-money Northerner, to go ahead on his own, even with backing from a major client. In 1964–65, with the SCA on the way to proving itself in the current F2 championships, Keith was already involved in the design of a 4-valve 1600 cc engine (FVA) for the new F2 formula and although he already felt capable of designing a complete racing engine he was not harbouring any F1 ambitions.

Ford's ebullient director of public affairs, Walter Hayes, on the other hand had already added Keith's talents, and those of Cosworth, to his personal memory bank. He also had close links with Colin Chapman.

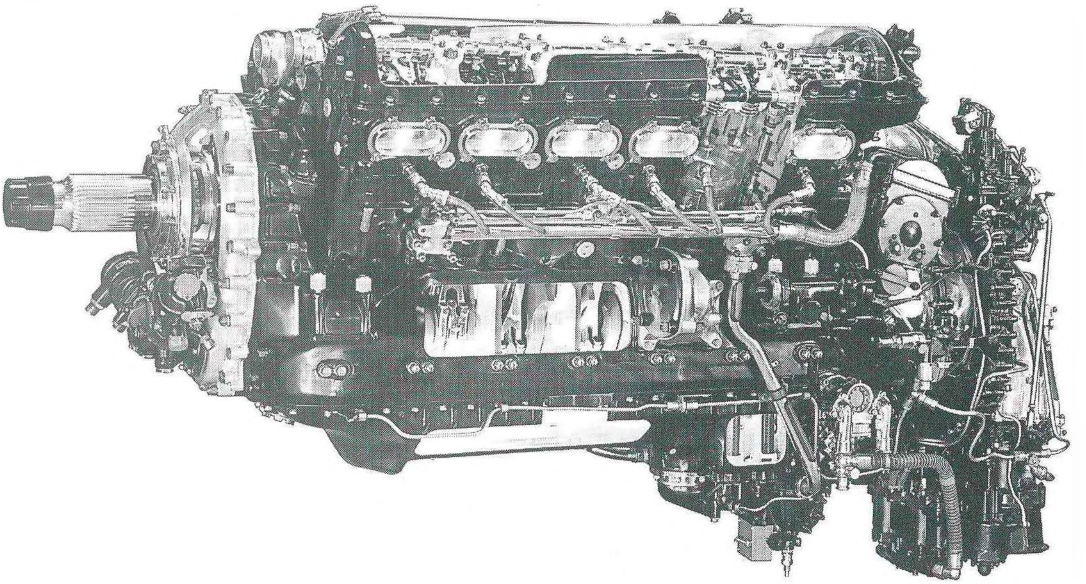
'I joined Ford in 1962, from Fleet Street,' Hayes told me just before he retired, 'at a time when Patrick Hennessy was beginning to build the company in a new fashion. The Cortina was already in the melting pot and it was going to open up the market in ways that had never been done before.

'Within a very few weeks of joining Ford, I decided that we would go into motorsport with it. Since I had a very broad brief, I could suggest anything that I liked to do. Even before this, though, when I was editing the *Sunday Dispatch*, I had hired Colin Chapman to write a new type of motoring column.

'By that time, too, I already knew about Keith Duckworth. He didn't strike me as the type of person who could ever work for another boss for very long. It wasn't that he was aggressive, or silly about the superiority of his ideas – it was just that he always liked to be in a position to follow his own ideas right through.

'Keith had a lot to do with the engines in the first racing Lotus Cortinas. I recall that those cars were so good that I once had to say to Graham Hill: "Don't go *too* far ahead of the Jaguars, because the TV people can't see that you're beating them if they're back out of sight . . ."'

When Coventry Climax announced an end to its Grand Prix engine building activities, it shocked everyone, not least Colin Chapman, who had built up something of a special relationship with Walter Hassan, Peter Windsor-Smith and the workforce in Coventry. Everyone had assumed that Coventry-Climax would continue into the new era, but as Walter Hassan later wrote, in his autobiography *Climax in Coventry*: '. . . we planned a clean break. Peter Windsor-Smith and I never even got round to sketching out 3-litre layouts, although we had a clear idea



No, this is not a Cosworth engine, but the mighty Rolls-Royce Merlin aero-engine. Keith Duckworth studied this engine, and many others, when formulating his own ideas about 4-valves-per-cylinder layouts.

of the sort of engine we *would* have designed.'

The problem which faced Lotus had obviously been relayed to Coventry, well in advance, as Hassan later wrote:

'The design of a completely new power unit of twice the size [as the 1½-litre V-8], with all the development costs, was more than we could swallow, especially as we had been led to believe from the customers that they would not pay up.'

Lotus, like Cooper, Brabham, and other constructors, did not have the financial backing to fund a major new programme. Early in 1965, however, Colin Chapman approached Keith Duckworth, asked him if he could produce a new Grand Prix engine, and offered to find the money to finance it. Keith replied that he had already decided to design a 4-valve F2 engine anyway, and that if that worked, then I really didn't see why we shouldn't knock up two of them, and make a V-8. He then said:

'Well, let's suppose we have to make five engines, do the design, and a bit of development,' on the back of an envelope basis,' about £100,000 will be needed to do the job properly.'

There was no detailed analysis, it was purely a 'think of a number' exercise.

Chapman's first approach was to the Society of Motor Manufacturers and Traders (SMM&T), but although he was as persuasive as only a Chapman looking for backing could be, he got nothing but sympathy – and the ear of the

SMM&T's President. Next, it was time to look for a Fairy Godfather from industry. As Chapman told motor racing authority Doug Nye, some years ago:

'On first contact with Ford, they didn't want to know, so we then had meetings with David Brown of Aston Martin in London. He was very interested, but he wanted far more control of the project than Keith was prepared to give him: he virtually wanted to buy Cosworth. Then we tried Macdonald of the British Sound Recording company, and there were several other interested parties, but we didn't really seem to be making much progress.'

Keith had approached Geoff Murdoch of Esso (Lotus was contracted to Esso), but also drew a blank. In the meantime, Chapman had already discussed the project with Walter Hayes, as the Ford man later recalled:

'I had got to know Colin well by this time, and I sometimes used to go round to Colin's house in Hadley Wood, for dinner, and a chat. On one occasion he said to me "This is getting serious, I don't suppose you would do an engine, would you?". Now, every time I saw Colin, he would have nine or ten ideas to discuss, he wanted to work on all of them at once. So, at that point I only needed to say: "Well, it's funny you should be saying that, because I rather think that I would like to do an engine now. I think we've earned our spurs at the lower level of the sport. I've been thinking about ways that we might go further, but I've been uncertain as to which way to go."

'In those days I was even considering trying to do a GP engine "in house", but that would have been vastly expensive, and anyway at that time I didn't know that you needed a special kind of expertise to do a racing engine. Colin then said to me that he thought Keith could do it. I knew enough about Keith by then – the only ability I've ever really had was to be able to pick people. I've always been able to smell them out from quite a distance.

'What was interesting to me was that Colin really didn't know *anything* about engines, I sometimes think he knew less than me. Whenever he sketched a car, he would draw it very exactly, but at the back he would just draw an oblong box, and write "Engine" on it. But he'd already worked out how to make a very light car on the drawing board he always kept at home. He sketched out the car with the engine actually bolted on, as part of the structure.'

Before long, Walter Hayes was sold on the idea, but before trying to sell the idea to Ford, he first of all had to prepare the ground. His chairman, Patrick Hennessy, was also President of the SMM&T, and Chapman's request to that body had to be suppressed before he could go further. In the meantime, Harley Copp arrived from Detroit, to take over as Vice President of Engineering at Ford of Britain. Walter Hayes soon discovered his new colleague's love for motorsport, and began to discuss his projects, and his dreams, with him:

'I talked to Harley, I talked some more to Keith, then to Colin. We had lunches, and dinners, and things, to see what could be done.'

In the end, it was Chapman who burst the logjam of understanding. As Nye's narrative makes clear, when he was invited to dine with Harley Copp, he burst out with:

'Look, you're missing out on the best investment you have ever made . . . for £100,000 you can't go wrong.'

Copp was convinced, and Hayes then thought it was time to talk things through in detail before formally asking for backing from his fellow directors:

'Keith then did what Keith has always done. I don't think that diffidence is the word, but what he does is to put up such a level of deterrence, to make sure that other people are really as enthusiastic as he is. Then he agrees, but he never actually tries to sell anything.

'Then we got down to the question of what kind of engine it should be. I then had a very good idea, and put it to Keith: "Why don't we start with a four-cylinder engine for F2, then double it up, and make it into a V-8? That way, half of it will be good for the Lotus Cortina too, and all of it will be a Grand Prix engine?"

'Nowadays, when anyone talks about the DFV [Double Four Valve], everyone forgets the FVA [Four Valves, Series A], but this was always an essential part of the programme for me. Big brother was fine, but little brother was equally important. It was always an important part of our agreement, that I wanted to see the little one built first, because frankly I thought that if the little one worked, then the big one was sure to work.'

Keith took the pragmatic attitude that if the four-cylinder F2 engine worked well, and produced around the 200 bhp which he thought was needed to make it competitive, then it would be worth going on to design a new F1 engine of about double the size.

And so, between the three men, it was settled. Assuming that Ford's various policy committees would 'buy' the project, Keith Duckworth would design a new F1 engine, Ford would pay for it, and Lotus would have first use of it. The difficulty for all concerned, however, was to get accurate cost estimates. Walter Hayes had a horror of going into such a programme without enough money to back it:

'The worst thing you can do, at Ford, is to cost a programme, then have to go back to ask for over runs. In any case, when we were going into business with an outside supplier, we always wanted to be sure they were happy too. But Keith thought he could do it for £100,000, and that's what we agreed upon.'

While all this was going on, Cosworth was settling into its new factory at Northampton, grappling with the development difficulties with the SCA engine (but still winning a lot of Formula 2 races), selling lots of pieces for race and rally-tuned Lotus Cortina Twin Cam engines, and turning out masses of single carburettor MAE engines for use in Formula 3. While Keith began to apply his enormous intellect to the double challenge which he was about to face, Mike Costin, Bill Brown and Ben Rood stayed behind to 'mind the shop'.

In the meantime, at Ford, there were two financial hurdles to be crossed. Walter Hayes and Harley Copp had to face a Ford of Britain Policy Committee meeting where, under 'Any Other Business', Walter Hayes casually said: 'Yes, Harley and I would like to do a Grand Prix engine.'

To you and I, the sum requested (£100,000) was a lot of money, but as it was only one tenth of the amount previously budgeted for adding synchromesh to the bottom gear of the Ford small gearbox, to make it suitable for

Keith Duckworth at his office in Northampton, in the late 1960s, his desk full of papers, calculations and sketches, and his drawing instruments near to hand. All Keith's concept design, and much of the drawing work, was carried out at home, away from the hurly-burly of the business (*Phipps Photographic*).

the Cortina, no one really flinched.

'After that,' says Walter Hayes, 'I had to go over to Detroit, to sell it at an annual review of world motorsport policy. It was rather a terrifying occasion. I said that I wanted to go ahead with a Grand Prix engine programme, and Mr Ford [Henry Ford II] who was sitting at the head of the table, said: "Well, what is this engine going to do for us?"

'To which I replied: "Well, in my opinion, it will win some Grands Prix, and I also think that it will win a World Championship."

'"And how much is this programme going to cost?", said Mr Ford. Now I can't remember how the figure had altered slightly, but I remember that I said "Oh, $323,000".

'Fortunately for me, the budget for the Ford USA motorsport programme had been presented immediately before I walked in, so $323,000, by comparison, did not seem quite as enormous to them as it did to me.'

The project was sold, and all that was necessary was for contracts to be drawn up, responsibilities to be agreed and for Keith to start work. Cosworth was to get £25,000 on 1 March 1966, when the contract was drawn up, a further £50,000 on 1 January 1967, and the final £25,000 on 1 January 1968. It was agreed by all concerned that the first £25,000 was to cover the design of the four-cylinder F2 engine, which was to use Ford's five-bearing 120E cylinder block.

In those days everything was much more casual than it became later. Rumours of a joint Cosworth Ford were spreading by September 1965, and Ford made an official announcement in October 1965. Keith worked hard throughout 1965 and the early months of 1966, but there was still no contract to cover all the work!

'Then came the question of getting Keith to sign the contract', Walter Hayes remembers. 'I don't think Keith had ever signed a contract before, and I don't think he had any lawyers. He wouldn't have *wanted* lawyers anyway, because that profession was already on his list of "Bad Things".

'So I wrote him a letter, then our lawyers said he had to have a contract, but when he saw one of our contracts he actually called me and said it was all too complicated: "Do you want me to read the contract, or shall I design an engine instead – I haven't time to do both?".'

In the end Keith signed the vital piece of paper on 23 June 1966, by which time the first F2 engine had started test bed running! Not that the signing of a contract was ever likely to kill the project, as Walter Hayes still insists:

'The main thing was that we all had the same objective. After all, if you have some beautiful girl who wants to marry you, the *last* thing you worry about is a contract. If you want to marry her as much as she wants to marry you, the rest is easy.'

By 1965, in any case, Keith had decided to tackle the design of his first 4-valve twin-cam cylinder head. His aim was to get better combustion and increased gas flow. Technically, and personally, he was sure he could do a good job, but the support of Ford made this financially feasible as well.

Although Keith insists that he doesn't read books ('I'd stopped consulting experts very early on, even before I did the SCA'), and that he never copies what other people have done, he was clearly well informed about design trends in racing engines. He had, for instance, seen how many noted companies had stayed loyal to part spherical combustions, through thick and thin, but he was not convinced that they were still relevant:

'The hemispherical head was correct many years ago, when engine strokes were very long, and the compression ratio you could get on available fuels was fairly low. Therefore, with a flat-topped piston, and two large valves fitting nicely into the chamber, and a spark plug fairly near the centre, you got rather a nice chamber. Flame travel near the plug was good, and the whole chamber was a nice shape.

'Once bores started getting bigger, and the usable or sensible compression ratio went up, then people started adding lumps to the top of pistons, and if there was a 90-degree included valve angle what remained was really a pent-roof chamber anyway. The chambers became orange peel shaped, with valve pockets in the side of the pistons.

'Even the first 4-valve engines of the 1960s which were motorcycles (and Honda did an F2 engine to compete with our SCA) still had 80 or 90 degree included angles.

'When I came to design my first 4-valve head, I looked around, said, "Well, hemispherical heads, they should have been turfed out yonks ago, they're wrong, and those angles are *all* wrong". My criteria were that I didn't want any surplus combustion chamber area, I wanted to use a pent-roof combustion chamber with the valve angles adjusted to make a flat top piston reasonable, with a compression ratio of about 10.0:1.

'It means that I am responsible, by a completely original piece of thinking, for the modern narrow-angle 4-valve head. In terms of air flow, and flow management, today's F1 engine uses exactly the same principles that I established 25 years earlier.'

No one else, it seemed, had thought this through in recent years, and there was only one learned journal that Keith trusted: Ricardo's *The High Speed Internal Combustion Engine*:

'I really did think he was pretty good. However, quite often he put in the Latin phrase *ceteris paribus* (other things being equal) the problem being that, in real life, you usually cannot make the *ceteris paribus*! If you could change just one thing at once, in a combustion chamber, and measure the effect, you might learn something, but that's impossible. However, I have a vast natural curiosity, so I'm always inventing things. I've always liked to make advances.'

Even by this point in his career, Keith had decided that gas-flow rigs had little or nothing to tell him. More than once he has told me that gas-flow rigs can show that certain changes to a head will improve the flow, but that the engine, on test, will actually be worse. In later years one of his most famous habits was to say that he could look at an engine, feel around in the ports with his fingers, and know if it was 'going to flow, or not':

'We always knew that the basic velocity in the ports was important, and the conditions around the valves and seats was equally important. Anyone who applies air flowing techniques arrives at bigger holes than I consider to be sound.'

There are some aspects of gas flow management that Keith, and his colleagues, clearly think they know more about, than their rivals, for further discussion on the subject was diverted. Keith rumbled, huffed and puffed, then abruptly clammed up. On two occasions, his experienced knowledge of cylinder head design, have entered folklore. An early visit to Ford USA, in Detroit, led to him being asked to inspect one of the cylinder heads of Ford's huge-capacity V-8 engines. He was apparently amazed by the sheer size of the inlet ports, and was heard to suggest that arrows should be cast on the port walls, to tell the air which way to go. Then there was the time in the early 1970s that Chrysler-UK's motorsport department couldn't make the 16-valve Avenger-BRM engine work, and took a head along to Cosworth to ask for advice. Keith helpfully looked at the head, squinting at the chamber and ports

Valve angles – and head layouts

In racing car engine design, is there *anything* new still to be invented? In detail, yes, but in concept, probably not.

Keith Duckworth, not a modest fellow where his own achievements are concerned, makes one emphatic claim – that he, and he alone, developed the 4-valve, twin-cam, narrow valve angle cylinder head for use in racing engines. As a package, that's true enough – what is interesting is that each of those features was developed *individually*, many years ago.

When I was writing this book, Keith lent me his own personal copy of Griffith Borgeson's book *The Classic Twin-Cam Engine*, stating kindly that 'It might teach you something'. He was right, it did. Keith might have been impressed by the author's knowledge of old engines, but not by his ignorance of new ones. Near the back of the book there is a posed picture of personalities around the DFV engine. The caption reads: 'Colin Chapman, Jim Clark, Graham Hill and friend at the dawn of the Ford-Cosworth era': the 'friend' is DKD himself!

No-one, for sure, had produced a head like that of the FVA/DFV before it was evolved by Keith Duckworth. However, the origins of each feature seem to stack up like this:

Twin overhead camshaft cylinder heads

There's no doubt that the first twin-cam head to appear in public, to race, and to win, was that used by the 7.6-litre Peugeot Grand Prix car of 1912. That self-titled *doyen* of technical motoring journalism, Laurence Pomeroy Junior, later wrote that these cars had 'startling technical novelty'.

Who actually inspired the engine? There has always been fierce debate about this, especially as three of the team's drivers (dubbed 'The Charlatans'!) were said to have great influence over designer Ernest Henry. That distinguished race engine designer Harry Mundy once insisted that one of those drivers, Georges Boillot, was the *real* inventor. Most historians, though, now credit Henry for the draughting, if not for the original inspiration itself.

The Peugeot engine, however, was not just a twin-cam, but it also had four valves per cylinder, opposed at an included angle which Pomeroy quotes as 45 degrees, looks more like 90 degrees in drawings, and according to Borgeson 'may have been 60 degrees'. No-one now knows, and no engines survive. The specific power output, very competitive for those days, was variously stated as 148 bhp, 175 bhp and (by Pomeroy) 130 bhp. A modern Cosworth race engine is eight to ten times more efficient.

Even though Mercedes-Benz then won the 1914 Grand Prix with a single-cam/4-valve engine, the twin-cam lesson had already been absorbed by many other designers. Except, that is, for Bugatti, who stuck stubbornly to his own ideas throughout the 1920s.

Four valves per cylinder

Here was a feature which came and went. There were four-valve engines of a sort, even before the arrival of the Peugeot and 4-valve engines as a result of the desire to copy the Peugeot, yet many Grand Prix engine designs then reverted to two valves per cylinder until the 1960s.

Famous '4-valve' engines of the pre-war period included W. O. Bentley's single-cam designs, the M25/M125 series of Mercedes-Benz Grand Prix engines of the 1930s, the 8CL Maserati units and the legendary Rolls-Royce Merlin aircraft engine. The type was rarely seen at all in the 1940s and 1950s. On the other hand, successful engines like the straight-eight and V-12 Delages of the 1920s, the straight-eight Alfa Romeo twin-cams of the 1930s, the V-12 Ferraris of the 1940s and 1950s, the Mercedes-Benz M196 F1 engines of 1954/1955, and all the successful Coventry-Climax F1 engines, relied on part-spherical combustion chambers and two valves per cylinder. Four-valve re-design was later carried out on the Offy, and on the Coventry-Climax FWMV.

The first successful 4-valve race engine of the post-war era was the Borgward F2 engine of the late 1950s, followed by the last of the Coventry-Climax V-8s, in 1965, this pre-dating the Cosworth FVA by one season. As Coventry-Climax design chief Walter Hassan wrote in his memoirs (*Climax in Coventry*):

'Technically this was the right thing to do, although very few racing engines with such a layout had been used since the war.'

It took a long time for Coventry-Climax to develop an engine which produced more power than its two-valve predecessor, but in the end Jim Clark won five F1 races with the same engine in 1965, thus securing the World Championship for himself, and for Lotus, in 1965.

Although the motor racing world was then on the brink of going 4-valve in a big way (Coventry-Climax with the unraced flat-16, BRM with the unraced version of the H16, and Ferrari with a V-12), it was Cosworth, first with the FVA, then with the DFV, which got there first. After that, everyone else rushed to catch up. Some are still struggling to do so . . .

Valve angles

Let's get one definition out of the way, right away. 'Valve angle' is actually short for 'valve included angle', which Harry Mundy always insisted should have been stated as 'valve opposed angle' – and is the measure of the angle between the inlet and exhaust valves in a cylinder. In most cases the valves are symmetrically disposed around the centre line of the cylinder itself.

Once the layout of twin-cam racing engines had settled down in the 1920, many designers settled on part-spherical combustion chambers, with widely spaced valves. A typical opposed angle was 90 or even 100 degrees – this allowing the use of two large diameter valves which would not push too far down into the bore when fully opened.

Bentley, which used a fixed cylinder head, and which had used the pre-war Humber engine as inspiration, settled on a 30 degree included angle which, if the designers had only realized it, was *almost* the benchmark set by Cosworth with the FVA five decades later!

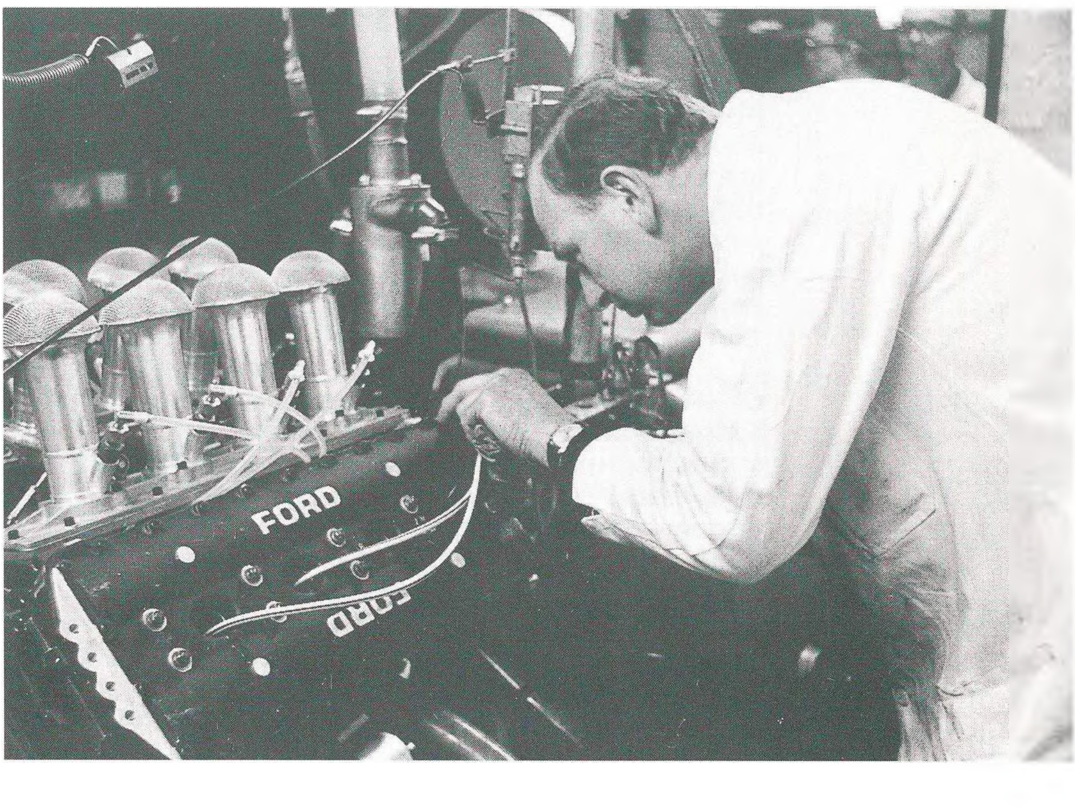
The famous Alfa Romeo P2 and P3 engines all had 90 or 104 degree layouts, while the Miller-inspired Bugatti twin-cams of the 1930s used a 90 degree angle. In the 1930s Mercedes-Benz settled on 60 degrees for its M25 units, then 70 degrees for the M125, and 56 degrees for the M165 1½-litre V-8s of 1939.

The trend-setting F1 engines of the post-war period were the Alfa Romeo Alfetta (100 degrees), the Ferrari V-12 4½-litre (60 degrees), the Mercedes-Benz M196 2½-litre (88 degrees), Vanwall (60 degrees), the Coventry-Climax FPF (66 degrees), the 1½-litre BRM V-8 (80 degrees), and the Coventry-Climax FWMV V-8 (60 degrees). The unraced flat-16 Coventry-Climax unit of 1965, which promised to be the most powerful 1½-litre F1 engine of all, used a 48 degree angle.

It was that gradual trend which Keith Duckworth nudged one entire stage further – the four-cylinder FVA of 1966 had a valve angle of 40 degrees, and the V-8 cylinder DFV of 1967 used a 32 degree angle.

A new benchmark had been set.

Mike Costin, in the testbeds at Northampton, bending over an early V-8 DFV F1 engine, in the run-up to public launch in 1967.



from every angle, grinned, then roared with laughter, and suggested that the engine should be junked.

Chrysler UK didn't like what they were told, but the fact of the matter is that the engine never worked properly, and it *was* eventually junked.

Keith himself, however, was not infallible. In 1965, at the start of the Ford F2/F1 programme, he carried out a lengthy, and carefully considered, non-starter of his own:

'When I did the first-ever schemes for the 4-valve head, I produced a diagonally opposed layout, with one inlet and one exhaust valve on each side of the pent-roof chamber. There was a compelling reason for this – I was looking for the circumferential swirl that the SCA had never had.

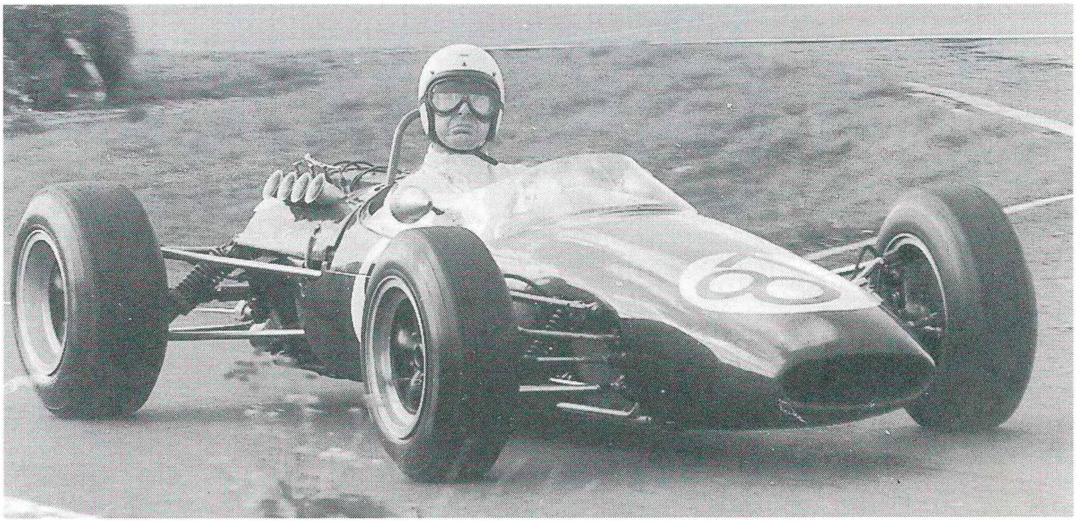
'In fact I had schemed everything, and drawn all the pieces, before it dawned on me that, relative to a central sparking plug, a circumferential swirl was in fact stationary – with the SCA, and a plug to one side, the swirl was effective. On the SCA layout we got some swirl, whereas with a central plug there would be no significant movement relative to the plug, and propagation of the combustion flame would not have been assisted. To make it work, I would have needed three sparking plugs, and I thought that was silly.

'So we scrapped the whole scheme. I'd done a complete set of drawings by that time. It was going to be difficult to plumb anyway – there would have been a set of inlets *and* a set of exhausts on each side.'

Keith, however, has always been ruthless, perhaps too ruthless, in cancelling projects which do not seem to be going well:

'Undoubtedly I have been wrong, sometimes, to stop projects being continued through further stages of development. Originally that was because we couldn't afford to produce triumphs of development over design. If, at that stage, we looked at a drawing, or a prototype, and it all looked fairly hopeless to me, if it was going to cost a fortune to proceed with, then I would stop it at that time.

'My first impressions are usually the right ones, I obviously have a lot of intuition. I sometimes look at things and think: "Crikey, there's something wrong there." If my intuition fails me, and it gets past me, then Mike can usually sort it out. Mike has a fantastic mind, almost his own computer. He's wonderful value to all of us, because he can turn over an idea in his mind, look at a drawing, or at a component, and come out with the answer "Yes I like it", or "No, it doesn't sound very



Mike Costin test-driving the FVA-engined Brabham at Brands Hatch in 1966. The engine worked well, right from the start, but clearly he is unhappy about something! (*Phipps Photographic*).

good.'' He has about a 95 per cent chance of being right. He's a wonderful counter to me, because I tend to be inventive and throw ideas out, when Mike will then say: ''Ooerr I don't like that.'' He can never explain *why*, but he always seems to know whether things are going to work or not.'

Keith thinks that many engineers are too proud to admit to their mistakes, and throw good money after bad to try to dig themselves out of a crisis. In the late 1960s he was amused to find BMW trying to produce a competitive F2 engine, first with the radial valve, two-stage valve gear 'Apfelbeck' engine (Jack Brabham once christened it the 'high and heavy' engine, and that name stuck), then with a diagonal valve head of the type which he had abandoned, and finally with a conventional 4-valve twin-cam arrangement. In the end, as Duckworth gleefully confirmed, they bought an FVA, tested it, and stripped it out, to get the measure of what they had to beat.

The moral of this story is that the Apfelbeck appeared in 1966, the 'Diametral' in 1968, and the FVA clone in 1970. It took BMW four years, and tens of thousands of hours, to produce a competitive engine. Keith Duckworth, by thinking hard about aspect of the design, produced a race-winning engine in about a year.

The story of the design, straightforward development, and sensationally successful race-winning career of the FVA (Four Valves, Series A) is well known. Keith started work in July 1965, the first engine ran on the test bed in February of 1966, Mike Costin first tested it in a Brabham single seater chassis later in the summer of 1966, deliveries began early in 1967, and it was immediately dominant when the new Formula 2 series began in March 1967.

It went on to dominate F2 from 1967 to 1971, there being no other engine – Ferrari, BMW, or whatever – which could match it. It was only the fact that it could not easily be stretched to a full 2.0-litre size in the early 1970s – it was, after all, based on Ford's 1.5-litre cylinder block – that allowed BMW to catch up. By this time, in any case, Cosworth had turned its attention to other projects.

'But we still didn't have a clue about costings,' Keith recalls. 'The FVA, in the 1960s, was sold for £3,000. I can well remember wondering, not what it cost to build, but what the market would stand.

'I discussed this with the others: "If we're going to sell twenty of them, maybe forty of them, for a couple of years, how much can we sell them for?". I asked Bill and Mike if we could make them for that, and we hadn't a close idea. Ben hadn't an idea either. It was then that I made a typical chairman's decision. I drew myself up, glared around, and said very loudly: "We'll charge £3,000. If we can't make that f***ing thing for £3,000 a throw, we should f***ing well give up!". *That* was how we arrived at the price.'

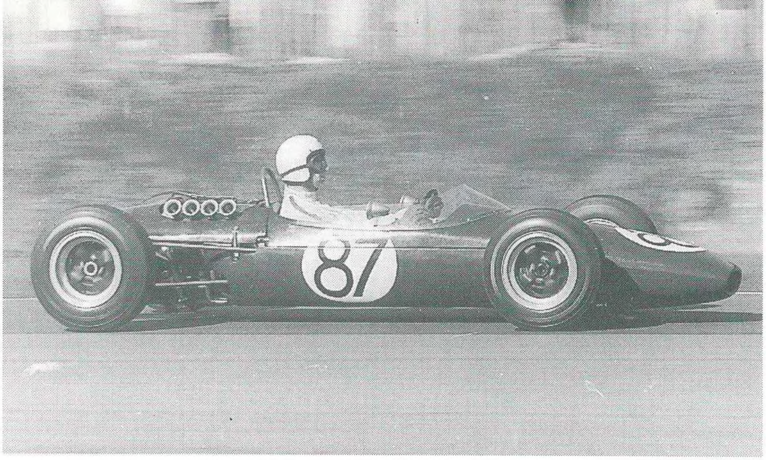
The FVA, therefore, was the first high-tech, low-volume, engine to be produced by Cosworth from its new

Rapid expansion with 4-valve engines

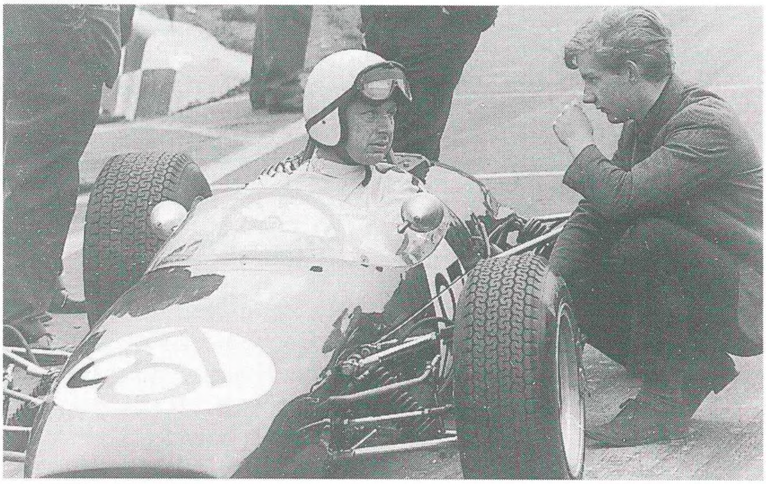
If Keith and Mike had not wanted Cosworth to expand (as they still insist about their business philosophy), they should not have designed such successful engines. Once the phenomenal FVA and DFV engines were launched, there was a growing queue of customers. In two years – 1965 to 1967 – Cosworth doubled in size, and the business became a high-tech operation.

Financial Year	*Turnover*	*Profit after tax*
Year ending 30 April 1966	£225,012	£30,796
Year ending 30 April 1967	£347,407	£36,145

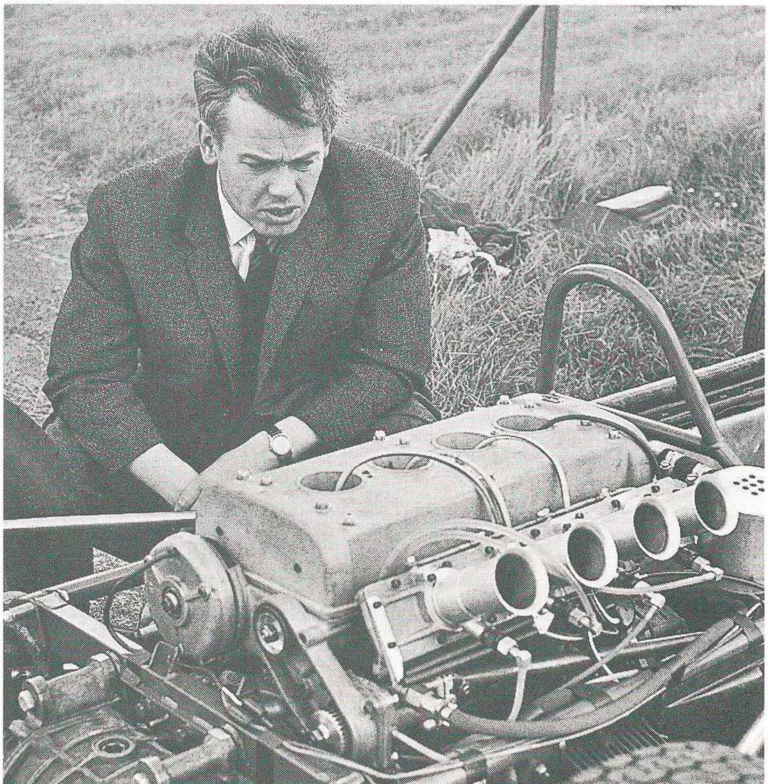
The first 16-valve twin-cam FVA F2 engines were delivered in the year ending 30 April 1966, but many more were delivered in the following twelve-months. The first £25,000 for the FVA/DFV contract was received in this period. In the year ending 30 April 1967, Cosworth received another £50,000 towards the DFV work, with first deliveries (to Lotus) taking place just before the end of April.



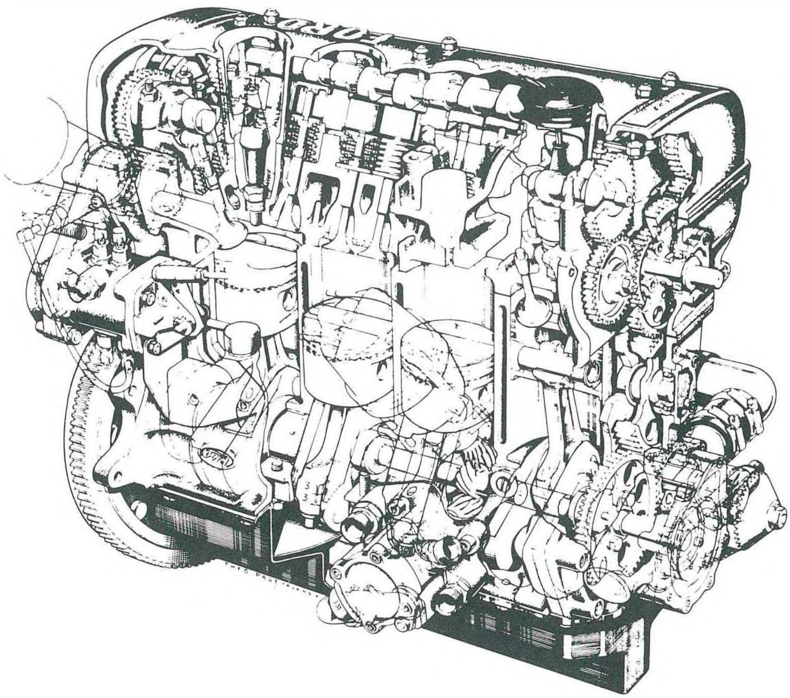
This side-on shot of Mike Costin in the prototype FVA-engined Brabham F2 car, taken in 1966, proves two things — Mike is a tall man, rather *too* tall for the tiny cars of the day, and the FVA engine was very compact indeed (*Phipps Photographic*).



Two personalities still very much a part of the Cosworth scene, captured during FVA engine testing in 1966. Driver Mike Costin became the company's chairman in 1988, while mechanic John Dickens became director/general manager of the Cosworth Engines Group in 1989.



Designed specifically for Ford, as the standard-setting F2 engine of the late 1960s, the FVA engine was neat, immensely powerful, and successful right from the start. Keith Duckworth, who by that time was immersed in the design of the DFV F1 engine, poses by an early FVA in 1966.



Theo Page's beautifully detailed cutaway drawing of the FVA shows how Keith Duckworth engineered Cosworth's first 4-valves-per-cylinder head. This new 1.6-litre engine took F2 by storm in 1967, and it was years before any other engine could match it.

factory in Northampton. Based on the sturdy cast iron Ford block, it had a light alloy cylinder head casting (like most such castings for many years, it was made for Cosworth by Aeroplane & Motor Aluminium Castings in the Midlands), with twin overhead camshafts driven from the nose of the crank by a series of gears. There were 16 valves, fuel injection by Lucas, and the name of 'Ford' was proudly cast on the camshaft cover. Target power, when the engine was designed, had been 200 bhp, but this was handsomely beaten on a very early test run. Most engines delivered in 1967 produced 220 bhp, and this figure was increased considerably in the years which followed.

'But I still got it wrong in one way,' Keith says. 'I had set the valve angle at 40 degrees, but that left me with a chamber which was too big. We found we could run with even higher compression ratios, and ended up with a piston growing up into the head. That's one reason the DFV angle came down even further, to 32 degrees.'

By the spring of 1966, therefore, Keith had proved, to his own and to Ford's satisfaction, that his ideas on gas-flow, cylinder head layouts, and structural design, were all sound, and he sat down to design the Grand Prix engine.

At an early stage Keith had to give it a project code. Like his opposite number in the motor racing business, Mike

Hewland, Keith had a healthy disregard for flowery names. Christening the new engine was easy – it was really double the FVA, in some respects, so it became the DFV, or Double Four Valve, engine.

[Mike Hewland, for instance, has been known to christen his transmissions by names like 'LG' – for Large Gearbox, or 'DG' for Different Gearbox . . . he and Keith had a lot of practical sense in common].

Keith Duckworth's regime, established to design the DFV, has been chronicled before. Using his drawing board at home, a few miles away from the factory, he settled down, in peace and quiet, to think things out. Mike Costin remembers that the initial thinking process went on for weeks, and that the biggest agonies seemed to centre around one vital 'bench-mark', the position of the holding down bolts for cylinder heads:

'In the end,' Mike told me, 'I really had to read the riot act, and point out to him that unless he made up his mind about these, we'd *never* get the DFV built.'

Keith agrees, but justified the delay, not as indecision, but as careful analysis:

'I tend to "think" with a pencil. The problem is that you start off with what you were originally thinking about, but by the end of the first page you've already decided that what you started with was a lot of nonsense. So now perhaps we'd better start again, from there.

'Mike reckons that it was always worth my while going away and spending a lot of time designing something to be small and simple. The longer I spend at it, the greater chance there is of it working.

'He doesn't think many designers do this. They sit down with a problem, think of a solution to it, then they draw it. They are so relieved to have found a solution at all, they don't think of any alternatives. When *I* design anything, I think of about six ways of doing the job.'

Sometimes working up to sixteen hours a day, and straining his eyes so badly that doctors feared for his well-being towards the end, he spent nine months and, incidentally, lost 40 lb in weight: 'As I was at home for all my meals, I deliberately went on a diet, which seemed to consist largely of steak and cabbage, and as a result I lost 40 lb.'

It is quite untypical of Keith that he now minimizes the sheer effort involved:

'In those days, when I started with the DFV, it was without management systems, with a fairly simple mechanical fuel injection system. It was possible for one bloke, me, to be sufficiently knowledgeable about all the aspects of the engine, to do a design as a one-man job. Later, when we got on to the days of turbocharged engines, and electronic management systems, that was more unlikely.'

At about the time Keith conceived the DFV, he hired Mike Hall, from BRM, as his *de facto* chief designer. Mike had been closely involved with the successful BRM V-8 engines of the early 1960s, but had become alarmed at the problems thrown up by the massive 3-litre H16 which BRM was developing for the new Formula:

'Geoff Johnson drew that up for Tony Rudd on a clean sheet of paper – a *very large* sheet of paper. It was a masterpiece of draughtsmanship, but I think that's all I could say for it. In fairness, it wasn't his concept.

'We knew a lot about V-8s, so my feeling (shared by one or two others) is that we should have gone for a compact V-8. As it turns out, that is precisely what Keith was

Mike Hall

When he joined Cosworth in 1966, Mike Hall was already 36 years old, and had a depth of engineering experience covering activities as diverse as Rolls-Royce diesel engines, Raleigh moped engines, and the BRM organization.

Born and bred a Midlander, where his father was an engineer with his own business ('We had a lathe in the garage, at the bottom of the garden'), he joined Rolls-Royce in 1947, served a five-year engineering apprenticeship at Derby and Belper, completed his National Service with REME in West Germany, then returned to Rolls-Royce:

'I became a research and development engineer in the diesel engines division, went from there to the detail drawing office, then graduated fairly quickly from there into the design office. My project engineer at Rolls-Royce, Geoff Topliss, then left to go to Raleigh Industries in Nottingham, to set up a motorized division. He asked me to join him there, where I stayed for six years, actually working in the Sturmey Archer division, designing small two-stroke engines for mopeds and scooters.'

In the meantime, Mike had also taken up motorcycle racing, and competed in the Isle of Man TT races, tuning his own engines, and getting parts made by the firms he was working for. For a year he was tempted to move away from Raleigh, to work with Joe Ehrlich at the Bristol Siddeley 'small engines' division, at Leavesden, near Watford:

'Then, I went to work for BRM. The original connection was that I bought my first racing motorbike, an AJS 7R, from Raymond Mays, but that was in 1948, and this was 1962. I wrote to Raymond Mays, he passed the letter on to Tony

In many ways Mike Hall was Cosworth's unsung hero in the 1960s and 1970s. He did much of the design work following up Keith Duckworth's concepts, then tackled many other design jobs (including the BD and GA projects) on his own.

Rudd, who eventually offered me a job as a development engineer . . .'

Mike's original work was with BRM's 'contract jobs' (Lotus-Cortina engines for racing, 'King Kong' engines and gearboxes for Chrysler USA), but then came a chance to work on BRM's successful 1960s racing units:

'I got the job of developing the "Tasman" version of the 1½-litre V-8. I did nearly all the work on that – it started as an 1800, then a 1900, and I think I got it out to about 1,950 cc.

'In tandem with that, BRM designed a 1.0-litre F2 engine [which competed with Cosworth's SCA], and I had the job of developing it. To make it an economical proposition, we had to make do with a cylinder head from the V-8, which was always a limitation, as this was really a 750 cc head and porting, which never gave the cam lift or the valve sizes that we needed. Geoff Johnson designed it, and he came to work for me at Cosworth in the 1980s.

It was while he was at BRM that Mike met Keith Duckworth:

'I used to go to all the races, particularly F2 events, and so did he. We got to know each other, and eventually I decided that Cosworth would be a good place to work. We talked to each other at various events, had a drink in the hospitality tents, and by this time I wasn't enjoying the way things were going at BRM with the H16 F1 project.

'I virtually said to Keith, "I'd like to come to work for you", but this went on for six months before I eventually moved to Northampton. I suggested to Keith that I should be a development engineer, because that was what I was doing at BRM. Keith didn't think he wanted one of those, so I moved to Cosworth as a designer.

'By this time the motor industry already knew that Cosworth was preparing to build Formula 1 engines. It was no surprise to Mike, therefore, to realize that his first job was to work on the design of the DFV.

What a baptism!

thinking, but at BRM we didn't know that at the time. Strangely enough, BRM had already been involved with 4-valve heads for the V-8, for they had bought a stake in Weslake, where Peter Berthon and Aubrey Woods had designed one, still with the same valve angles as the existing V-8.

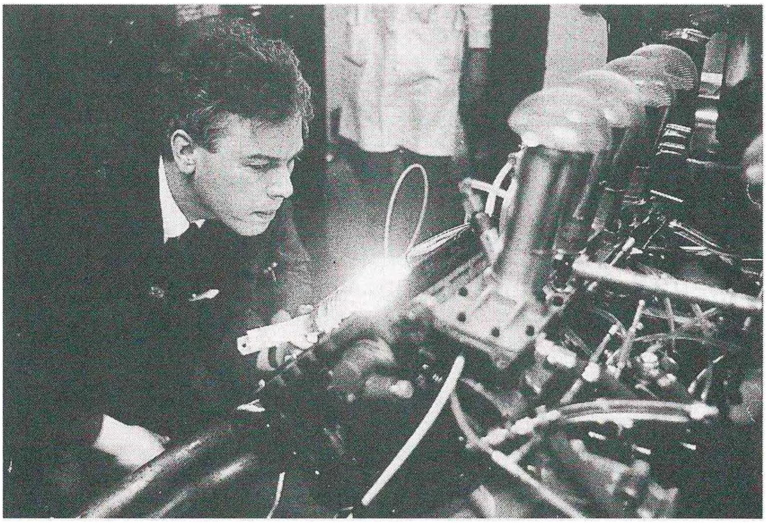
'When I arrived at Cosworth, the drawing office at Northampton consisted of Roy Jones (he is still at Cosworth), Pete Stemp, me, and the odd youngster. There would only be forty or fifty people in total, at Cosworth, then. 'Keith didn't design in the office – he worked from home. I used to have to go up to Keith's house once a week, where we used to talk about everything. In the main, I designed most of the accessories on the DFV, I did the inlet manifolds, the water pumps, the accessories down the side.

'Keith would provide schemes for what he wanted, fairly vague in the case of accessories. However, he knew enough to say that he wanted the pumps to be a certain diameter, and where the volute should go. Even so, I had to do a lot of detail design development on my own.'

Ford offered help and support, at all times, but Walter Hayes was careful not to smother Cosworth with sponsorship:

'I was very careful to offer Keith help, but not to sit on his shoulders during this period of time. It was obvious that we had much greater engineering resources than he had, particularly where metallurgy was concerned.

'Occasionally he would come down to Dunton, to see Harley Copp, and he used to wander around talking to



If Keith Duckworth does not understand, he works through every detail until he finds the answers. The problem, here, was connected with the DFV, just before it was unveiled in the spring of 1967.

engineers, but it was always obvious that he would do *his* programme, *his* way,

'It was at about this time that I discovered something quite remarkable about him – that he designs everything, completely, in his mind before he starts drawing. For the original DFV, he did all the thinking, and he did all the scheming and designing – it really was the nearest thing to a one-man engine that there ever has been.

'Well, in later years, people would sneer that it wasn't a Ford engine, but it absolutely *was* a Ford engine, because he did it all for us.'

Ford, and Walter Hayes, in the meantime, were keeping the general layout of the new engine completely under wraps:

'I actually leaked the existence of an F1 plan to Denis Holmes of the *Daily Mail* at a foreign motor show, and it was only then that I discovered how romantic people were getting about engine layouts. They were talking about V-12s, H16s, and here was I wanting a V-8. I didn't see why a V-8 should not work, for I've discovered that in racing what you really need to win is dedication to the utmost simplicity.

'Even so, I had to swear the only people who knew, into secrecy. I said that if anyone stood up and revealed that it was going to be a V-8, it would be laughed out of court because everyone else seemed to be going for more complex engines.

'I was right. When we unveiled the engine in our Regent Street offices, in London, there was a bit of stunned silence at first.'

Keith Duckworth first went to work for Colin Chapman in the 1950s, then started selling him engines in 1959. The relationship was robust, rather than placid, but they could always do business with each other. No wonder there were smiles on this occasion — Silverstone, Easter 1967 — for the debut of the FVA-powered Lotus 48 F2 car.

There was, in fact, an enormous amount to be done if the engine was to be ready early in 1967 and Keith was quite determined to control every aspect of the design. At one time he came dangerously close to damaging his health, and it was only a serious, though temporary, problem with his eyesight which caused him to back off a little. Perhaps Walter Hayes' memory has taken on a touch of hyperbole over the years, but he insists that:

'I think that obsessive is a dangerous word to use, because I think the last word I would apply to Keith is "obsessive", but the fact is that at one time the pressure on him caused him not to leave his drawing board for nearly ten days and nights. But I could see why he did this – it was *his* engine, and it was a masterpiece. It was really a piece of unique sculpture.'

According to Mike Hall, whose contribution to the birth of the DFV should never be ignored, Keith never had any doubt that the new Formula One engine would work, first time, and give the predicted power.

'In our wildest dreams, we even hoped that it was going to win straightaway, but I don't think anyone really *expected* it to win, in Holland, on its first race.'

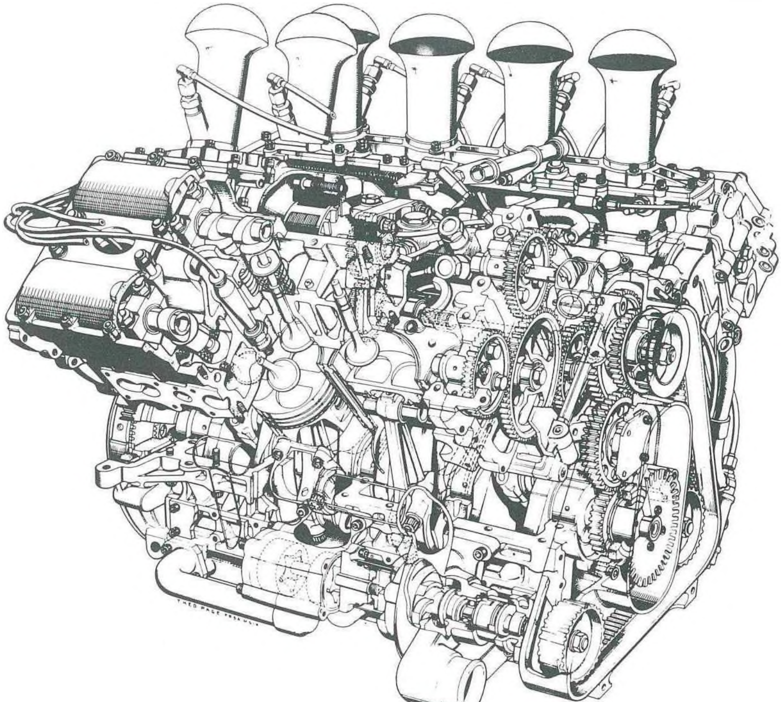
The torsional vibration problems which led to timing gear failures soon became known, as did problems with the lubrication system:

'Let's face it, the original system was a cock up. The oil drains and vents weren't sufficient, the "blow by" was trying to get up, the oil was trying to get down, they met in the middle, and it wouldn't drain. That's why we had those temporary external pipes on the early engines.'

The fact is, however, that Keith had expected the DFV to produce at least 400 bhp when it first ran up to power and that target was slightly exceeded at once. In the spring of 1967, therefore, Cosworth's problem was not to meet its performance targets for the engine that was to underpin its future, but to build the five engines demanded by the Ford contract.

While all this was going on, Colin Chapman was designing a new F1 car, the Type 49, and Walter Hayes had influenced a major change in the driving team:

'I had a bit of conflict with Colin Chapman when I insisted that he took on Graham Hill. With other teams, I had already observed that they had No. 1 drivers and No. 4 drivers, with nothing in between. I felt that this really meant that they produced one absolutely gorgeous car, and another that really was a lot less than gorgeous. I thought that if I could insist on two demanding drivers,



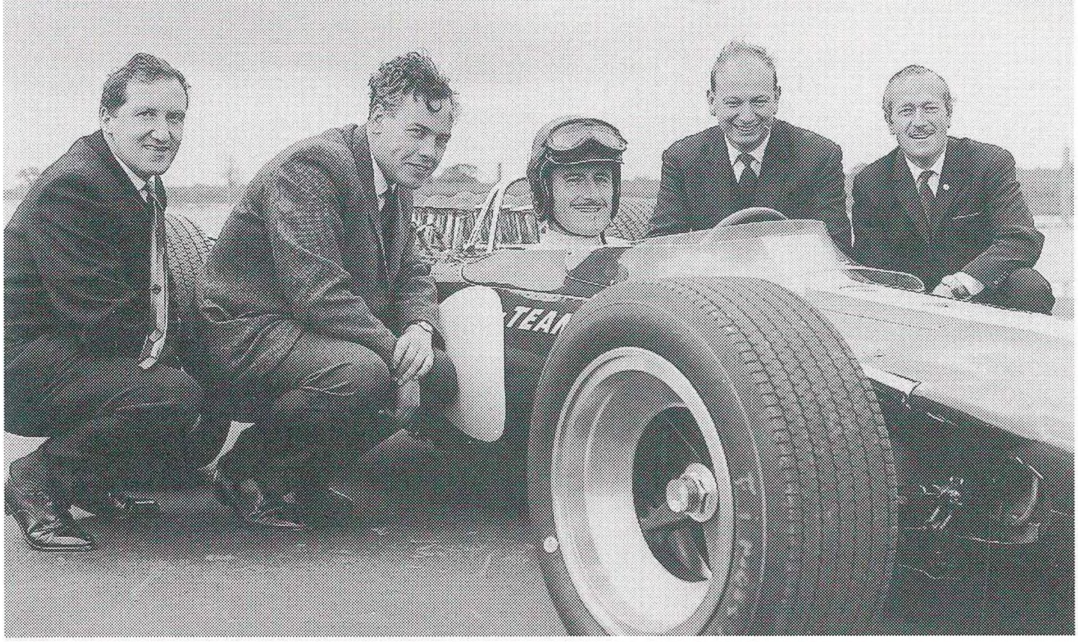
The original DFV of 1967, as shown in cutaway form. Students of engineering detail will see that the cylinder head layout was similar but not the same as that of the FVA four-cylinder engine, which preceded it.

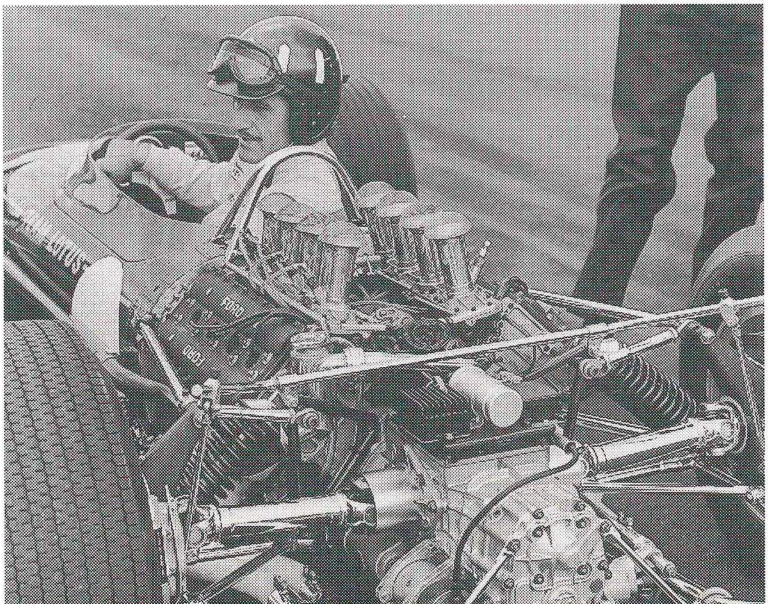
my engine could be in two first class cars.

'Jim Clark and Graham Hill were two great names, but I also wanted to make sure that there were two No. 1 cars to be driven. Well, of course, there was conflict as to who actually *was* the No. 1 driver, but everyone really knew that Jim was always tops in Colin's eyes, and Graham Hill was sensible enough never to argue with that. There were huge personal differences too – Jim was a ballet dancer in a car, while Graham was a real powerhouse; their driving techniques were completely different.'

The new Lotus 49's design relied on the DFV for much of its structural integrity, so it could not be completed much before the first unit was handed over on 25 April 1967. It was too late for the car to tackle the Monaco GP, but the first appearance was re-scheduled for the Dutch GP, at Zandvoort, on 4 June. Lotus, however, had a further problem with drivers. Jim Clark's earnings had risen so much that his advisers had told him to take a 'tax break' (to live out of the UK) for a year. Accordingly, he not only shared a flat in Paris with Gerard ('Jabby') Crombac, but he also had a place in Bermuda.

The honour of making the very first test drive in the 49 went to Mike Costin and Lotus mechanic Dick Scammell (who later became a much-respected director at Cosworth)





Above Smile please! The Cosworth-Ford powered Lotus 49, when unveiled in 1967, is surrounded by personalities — left to right, Maurice Phillipe (Lotus designer), Keith Duckworth, Graham Hill (at the wheel), Mike Costin and Colin Chapman.

Above right Graham Hill, Colin Chapman and Keith Duckworth, deep in discussion at an early Lotus 49 test session, Snetterton, May 1967 (*Phipps Photographic*).

Right This is a familiar picture, of Graham Hill in the original DFV-powered Lotus 49 of 1967, but it serves to show how neatly the engine had been integrated with the gearbox and chassis design. The ZF gearbox, incidentally, was originally the weak link in this innovative design.

also built up some mileage, but all the serious testing of the 49, thereafter, had to be carried out by the team's 'new boy', Graham Hill. Jim Clark's first introduction to the Lotus 49/Cosworth DFV combination was in Holland, before practice began, in a car which had not then turned a wheel!

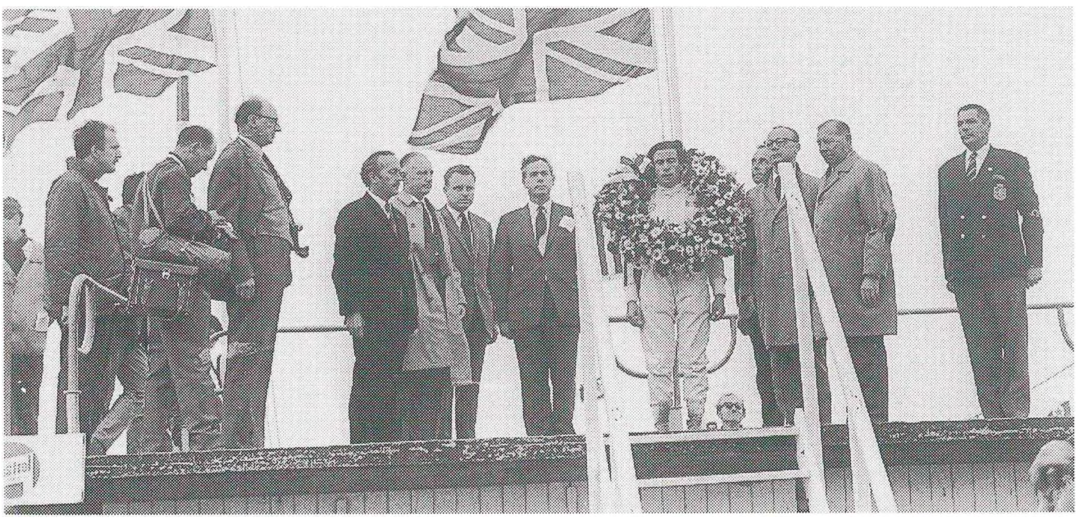
As everyone now knows, the Lotus 49, and the Cosworth DFV engine, made an explosive impact on Grand Prix racing. Graham Hill's car took pole position at Zandvoort, and no other type of car was to take pole position until a year later. In the Dutch GP, Graham Hill led from the start, but retired after eleven laps, the timing gears in his DFV broken. Clark, who had started eighth on the grid, soon took over the lead, and held it to the very end.

Ford, and Walter Hayes, might have hoped for a debut victory, but were not about to make a song and dance about the new engine at that stage – just in case there was a fiasco, or the engine (perish the thought) was not competitive. Walter Hayes played it all very quietly:

'I told Harley Copp that we should go quietly to Zandvoort to have a look. We hired a very light, single-engine, aircraft in Southend, and flew to Holland, where we were met by a car. That evening we dined with Ted Edwards, managing director of Ford Holland.

'We went to the track, we saw the victory, we shook hands, and then we slipped away. On the way back to Schipol airport we stopped the car outside a shop, bought two bottles of beer – no champagne, certainly not, we hadn't made any such plans – which we then drank in the car, on the way to the plane.'

With the British National Anthem being played at Zandvoort after Jim Clark's fine victory, Colin Chapman (dark-suited), Keith Duckworth (under the Union flag) and Jim Clark (nearly submerged by the winner's wreath) stand to attention (*Phipps Photographic*).



Right Lotus and Cosworth personalities confer at Zandvoort 1967 — left to right Jim Clark (in blue helmet), 'Jabby' Crombac, Keith Duckworth, Colin Chapman (in sun glasses) and Dick Scammell (then a mechanic, now a director of Cosworth) (*Phipps Photographic*).

Right Bird's eye view of the Ford-Cosworth DFV V-8, in the Lotus 49 of 1967. The location is Zandvoort, and the driver is Jim Clark.

Far right The stuff that dreams are made of . . . the DFV-powered Lotus 49 started its first F1 race, the Dutch GP of 1967, and won it outright. Jim Clark was the driver, while engine designer Keith Duckworth looks proudly on (*Phipps Photographic*).

Neither Hayes, nor Cosworth, did too much shouting about that first result, as they all knew how fickle the fortunes of motor racing could be. The DFV, indeed, had already shown its frailties – the lubrication problem would soon be sorted but the timing gear problems would not be eliminated for two or three years. Right away, though, it was clear that the Lotus 49/Cosworth DFV combination had changed the shape of GP racing. For the rest of 1967, a Lotus 49 led every race that it started, and by the end of the year there was still no challenge in sight.

Keith and Mike, whether they were prepared to admit it or not, were delighted that they had made such a startling entry into motor racing's top level, but Walter Hayes was not so sure:

'Almost at once I began to think that we might destroy the sport. I realized that we had to widen the market for the DFV engine, so that other teams could have access to it

Autocar: 8 June 1967

Part of Peter Garnier and Innes Ireland's joint report on the Dutch Grand Prix read:

'Jim Clark, driving the brand-new Lotus Cosworth-Ford 3-litre V-8 formula 1 car in its first race, scored a convincing win in last Sunday's Dutch Grand Prix at Zandvoort – leading the race unchallenged from the 16th of its 90 laps. Graham Hill had put up an equally impressive performance in the second of the Lotus-Fords during practice, securing pole position on the grid . . .

'Colin Chapman produced yet another masterpiece in racing car design. It is what one might truly call 'a new car' . . . The new Cosworth engine is obviously giving well over 400 hp, and is a beautiful example of brilliant thinking and engineering . . .'

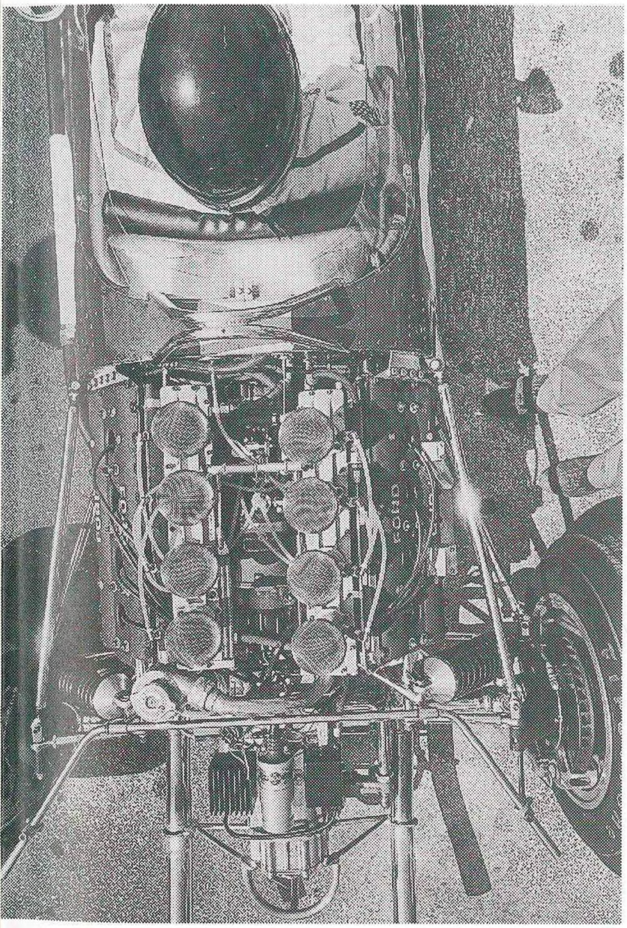
Autocar: 15 June 1967

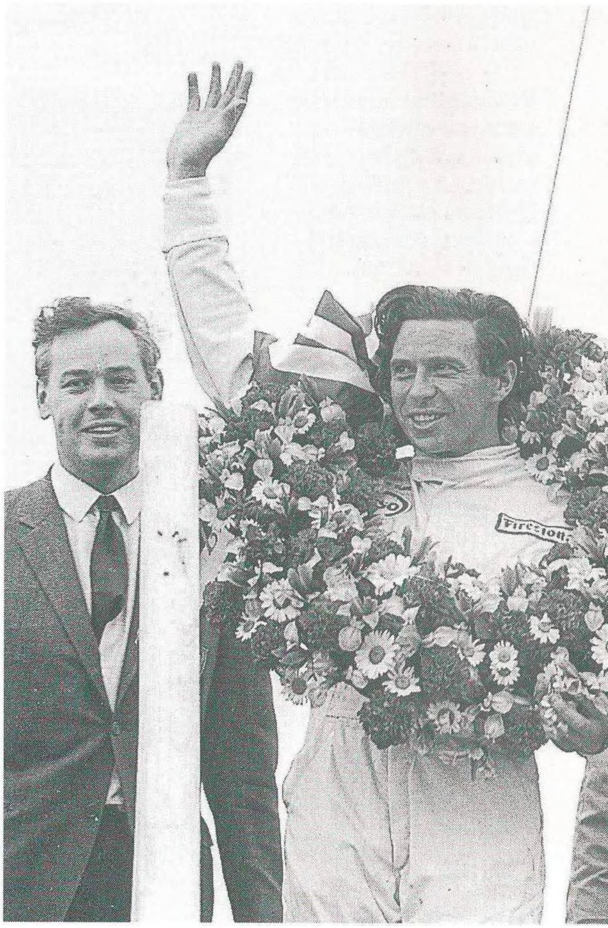
In Eoin Young's 'Straight from the Grid' column:

'I gather there is no truth in the rumour after the Dutch Grand Prix at Zandvoort that Formula 1 will now be called Formula Ford. But judging by the looks on people like Jack Brabham, Ron Tauranac, Raymond Mays and Bruce McLaren as they surveyed the new Lotus, the rumour did have a spark of feasibility.'

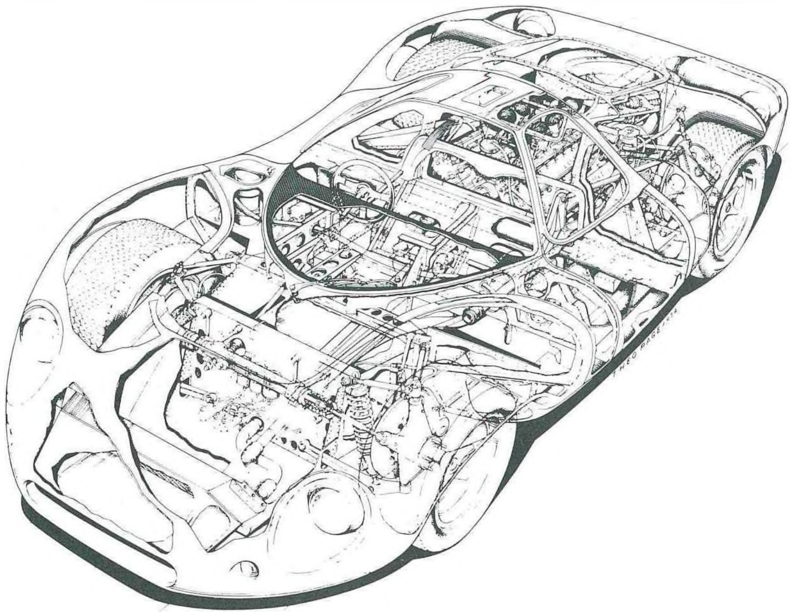
At the end of that 2hr 15min race, Jim Clark's Lotus 49 had not only won by 27 seconds, but it set new Formula One performance standards into the bargain. The DFV era had begun.


Firestone

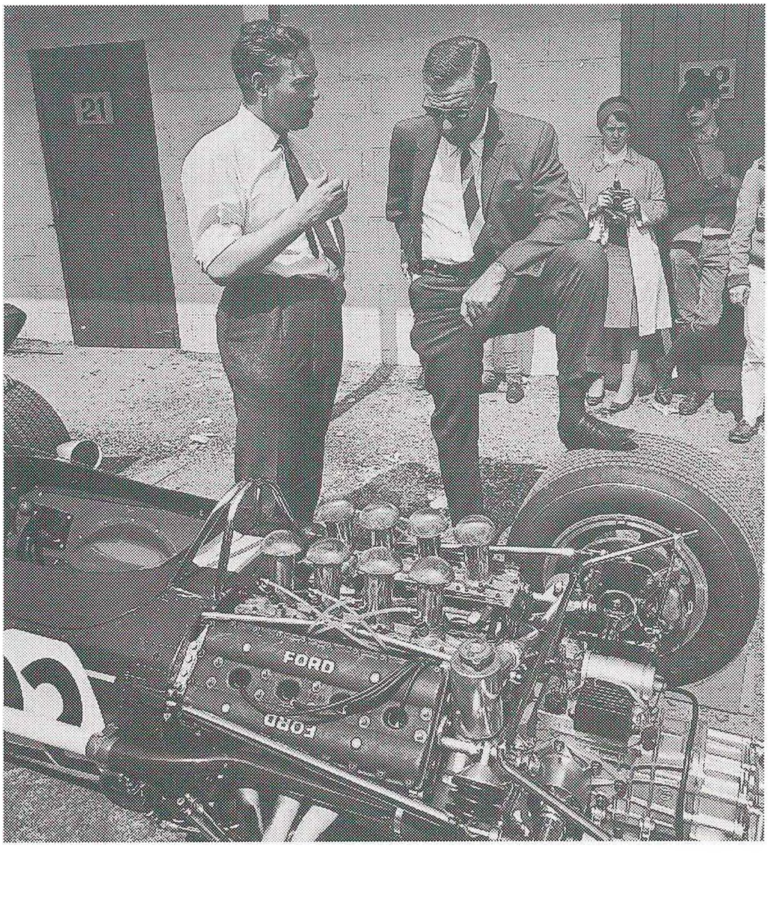



Firestone

The first two-seater to use a Cosworth DFV V-8 engine was the Ford F3L of 1968. Although it looked sensational, and was occasionally very fast, it was never lastingly successful. Quote from Keith Duckworth: 'If they *wanted* an endurance engine, I would have *designed* an endurance engine . . .'



Keith Duckworth, the designer of the Ford-Cosworth DFV, making a point to Harley Copp, who was Ford's technical chief at this time.



Walter Hayes of Ford was always happy when his contractees made enough money to buy expensive toys. In front of Colin Chapman's Piper Comanche aircraft are Bette Hill, Ursula Duckworth, Colin, and Keith Duckworth (*Phipps Photographic*).

1968. In the next-to-last race of the year, we went to Watkins Glen. It was the first time we had raced in the States, and since we had got our money from there, I was particularly anxious that we should shine.

'Jimmy and Graham were particularly foolish in practice, blowing one another off from pole position. It was at that point that I said to Chapman: "Will you please tell your drivers to report to me, in my room". I was playing the headmaster, but on that occasion I *had* to.

'They came to my room, and I said, "Right, we are now going to decide who is going to come first, and who is going to finish second". There was no argument about this, and don't forget that I was talking to two of the best drivers in the world. Even so, Keith says that he had never heard anybody in his life say such a thing.

'I tossed a coin, Graham called, and Graham won. At the moment I said: "Fine, Graham, you can come first, and Jimmy, you come second".'

Except that Murphy's law then intervened, for Graham's ZF transmission began to give trouble during the race, Clark led until it was too late for 'team orders' to be applied, and even then his car almost let him down when a rear suspension link failed. Lotus and Ford got their expected one-two, but not in the order agreed in the Glen Motor Court on the previous day!

On his way back from Watkins Glen, with the race trophy cradled on his lap, Walter Hayes recalled his original forecast for the Cosworth DFV to the Policy Board: 'In my opinion it will win some GPs, and I also think that it will win a World Championship'. One half of this prediction had already been justified. The second would follow in 1968.

Belt-drive – BDA and its successors

'He *had* to be a great character, the whole Cosworth thing wouldn't otherwise have worked . . .'

'You can't believe how quickly I arranged for an engine to be slotted into an Escort. You should have seen Stuart's face when I showed it off, and as for Walter Hayes . . .'

'By the mid-1970s BD work probably accounted for about half of our turnover.'

'Alf Vickers put sufficient organization into us. I really do not think we could have built 100 GA V6s without his advice.'

Once the DFV had proved itself in Formula 1, Cosworth suddenly found that it was famous. Companies which had previously ignored the company suddenly began to offer work, and several ambitious young men started asking for jobs.

When Ford decided to make the DFV engine available to other teams, it put the business under strain. In no time at all, the original buildings were full, and an extension had to be erected. Before long, too, that was full, and yet more buildings were put up in Northampton. This put Keith and Mike in a real dilemma. They had never planned a massive business expansion, but they were certainly not willing to turn away good business at this time.

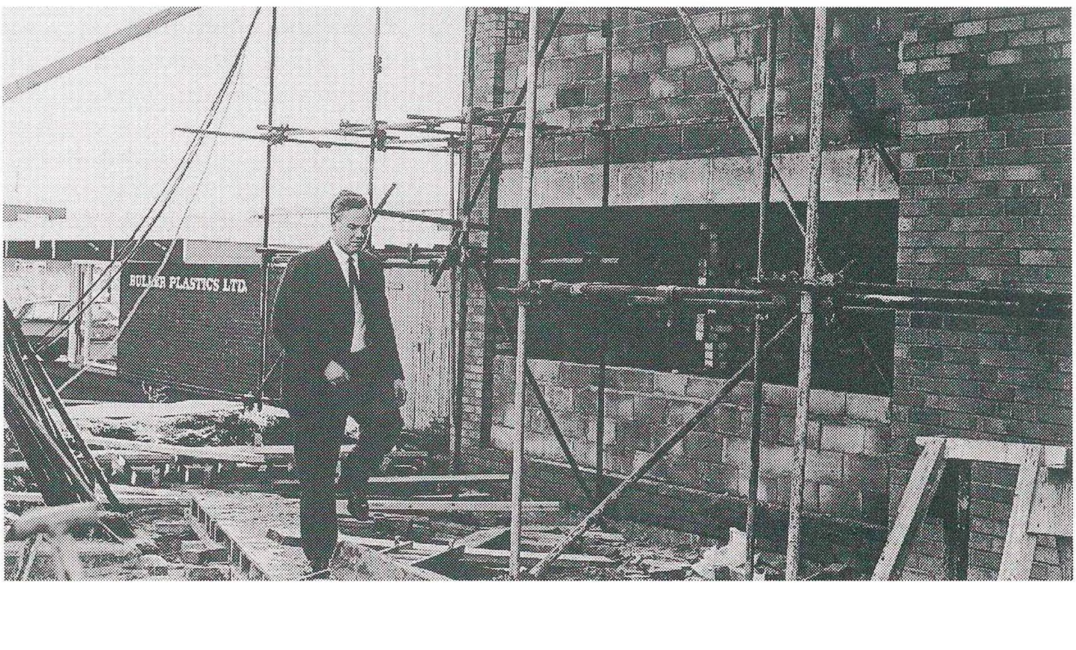
It would have been ludicrous for motor racing's most fashionable business to carry on operating as a £100 limited company, but Keith, in any case, had already taken steps to change Cosworth's financial structure. Even while the FVA/DFV design and development programme was going on, in 1966, for the first time since Cosworth Engineering was set up in 1958, the issued capital was increased – from £100 to £1,000.

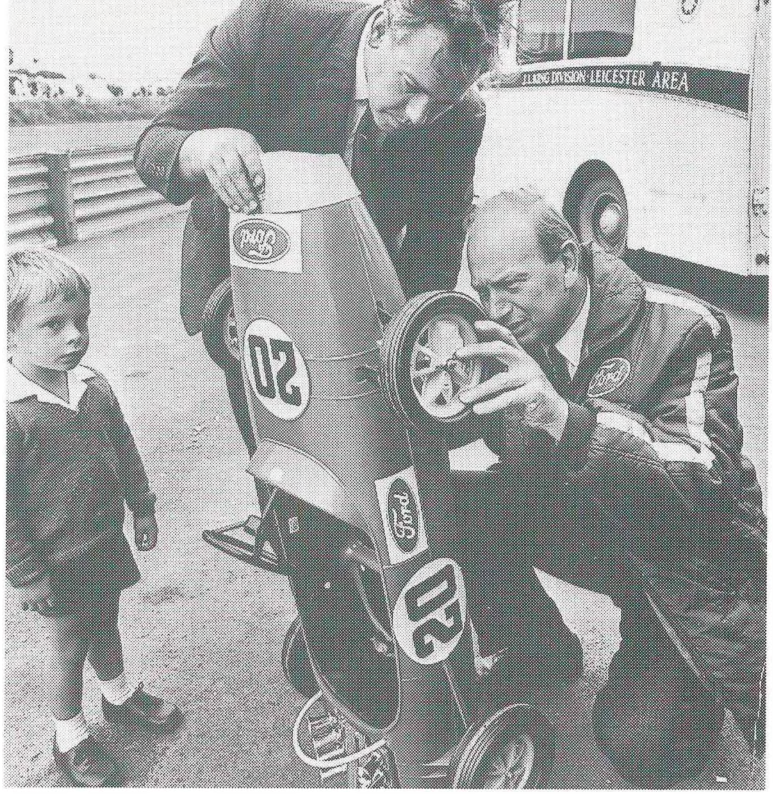
Mike Costin, Ben Rood and Bill Brown's families all received shares in this expansion, and the company's structure was therefore stabilized for the next decade. Keith, however, saw no need to look around for other sources of money – as ever, he was much the largest shareholder in the business. Even so, Cosworth was still a small company. In the financial year ending 30 April 1967, Cosworth Engineering's annual turnover was £380,470, and its after-tax profits were £44,238 – though that profit was nearly 50 per cent higher than it had been a year earlier.

Keith's 'Jewish accountancy' methods had clearly worked well in the early 1960s, for the company's reserves were no less than £112,188. [For comparison, by 1967 Lotus was a much larger company, and was making at least five times as much money as Cosworth – in 1967 its pre-tax profits were £324,000.]

The huge success of the DFV, especially by 1969, when it began to be supplied to teams like McLaren, Tyrrell, Alan Mann, Frank Williams and Brabham, and the continuing success of the FVA and all the pushrod engines, all helped to expand the business. The 1967 financial figures were soon left behind. In the year ending

The new Northampton factory had looked large enough when built in 1964, but within five years Cosworth had outgrown it. Here, at the end of the decade, Keith Duckworth picks his way around the half-completed site of 'Factory 2'.





Serious motor racing! Keith and Mike deal with the 'setting-up' of young Roger Duckworth's model race car, at a Fordsport day at Mallory Park.

30 April 1968, after-tax profits surged ahead to £71,035, and a year later that figure increased, yet again, to £111,396.

Cosworth was, as Keith has always been proud to repeat, a remarkable and efficient little company – not only successfully in business to make racing engines, but always expanding, and always making a profit. It was also an essentially practical, and down-to-earth business, and the directors knew that new work would always be needed to keep the designers, and the workforce, occupied. By mid-1967, with the DFV not even blooded on the race tracks, another major design project – the BDA – was under way. Mike Hall, who shouldered the entire design job, remembers it like this:

'It all started in May 1967, very much as a "handshake job". Harley Copp, who was director of engineering, Walter Hayes, and Henry Taylor, who was competitions manager, were in on it. For a time, very few people at Ford knew about it. I only dealt with Henry Taylor. It was all rather informal. I don't think there was a written contract, but Ford gave us some money [Keith remembers it as £40,000, and a £1 royalty on every engine subsequently made], and asked us to build about ten complete engines.

'There was no specific performance target, though naturally it had to be better than the Lotus-Ford

Twin-Cam. We aimed for 120 bhp for the road car's engine, which it achieved quite comfortably. At the time we even found that it would run on 2-star petrol.

'There was never any intention, though, that Cosworth would build the engines in quantity. Ford was going to look after that – we were just the design and development contractors. We started in May 1967. I designed the whole thing, with the help of three or four detailers, and the first engine must have run in June 1968. That, by the way, included developing all the patterns, and as we didn't have a foundry in those days we had to get heads cast by Aeroplane & Motor, in Birmingham.'

This was the genesis of the famous BDA engine, the Ford-based 16-valve twin-cam unit which was to mean as much to Cosworth, and to Ford, in the next two decades, as did the DFV. Lovers of 'Cosworth-speak', by the way, will already know that BDA means 'Belt-Drive, Series A' – a description which refers to the way the camshafts were to be driven.

'Basically, it was a requirement for a 4-valve, four-cylinder engine, the productionized version of the FVA Formula 2 engine, for use in a road car. It was to replace the Lotus-Ford Twin-Cam, and it had to be suitable for racing, for rallying, and for use in a road car. All the work we did here, initially, was for the engine to go into a Lotus-Cortina. In fact the first road work we carried out was in two Lotus-Cortinas – I ran one of them for around 40,000 miles.'

This was the first of several Cosworth engines to be completely designed by Mike Hall, who recalls that, in 1967:

'The BDA was my first total job, here. Keith was totally pre-occupied with the development of the DFV, which had timing gear problems, and the like. He was away from Northampton a lot, at the races, and he liked to be able to concentrate on everything that was happening with the DFV.'

Keith Duckworth confirms this:

'I made suggestions as to how it should all be done, and what should be changed from the FVA, but Mike Hall did all the actual designs.'

It might be romantic to suggest that the BDA was a 'productionized FVA', but the truth is much more mundane. Except that both engines used Ford 'Kent' family cylinder blocks, twin overhead camshafts, four valves per cylinder and valves opposed at 40 degrees, they were almost completely different in detail.

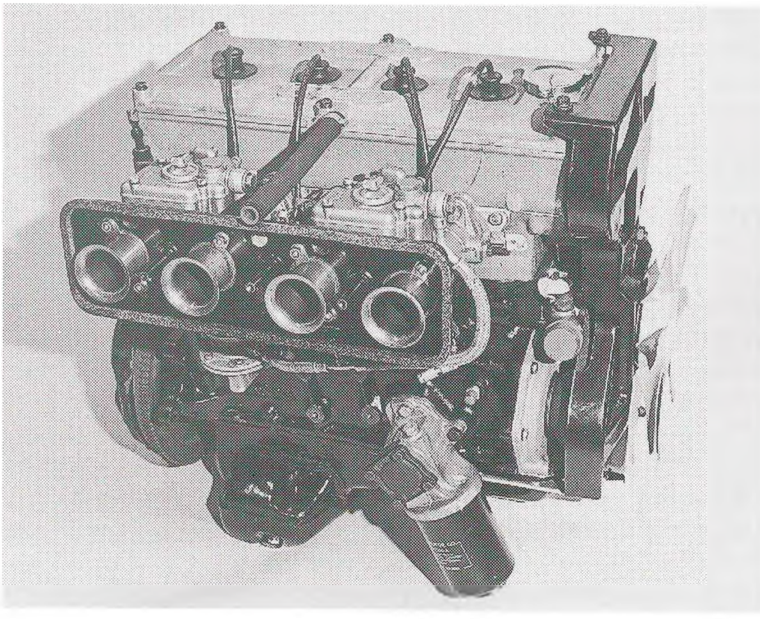
The Formula 2 FVA, after all, had been designed around the 1,500 cc cylinder block of the current Cortina GT, and had extremely oversquare, non-standard, bore/stroke dimensions, whereas the BDA was to be designed around the taller 1,600 cc block, retaining the same bore and stroke.

'The head, basically, was very similar to the FVA,' Mike Hall told me. 'It had the same valve angles, though the valves were different sizes, the ports were different sizes, and they had to be aligned so that they would easily fit a road car.'

When the engine was unveiled in 1969 the real surprise, for the pundits, was to see that cogged belts were used to drive the camshafts – for this was the first use by a British concern. Glas had been the first company to fit cogged belts to its production engines, but the seal of approval had come from Fiat, in 1966, when a belt was adopted for the new twin-cam engine fitted to the 124 Sport Spider. At Cosworth Mike Hall, rightly, claims the innovation for himself:

'Belt drive was fairly new in those days. It was my idea to use it. It was fairly obvious that we couldn't use the gear drive from the FVA engine, because apart from the expense it was also very noisy. This engine, don't forget, had to be used in road cars as well as in motorsport.

[Keith emphasizes the noise problem by quipping that: 'at odd periods you get gear crash occurring and it makes a



The BD-Series engine was designed for Cosworth by Mike Hall, and was the first Cosworth engine to use belt drive to its camshafts. It had a phenomenal life, being built in many different versions for two decades. This was the original Escort RS1600 installation of 1970.

noise enough to wake the dead . . .']

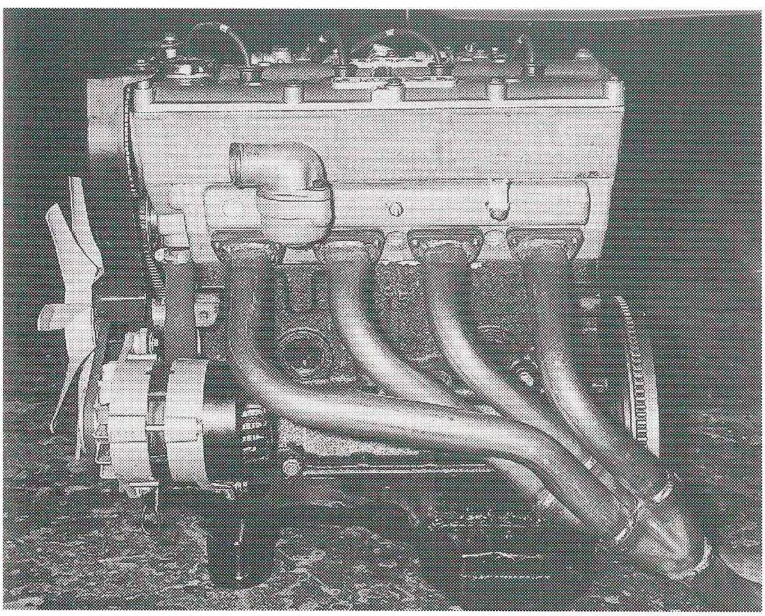
'There was a choice between a chain, and a belt, but the belt proved to be very light, efficient, and quiet. Obviously we talked a lot to Uniroyal, right from the start, but what worried us all was not the efficiency, but whether the belts were going to survive.

'Completely unbeknown to me, it turned out that the belt I needed from Uniroyal, to fit my design, happened to be exactly the same length as that Fiat was using in the 124 Sport engine. How convenient – it saved us a lot of development time and money.

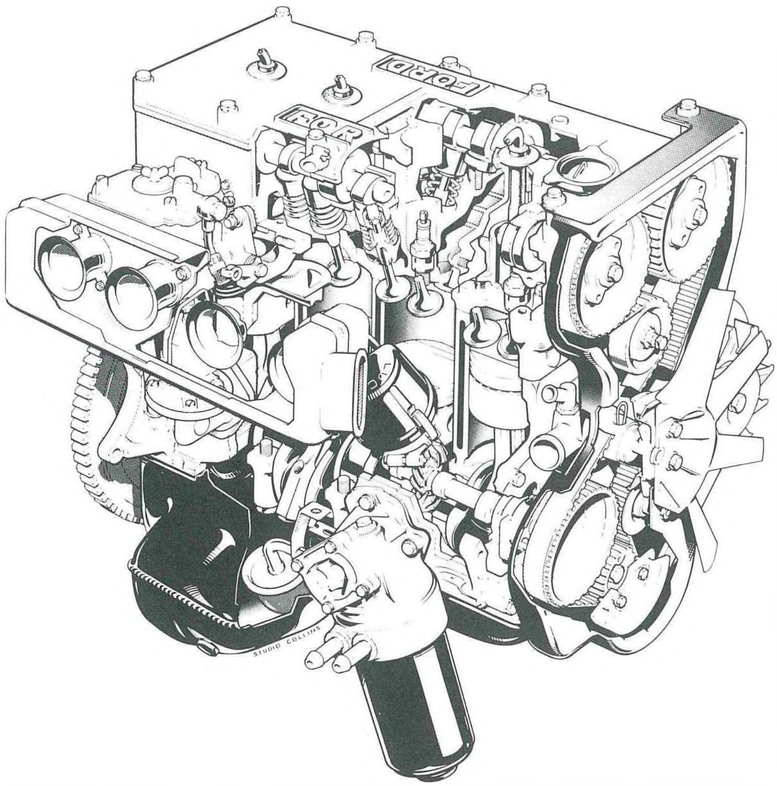
'Once we had increased the width of the belt, and added an extra idler to give sufficient belt "wrap" there was never any belt problem with the BDA. Even in the 1980s, though, I notice that certain people continue to have trouble with their belt drives . . .'

He was much too much of a gentleman to spell out which engines he was referring to.

Then, as later, Cosworth was never willing to do a rush job, a bodged job, or merely 'make do' by modifying an existing design. To modify the FVA was never even considered, as the list of changes summarized by Mike Hall makes clear – the head casting was new, the exhaust ports curled over, the water flow was utterly different, the cam carrier design was simplified, the valve actuation was changed, the oil flow along the head was different, there were carburettors instead of fuel injection . . .



The BDA engine combined 4-valves-per-cylinder with very good gas flow, while exhaust systems like this all helped. It set the 1970s' standard which other manufacturers took many years to match.



This Ford cutaway drawing shows that the design of the BDA engine, though influenced by what Cosworth had already done, was very different in detail. It was not, repeat *not*, a 'productionised version of the FVA'.

It was, in effect, a new engine using race-proven principles. Not only that, but it would soon become a very effective competition engine. Keith and Mike both thought that the bore/stroke ratio was unfavourable, and would hinder its potential, but they were amazed to discover that it would rev very fast indeed.

When what Keith describes as an FVA/BDA was built (FVA bottom end, and much over-square layout, mated to a fuel-injected BDA top end), it produced 238 bhp in its first power test, which was at least as much as any 1.6-litre FVA had ever produced. Which was better? The ever-diplomatic Mike Hall puts it this way:

'I think there was very little between them. If anything the BDA could have been slightly better, and I think that was *only* due to the efficiency of the cam belt system – a belt instead of a lot of gears all churning around.'

Like several other engines, or derivatives of its own engines, that Cosworth was to design in the 1970s and 1980s, there was never any question of the BDA being built in quantity at Northampton. The factory, quite simply, was not intended for series-production use.

At first it looked as if Ford didn't know how to use the new engine. Cosworth's original commission had been for an engine to replace the Lotus-Ford unit, which at the time was only used in the Lotus-Cortina. Nothing came of that. Then, in time for the launch of the Capri in January 1969, Ford built a handful of BDA-engined Capris. 100 such cars, it was suggested, might be built. Cosworth built 32 engines but nothing came of it.

It was not until Ford's new competition manager, Stuart Turner, met Keith Duckworth over dinner at the author's home in the Midlands, that the definitive solution was hatched – the BDA would find a home in the Escort in 1970. You could say that Keith and Stuart took to each other in a big way, that evening, for they talked for hours about every aspect of motorsport. As Stuart later commented:

'I've always been lucky to work with great characters, because otherwise business can be too grey and dull. Keith was a great character, no doubt about that. The very first time I ever saw him in a Ford environment, he was arriving at Dunton [the Ford design centre in Essex] in his helicopter, and there were firemen everywhere in their gleaming brass helmets, with a beaming Duckworth grinning at the hilarity of it all – it was almost like a Royal visit, and he loved that . . .

'Once I got to know him well, I tried to get an agreement with him – every time the DFV engine won a race we would call it a Ford, but every time it failed we would call it a Cosworth! I really can't see why he wouldn't have that. He *had* to be a great character, the whole Cosworth thing wouldn't have worked otherwise. If you're going to motivate a roomful of engineers to create something in your image, you've got to be self-confident.

'Keith was always confident in his own abilities, but I never found him arrogant, though I gather other people did. He was humorous, entertaining – but he could also be boring, can't we all? The problem, though, was that he used to get bees in his bonnet. If I wanted information from Cosworth, and I was in a hurry, I tended to call Dick Scammell for a mere twenty-minute chat, because I didn't have time for a short "talk" with Keith.'

As far as Cosworth was concerned, however, the BDA then took on a life of its own. In the initial stages Mike Hall wrote out all the specifications, consulted with Ford on the question of making all the pieces, but was not originally involved in building engines or supplying parts:

'In those days we were still very small. We couldn't have made the parts anyway. We were up to our ears trying to make DFV parts at the time. I know it doesn't sound very romantic, but here was a job, we did it well, then we handed it over to Ford, and thought: "Right, that's that, let somebody else have the job of producing the engines." Harpers of Stevenage – they had once built Vincent-HRD motorcycles – were the first to assemble engines for RS 1600s, but several other companies later got involved.

'But yes, of course, it was, and it still is, an engine to be proud of. I certainly didn't lay it out to have an incredibly long life, or for an incredible number of derivatives to be made. Somehow, it just snowballed into the "Meccano set" that we now have. We still make a lot of versions, one way or another. By the mid-1970s, indeed, BD work probably accounted for about half of our turnover!'

Ford, in fact, was very relaxed about the modification of the BDA engine, not only by Cosworth, but by several other companies. Some of the most successful derivatives of the original BDA – the aluminium cylinder block, and the turbocharged versions, for instance – had little or no connection with Cosworth. Even at the end of the 1980s, twenty years after the BD series was designed, Cosworth was still building kits in their hundreds, and parts in their thousands. More than any other race engine supplier, Cosworth diligently services its old engines, as Jack Field told me in 1989:

'People have got to the stage where they *expect* Cosworth to be able to supply the bits they need, even if they're not exactly sure what type of engine they've got. We have our pride – not only do we like to supply parts (it's very profitable, you know), but we always like to be able to supply the correct bits too.

'I could still supply pistons, gasket sets and valves for MAEs and single-cam SCAs, even a few bits for Lotus-Ford twin-cams. But we're still building complete new BDs, or should I say complete kits of parts to build BDs: if you look across the road, in Ben's machine shops, you'll see new cylinder head castings being machined.

'At the moment [1989] our turnover on BDs is still going up. We've done quite a lot for Caterham, for the Super Seven, then we supply BDPs to the States, to run on methanol. There are probably 1,250 complete BDPs out there in the States, running and winning races.'

Once the BDA engine was up and running in the early 1970s Cosworth, and several other concerns, started the never-ending business of race and rally-tuning it. One way to gain power, of course, was to enlarge the engine,

Stuart Turner became Ford's competitions manager in 1969, and soon persuaded his bosses to fit Cosworth's new BDA engine to the Escort body shell. The result was the Escort RS1600 and the rest, as they say, is history . . .

which Cosworth speedily began to do.

In rallying, if it had not been for Stuart Turner's devious mind, there might have been no incentive to make the engine bigger, as the original BDA engine was a 1.6-litre unit, right up against the class capacity limit. Stuart knew that Twin-Cam success had always been frustrated by this class limit, and he was determined that it should not happen again. Keith Duckworth now takes up the story:

'By a strange and very lucky coincidence we found that top tolerance engines with the longest strokes and the biggest bores slipped over the class limit to 1,601 cc. Well, of course, it would have been quite *unfair* to allow the engine to be homologated in a smaller class, so we had it approved at 1,601 cc instead!'

The tolerances in question were minimal, and in fact the BDA used the same engine bottom end as the 1,598 cc Cortina GT/Capri GT pushrod unit, but no-one seemed to mind. Publicity material, and the homologation forms, quoted a marginally longer stroke, and the job was done. For the next few years, however, there was a struggle to gain more capacity, as there was a definite limit to the enlargement of cylinder bores without ruining the integrity of Ford's cast iron block. Cosworth, on the other hand, was adamant that an increased stroke dimension was not the way to go.

Ford's engine specialist, Peter Ashcroft, nagged away at the foundry to make changes to the cores, eventually getting his way, which explains why a special casting known as the 'Ashcroft block' eventually came along. But there was more to come, from an outside source. Brian Hart, once one of the stalwarts who had helped to build the Northampton factory test cells, eventually pulled out of racing, and founded his own engine-building concern in Essex:

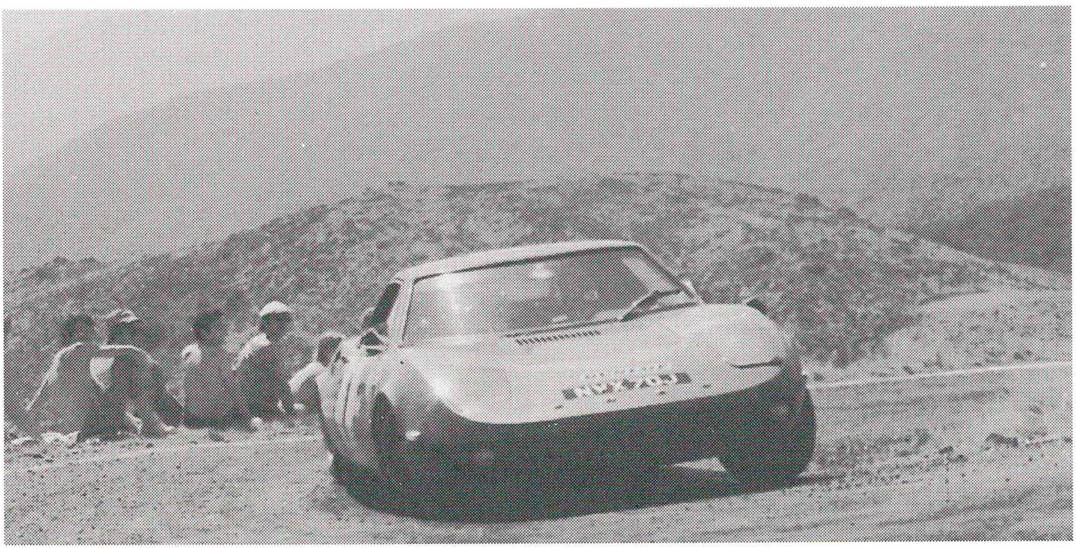
'I stopped racing for Team Lotus when I realized how slow I was, compared with Jim Clark, then I moved down to Harlow, set up Brian Hart Ltd, and started by servicing the highly-successful FVA Formula 2 engine.

'Then we started working on BDAs – there were plenty of parts available from Cosworth, it was really *the* kit engine of the 1970s – but I soon saw that it needed to be larger, and that the cast iron block was the limiting factor.

'We could recognize a need for a new 2-litre sports car, cum Formula 2 engine, and because of this I started looking at the BDA engine. I may have been over-confident at the time, but it worked – as I was drawing-board trained, and I had already done quite a lot of design work at Cosworth, I decided that I knew enough to design a light-alloy version of the cylinder block, with siamesed bores and other changes. I also did away with liners – we ran the pistons direct in the bores, which were direct plated. That gave me 2-litres, right away, and it was a lot lighter too.'

It was a complete 'private-enterprise' project, but no

Ford's mid-engined GT70 rally car, if it had gone into production, would have been powered by the BD-Series Cosworth engine. The car looked good, but never fulfilled its promise.



sooner had the first block been cast by Sterling Metals, and machined at Harlow, when fate intervened. Early in 1972, when Peter Ashcroft was on one of his regular visits from Boreham, he actually fell over the evidence, in the workshop. Brian remembers that he actually tripped over the casting, and exclaimed: 'What the devil's that?'

Peter looked at the block, was immediately impressed, and:

'You can't believe how quickly I arranged for an engine to be slotted into an Escort. You should have seen Stuart's face when I showed it off, and as for Walter Hayes . . .'

Within months that block had been adopted by Ford, put into production for late-model RS 1600s (and, to follow up, in the RS 1800s), and eventually became a very major alternative to the cast iron block used in many of Cosworth's own kits. Keith, being Keith, did not rush in to give this new block his immediate acceptance, for he had a serious objection to siamesed cylinder bores, and their effect on the integrity of cylinder blocks – in fact it is a feature he will never willingly design into a new engine. Brian thinks that it took years for Keith to come to terms with the merits of this block, but knows that eventually he was won round. Mike Hall confirms that Keith originally didn't approve of the aluminium block:

'I think it's fair to say that the *whole* BD engine project suffered a bit from Keith's NIH ('Not Invented Here') attitude. It was invented at Cosworth, but really not by Keith. He was never very interested in it. 'Keith's standards are very demanding. He admits that sometimes he finds it difficult to give credit to anyone for doing a good job. But then I did the next job, and the next job, and I'm still here, so I guess he respects what I do.'

GA – Cosworth's first V-6 project

In the early 1970s Walter Hayes decided to move Ford of West Germany into motor racing, with the motorsport department successfully developing the Capri RS 2600 as a Group 2 touring car. But it wasn't easy, as Walter Hayes recalls:

'I tried to find a German Ralph Broad, or an Alan Mann, but there wasn't that sort of cottage industry in West Germany. I had to come back to the UK for that.'

The original Capris used German V-6 engines, which were race-tuned and developed by Harry Weslake's concern in Sussex, but by 1972 it was clear that the engine was running out of stretch, and potential; it was stuck at

Mike Kranefuss first came into contact with Cosworth when he was running race Capris for Ford of Germany. Cosworth designed the GA V-6 engine to power these successful touring cars. Later, in the 1980s, he had moved to Detroit, and commissioned Cosworth to produce a turbocharged V-6 F1 engine.

about 320 bhp. A bigger and more powerful engine was needed. Fortunately, a change of regulations allowed manufacturers to use alternative cylinder heads in touring car racing, but at least 100 sets of parts had to be built to allow homologation to go ahead.

'I first met Keith when we were running BDA-engined Escorts in European Championship races,' Mike Kranefuss recalls. 'My English wasn't good enough, then, to realize the stories he was telling – but people around me would suddenly start grinning and laughing, or even looking upset – I improved, later.

'By this time he had produced the DFV, which was winning everything, and everyone I knew was in awe of him. So, when I first visited him in Northampton, I was expecting him to be in a welcoming and wonderful office – but I found that it was crummy and small instead.'

'He never struck me as a man who was completely sure of anything. He seemed to have an unbelievable talent for swallowing all the influences, all the elements which would eventually let him decide what he thought the best engine solution was, and we could never really get a straight answer out of him, certainly not immediately.

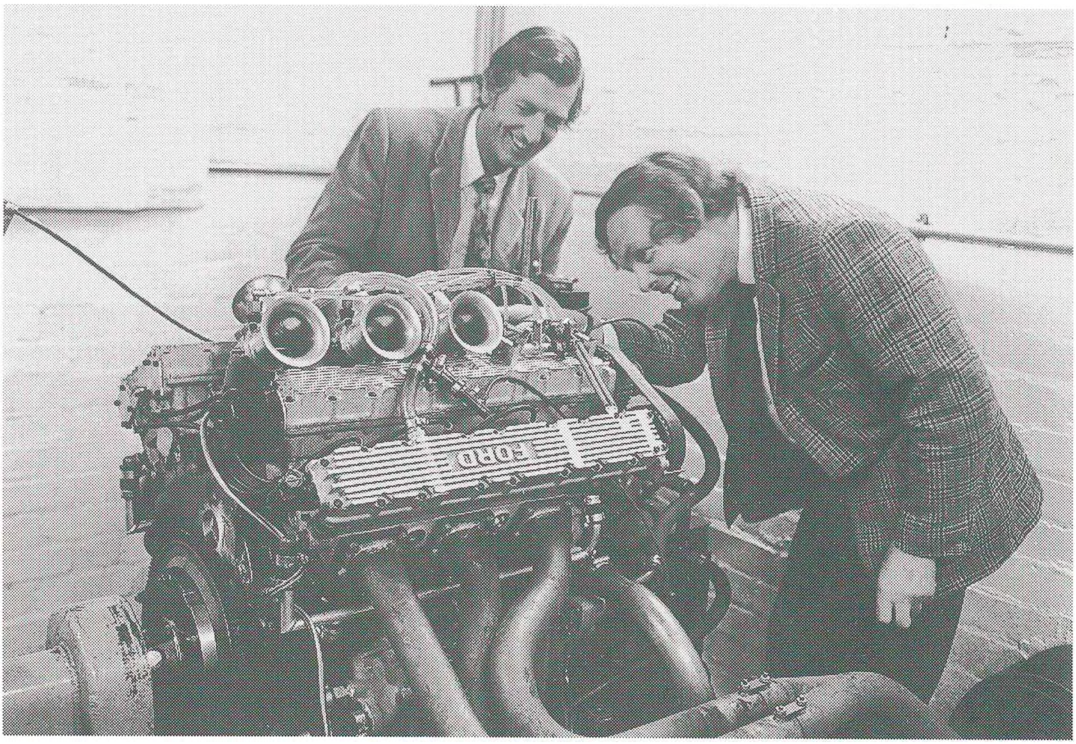
'If I asked him a question – if *anyone* asked him a question – there wasn't one answer. There were several different answers.'

Even so, Kranefuss was impressed. In 1972, Ford decided to abandon the Ford-Cologne V-6, and to use the entirely different Ford-UK 'Essex' V-6 engine instead. Cosworth was commissioned to 'do a BDA', to design a four-cam engine conversion for the 'Essex' engine, with a target of more than 400 bhp! This was the Cosworth GA project, an engine which was designed completely by Mike Hall.

It is now well-known that Ford and Cosworth had a great deal of trouble with this project. There were two interlinked problems – one was that Ford wanted to push the capacity of the racing engine out from 3.0-litres to 3.4-litres, the other was that the production cylinder blocks had very variable castings. The standard engine, of 2,994 cc, used a cylinder bore of 93.66 mm, but Ford wanted that to be increased to 100 mm for the GA racing application. Although theoretically there was a great deal of cast-iron 'meat' in the metal surrounding the bores, this was a near-impossible task, as Mike Kranefuss confirms:

'Out of 200 blocks we took from the foundry, we ended up with only one or two which survived the machining process. There were moments when Keith was absolutely disgusted with the whole business. He couldn't relate to

Mike Hall (designer, behind the engine) and Bill Brown, find much to amuse them in the Cosworth testbed, where the new 24-valve GA V-6 is on test in 1973.



this sort of awful quality, the unions didn't like us going into the factory to try to sort it out, and Keith simply couldn't stand stupid people.'

Keith makes the valid point that, in any case, production engine castings are rarely strong enough to cope with the stresses of racing engine horsepowers. After all, he says, if a casting can put up with two or even three times the power, without breaking up, then it must have been badly overdesigned in the first place.

[When I then suggested that BMW must have been proud of its four-cylinder block, which was used as the basis of the turbocharged F1 engine, Keith flatly refused to believe that the block used *was* standard, or even nearly standard.] Mike Hall told me that Cosworth had to 'fiddle around', within the regulations, to make the block live, that four-bolt bearing caps had to be used, but that blocks still failed. Nevertheless, Mike did a great design job:

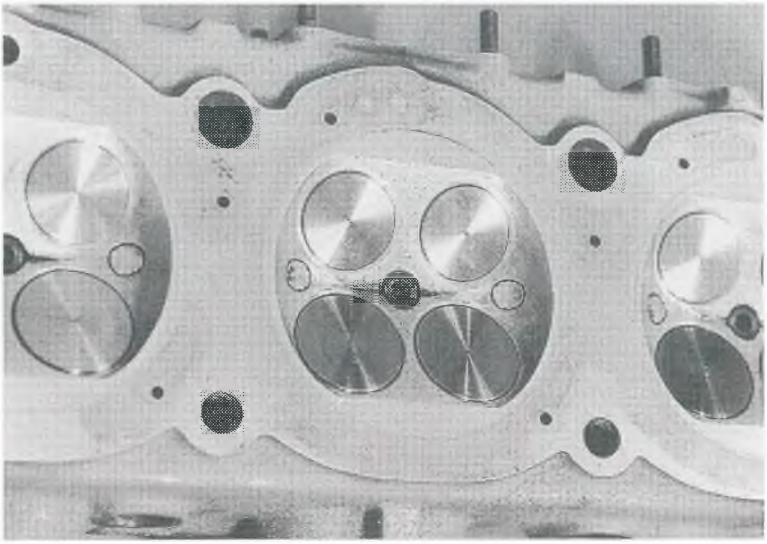
'This was my favourite engine; I was proud of what I did. I designed a cylinder head which could be used on both banks – there was just one cam carrier casting, and one cam cover casting too. The cams were belt driven, in fact the engine looked to be festooned with belts.'

Much of the 'bottom end' detailing, crank balancing, and related work, was done for Mike by Graham Dale-Jones. Except that the machined faces were not parallel with the cylinder head face, the general layout of the GA's top end was like that of the famous BD, for it had four valves per cylinder, a central sparking plug position, and a valve-included-angle of 40 degrees. The camshaft profile used was the same as that also employed on the Chevrolet EA, and the racing BDG engine.

In fact there was provision for up to three plugs/cylinder in the design, but tests showed that this arrangement provided no more power and torque than the classic single plug layout.

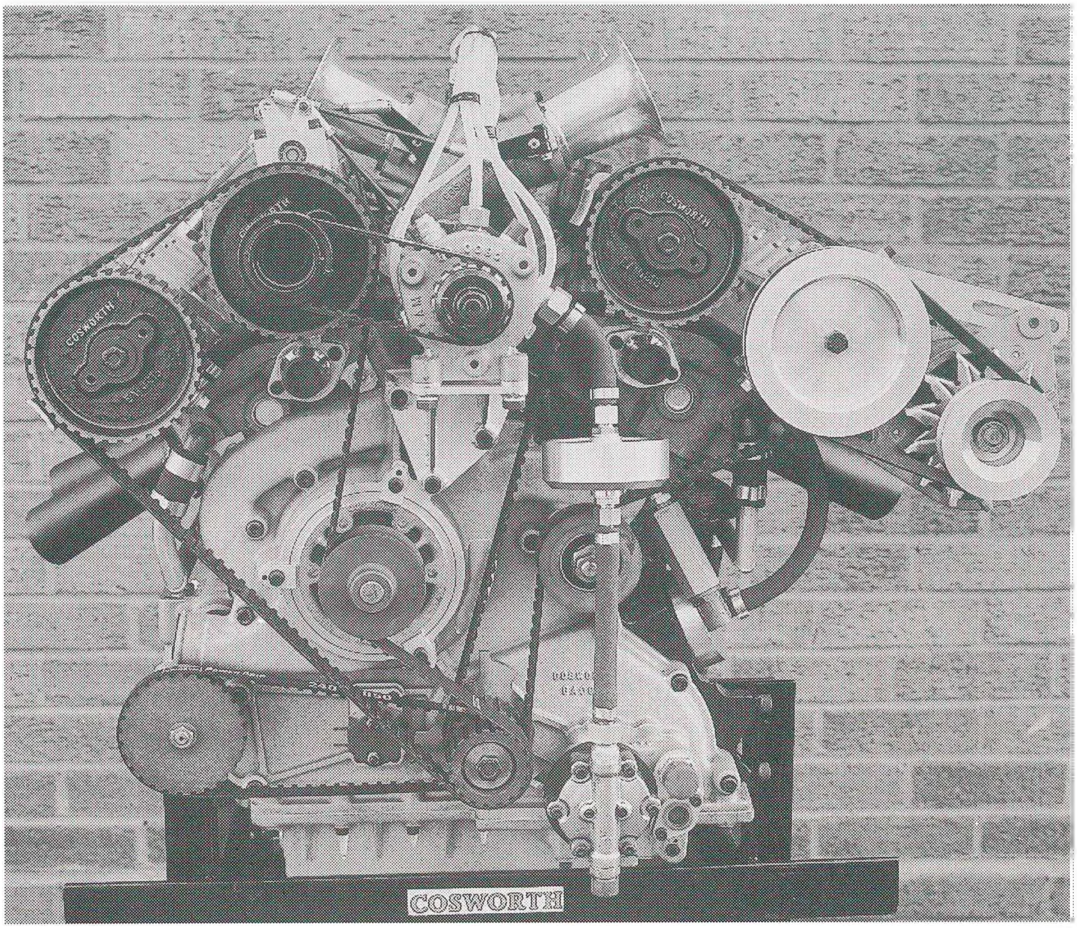
The engine began test bed running in the winter of 1973/74, and the Capri RS 3100 for which it was intended was unveiled in November 1973, but as this was the period in which the Energy Crisis gripped the world's motor industry, it was a project which ran into trouble from the beginning. By the time it was made public in the spring of 1974, Ford's own plans for its use were on the wane. Even so, Cosworth fulfilled its own side of the bargain. Rated at 420 bhp at first, it was eventually improved to 455 bhp, and achieved reliability, and success.

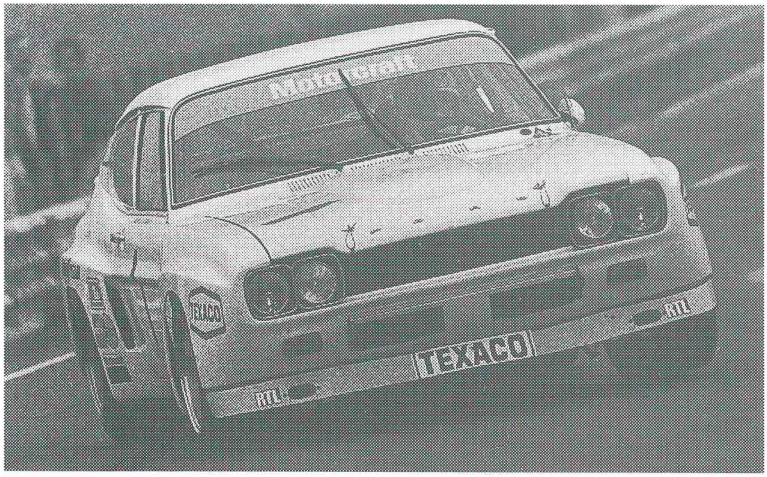
Keith insists that the necessary quantity could never



Left This detail shot shows that Cosworth considered using three sparking plugs per cylinder in the big-bore GA V-6 engine, but in practice only a single, centre, plug was ever needed.

Below The GA V-6, as designed for Cosworth by Mike Hall, was a mass of belts, gears, and pulleys. It was also very effective — for it produced well over 400 bhp (from 3.4-litres) on its first run.





The GA-powered Capri was ready to race in 1974 — just in time for the Energy Crisis, and a chance in marketing strategy, to kill it off!

have been made if Alf Vickers had not recently agreed to become a production consultant, and had sorted out machines, planning, and the whole process.

Ben Rood's machine shops managed to produce the 100 sets of parts which Ford needed for homologation purposes, with about thirty being built up as complete racing engines for Ford-Germany, supplying the balance as boxed kits, to the Boreham motorsport centre. Ford then quoted £4,000 for a kit of parts, and a further £750 to build up an engine.

To machine the 200 GA cylinder heads which were needed, Ben Rood devised the simple 'machining between centres' method which is now used to make all Cosworth engines, even the volume production castings, and Mike Hall remembers it as the first complete engine which Cosworth actually built in numbers.

In 1974 and 1975 the 'works' Capri RS 3100s won major races at the Nurburgring, Zandvoort, Hockenheim, and Jarama, beating the bewinged BMW 3.0 CSLs in every case, but the project was then terminated.

The engines, however, found a new home in F5000 single seaters, where drivers like Alan Jones found the 3.4-litre quad-cam units to be more than a match for the 5.0-litre push-rod Chevrolets favoured by other teams. Even so, many of the Cosworth-built kits hung around at Boreham for some time.

In recent years the engine has seen something of a renaissance for use in non-homologated cars, particularly as Swindon Racing Engines (which had the original service/rebuilding contract) are now manufacturing light-alloy versions of the cylinder blocks, which pares a great deal of weight from what was always a bulky engine.

Turbocharged BDs

Two decades after it was born, as a 120 bhp road-car engine, the BD had evolved into a fire-breathing, 650 bhp, rallycross engine of awesome character and performance. Yet Cosworth had little or nothing to do with the turbocharging of one of its most famous designs. The turbo story really began in West Germany, with Zakspeed, where turbocharged versions of the iron-block BDA were fitted to racing Escorts in the mid-1970s. By 1978 a 1.4-litre development of this engine was producing 380 bhp, and by the end of 1979 that figure had risen to 460 bhp, developed at 9,000 rpm.

Zakspeed's own design included a KKK turbocharger, Garrett intercooler and blow-off valves, and Kugelfischer fuel injection, but retained many Cosworth-developed components too – it was a very effective hybrid. Before long Zakspeed had also developed a 1.7-litre version, this pushing out 600 bhp, on 1.5 Bar boost. These engines never officially carried a Cosworth type name or number.

The next turbocharging impetus came from Boreham, where Ford's rally team began the design and development of the Group B Escort RS1700T in 1980. Much of the concept work was carried out 'in house', to Peter Ashcroft's direction, by John Griffiths and ex-Cosworth design engineer Graham Dale Jones, on a 1.78-litre alloy-block version intended to produce 200 bhp in 'homologation special' road-car trim, and about 350 bhp in its initial 'works' rally trim. To meet the regulations, 200 of these engines were to be made.

Cosworth was then contracted to supply all the major components (Brian Hart is delighted to confirm that Cosworth produced its own version of the light-alloy block which he had 'invented' in 1971/72, using modified versions of the 'Hart' pattern equipment), and at one time hoped to direct assembly of the engines to Swindon Racing Engines. In the end, however, Ford chose JQF Engineering of Towcester to assemble the engines instead. John Dickens, of Cosworth, notes that there was considerable confusion over an engine title:

'We had to designate the project in some way: originally we chose BDP, since "P" was the next available letter, but since BDT had already been established at Boreham by that stage, we quietly dropped BDP and later re-used that for our Midget-racing specification!'

As every Ford enthusiast now knows, the RS1700T project was cancelled after the engines had been assembled, the engines then remaining in store for more than a year before the mid-engined RS200 project was finalized. In time for original assembly of 200 cars at Shenstone, in the winter of 1985/86, the existing engines were all stripped out, with the blocks going to Mahle for reboring to a 1,803 cc dimension. Although many parts had to be renewed, many could also be retained, and RS200 project manager Mike Moreton estimates that more than £5,000 was saved on every engine, by comparison with starting afresh.

This busy scene at Ford's temporary Shenstone factory shows RS200s being constructed in 1985/86. The engine used was a turbocharged 1.8-litre version of the light-alloy BD unit, known as the BDT. In standard form this produced 250 bhp, but the ultimate development, the BDT-E, could produce up to 650 bhp!

This engine produced 250 bhp in 'road car' form, 300 bhp or 350 bhp in Ford 'conversion kit' form, and 420 bhp (later 450 bhp) as used on full-tuned 'works' rally and rallycross' cars.

Lastly, there was the mighty BDT-E engine, where 'E' stood for 'Evolution'. This was a much-modified BDT, produced entirely for Ford, by Brian Hart Ltd. As Brian recalls:

'Stuart Turner of Ford approached us, with what promised to be a five-year programme. His 200-off RS200s were built with 1.8-litre engines, but he was looking for a lot more power in his 'Evolution' cars. Before FISA's axe fell on Group B, we had work planned, on contract, for several years, and there's no doubt that the killing off of Group B was a major blow to us. We had carried out a complete internal re-design of the cylinder block, and we had pushed out the capacity to 2.1-litres (that was 3.0-litres with FISA's turbocharger "factor" applied. Ford asked for 500 bhp, and after the FISA axe fell the very first engine we ran up to power produced 530 bhp.'

In the end, Brian Hart's business produced 25 complete engines, another 25 sets of parts, and carried on making replacement items to service and rebuild the engines into the 1990s. Rallycross cars were soon using more than 600 bhp, and the very special 2.3-litre units produced by Martin Schanche produced more than 650 bhp.

Cosworth in the early 1970s

This was the period when Cosworth was eased into a massive expansion of its machine facilities, when a new building took shape across the road from the original site, and when several very bright young men joined the firm to make sense of the new machinery. Graham Dale-Jones, who later moved to Ford at Boreham, and eventually became Terry Hoyle's partner in the well-known engine-building business in Essex, was one of them:

'I did a mechanical engineering course at Portsmouth Polytechnic, and as I had always been interested in motor racing – I'd always wanted to be a designer – I wrote to Cosworth, saying that I'd like to be the tea boy!

'I joined in 1970, as an engineer – but no particular type of engineer, that wasn't specified. Neil Lefley, Paul Morgan, John Hancock and I all arrived together. Ben Rood interviewed me, I remember.

'There wasn't any formal training. The training, such as it was, consisted of: "Here, start making these". I was given various drill jigs and told to get on with it.

'After making valve guides, drilling bearing caps, and little things like that, I ended up running a CNC (Computer Numerically Controlled) machine tool. At that time we were still on the south side of the road – the new extension hadn't been built – and we used to meet all the 'stars', all the bosses, at tea-break time. All the time, I had an ambition to get in to the drawing office, so after eighteen months in the machine shop I was allowed upstairs to start drawing jigs and fixtures. But it was another year before I started designing anything.'

A young man called Geoff Goddard, who later went on to become Chief Designer (Racing Engines) had a similar informal introduction to Cosworth:

'I started out by doing an engineering sandwich course at Lanchester College, Coventry. In my first job, I worked for Rolls-Royce in Derby as an ex-University apprentice, on aero engines of all sorts. Towards the end of my time at Derby I wrote a dissertation on why I thought the RB 211's carbon fibre blades wouldn't work, gave it to various directors, and got criticized by them for writing such a thing!'

[In 1971, one of the reasons for Rolls-Royce's financial collapse was that the RB211 was in all kinds of development problems.]

'The beauty of Rolls-Royce as a training company was that afterwards you could go anywhere, I did a stint in marine and industrial turbines at Ansty, I did a stint in rockets, I even did some work at Shrewsbury, which was not only building diesel engines, but was making combustion cans for gas turbines. I never had a single thing to do with Rolls-Royce cars, though.

'When Rolls-Royce went bankrupt, I was at the end of my apprenticeship, and I was soon told that all of my year's intake was redundant. The company set up a wondrous system to help us find jobs – and I remember being sent for interview to a company in Glasgow which was making sausage skins! Somehow I didn't think that fitted the bill at all.

'I thought that was a huge joke, so I did my own searching. I decided on two companies – one was McLaren and one was Cosworth. Then I looked at the different house prices, decided I didn't want to work for McLaren after all, and concentrated on Cosworth.

'One day I came to Northampton, marched up to the sales counter, and asked for a job. That threw everybody, but eventually Keith gave me a brief interview. Like most of Keith's brief interviews, this went on for hours. In the end he took me on as a Project Engineer, and I joined in February 1971. At the time Cosworth had just bought its first CNC machine tool, and the conversation with Keith went something like this:

"Can you programme an NC machine?"

"Yes, I'm sure I can"

"Have you ever programmed one?"

"No"

"I admire your confidence – go and get on with it . . ."

'So I had to do it, and make a good job of it. Graham, Neil, Paul Morgan, John Hancock, and now me, we all had similar responsibilities. If Keith wanted a particular rig running, he would pick out one of us, or if he wanted a new programme writing, one of us would have to do it. The point about Cosworth, I soon learned, was that there were so many incredibly talented people around – Keith, Mike and Ben all had overlapping talents. It was different at Rolls-Royce where only one person in a department tended to be technically competent.

'Keith soon got me on to camshaft design, which I've been interested in ever since. He soon proved to me what an amazing applied mathematician he is. He'd go away with a particular problem to solve, and apply his withering concentration to it. It might take him weeks to solve the problem, but he would have examined *all* the ideas, *all* the possibilities, before settling on the right one; Keith never stops until he is 99 per cent sure he has the solution. I learned a lot from Keith, that way, in the 1970s. Nobody at Cosworth ever sat down to teach us anything. Everything is learned by: "I see this has failed. I wonder what failed first, and how did it happen?''. Then one tended to get a lecture around the problem.

'Nowadays, in the late 1980s, we tend to take in graduates and move them around a lot, but they still have to learn by example. Eventually everyone comes back and tells us which department he would like to settle in, and usually he will be quite brilliant there . . .

'One of my first major jobs was to help set up the big machine shop on the north side of the road. But obviously I'd already been drawing things at Rolls-Royce – bits of RB211s and things – and eventually I went full-time in the drawing office in 1976/77.'

Both Geoff and Graham recall that the drawing office was still very small in the early and mid 1970s. Graham Dale-Jones: 'Keith used to do all his own drawing, designing, and thinking, at home. Mike Hall was chief designer, and he had his own office. There were only eight drawing boards upstairs in the main office – one was a design board, one was for copying, three were for detailing, and three for production engineering. I gradually wheedled my way in there and started drawing engine bits. I suppose because I was slightly mathematical, I ended up working on balancing, crankshaft design, crankshaft flexing, that sort of thing.'

Geoff Goddard: 'None of us specialized at first. All projects were run by Keith, or by Mike Hall. Keith, though, was a great arguer. He would usually start by arguing against a particular proposal at great length, because he hadn't thought of it first. You had to be sure of your ground, for he would never give in.

'On one occasion, we had been arguing something out from lunchtime on, I knew that my solution would work, and this led to quite heated debate. When that happens, with Keith, the volume tends to go up! It was well into the evening when he said ''Go home'', and more or less threw me out of the office, he wouldn't discuss the subject any further. Then, when I got in the following morning, my desk had been swept clear of all its paper, and Keith had written a short note, agreeing to my views, and finishing: ''Yesterday I talked rubbish – DKD''!

'He can be gracious *sometimes*, and if ever he had a real row with someone, within twenty minutes the slate would be clean, that would be forgotten, and we could get on with it. He always worked on logic, and reasoning, never on emotion.'

Both agree that Cosworth was, by definition, Keith Duckworth – and that it remained so until the 1980s.

Unless he was totally uninterested in a project which was taken on, Keith would produce the concepts, usually on his own drawing board at home, a few miles from the factory. There would be a brooding silence for some weeks then, after a time, he would reappear (as Geoff Goddard quips: 'like Moses bringing the tablets down from the mountain'), discuss the whole thing at length with the two Mikes – Costin and Hall – and usually leave Mike Hall to get the whole thing designed in considerable detail. More discussions, arguments, and re-design would then take place, and it was only then that the detail designers would be brought in.

Ben Rood, in the meantime, was adding to his formidable reputation as the man whose machine shops could do anything, given time. Not only did he design the jigs and tools to do the machining work, but it wasn't long before he was designing the machines (or, rather, completely rebuilding old machines) as well. Like Keith he 'spends a lot of time sitting down, and thinking':

'One day I was driving down M1 to London – I get a lot of ideas when I'm just sitting there, in the car – when a picture of how to produce cam masters suddenly blossomed in my mind. I came home, we made that machine, and we've been using it ever since. I don't often need a CAD/CAM video screen when I'm designing tooling, because I've already got one, in my head.'

By the mid-1970s, indeed, Cosworth's machining capability was so immense that the racing car industry, and later the production car industry, was already offering a lot of business to Cosworth. There was little, it seemed, that couldn't be tackled ('We've even tackled crankshafts for Wankel engines. But not the rotors though that would be interesting – I'd like to have a go at rotor machining'), and as Ben Rood told me when I was preparing this book:

'If you want someone to do a job right, to do it first time, and to do it without tears, Cosworth is probably the only company who can deliver.

'Look at one of our F1 crankshafts, for example. We're the only people who can grind with the degree of finish, and control of radii, that's *really* needed. Yet some of our rivals [Judd and Ilmor weren't actually mentioned, but the inference was there] seem to manage. I don't think that's fair, somehow.'

Life at Cosworth, however, has not always been logical, as the list of odd-ball projects, cancelled designs, and whimsical diversions proves. That's a subject, now, which deserves a chapter all of its own.

CHAPTER 6

Diversions – cars, motorcycle engines, and automatic transmissions

'The best way to avoid going broke is to spot that you are well on the way to this state, then call a halt . . .'

'Nobody can recognize a phoney at a greater distance than Duckworth! He has this early bullshit detector . . .'

In October 1967, someone 'leaked' a sensational rumour to the press – that Ford was considering designing a Grand Prix car. Or, rather, that Cosworth was designing it for Ford. Or rather, that – well – let's just say that it made a good story at the time, even if it wasn't all true.

Never let the facts get in the way of a good story? At that time, for sure, the 'car' only existed in Keith Duckworth's fertile 'why-don't-we-do . . .?' mind, and in any case it wasn't to be Ford-badged at all. For once, however, here was a Cosworth rumour which did, eventually, come true. It was the first of several diversions which Keith Duckworth allowed himself in the years when the DFV and BDA engines were underpinning the company's finances.

There are some projects which Keith and Mike will not talk about, even today, but the list of those which *are* admitted to, makes fascinating reading. There might, for instance, have been a Cosworth Grand Prix car, an automatic transmission for Formula One use, a V-6 F2 engine, a V-8 F2 engine, fuel-flow limiting valves for the F1 scene, desmodromic valve gear for F1 engines, a gas-turbine engine for light-aircraft use and of course there was the little known Cosworth motorcycle engine, which would surely have been a world beater if its sponsor had not gone spectacularly broke in the mid-1970s.

With the DFV safely launched, and with BDA design forging ahead under Mike Hall's direction, Keith Duckworth could afford to indulge himself a little. Even though the DFV still had many development problems to be sorted out, Keith allowed himself a diversion – and this diversion turned out to be the design of a complete four-wheel-drive car.

Even so, the motoring press know-alls only got hold of half a story when the first rumours began to spread. *Motor* was guarded about the rumours, while *Autosport* merely commented that these rumours were growing all the time. *Autocar*'s sports editor, Innes Ireland, suggested that the new car would be a Ford, that it would not appear until Ford's contract with Lotus expired at the end of 1969, but Cosworth's name was not even mentioned.

Two pages later on, in the same issue, Eoin Young's 'Straight from the Grid' column asserted that: 'The newspaper leak that Cosworth were building a four-wheel-drive formula 1 car raised a storm in several quarters: although talks on the project have taken place, no firm decisions have yet been made and plans were certainly not ready for public airing. People wondered what Ford [which really meant "Walter Hayes"] were thinking about, getting Mike Costin and Keith Duckworth to design the complete car. An engine, certainly, but the transmission and chassis as well?

Eoin Young's column, at least, attributed the project to Cosworth, which was correct, but both were wrong in one major respect – that Ford was not at all involved. The truth was at once less exciting, and more exciting, than this.

'Mike and I were both quite keen on cars,' Keith told me, 'and I was quite keen on structures. I also think that one of the advantages I had, as an engine designer, was that I soon appreciated that the important thing in racing is that it is really all about the proper utilization of rubber. The proper use of the tyre was "Number One" priority. How you applied the tyre to the ground, how you trimmed the aerodynamics, and how you built the chassis was next; the engine and the driver came along behind that.

'Well, with the DFV it was certain that we had produced more power than the chassis of the day could cope with. It looked to me as if four-wheel-drive must soon be coming in, and that would be a complete breakthrough.

'Once we had established that we were going to be

It doesn't matter how talented you are — sometimes you end up making the tea! Robin Herd in his McLaren days, just prior to joining Cosworth to design a new 4WD F1 car.

completely fair with everyone when it came to engine supplies, we felt we could even get away with running a complete Cosworth car, or at least experimenting with it. Not only that – by going to 4WD it looked as if we might be able to catch up with the technology, whereas to mess about with a two-wheel-drive car starting from scratch, might take too long. I thought we could at least start equal in a 4WD situation.

'I felt that I had a fair idea as to the requirements for a 4WD car. So in 1967 we decided, I suppose just for fun, really, that we would have a go at building a car. We needed a designer, and I heard that Robin Herd wasn't very happy with McLaren at that time.'

Robin Herd, indeed, was not completely happy with McLaren ('I thought I was really living off the back of other peoples' experience'), but an approach from Keith Duckworth, muttered as an aside in the paddock of the Italian GP of 1967, at Monza, was a real surprise. Unlike many people who went to work at Cosworth, Robin did not complete any type of apprenticeship, but went smoothly from Monmouth school to Oxford University (where he gained a brilliant first in engineering) and then moved straight on to work in the National Gas Turbine Establishment at Farnborough, where he eventually worked on supersonic nozzle studies for the Concorde airliner:

'I went there as a scientist and an applied mathematical engineer in 1961, but my first love was motorsport, and I soon persuaded them that I ought to spend some time "training" at Lotus! I was there for two months, sweeping the floors, making the tea, and learning. Then, through Alan Rees, and Howden Ganley, I got to move to McLaren, where I became Bruce's chief designer, even though I hadn't then designed anything in my life.'

At McLaren, Robin went on to design several successful McLaren racing cars, including the M5 and M7 single seaters, and the M6 and M8 sports racing cars. He also delights in claiming that he and Bruce were the first to try wings on single-seater racing cars, but is ashamed to admit that neither had the courage to follow up successful tests by fitting them to race cars.

'On its first time out at Monza, in September 1967, the BRM-engined M5 was on the front row of the grid, which was very pleasing. It was there that I talked to Keith, who asked me to go along and talk to him about designing a car. Two weeks later I called him, we met one evening in a pub, and discussed everything. He assured me that he didn't have a master plan, that he certainly wasn't going to build three cars and a team, but that he was just going to build one car to start with.

'He made me an offer I couldn't really refuse. I'd only been earning £35 a week at McLaren, but he offered me a lot more – £2,750 a year and a car, or permutations around that. Not only that, but he wanted me to join Cosworth as "Chief Chassis Designer". Keith proposed to fit me in, with a drawing board, in his office.

'I was very flattered. This was a real education, a real chance to learn, to sit at the feet of Keith and Mike. Keith, incidentally, must have been shocked when he learned the depth of my ignorance, for I was only 28 at the time. I wasn't just confined to designing the car, either. There was always a chance to get involved in policy discussions, financial planning, and the other projects which were going on. It was a real education, and a joy to be there.

'At the time, I think Keith had a slightly romantic idea of what he wanted to do. Compared with his expertise, I think he felt that most chassis designers were second class. He also had an on-going love-hate relationship with Colin Chapman of Lotus. But he obviously thought the world of Jim Clark, I'm sure that the original romantic concept was that here would be a Cosworth car, with a Cosworth engine, and a Cosworth transmission, for Jim Clark to drive.'

Keith and Mike realized that it was not going to be easy to be competitive right away and Keith was determined not to let his car project bankrupt the Cosworth business. Robin recalls that the whole project eventually cost about £30,000, which was a great deal of money for one car in the late 1960s.

COSWORTH ENGINEERING LTD.

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RACING ENGINE DESIGN, DEVELOPMENT & MANUFACTURE

OUR REF. DKD/VL YOUR REF.

27th October 1967

Robin Herd Esq.,
18 Long Close,
Farnham Common,
Bucks.

Dear Robin,

Further to our meeting last Thursday when we discussed the possibilities of your joining this firm to design, for a start, a four wheel drive Formula I car, I now enclose our formal offer.

I would definitely like you to join us, as I feel we think fairly similarly about design and engineering, and should be able to make a good team.

We would offer you the newly-created post of Chief Chassis Designer - or some title that appeals to you! You would be directly responsible to the directors only.

I confirm that:

a) The beginning of January would be acceptable for the start of full-time work.

b) That some preliminary discussion and part-time design should be done during December

c) That during the intensive design stage, you can work at home, with periodical meetings to report ideas, discuss schemes etc.

We are hoping that should you join us, we would have a long association. We feel that our good position is largely due to good design and engineering and that by maintaining good engineering standards and equipment, we should survive even if motor racing should fall into difficulties.

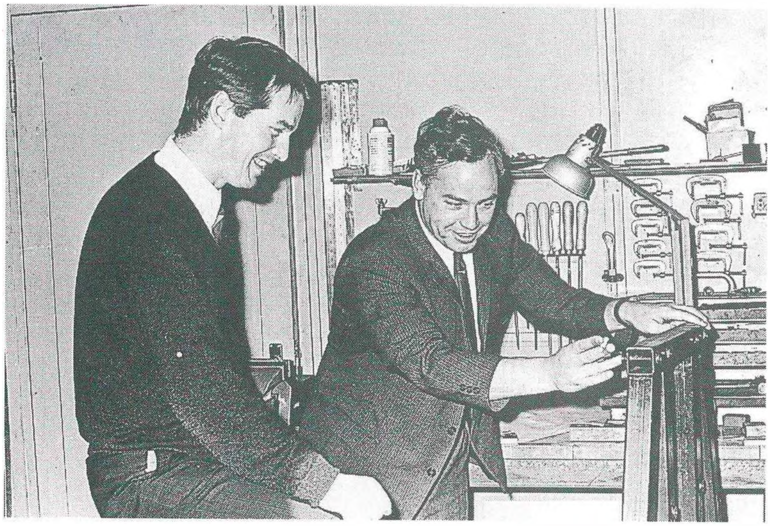
I hope I have managed to make our intentions clear, but should you have any queries I will be pleased to discuss them at any time.

Yours sincerely,

Keith

D.K. Duckworth
Managing Director

Robin Herd lent me his original letter of appointment to Cosworth, which shows how serious Keith Duckworth was about designing the new F1 car.



'Now Robin, at Cosworth we do it *this* way' — Keith Duckworth and Robin Herd in jocular mood, at Cosworth, in 1968.

The concept was settled between Keith, Mike and Robin Herd, with speedy agreement to use the same tyres and suspension geometry at front and rear, and 50%/50% weight distribution front-to-rear. Keith, Mike and Robin would meet at least every week to discuss progress, but Robin worked up the concept, including the layout of the four-wheel-drive transmission, and drew most of the car. Keith designed the centre gearbox, the torque splitting differential, and the road wheel design, which he later claimed was stolen by Robin Herd for use in the original March F1 cars – Robin, by the way, cheerfully agrees with him!

Although Robin had used aerospace-type Mallite honeycomb material in some of his McLaren designs, the new Cosworth car was a conventional, but nicely detailed, aluminium monocoque. There was also a fairly serious stab at getting the aerodynamics right – and this, please note, was immediately before wings began to sprout atop other F1 cars.

Several other people were involved – Mike Hall drew the gearbox and the casings for the centre box, while Alistair Lyle (who went on to design a 5-valve cylinder head for Tickford) was also involved. Cosworth built and machined as much as possible, but some Hewland gears were used in the main casing. There were endless discussions about the torque split, and a gear consultant, Dr Merritt, was brought in. At first the view was that a 40/60 percent torque split (biased towards the rear) would be ideal, though some thought was given to a 30/70 split, as Keith later recalled:

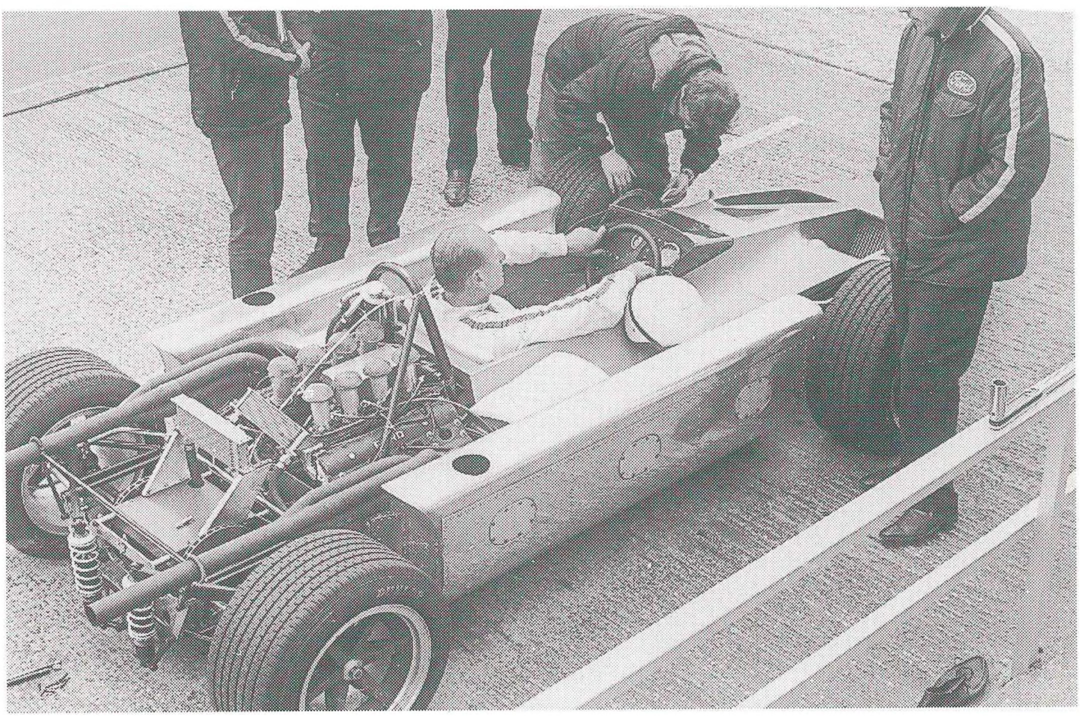
'But no more extreme, on the grounds that we couldn't possibly justify having all that weight around unless we were actually putting a fair amount of urge through the front wheels. Some people eventually put so little power to the front that there was really no point in having four-wheel-drive at all.'

Robin started work on the car at the beginning of 1968 (which confirms that the October 1967 leaks had been about a phantom car which only then existed in the mind of Keith and, who knows, Walter Hayes?). Everything went ahead well until that tragic day in April 1968 when Jim Clark was killed in a Formula 2 race at Hockenheim, in West Germany. After that, Robin Herd told me, the impetus was gradually lost:

'The problem was that it was always a very technically elegant piece of design, and Keith came to love it, for its own sake. Once Jim had been killed, somehow, it became more of a design exercise than a serious race project. After about a year, by the end of 1968, I sensed that Keith had begun to lose interest, and the building of the car went into the back shed.'

The back shed at Northampton, in fact, was also known internally as the 'toy shop', or the 'hobbies shop', where Keith kept his Brantley helicopter, Bill Brown kept his

The DFV engine of the Cosworth F1 car was fitted 'back to front' (the clutch was immediately behind the driver's body), with the various drives to front and rear on the left side of the structure (*Phipps Photographic*).



Mike Costin's expression mirrors the problems Cosworth was experiencing with the 4WD Cosworth F1 car in 1969. The scene is Silverstone, the date 10 July 1969. The car *should* have started the British GP, a few days later, but was withdrawn.

The Cosworth F1 car being tested at Silverstone in 1969. Mike Costin is at the wheel, talking to designer Robin Herd, with Mike Hall leaning over the other side of the cockpit to listen in. Behind Herd, Ian Norris (Dunlop's motorsport PR man) looks disgruntled, while Dunlop designer Iain Mills looks more cheerful (*Phipps Photographic*).

Mike Costin at speed, at Silverstone, in the one-off Cosworth F1 car. The grip was impressive, but the company could never get the transmission — particularly the front differential — to work consistently (*Phipps Photographic*).

boat, and where Ben and Mike could house their gliders. The Cosworth car, therefore, was gradually built up by John Thompson, who had moved north from McLaren at the same time as Robin joined the firm, and by Keith Leighton, who had previously been building F1 DFVs. John fabricated the tub, while Keith looked after the mechanical side of things.

In the end the one and only Cosworth F1 car took to the track in the spring of 1969, with the general intention of making it competitive for Trevor Taylor to drive at Silverstone in the British GP of that year.

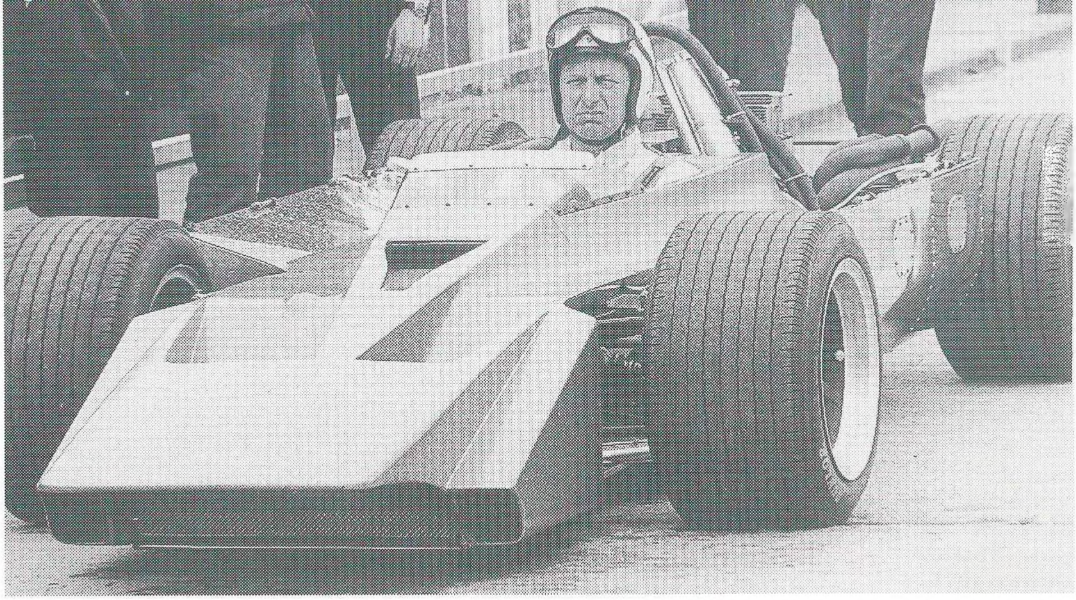
Right away, however, there was a great deal of trouble with the transmission, all centred on the behaviour of the front limited-slip differential, and breakage of the front disc brake bells didn't help either. Mike Costin did the initial shake-down driving, and Keith's interpretation of his views are fascinating, and rather chilling:

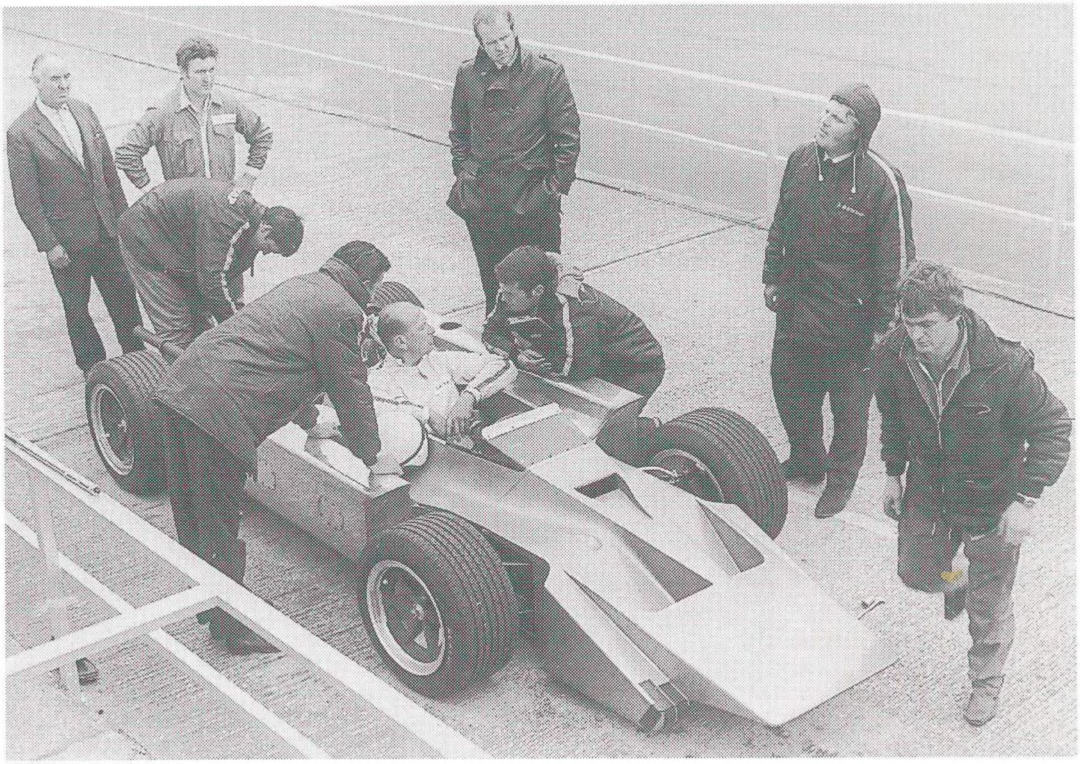
'Mike said he'd go down the straight, the car would gradually be trying to go off one way, to one side, and he'd be winding on more and more lock to stop this. Suddenly it would all let go, and dive the other way, but he couldn't get the lock off fast enough to catch it! Then it would do it all over again.'

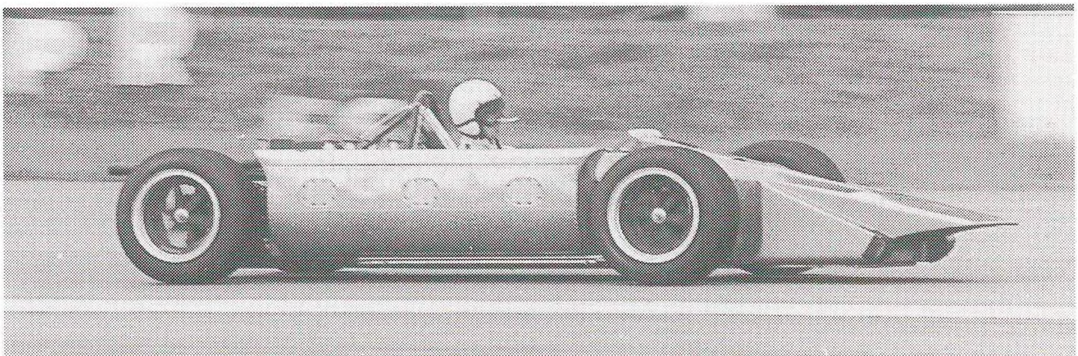
Mike, Trevor Taylor, and even Jackie Stewart all observed the same phenomenon, which Keith put down to the effect of slightly different tyre diameters on the limited-slip device. Cosworth eventually modified its limited-slip mechanisms so that they did not work on the over-run, and in that way the car's behaviour, and its into-corner characteristics, were much improved. Even so, Keith was concerned that in its current state of development, the car was altogether too difficult to drive fast, that it would impose too much stress and physical effort on the driver, and that it might exhaust him before the end of the event:

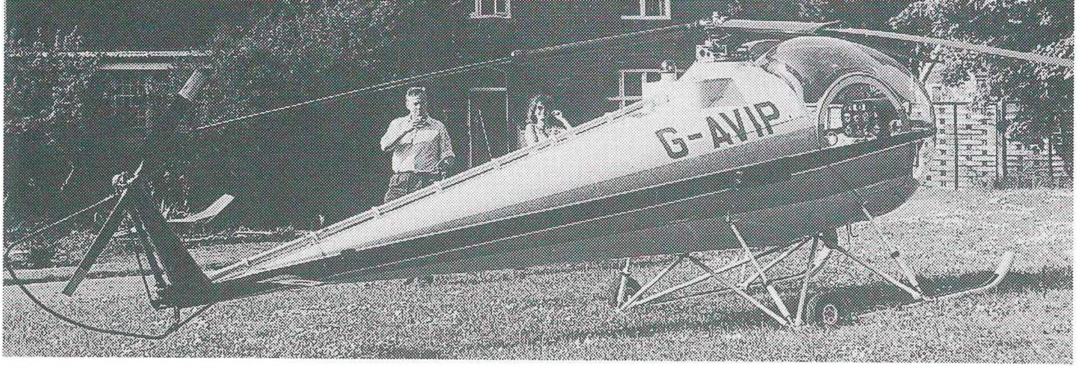
'I looked at all this, looked at the diff problems, noticed that wings had become dominant since we had started designing our car, and thought that we really were wasting our time, and that we should stop before we began to look even more foolish. There was no way that I was going to compromise, by using only about 20 per cent torque on the front wheels and 80 per cent on the rears.

'At the time I didn't want much, strong differential action at the front wheels, and I simply couldn't come to terms with the efforts needed. Looking back, now, perhaps I was wrong to a certain extent, because front-wheel-drive cars with limited-slips are doing a whole lot









Above Keith Duckworth's first big 'toy' was this Brantley helicopter, which he bought in 1968. Note the registration — *G-AVIP*! (*Phipps Photographic*).

Right Keith delighted in flying his helicopter until he was 'grounded' by a heart attack in 1973. Even so this Brantley is still in the 'hobbies building' back at Keith's Northamptonshire home.

better than they ought to be. You would have thought that my "wearing out the driver" problem would still be there, but no doubt the new generation of viscous couplings, or "sticky diffs" have helped enormously.

'No sooner had we got the car running than wings began to come in. That caused the first great deal of doubt. When we built ourselves a wing, we found that we could get substantial downforce, and we could eliminate wheelspin, so there was really then not much point in driving the front wheels any more. So, when the crunch came, I killed off the project. We were about to go on throwing good money after bad in this manner, and I wasn't having that. The best way to avoid going broke is to spot that you are well on the way to this state, then call a halt!

'I think I allowed the Cosworth car project to go on for too long. In fact, we really shouldn't have started it. This was one of those cases where we built something, but which with a bit more thought before starting, we would have been able to see where the problems were.

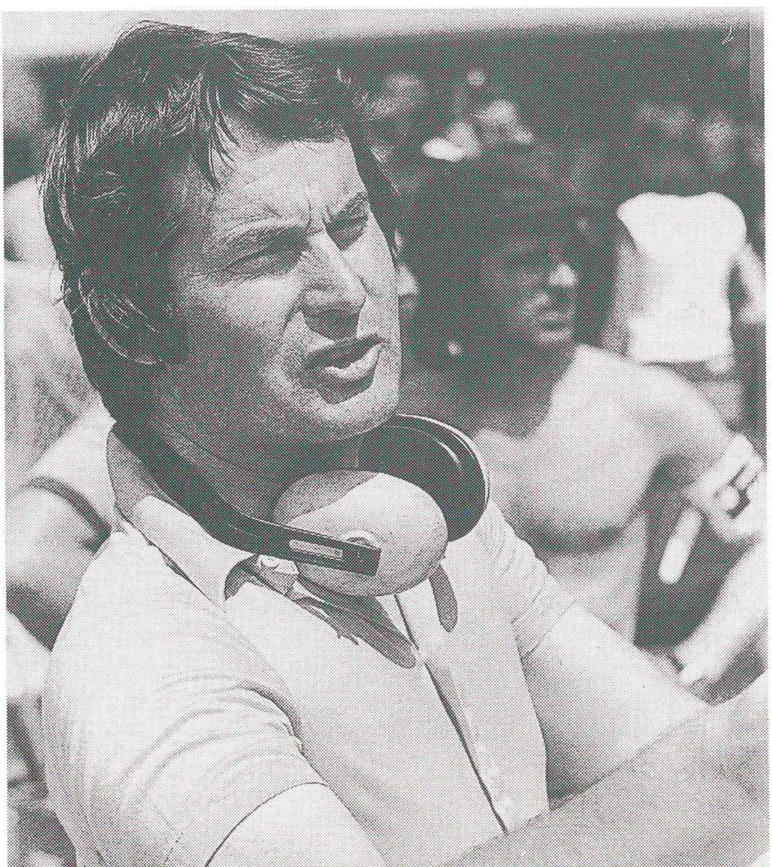
'Generally speaking, I think I have saved more money for the company by analysing on paper, and not starting things, than in any other way. The car *was* a mistake, of a failure to analyse the problem.'

Even before mid-summer 1969, Robin Herd realized that the car would soon be cancelled. Keith, he says, had lost interest, the car had gone on to the back burner, wings had come along to change the shape of F1 cars, tyres were a lot better, and the basic need for any sort of four-wheel-drive had become questionable. When Cosworth saw that no other four-wheel-drive F1 car was working well, it was the end:

'Keith was very kind about everything, and offered me the chance to stay on at Cosworth. He even offered me shares in his company, which was a rare honour. Keith was very interested in building a small gas turbine engine for jet aircraft. Obviously I knew a certain amount about those, the theoretical and thermodynamic problems. He offered me the chance to get on with a design, and I was sorely tempted. We went along to see the gas turbines people, and talked it all over, but in the end I decided I wanted to stay in motor racing.

'That was when I started to get approaches from other people (including the chance to set up in business with Jochen Rindt and his manager Bernie Ecclestone), but in the early autumn of 1969 I left, to found March.

'I thoroughly enjoyed my time at Cosworth. Even



After leaving Cosworth in 1969, Robin Herd went on to found March Engineering, which 'went public' in the mid-1980s. Herd finally left the company which he had founded, in 1989.

Mike Costin was always a keen aviator, and was always happy to get up in the air in his glider. Mike, and his wife, caught in a happy, relaxed, mood (*Phipps Photographic*).

though I was there for less than two years, it taught me a lot about engineering. Even though Keith could be very difficult at times, very stubborn, I thought the world of him. I still do.'

Occasionally, in the 1970s and 1980s, Keith thought again about building a Cosworth racing car, until he became thoroughly disillusioned about the way the sport was developing:

'I think this business of grovelling around an inch from the ground is ridiculous; the whole thing has become an utter farce. Unless we can get racing cars up to a sensible ground clearance – say about three inches off the ground – I think racing has become a complete waste of time.

'Now what *would* be fun, would be for race organizers to corrugate some of the track, overnight, or put a lump on the road "on the racing line" – now that really would be demanding, wouldn't it?'

In the next few years, Keith spent a lot of time thinking and planning, but very little time actually designing, new products. At one time Graham Dale-Jones recalls spending some time working out schemes for a 2-litre 120-degree V-6 engine, which was intended for use in the 2-litre Formula Two category – 'It was a private venture idea, but because nobody was prepared to pay for the development, we abandoned it.'

Cosworth started work on this F2 V-6 in 1972, when it became clear that BMW's 2.0-litre 'four' was likely to be more powerful and more durable than the Cosworth BDG unit. Renault had also come on to the scene with its own purpose-built V-6, but since Keith was not willing to go further than designing the engine (but not actually building prototypes) unless he could see a market for twenty or thirty sales, the project died there.

This also coincided with the frustrating period in 1973, when Keith had just suffered a heart attack, and was confined to bed for several weeks. It is typical of Keith that he took the trouble to learn all about the plumbing of his body, and all the appropriate fluid flow engineering, which affected his health, but there is no doubt that he was frustrated by the need for inactivity:

'In those days one was supposed to do nothing for about three months. Well, I wasn't having that. So, I got hold of lots of paper and pencils, and spent a lot of timing working out the balancing of every possible V-8 layout, then I had lots of arguments about the balancing of the 60-degree GA V-6 – some with myself, and others with Graham Dale-Jones who was designing the crank. I also sat up and designed the small 2-litre V-6 engine, which would have been ideal for use in Formula 2. Then I also sketched up a 2-litre V-8, which had cross-bolted bearing set-ups, and I got as far as arranging the crankcase. I sorted out a fair bit of the detail, but that was all. But we never actually started to make either one of them.'

It was after this period, which is covered in more detail in the next chapter, that Keith persuaded Alf Vickers to join the company, first as a consultant, then as his managing director. Alf released Keith from many day-to-day administrative jobs, which directly led to two more Cosworth projects – the automatic transmission and the motorcycle engine.

By the early 1970s, Keith had also come to know, and to respect, Howard Hobbs, a very capable designer, and specialist in automatic transmissions. Hobbs spent a lot of time working on a variable kinetic drive transmission with Ford, but that project was eventually cancelled:

'I was then talked in to putting some money into his company, Variable Kinetic Drives Ltd, and I bought some shares. I looked at his design, and thought it had all the fundamental making of a viable racing automatic transmission. Because it was automatic, it would be able to allow a racing engine to run at almost constant speed, you could run it as an infinitely variable gear. It was stepless, with a wide-ranging torque converter.'

The design was complex, and although work on it began in 1973/74, it dragged on for at least three years without ever coming to fruition. It took the first two years to get the transmission designed in its vastly larger 'F1' size, and for all the prototype parts to be manufactured.

To try to describe its technicalities here would not only show up the author's ignorance, but it would fill out the rest of the book. Keith summarizes that: 'you recirculated some of the torque back to the flywheel. There was an epicyclic gear set in the middle of the flywheel.

'Well, we decided to have a go at making a proper Formula 1 transmission out of this idea. I couldn't spare the time to do all the work – that was where I went wrong – so we hired a man from Borg Warner called Cecil Schumacher, to be our specialist designer. Once Cec had begun to churn out schemes, Graham Dale-Jones and John Hancock, who would normally have been working for Mike Hall, were brought in to design many of the detail pieces.

'Well, we kept on blowing it up on the test beds. One of the major problems was that we got cavitation around the blades, and this eventually damaged the torque converter. It was always very difficult to run this transmission for more than about five seconds at "stall", which was at about twice the usual rpm for a normal automatic.

'We were trying to transmit about 500 bhp, no automatic transmission had achieved that before, and trying to turn that into thermal energy was a tall order. There were several mistakes in the design, and I blame myself for not being able to keep on top of them. One was the way in which the oil was fed through the centre of the converter, the lack of pressure at the right points, and other details like that.

'If we could have solved the torque converter pressure problem – and at the end of the project I discovered what was wrong with the design – we could have been competitive with a box of mangle gears. It was all going to hinge on the efficiency, whether it would have been high enough to compensate for other losses. The fuel consumption wouldn't have had to matter though – we were proposing to stick the engine on full power a lot more often than you use full power with mangle gears.

'We hadn't even got to the position of fitting it to a car, and we hadn't committed ourselves to make any more boxes – though we had talked a little to Hewland about the supply of some components – so I then took the decision that as we didn't have a sponsor to fund us to the tune of a million pounds or so, we should cancel it.

'I think that, on reflection, the gearbox came to grief, and it was always going to come to grief, because it was too complicated, a real bag of tricks in the end, a bit big and too heavy. But maybe I should have gone out, looked for someone to give us some support, and then carried on.'

Cecil Schumacher left Cosworth soon after this project was cancelled, and later carved out fame, and considerable fortune, in making 1/12th scale radio-controlled model racing cars ('he's a very successful maker of model racing cars, he's a good engineer'). Graham Dale-Jones remembers just how much time Schumacher put into this project, which dragged on into 1978:

'It really was *very* complicated. Nowadays, with the help of electronic controls I reckon it could have been made to work, but just to try to make it work with fluid pressure was probably impossible. It really was *very* complicated.'

Geoff Goddard told me that although it was no larger than a normal Hewland gearbox, 'the amount of metal inside the casing was mighty impressive.' There was also the complication factor:

'I once saw Cec carefully drawing a cross-sectioned layout of the assembly. He was cross-hatching the various bits – but at one point he was cross-hatching metal, and at the other end he was cross-hatching fresh air. It had so many bits, one inside the other, that it was very easy to lose track of which bit was connected where . . .'

Once he had cancelled the project, Keith clearly had no regrets. He told me that only one complete transmission was every built, although there were sufficient parts to make two complete transmissions. When I asked him if the transmission had been preserved, if only in a dark corner of the factory, he confessed not to know, and I got

Mike at the controls of his new glider in 1968, ready to lift off for some brief relaxation (*Phipps Photographic*).

the distinct impression that he no longer cared.

The problem, I am sure, is that this was one of the rare engineering projects which defeated all his good intentions. As Keith has emphasized, so often, and at such length, there is invariably an answer to every technical question – but in the case of the automatic transmission it was never found. The motorcycle engine, on the other hand, proved itself in the end, though success came years after it had been designed. Until 1988, Cosworth was afraid that this was going to be one of the few racing engines which it designed, which would not win a race – but the 'Battle of The Twins' race, at the Daytona Speedweek in 1988, changed all that.

The story starts with Norton, the famous British motorcycle manufacturer, which had persevered with its own design of air-cooled vertical twin-cylinder engine for decades. As motorcycle historian Roy Bacon related in his book *Norton Twins*:

'By the early 1970s it was very apparent that the old twin . . . was rather long in the tooth, and stretched to the limit of its road racing and street development. Something new with the old problems removed, unit construction and a five-speed box was needed, but that something had to fit Norton's image, and their budget. At the time a big twin still seemed to be a successful base for both a road and a race machine.

'Rather than try to develop a new power unit from scratch themselves, which was a very time-consuming job, Nortons commissioned Keith Duckworth, the man behind Cosworth Engineering, to design and build them a 750 cc twin, in 1973.'

The approach came direct to Keith Duckworth, from Dennis Poore. He was a well-known businessman, had been a successful racing driver in previous years, and was the chairman of Manganese Bronze, the company which then controlled Norton and Triumph. Keith told me that:

'He came to us and said: "We need a new motorcycle engine, for a new bike, to replace the Dominator." It was to be a road motorcycle engine, with water cooling, but as he thought that future bike racing was going to be production-based, and that two-strokes would be ousted, he thought we would be interested in taking on the job.

'He wanted us to design him a racing-plus-production engine, and the proposed deal was that we would build and sell the racing engines, while his companies would be able to use the designs in production bikes.'

As far as Cosworth was concerned, this was the JA project, but for Norton there was a dramatic new name for the engine – the 'Challenge'.

'The contract was that we should design it, develop it, produce 65 bhp for the road bike, and get up to 90 bhp, or whatever we could get out of it, in racing form.

'Norton would make all the production engines, but we were contracted to build 25 racing engines. That was to satisfy an homologation requirement for the eligibility of production bikes in the States. Of those initial engines, we would be allowed to keep five engines, the other twenty were to go to them.

'He'd done his homework very well. He wanted a parallel twin – that would fit the sort of bike that his designers had in mind – and he wanted a 750 cc engine. Well, if you took two cylinders off a DFV, that looked to be a sound basis on which to work, for it had been proved to work well.

'The bag of gold that was offered look very reasonable, and since this was some time after my heart attack, the DFV was building itself, Mike Hall had done the Ford V-6 GA, and Cec was going to design the automatic transmission, I thought I would have a go at it myself. So I took out a piece of paper and started.

'We had to produce a 750 cc vertical-twin water-cooled engine. Dennis Poore had done the concept, but there was still a lot of thinking to be done. After all, the biggest problem was that it had to be balanced properly. I did an awful lot of work on crankshaft weights – Dennis Poore wanted the engine to be narrow and low – and therefore I chose a very peculiar layout, where I placed two balancer shafts, Lanchester fashion.

'There was one at each side of the crankshaft – which, as the engine was transversely installed in the bike, meant that there was a shaft at the front, below the head, and another behind the block. One was driven by the camshaft drive belt, the other by a gear from the crankshaft.

'In addition, the crankshaft had to allow 360 degree firing – most parallel twins were like that – so that the carburation would work properly. One of Dennis Poore's forecasts was that pollution control would soon be applied to motorcycle engines, and that the best solution would be to go for a single carburettor – I decided that unless the intake "sucks" were equally spaced the carburettor simply wouldn't work properly. It *had* to be a 360-degree twin.

'For the original racing set up we chose two motorcycle-type Amals, then we also had a fuel-injection scheme as well. I also had to get some flexibility, some "give" in the transmission. In the end I had a crank gear driving the balance shaft, a long quill shaft going right through the centre of the balance shaft, and then I used a Hi-Vo chain to drive the gearbox from the other end of that quill shaft.

'The problem was that where the engine was wide, it was also high up, so the centre of gravity was quite high. Incidentally, the engine was also designed to be a part of the frame, so that part of the motorcycle frame would bolt on to the head, while the bearing for the swinging arm rear suspension was built in to the integral gearbox casing too.

'Originally Norton had designed the gearbox, but we ended up re-designing it. I can remember doing reams of dog calculations, gear drawings, and getting involved in the amount of backlash which was desirable. I was responsible for a lot of the layout of the engine, the concept, its installation angle, how it was going to go into the frame, the positioning of the swing axle pivot, and the geometry to minimize chain length from bump to rebound, but most of the actual drawing work was done by Mike Hall.'

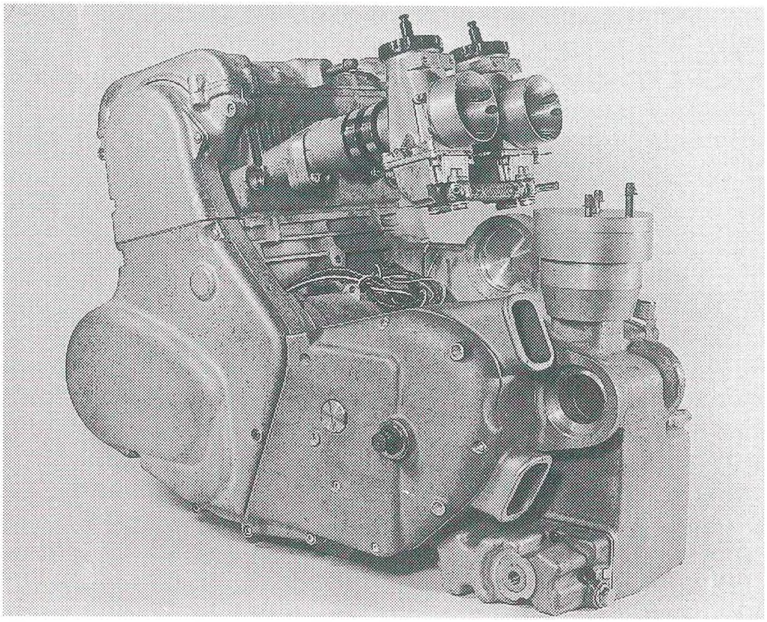
So far, so good, but Keith then had the grace to admit that he was human:

'It also embodied one of my biggest mistakes! I didn't see why the water pump should not be placed where the water was leaving the head, driven off the end of a camshaft. It was the easiest possible place to put it. But it didn't work, and when I designed it like that my mind had obviously taken a holiday. I had forgotten that after a hot engine is stopped, the water in the head then boils. In my original design this steam then got through into the pump, and the pump never worked again . . .

'I didn't even realize this before the head design was finished, and the castings already done – which explains why all the 25 prototype engines Cosworth built had some wonderful welding, fabrication, and bits and pieces, to make sure the water went through the head and then into the block.'

Unhappily for Norton-Villiers-Triumph (NVT), the engine was ready, and power-tested, at almost exactly the same time that it descended into bankruptcy, into a workers' sit-in, and into an ill-judged attempt to set up a workers' co-operative at the Meriden factory near Coventry. The production motorcycle designed to use the Cosworth engine was cancelled, and the racing programme was under-funded and ended in failure.

Cosworth now has very trenchant views on what Keith



The Cosworth-designed Norton motorcycle engine, designed in the 1970s, but not gaining success in racing until 1988. The cylinder head layout had much in common with that of the DFV, there were two 'Lanchester' balancer shafts, and the gearbox was an integral part of the new concept. This is the racing version, complete with two Amal carburettors. Later, for the Quantel motorbike application, fuel injection was developed.

describes as the 'stupidity of government, the pie in the sky and the political ideas of those running the co-operative', but at least the 25 engines were completed, and the company was paid for its work. For Paul Morgan (who later went on to co-found the Ilmor racing engine concern), it was no reward for all the work put in on test bed running, and development. The racing engine was finally refined to produce at least 110 bhp at 10,500 rpm.

And so, for several years, the Norton/JA engine disappeared into limbo. Then, in July 1984, an ex-road racer, and newly appointed Cosworth director Bob Graves, whose Quantel company had joined Cosworth's controlling company, UEI, was shown round the Northampton factory by Keith Duckworth. Bob spied a few dusty engines on a shelf, asked what they were, and learned the sorry saga from the Chairman, who ended up by saying: 'You're looking at the only engine we have ever built which has never won a race.'

Keith was happy to get rid of a couple of engines, but wanted no more to do with this failed project. The story is that Graves then spent four years – and £100,000 – to prove him wrong. In 1988 he made his point – not only did Roger Marshall win the Daytona 'Battle of the Twins' on his Cosworth-Norton engined bike, the Cosworth-Quantel, but the machine then went on to win major events at Spa (Belgium) and Assen (Holland) later in the year. Then, as Keith told me:

'After the Daytona win we had the chance of taking more orders for this old engine, but by that time Cosworth was far too big to be playing around with things like that.'

Once Cosworth's finances were underpinned, and its reserves continued to mount, year by year, there was always enough money to back any other flights of whimsy which Keith and Mike Costin wanted to pursue. The problem, though, was that logic (the stuff which seeps out of every pore at Cosworth) usually intervened. Keith analyses his standards like this:

'The reason we've survived in the business of making racing engines was that we didn't try things which weren't likely to work. We always thought very hard about everything, hoping to make sure that things would work with the minimum of development. I think that that was essential for the company in the early days. As we became better off, and more soundly based, we could have been able to take on more projects, and perhaps been able to achieve a lot more, if I had allowed things to be done in the fashion that they were normally done – in a fashion less like my purist approach, with design, manufacture of prototypes, appreciation of the problem and the snags, then the re-design, then the normal development/re-design process . . .

'I think that's one of the reasons we never made W12s, and things like that though we certainly *looked* at W12s, and decided not to make them. We also looked at rotary valves, and decided not to make them either . . . I would say that I have ranged fairly widely over all the possibilities of piston engines, and the reason why I haven't done anything outlandish is that I have conducted an analysis of their problems and come to the reasonable conclusion that none of them stood a chance.'

The nearer I came up to the present day when researching this book, the more difficult it became to squeeze admissions out of Cosworth staff. Occasionally, though, I would mention things like Jaguar V-12 engines, desmodromic valve gear for F1 engines, or massive contracts for North American manufacturers, and get hints, enigmatic smiles, or even the hasty closing of doors or covering up of drawings. Geoff Goddard even let slip that he had once been asked to design a 38 bhp flat-twin engine, but would say no more on *that* subject . . .

There is always something going on at Cosworth, and always plenty of closed doors, or locked filing cabinets, to muse over. One day we may know more. One day . . .

CHAPTER 7

The world's motor industry comes shopping

'The next break-through came in 1980. It was Daimler-Benz, straight out of the blue . . .

Mike Costin is quite sanguine about the continuing growth of Cosworth:

'My view is that we are a very different company, now, from what we were in the 1960s, and this would have been so whether or not we had merged with UEI. Although our policy in the 1950s and 1960s was that we would *never* expand, in fact we continuously expanded. We kept on saying "We are big enough, we can manage as we are . . ." We said that when we were employing 50 people, we said the same when we employed 100 people, then 150, then 200 . . .'

Keith Duckworth agrees that for some years the company was almost run as a co-operative – even if it was run on strictly capitalist lines: 'I think that sometimes, when we were totally bound up in some racing crisis, then Cosworth was being run by its second-line management.'

'I actually tried to control the growth,' Keith confirms. 'Originally when we took on F2 engines, we immediately decided to stop selling complete F3 engines, but merely to supply pieces, and kits. When we moved up to F1, that was the time to drop F3 all together.

'At one stage we actually set up Cosworth Components, to look after the old engines, but we found that that distracted the main team from its endeavours. What we ought to have done was to make it a separate limited company, and I should have made someone else responsible for it – *and* to forbid too much movement from one company to the other. But that didn't work out, and we find that we're still making a large number of pieces for obsolete engines, which tends to clutter up the machine shops, which ought to be doing something else.

'On the whole, I would far rather run a small, efficient, business, than a large organization. I always worried about expanding too far, to be able to cater for a maximum demand that you could forecast, but perhaps never see.

'If demand slumps after you have expanded, you are in terrible trouble. I've always thought that we should put excess demand out to sub-contract. In fact I think we should have sold off the BD engine to another company years ago.'

Keith, being a Northerner, had a healthy respect for money, understanding from an early age the fundamental principle that if you commit yourself to paying out, it must be balanced by income. Keith recalls Colin Chapman of Lotus and his colander theory: 'You liken your business to a colander – with water spouting out of all the holes, those are the costs, while the profit is the water that overflows from the top.

'Colin pointed out that there were two ways forward – to pour more into the colander, to increase the turnover, or to go round plugging some holes, to make yourself more efficient. I was always in favour of plugging holes *and* making sure that more flowed out at the top.'

By the mid-1970s Cosworth's 'we really don't want to expand any further' strategy was in tatters. Companies asking the company to design new engines were welcomed, but it was becoming more and more difficult to convince Europe's motor industry that Cosworth could not, or would not, then build the engines in quantity. It all depended, Cosworth found out, on what was meant by 'quantity' and 'production'. Ben Rood's machine shops could certainly tackle the manufacture of BDA, or even GA, parts in batches of 100 or more, but there was no way that space could be found in the cramped assembly shops for building to take place.

Even so, as company expansion continued – 1973's turnover of £1.15 million rocketed to £1.64 million in 1975, and to £1.88 millions in 1976 – the directors were reluctant to turn away new business. This, incidentally, was achieved with minimal increase in staff: from 147 in 1974 to 155 in 1976.

Then, it seemed, the company engaged overdrive, and business really rocketed. Turnover in 1977 was £2.23 million, in 1978 it was £3.46 million, and in 1979 it pushed ahead to £4.1 million. The business was healthy, and profitable, too – after tax profits in 1973 were £170,294, in 1975 they were £207,060, and by 1979 they had surged ahead to £607,962.

As ever, Keith invested most of the company's profits into machinery, which caused something of a virtuous circle at Northampton – more profits = more machinery, more machinery = more work needed to keep them busy, more work = more profits, more profits = more machinery . . .

Along the way Keith, still by far the largest shareholder in the business, became a rich man, but as he spent most of his time working, and some of his so-called leisure time thinking, his only indulgence was to fly his helicopter, for business *and* for pleasure. Throughout the 1970s Mike Hall ran the design office for Keith (who spent much of his time working at home):

'We didn't expand much; we were only taking on about one new project a year or two years. Geoff Oliver arrived in the early 1970s, then Geoff Goddard, Graham Dale-Jones and John Hancock. We were still in the old office then, bursting at the seams.

'Companies would come knocking on our door saying: "We can't get our engine to go, will you have a look at it?". We didn't often take things on, because we didn't want to give out our secrets without getting very well paid for it. Even today [the end of the 1980s] we are very selective about the type of work we do . . .'

General Motors was the first company to knock on the door at Northampton, offering a major design job based on the light-alloy blocked Vega engine. Ford was next, asking Cosworth to design an 'homologation special' for its Capris. Soon after this, Vauxhall would ask the company to bail it out of trouble with the Chevette HS project, Opel would ask for advice with the development of its 16-valve rally unit, and Mercedes-Benz was not far behind. By the 1980s Cosworth was actually having to turn work away.

Each of these projects, in its intricacies, its political implications, and its design details, was handled by Mike Hall's design office, rather than by Keith Duckworth himself (who was still heavily involved with DFV developments, and on the various 'new-product' schemes already described).

By the early 1970s Cosworth's reputation was firmly underpinned by the enormous successes chalked up by the DFV, the FVA, and by the BDA engines. Other manufacturers, clearly, wanted to 'drink from the same well', and each new product, in its own way, enhanced Cosworth's standing, and made the pressure on its factories even more intense than before. First in line was

Chevrolet of Detroit, the largest individual marque in the mighty General Motors corporation, which had revealed the four-cylinder 'XP887' Vega engine in the summer of 1970. After the debacle of the rear-engined Corvair of the early 1960s, it was a miracle that Chevrolet was still allowed to dabble in engineering that was advanced by United States standards.

Not only was this much the smallest engine that Chevrolet had ever made – in standard form it was a 90 bhp/2.3-litre unit – but it was technically strange, having a cast iron cylinder head but a light-alloy cylinder block. The block had no separate cylinder liners, but had specially-treated cylinder walls, and the cylinder head had a single-overhead camshaft, driven by a cogged belt.

Chevrolet engineers, led by its president, Ed Cole, and by publicity-seeking John DeLorean, were proud of their new toy, though by Cosworth standards it was nothing to get too excited about. Single-cam engines, as far as they were concerned, were old hat, and as for cast iron cylinder heads, well . . .'

'GM came along to us, and offered us the Vega engine as the basis of a racing unit,' Keith Duckworth told me. 'I can only think that they had heard of us because of our DFV and BDA racing engines – I didn't know *anybody* at GM in those days. In theory, of course, GM's policy was not to get involved in motor sport, but the definite intention with the Vega was to make a shorter-stroke 2.0-litre F2 engine out of it, and a sports car racing engine too.

The Chevrolet Cosworth-Vega of the mid-1970s was a limited-run road car, powered by a de-tuned *and* de-toxed version of Cosworth's EAA engine.

'Well, because the engine was already a 2.3-litre, and the cylinder block was an aluminium die-casting, at first I thought this was a *very* good idea. We certainly got a lot of power out of it, more than we could get from the BD at the time. That was before we found out about the weaknesses in the block . . .'

Mike Hall takes up the story, more in sorrow than in anger:

'It was intended to be a very light F2 engine which Chevrolet sponsored. We designed the full-race conversion – new head with valves at 40 degrees, just like the BDA, dry sump, all the pumps, everything. It was all very encouraging, and it all went extremely well, performance-wise, but then we had an awful lot of trouble with the cylinder block. They suffered from porosity, quite a lot.

'That was the only Chevrolet part left in our EA engine! The problem was that it was a high-pressure die-casting, which meant that it wasn't possible to fiddle the cores to stiffen up the block. The blocks used to split the bores, from top to bottom. Chevrolet tried very hard though – they changed the material for us, they changed the heat treatment, in fact they were quite open about their own problems, and that was with an engine only producing 78 bhp!'

If only they could keep the block in one piece, Cosworth engineers reasoned, the Chevrolet EA had the potential to take over from the Ford BD design, to save weight *and* to be more powerful. A great deal of detail work was carried out, as Keith reminded me:

'It got to the stage where John Dickens (who was chief quality engineer at the time), and Mike Costin were spending a lot of time looking at every block, and looking at X-rays of every block, to determine whether or not we dared to use them. Not only that, but those blocks which *were* accepted were then subjected to high pressure water testing of the bores to see if they would split.'

One of the problems seemed to be that some engines detonated, and Keith now wonders if Cosworth was a touch too ambitious regarding compression ratios. What completely mystified Cosworth – and neither Keith nor Mike likes to leave a problem unsolved – was that some engines would run and run. Everyone at Cosworth recalls Tommy Reid's 2.0-litre sports car engine, which never gave trouble, won a lot of races, and even a championship or two. But, as one of them later quipped: 'We couldn't take it back and cut it up to see what we had been doing right. We might never have been able to build another engine which was as good!'

It was when the X-ray and pressure test treatment was at its height that Keith called a halt to the programme. He simply could not see the logic of using high-calibre staff on work which should never have been needed. Chevrolet, though unhappy about the race potential of its engine, then decided to turn it into a 2.0-litre production car unit. Managers with experience of European cars had seen the impact made by cars like the Escort RS 1600, liked what they had seen, and determined to repeat the trick in the USA.

'Of course,' Keith snorted in a recent interview, 'they did it all wrong. They actually took the racing engine, with all its big valves and its biggish ports, and tried to make a road engine out of it. We wouldn't have tried to do that.'

In August 1973 Chevrolet released provisional details about the Cosworth-Vega hatchback. This, by the way, was the very first production car to carry the name of 'Cosworth' as a part of its title. By chance, the timing was all wrong, for within weeks the world was plunged into the Energy Crisis which followed the short-lived Arab-Israeli war. Initial plans were for 5,000 cars to be produced.

Everything then went quiet, until the spring of 1975, when the car was relaunched, when it was stated that engines were being built in Chevrolet's Tonawanda plant, where thirty engine builders could assemble 25 engines a day. It was claimed to be the first American twin-cam 4-valve engine since the days of the Duesenberg of the 1930s.

By this time, as with many such much-delayed projects, it was all a bit too late, as ever-tightening exhaust emissions laws had emasculated the peak power to a mere 122 bhp. The car was only in production for sixteen months, and just 3,507 examples were produced.

In the meantime Keith, and Cosworth, were severely shaken when he suffered a heart attack in 1973, and was confined to a hospital bed for several weeks. It was this shock – Keith actually felt quite insulted by it – which caused a big sea change in Cosworth's organization for the mid-1970s:

'Perhaps I had been getting uptight in the early 1970s. We'd got the DFV done, and winning, we'd done the BD, we were still working away on the Chevrolet EA engine. But our organization wasn't capable of defining priorities, and we seemed to have little idea of our capacity, or our capabilities. I'd always thought of myself as a cheerful, well-adjusted, chap, and I didn't regard myself as a significant worrier. But I was smoking quite heavily, and I suppose I must have developed some sort of heart disease. There must have been some thing, some crisis which brought it on, because suddenly I had a heart attack, and was carted off to hospital.'

Keith, still smiling, and still pulling his own leg, more than fifteen years later, could afford to be flippant about cause and effect:

'It wasn't a very bad attack, just a standard coronary, a blood clot: it didn't seem to cause much heart damage, and I seemed to be OK afterwards.'

Nevertheless, it was this rather serious warning which caused Keith and his fellow-directors to think rather deeply about the future. Keith decided that more, and more highly-experienced, management, was needed:

'This was where I went out to find someone to assist me as a consultant. I ran into Alf Vickers at an *Autocar* "Thursday Club" dinner at the Saxon Mill hotel, near Warwick. Alf had been managing director of Jensen for some years, and he'd just had a heart attack too, and he was away from his office, so you could say that we had a mutual interest.

'I set him the test I gave to all new graduates – about bolt stretching. I was mighty impressed. He answered it there and then, over the dinner table . . .

'He agreed to come and have a look round at Cosworth during 1973, and the first things he did was to assess our machine capacity, then to establish a sensible costing system. That, by the way, was the *first* costing system we had ever had!

'We needed Alf's skills very much. We already had one Milwaukee NC automatic machine, which I'd bought for tax reasons, and I wasn't really worried whether it was being used, or not. There was another one on order. By that stage I was so appalled by the unreliability of NC machines, that I decided I couldn't make do with one, I needed two, with the same control systems, and the tapes usable on either machine.

'In addition, I wasn't able to spend enough time doing what every sensible engineer should do – which was to design carefully and cheaply. A good engineer is definitely someone who can do for a Bob [5p] what any idiot can do for a Quid [pound].'

Alf Vickers, who was already past what you or I would call a desirable retiring age, joined Cosworth as a consultant in 1973, but became a director from October of that year, and soon rose to become managing director, from the end of 1975. Keith, to this day, regrets that the inevitable result of this appointment was that his old college chum Bill Brown would feel left behind. Bill drifted away from Cosworth in the mid-1970s, though he was still a director of Cosworth when it was sold to UEI in 1980. At that point his final links with Cosworth were severed, he spent more and more of his time involved with his powerboats – and he is no longer connected with the UK motor industry. It is all rather sad.

'After Alf arrived,' Keith reminded me, 'we were staggering on, getting bigger, and doing fairly well. I only ever talked occasionally to Alf about matters of significant business importance. Generally speaking, he was running the whole place, in a dictatorial fashion.'

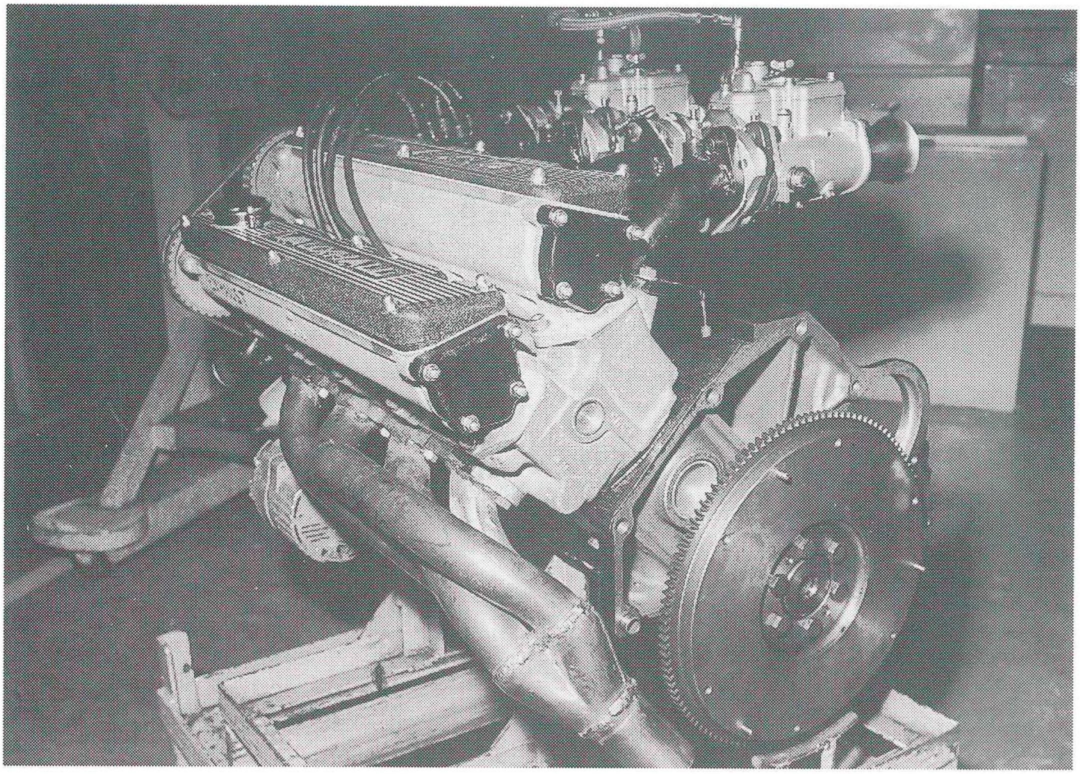
It was in this sort of busy, entrepreneurial atmosphere, that Cosworth received its next approach from GM. GM, in fact, had been delighted by Cosworth's design work, by its high standards, and by its remarkable ability to make much out of little. The frustration of the Vega project was not wasted, for in the next few years two other GM projects – one for Vauxhall, and one for Opel – both came to Northampton.

Vauxhall announced a new high-performance Chevette, the 2.3-litre 16-valve HS model, in November 1976. To the astonishment of everyone except, it seems, the authorities in the RAC MSA, the car was immediately homologated, and began to win rallies, using Lotus Type 907 16-valve heads, well before a single car had been sold.

Vauxhall's credibility was strained even further in the spring of 1978, when road car deliveries finally began in numbers, with an entirely different cylinder head from that which the rally cars had been using for eighteen months. An homologation scandal followed.

Vauxhall's problem was that its sporting fervour had run well ahead of its production facility. Its own cylinder head design was ready, but the company was not able to manufacture these at Luton. Original contract arrangements – to have it machined and assembled by Jensen – also fell through.

This was where Cosworth had become involved. Vauxhall cast around, looked for another specialist concern to help it out of the mire, and discovered that only Cosworth had the know-how, the bustling enterprise, and was flexible enough, to do the job. In a great hurry, and in a high state of embarrassment, Vauxhall came to Northampton – could Cosworth take on the machining, and the



This strange-looking cylinder head, with cam cover machined faces considerably canted over, was designed by Vauxhall for use in the Chevette 2300HS 'homologation special'. The engine was always installed with the block at this angle, of 45 degrees to the vertical, to fit in under the bonnet.

The original supplier could not tackle the machining job, which was successfully completed by Cosworth in 1977 and 1978.

assembly, of 400 Chevette HS cylinder heads? And, by the way, could it please do it *now*?

Not even Cosworth could produce machined and assembled heads at once, but Ben Rood's machine shop set to, the already busy assembly shops somehow found space (and man power) to build the head assemblies, and by early 1978 the job was done. It was only after the heads were fitted to cars, the cars were sold, and the motoring magazines noticed the difference, that the scandal broke.

Ben Rood is quietly proud of his machine shops:

'We can virtually do anything. We've always seemed to have fairly good capability. We could always do a good job, just as long as we didn't have to make too many of anything. Quite a few people can make one, two, three or maybe half a dozen of anything – the real trick, in my opinion, is to make up to a thousand all the same, that's a lot more difficult. Anyone can make two, and anyone can make a million. With two you can do it by hand, and to do a million you can afford to throw so much money at it that you can solve any problem. But between 500 and 10,000 of anything, that's the most difficult production problem, where you can't afford to get anything wrong. I like to think that Cosworth is in that market and, yes I'm boasting, we're the best in that market, because we can always tackle it without a lot of hesitation.'

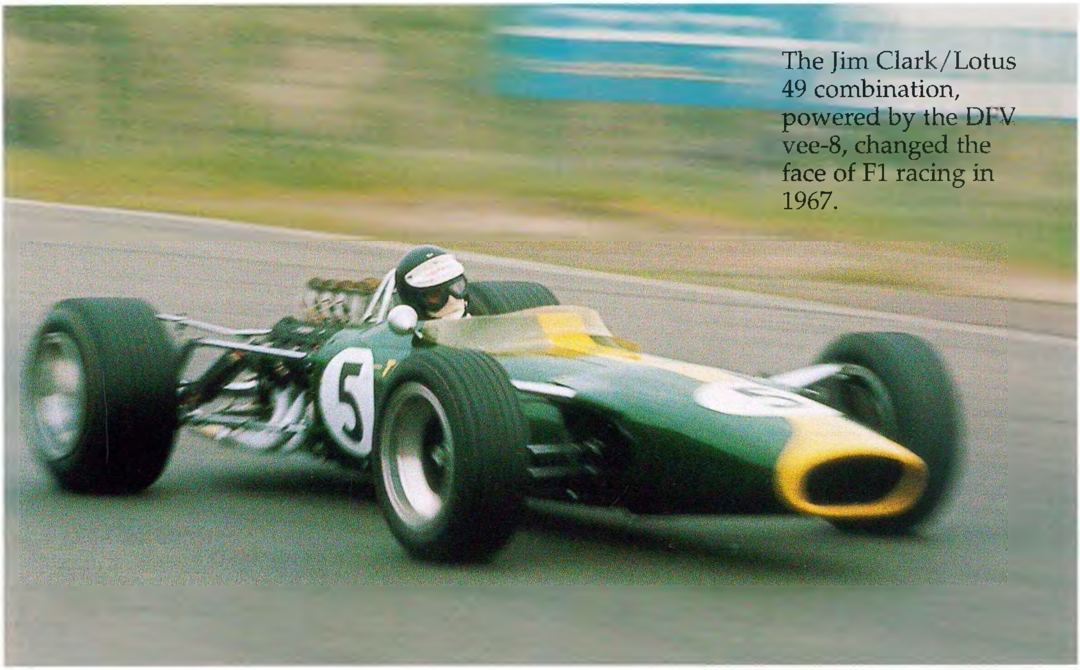
It was Cosworth's success in saving face for Vauxhall, and its growing reputation as limited-volume manufacturers, which prompted an approach from Opel. Opel, like Vauxhall, was in trouble. In the mid-1970s the West German concern (which, like Vauxhall, is owned by General Motors), had designed a 4-valve, twin-cam conversion of its mass-production Ascona/Rekord unit, originally aiming it for Formula 2 racing, where BMW was dominant.

The engine had originally been designed, in West Germany, in the mid-1970s, and was unveiled in September 1975, with the intention of homologating it as the alternative engine for use in Group 4 rally cars. Unhappily for Opel, it was not an immediate success, as several well-publicized blow-ups on major rallies proved. Because of GM's standing in the world of motoring, this was one of those occasions where Cosworth accepted a 'Please have a look at this one, and make it work' proposals, as Mike Hall confirms:

'It was Manfred Tholl of PEK (Opel's design/development centre at Russelsheim), who dealt with us. What swung the decision was that Opel were also interested in productionizing the design after we had made modifications.

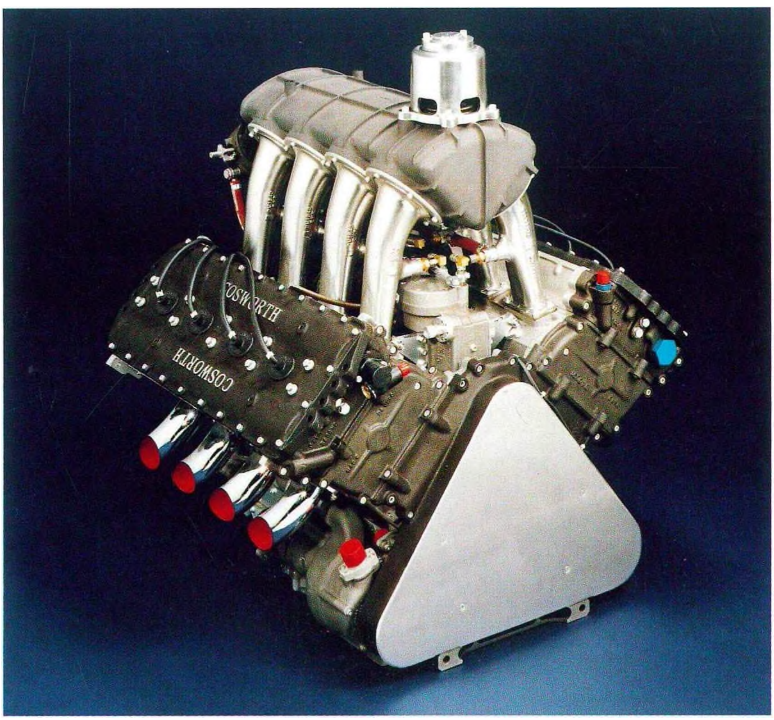
'The engine, as delivered to us, wasn't a howling

The Vauxhall Chevette HS production car of 1977/78 was 'powered by Cosworth', though few enthusiasts realized this at the time.

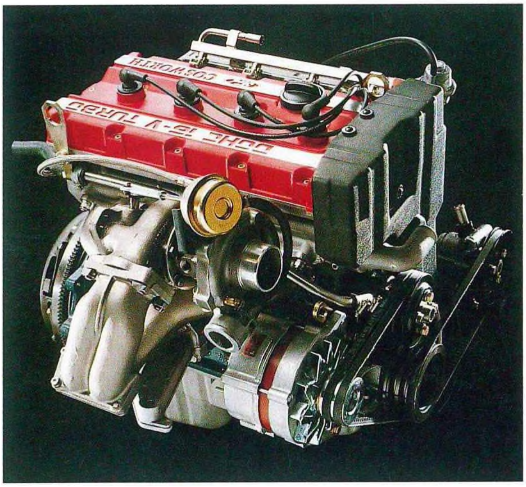


The Jim Clark/Lotus 49 combination, powered by the DFV vee-8, changed the face of F1 racing in 1967.

Cosworth in colour



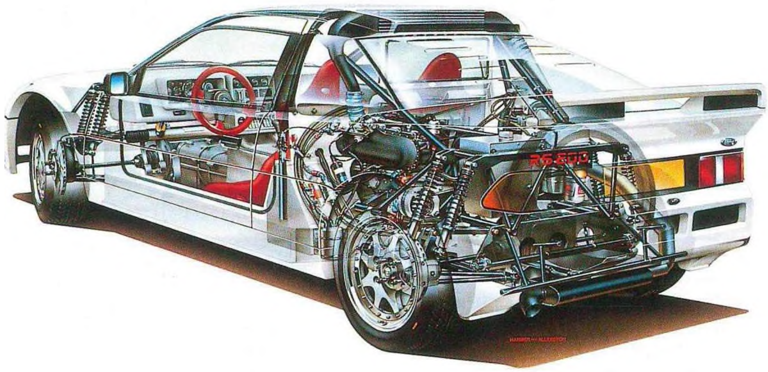
The turbocharged DFX engine, which powered CART/Indycar race cars to more than 150 wins in 10 years.

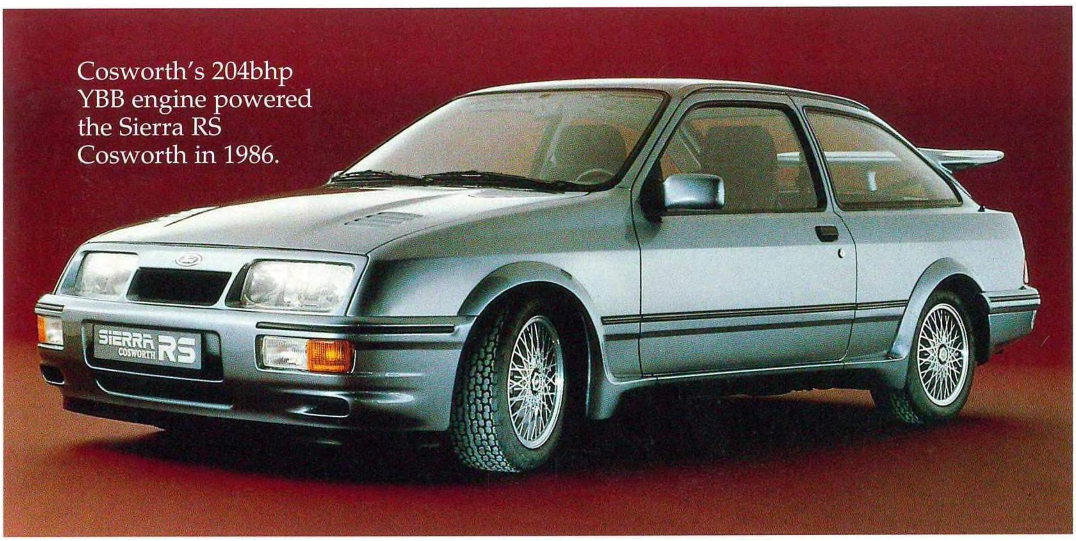


Above The YBB engine for Ford's Sierra Cosworth – this was Cosworth's first true series-production road-car engine.

Above right The BDT-powered Ford RS200 car in rallying, in 1986.

Right Ford's Group B RS200 – combining Cosworth BDT power with four-wheel-drive.

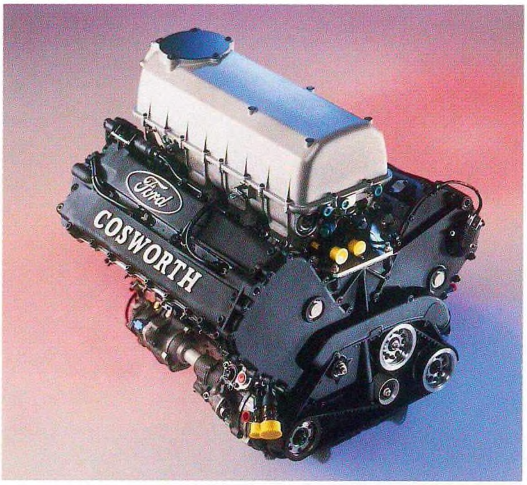


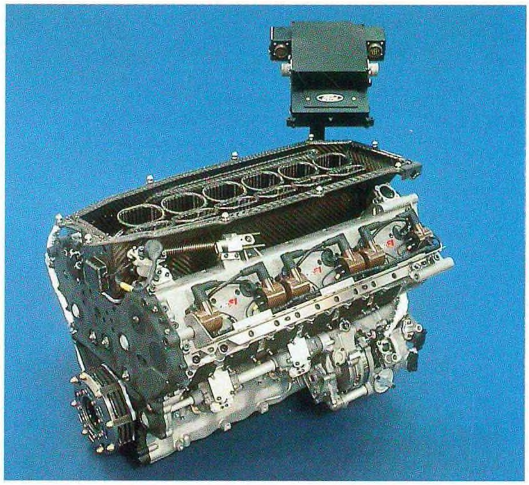


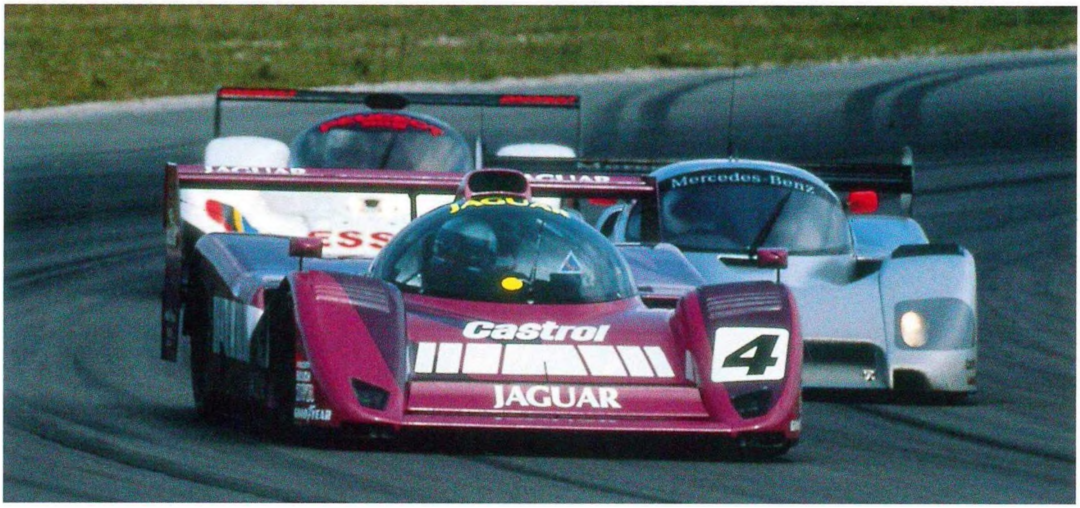
Cosworth's 204bhp YBB engine powered the Sierra RS Cosworth in 1986.

The Eggenberger-powered Sierra RS500 Cosworths were supreme Touring Car racers in the late 1980s.

This 'works' Ford Sierra Cosworth, driven by Didier Auriol, won the Tour de Corse in 1988.



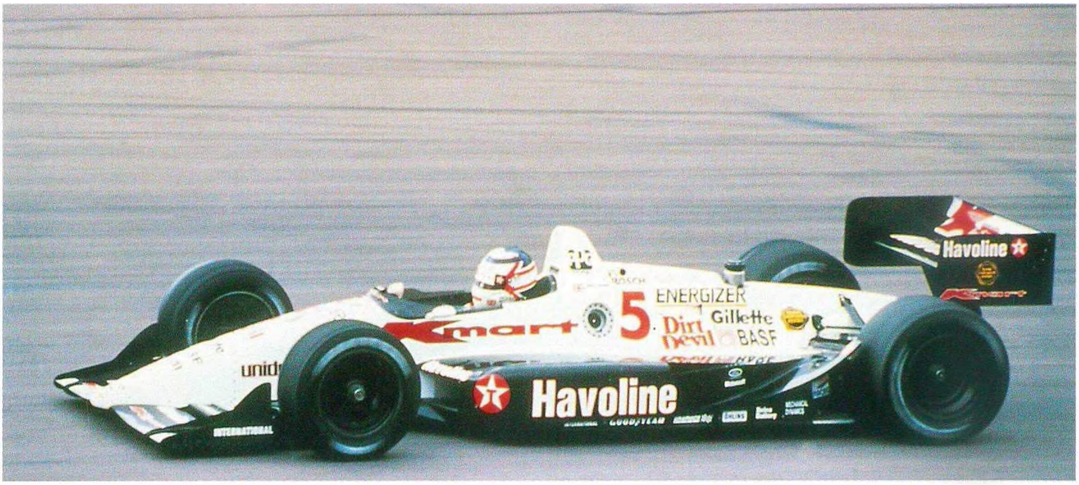




Top left The famous Cosworth XB Indycar engine helped Nigel Mansell to his Indycar Championship in 1993.

Top right The VB vee-12 F1 engine was tested, but not raced, in 1991 and 1992.

Above The Jaguar XJR14s won the World Sports Car Championship in 1991, using Ford-Cosworth HBC engines.

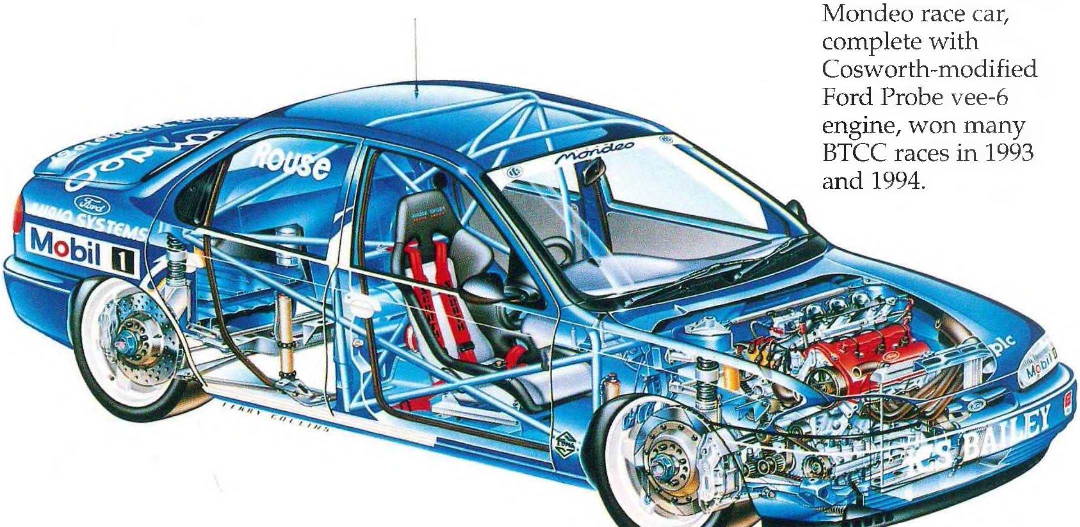


Above Nigel Mansell used XB-powered Newman-Haas Lolas to win the Indycar Championship in 1993.

Left Miki Biasion's Ford Escort RS Cosworth, winning the Acropolis rally in 1993.

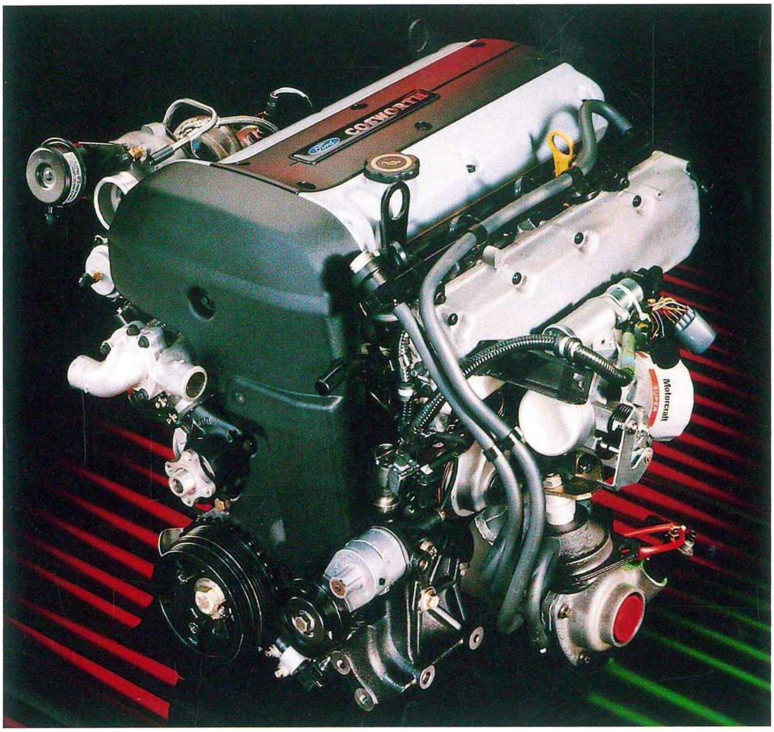
Bottom left The BDA was a rally-winning engine from the 1970s to the 1990s – this was Roger Clark's Escort RS1600 winning the 1972 RAC rally.

Below Ford's Team Mondeo race car, complete with Cosworth-modified Ford Probe vee-6 engine, won many BTCC races in 1993 and 1994.



Cosworth sponsorship of Escort RS Cosworth – Gwyndaf Evans GpN Champion, 1993.

Below Rolls-Royce Concept Java of 1994, powered by a Cosworth turbocharged vee-8.

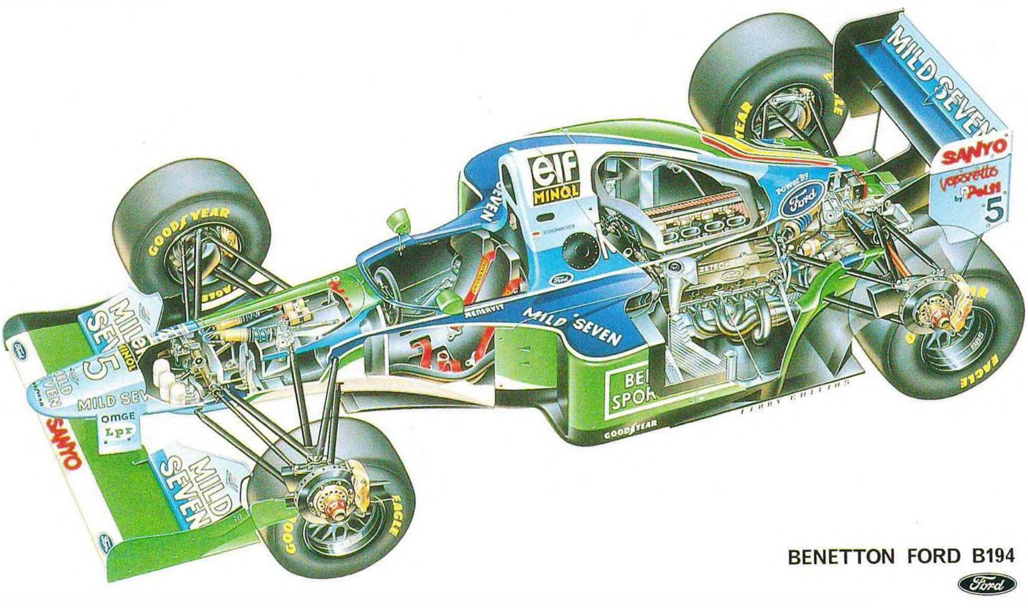


The second-generation Escort RS Cosworth engine with smaller turbocharger, as used in the 1994 model.

Race engine assembly, at Northampton in 1994.

Michael Schumacher, who used Zetec-R-powered Benettons to win the F1 World Drivers' Championship in 1994.

The 1994 Benetton B194, powered by the Ford-Cosworth Zetec-R engine, was the most successful F1 car of the season.



BENETTON FORD B194

success: it kept blowing up, the rods broke, and various other things went wrong. The basic head design was already frozen, as was the chain driving system up the front. It had a *very* narrow valve-included-angle, even by our standards – it was only 20 degrees. We modified the ports, changed the camshaft profile, did a lot of development work, and made it reliable.

'Opel had already designed the manifolds, so that the road car would have long manifolds sweeping across the top of the engine with fuel injection, though the rally engine would have short stub manifolds and Weber carbs. We only did design work on the rally engine but we advised on the road engine, and were able to improve it significantly.'

Alistair Lyle and Geoff Goddard did most of the work to Mike Hall's direction, and the revised engine was 'right on the numbers' as soon as test bed running began. Opel was so pleased with the rescue job carried out at Northampton that Cosworth was then asked to machine and assemble cylinder heads. Opel supplied unmachined head castings from West Germany: Ben Rood's machine shops and the assembly shops then did the rest.

Cosworth built 400 Ascona 400 engines in 1978/1979, then followed them up in the early 1980s with a further 400 engines for use in the Manta 400 coupe. At the same time the rally engine was completely redeveloped, and before the Manta 400 ran out of development the engine had been pushed up to 280 bhp, which was significantly more than had ever been achieved on BD-type engines intended for the same rallying Group.

All in all, Cosworth built between 1,000 and 1,200 production cylinder head assemblies, and also supplied all the 'works' rally engines, many of them through Swindon Racing Engines, a company profiled in more detail in the next chapter. The real accolade, however, was still to come, as Mike Hall recalls:

'The next breakthrough came in 1980. It was Daimler-Benz, straight out of the blue. They wanted us to design a 4-valve rally engine based on the bottom end of their new 2.3-litre M102 single-cam four-cylinder unit. They had already done their own 4-valve twin-cam design, but they were happy to admit that it wasn't good enough. They came to us because of our size, and our capability. If they had just wanted a design, and the odd prototype, several other companies (like Porsche) could have done that.

'However, where Cosworth is totally unique is that it can start from a clean sheet of paper, design something, detail it, test and develop it, cast and forge the major items, then manufacture it in reasonable quantities. I don't think there is any other business which can do this – certainly not in the UK, probably not at all in Europe.

'This was fascinating, because they gave us a completely free hand – they were super people to work with, and it was almost like getting the Royal Warrant. Although we had to use their cylinder block, they wanted a no-holds-barred race/competition engine for a special Mercedes-Benz model.

'Their engine had a chain-driven camshaft so we stuck with that, and for the first time I decided that we had to go for one-piece cylinder heads. The fact that we had by then the Cosworth foundry at Worcester, which could make much better complex castings than anyone else, helped enormously.

'Our first target for the rally engine was 270 bhp, in driveable "forest" trim. For tarmac use, or racing, we were looking for more than 300 bhp. In both cases, we were to use Kugelfischer injection. We didn't ever run one of those engines at Northampton. Two fitters came over from Stuttgart, and between us we built up an engine to make sure that all the parts fitted together, then shipped it over to West Germany. I was asked to go there, we started it up on their dyno, ran it in, put it on power, and on the very first run it produced 267 bhp. They were fairly impressed – and I was quite proud of that.

'By that time we had so much experience that we could target an engine, specify it, and predict fairly accurately what we could produce.

'We built the parts for a few engines – about a dozen, if I remember correctly – and the idea was that we would eventually build a few hundred so that a car could be homologated.'

By this stage, however, Daimler-Benz had discovered that dominance in rallying was hard to achieve. A costly 1980 programme had been highlighted by failures and humiliations, for the cars chosen (450SLC/500SLC coupes) were far too heavy and unwieldy. After signing Ari Vatanen and Walter Rohrl, in preparation for 1981 (with a new car), Daimler-Benz abruptly cancelled its motorsport programme, and all Cosworth's work seemed to have been wasted. But not for long. According to Mike Hall:

'This was the best thing that could *ever* have happened to us. Instead of doing 200 sets of racing bits, we were then commissioned to do 5,000 production head assemblies every year. I had to modify the head a little bit, to make assembly easier – this was the first time we had ever had to think about production in such numbers. I'm sure Daimler-Benz could have tackled the job themselves, but the numbers were really too low, and in any case the link with Cosworth gave them a certain amount of prestige.'

The result, unveiled in September 1983, but not entering production until 1984, was the Cosworth-designed road-car engine for the 190E 2.3-16 model. For Cosworth, it was the very first volume-production road-car engine contract, where the heads were cast at Worcester, then machined at the new Wellingborough factory, and where Cosworth produced complete cylinder head assemblies before shipping them to West Germany. Cosworth, which had signed confidentiality agreements with Daimler-Benz, was delighted when the West German firm leaked the source of its new engines, and there is now no secrecy about the arrangement.

Five years on, that arrangement continued, although for a time Daimler-Benz also machined a series of heads. In the late 1980s the engine was enlarged to 2.5-litres, and in 1989 an 'Evolution' type was also produced, to allow the 190E 2.5-1.6 to be competitive in touring car racing. Cosworth also produced the specially gas-flowed cylinder heads, and some of the competition pieces, for the racing versions of that car.

GM, having relied so heavily on Cosworth for its Chevette HS and Ascona/Manta 400 cylinder heads, came

Mercedes-Benz contracted Cosworth to design, develop, manufacture and assemble 16-valve twin-cam cylinder heads for the Mercedes-Benz 190E 2.3-16 model of the early 1980s. It went on to become this, the 2.5-16, a few years later.

back again in September 1983, this time asking if Cosworth would produce a new 4-valve twin-cam engine for use in road cars. In terms of projected numbers, the GM contract was as important as that from Daimler-Benz, for GM was proposing to use 16-valve engines in Kadetts and Astras, Vectras and Cavaliers, some with front-wheel-drive and some with four-wheel-drive.

'We designed and made the prototypes', Mike Hall told me, 'then we went on to produce several hundred pre-production heads, for test and proving purposes. It was always envisaged that we would then manufacture the first few thousand, but that if the project was a success, then GM would also make heads in West Germany too.'

Which is precisely what has happened. From 1987 Cosworth's production factories were busy casting, machining, and assembling 16-valve heads for GM – but before long GM's own factories were outstripping them.

Strangely enough, GM was very reluctant to admit to any Cosworth involvement at first, and it is still rare to see the Northampton concern credited with any of the work.

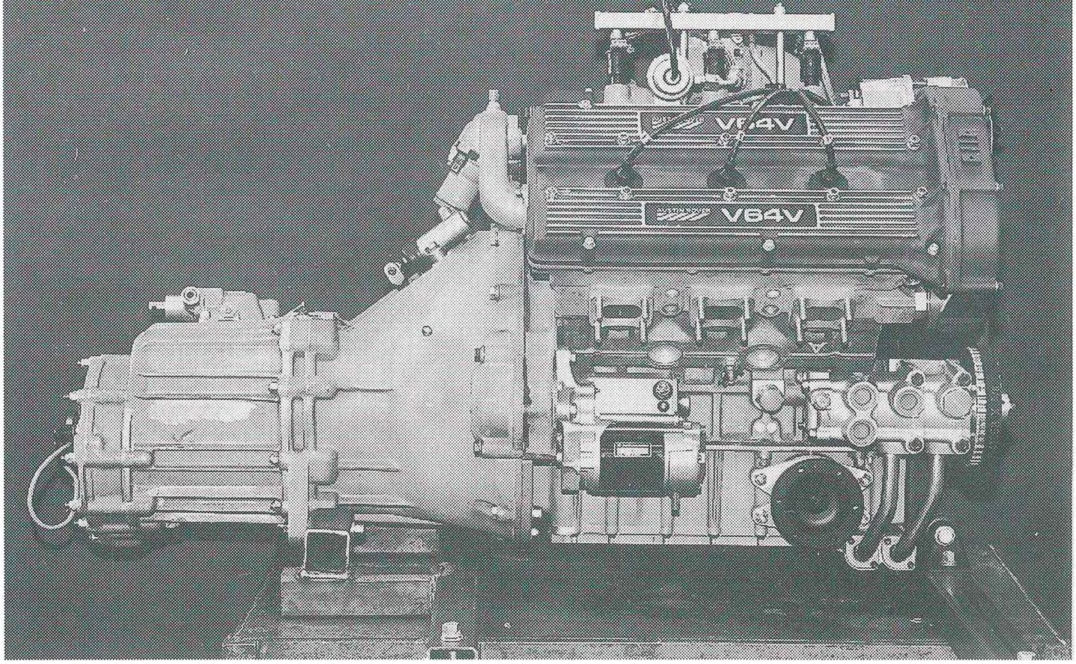
Cosworth, incidentally, have developed, and made, many Group A parts for this engine, while the Swindon Racing Engines concern (once controlled by Cosworth) held the contract to prepare and rebuild 'works' engines in the late 1980s.

Other projects

Several other projects are listed in Appendix 2, and it is certain that others have been carried out, if not widely publicized, over the years. Here are a few examples:

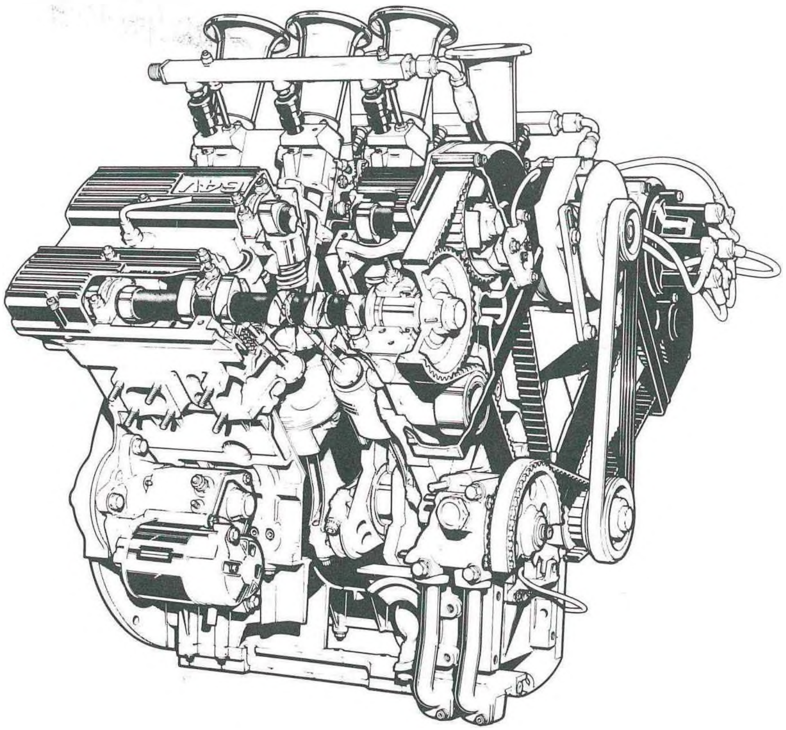
The **MG Metro 6R4** 90-degree V-6 engine was, in concept, designed by David Wood for the Austin Rover Motor Sport division. It had, shall we say, certain obvious likenesses to existing Cosworth designs. When the press first saw the engine, in 1985, several observers likened it to a more modern version of Mike Hall's Ford GA design. Mike Hall, however, corrected this impression:,

'I did quite a lot of consulting with David Wood, who had once been an engine builder with a great deal of BD and DFV experience. He wanted to use as many proven parts as possible. In the end, we supplied all the valves, the springs, guides, and so on – they were straight DFV parts – as well as pistons. We also cast and machined all the cylinder heads – in layout these were almost three-cylinder versions of the Mercedes-Benz design, and they used DFV type ports.



'There was a certain amount of trouble with timing belts, but we had nothing to do with that, or with assembly of the engines.'

Geoff Goddard confirms that the whole of the engine's breathing arrangements were near-identical to the DFV, and that this was arranged with the agreement of Cosworth.

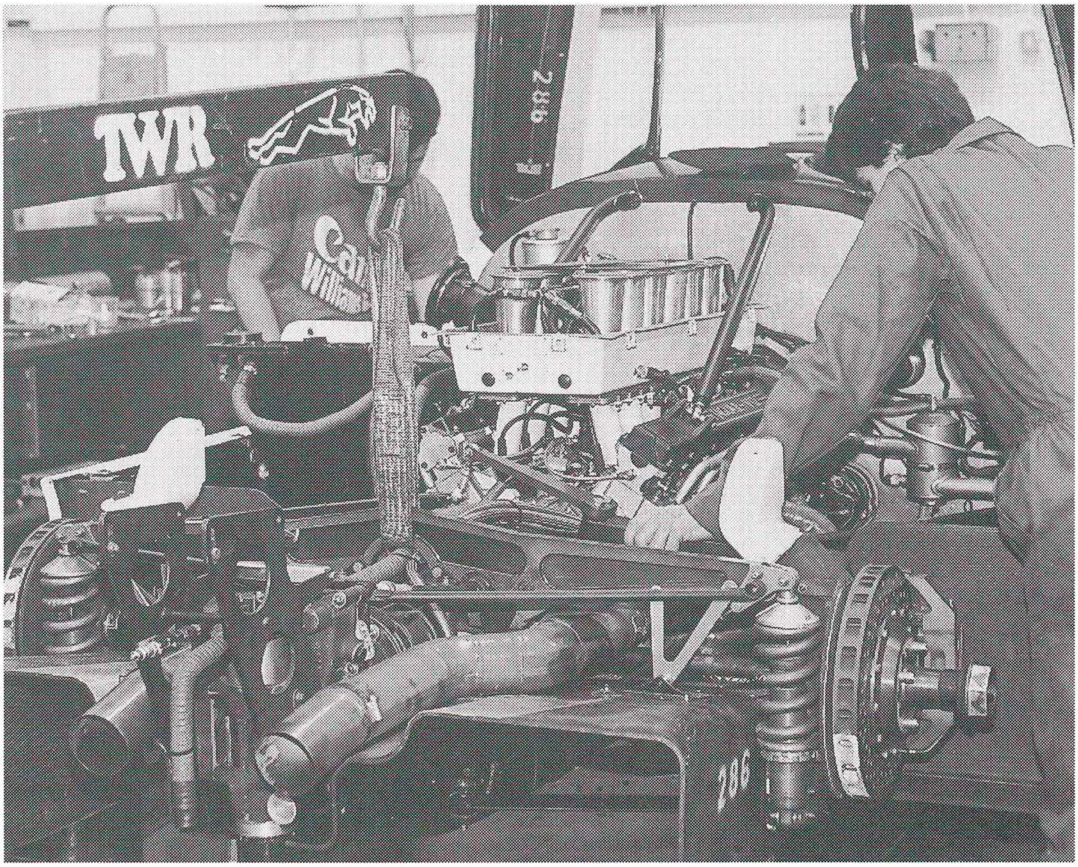


Above Williams GP Engineering developed a mid-engined four-wheel-drive rally car design, the Metro 6R4, for Austin-Rover, but they designed their own 90-degree V-6 engine. The heads were cast, machined and assembled by Cosworth, while most of the valve gear, and many of the cylinder head porting dimensions, were 'lifted' from the legendary DFV. TWR bought the manufacturing rights in 1988.

Left The 6R4 engine. Seasoned Cosworth-watchers could probably see several familiar features in the top end and valve gear. Cosworth was consulted, and manufactured many pieces, but did not carry out any actual design work.

Right The MG Metro 6R4 was designed as a mid-engined four-wheel-drive Group B Rally car, and was fitted with a normally-aspirated 3.0-litre V-6 engine. Cosworth manufactured many pieces for the 200-off production run.

Below During the 1980s TWR's racing Jaguars were extremely successful. TWR have now revealed that many parts were built for them, under contract, by Cosworth at Northampton (*Zoom*).



There is also the rather mysterious involvement with the TWR **V-12 Jaguar engine,** so successfully developed, during the 1980s, for use in XJ-S Group A cars, then in the XJR-series of Group C and IMSA racing sports cars.

I use the word 'mysterious' because TWR has always been very reluctant to spell out its links with Cosworth. The fact is, however, that Cosworth was first approached in regard to the XJ-S Group A engine, producing cylinder heads, camshafts, pistons, rockers and many other details. It carried out more and more sub-contract, machining, and consultant design work on this engine as time progressed, and in due course TWR came clean.

TWR's own engine design engineers were always ultimately responsible for the unit, though Cosworth's race-engine designer Geoff Goddard was certainly involved in camshaft design, while marketing manager Jack Field confirms that he machines and supplies many parts to Kidlington.

By the late 1980s the only pure Jaguar component used in that engine was the cylinder block itself, which was supplied in partly-machined condition.

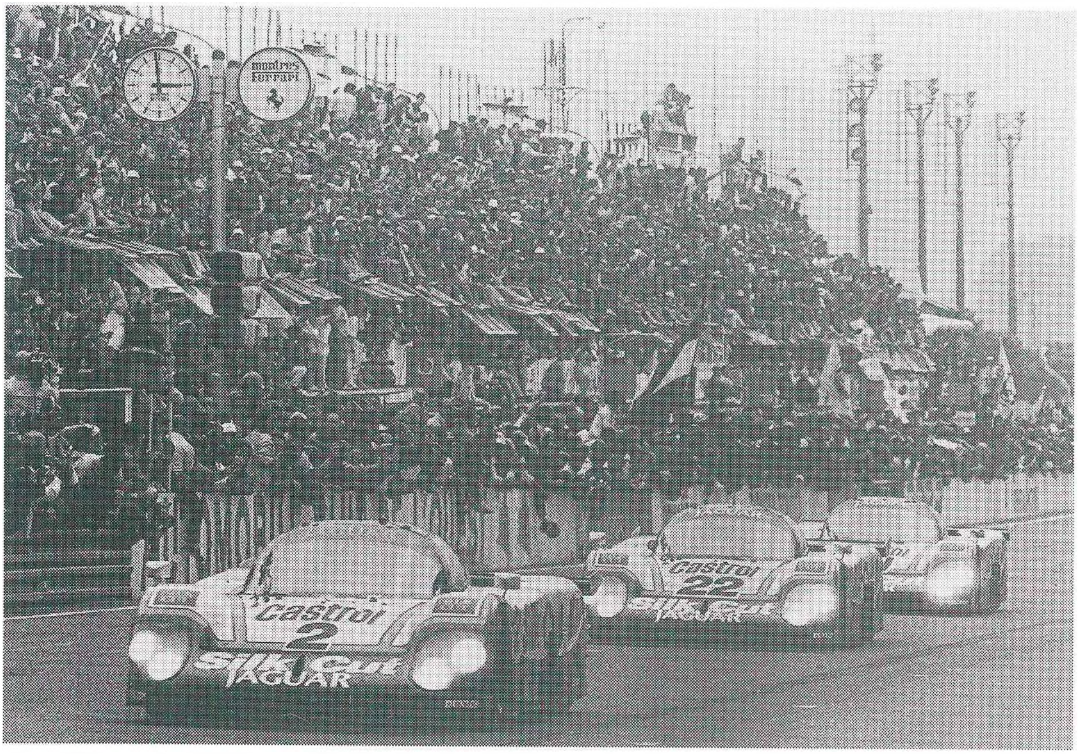
Cosworth was also involved in the machining of some parts for TWR's newly-developed twin-turbocharged V-6 unit, which was unveiled in the spring of 1989.

Marketing manager Jack Field admits that in some cases he machines and supplies parts to 'middle men', and is not at all sure where they eventually go:

'People tend to discover a use for things. Take a little fuel filter we did for the DFV. We decided to sell it to other people, had it anodysed gold, called it the "Gold Filter" – and now we sell them fifty at a time.

'The original oil pressure and scavenge pumps we designed for the DFV are now being used by almost every V-8 engine running in IMSA, or NASCAR racing, in a DFX, a Chevvy, a Buick or whatever. We get orders in batches of twenty sets, at £5,000 a set! Sometimes we have had orders for water pumps, and discovered that they were going into turbocharged marine engines. Then, of course, we get people coming to us, asking for Cosworth to machine a camshaft profile onto the customer's cams. If they didn't mind using one of our range, from DFVs, BDs, YBs, and such-like, we don't mind that either. We certainly make pistons, we don't mind making conn rods, though we don't like to do crankshafts.'

If, indeed, this wasn't such a high-technology, high-turnover, business, one would be tempted to call this the 'jobbing engineering' side of the business. No wonder that



The TWR Jaguar XJR-9 triumphed at Le Mans in 1988, with 7.0-litre V-12 engines. Many pieces for these engines were manufactured, for TWR, by Cosworth.

Keith Duckworth set up an ostensibly separate Cosworth Components for a time.

Other companies, on the other hand, think they need only buy a Cosworth head from another engine, copy it, and save themselves many thousands of pounds. Keith Duckworth, however, chortled merrily for some time when I raised this point with him:

'The easiest way to get a fair performance out of a new design is to do a good copy of what is known to work. That is *if* you do a fair copy, and not try to improve it. It is the so-called *improving* of our designs that has wrecked some other designs! Negative improvements have occurred on a number of occasions.'

CHAPTER 8

DFV developments – Cosworth's amazing V-8

'It soon became evident that this could be Lotus-Ford, Lotus-Ford for ever . . . I said to Colin Chapman: "You do realize, don't you, that we're going to have to let other people use this engine?" . . .'

When Ford asked Keith Duckworth to design the DFV, the original agreement did not specify the car or cars in which the engine was to be used. The agreement actually stated that: 'The choice of team will be at Ford's discretion, Cosworth being available in an advisory capacity if required.' Even so, Keith designed the DFV around the new Lotus 49 (and, specifically, the rear engine mountings were placed a mere nine inches apart 'to suit the structure, and the size of Jim Clark's bottom . . .'). It was always understood, though never specified, that only Lotus should have the use of the engines in the first year. Walter Hayes summarized this concisely:

'Well, we *could* have given them to other people, but since the engine and the car were being developed together, and since we were all part of this great enterprise, it would never have occurred to me to give them to anyone else.'

Cosworth's contract, as it stood, merely obliged it to produce a total of five engines by the end of 1967, and to maintain them until the end of 1968. Ben Rood, certainly, did not plan a production run:

'In the late 1960s I never even stopped to think about twenty years on. We never envisaged the DFV going on for that length of time. We only changed the way that we made the DFV in the mid-1980s. I think we should have tackled that job a lot earlier than we did. Originally we just organized ourselves to build a few – and now I'm talking about less than twenty engines – then we had to carry on making batches, a few at a time, for year after year. The tooling, such as it was, was almost non-existent.'

By the autumn of 1967, however, Walter Hayes could see that the DFV had already changed the face of Grand Prix racing:

'It soon became evident that this could be Lotus-Ford, Lotus-Ford, for ever. Although this sounds a bit like evangelism, I had always thought that the important thing for Ford in motorsport was for *motorsport* to be successful, and to encourage more and more people, not necessarily for one team to be supremely dominant.

'At dinner, one evening, before the German GP, I said to Colin Chapman: "You do realize, don't you, that we're going to have to let other people use this engine?". Colin, without any argument at all, said: "Yes, I can see that." No argument, no histrionics, nothing. In later years I used to wonder about that – was he so supremely confident in his ability, or whether he had the same sort of vision as me?

'We were very confident with the DFV, even by that

Who is trying to do deals with whom? Ken Tyrrell (centre) makes his play to Ford's competitions manager Stuart Turner (in glasses), with Colin Chapman missing nothing. Somebody doesn't trust the cameraman though . . .

stage. It had really not been tuned, or developed from the very beginning, but people were queuing up to buy it. It was an amazing engine, *much* better than its competitors. Jim Clark used to say: 'You start with one engine, then you put your foot down and above 6,500 rpm it's like getting another engine as well!''.

'It became obvious that if we, and Cosworth, did it right, we could become purveyors of DFVs to the whole world. I know people began to call it Senior Formula Ford, but I know of no period when Grand Prix racing was more appreciated than it was in those days.'

The records show that Cosworth built its five contracted engines by the summer of 1967, but that by the end of that year a total of ten had been delivered. Then the rush set in – by the end of 1968 a further 22 were delivered, and the fiftieth engine was completed before the end of 1969.

Not that there was ever a surplus of DFVs to go round. A few, for no very good and obvious reason, never performed as well as they should, and although Dick Scammell's experts took them apart, even cut them up, to find out why, it was never obvious. Walter Hayes told me that there was one occasion when one of his teams had a shortage, but that on a visit to Northampton he noticed what looked like a spare DFV sitting in a corner. 'Why can't we use that?' he said. Keith, in a single, throw-away remark, merely commented: 'Oh no, you can't have that. It's a bad-tempered engine.'

At first it was Ford which vetted the customers, and decided who should use the DFV, but by the early 1970s Cosworth was set free to market the engines in almost any way it wished. Several years earlier, Walter Hayes had spotted the precocious talent of a beady-eyed young Scot called Jackie Stewart, and it was almost inevitable that he should steer the first 'customer' supplies of DFVs towards Jackie, and the Tyrrell team:

'My first contact with Jackie was at an Earls Court motorshow in the mid-1960s. Jackie was driving BMC-engined F3 cars at the time, and I heard that BMC had just refused to lend him a road car. I talked to Jackie on the stand, showed him a big Zodiac on the turntable, and asked him if he would like to have it? "Yes, obviously", he replied, so I said "Well, if you would come to do some driving for us, I will give it to you . . ." In fact, we gave him the car even before he could drive for us, but I knew we were going to need him soon, and at that stage I just wanted to make sure that he was ours.'

In 1968, the other lucky recipient of Cosworth DFV V-8s was McLaren, another team personally chosen by Walter Hayes. His talent spotting was uncannily accurate. In 1968 there were twelve F1 GPs, of which Lotus won five races, McLaren won three, and Tyrrell-Matra won three. Hayes now insists that he never wanted to see Ford making big money out of the DFV programme:

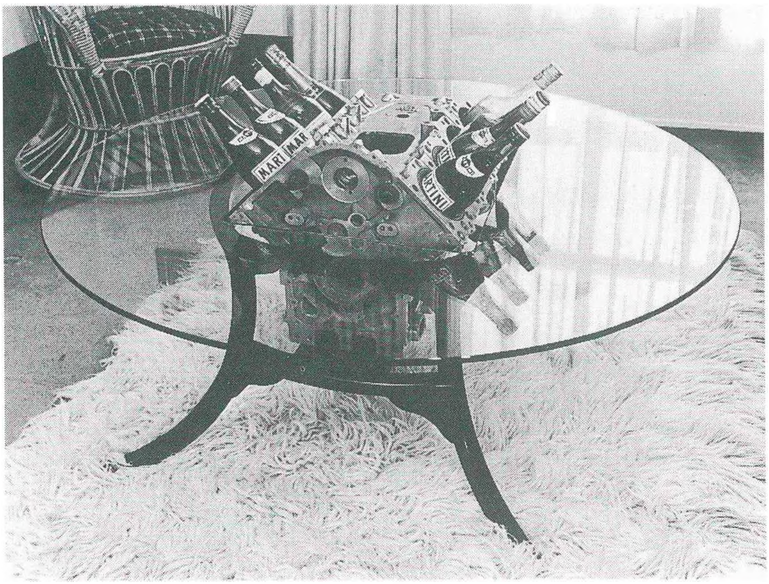
'I thought it important that Keith should price the engine, and then he should sell them all. He would keep all the money he made – none would come to us – he would sell all the spare parts, and he would keep all the money he made from servicing and rebuilds. I hoped, I sincerely hoped, that this would make him rich enough to invest in a much more comprehensive facility to go on, and to do even greater things. I wanted to make Cosworth bigger, more powerful, and I wanted it to have more resources.

'My ulterior motive? Well, my experience is that you get better work from rich people than from poor people. If an engine builder cannot afford the money to do his own tinkering, and further development, you lose the opportunity of his continuous efforts. When I saw that Keith had bought his first helicopter, I knew that everything was working out!

'In the end, too, I had another motive. When Keith, Mike, or whoever would come back to me and say: "Look, we were screwed, you got all this publicity for only £100,000", I could always reply that we had helped him to have a product which had enabled him to make a great deal of money . . .

'On the other hand, too much money spoils some people. I always said that the decline of a Grand Prix team began when it got its first motorhome. *Certainly* I always began to worry when they bought their first executive jet!'

The DFV story has been told, and told well, by any number of people, but not all of them have realized just how much Keith (and to a lesser extent, Walter Hayes) treated it as a personal 'pet' project. Keith, perhaps not by work, but certainly by attitude, always let it be known that *he* had designed the DFV, and that *he* would decide what was needed to make it go even better in the future. At Cosworth, therefore, the DFV engine revolved around Keith, around Mike Costin and Dick Scammell, who carried on the development of the year-on-year improvements, and on Jack Field, who had the demanding job of balancing demand against supply. Throughout the 1970s Cosworth was in what economists would call a 'monopoly situation', for it always had more people wanting to buy



Old DFV blocks never died — they were merely re-cycled for use as exclusive drinks holders and tables! The year was 1976, and the tables were marketed by Planners International.

the engine than it could satisfy. From time to time Keith would let Jack Field know who was 'in', and who was 'out' of favour.

This, of course, only applied to delivery priorities, for it was one of Keith's axioms that as far as possible everyone should get the same engine specification. The engine, if correctly installed, and correctly plumbed, should perform in the same way for every customer. As an example, therefore, an up-and-coming chassis manufacturer like

The DFV also found a use in special record-breaking speed boats too . . .

Williams could be sure in the late 1970s that it *ought* to beat Lotus or Tyrrell if its chassis, and its drivers, were superior.

'An important part of Cosworth's ethics was that we succeeded in business because we standardized pieces, and made everything so that outside people could buy bits, and they would automatically fit together. That was an important difference between us and most of our competitors.

'That was one of the reasons why the Gurney-Weslake V-12 engine didn't work properly, because the bits weren't made well enough, and the amount of hand fiddling and fettling was horrendous.

'Coventry-Climax was supposed to have a philosophy of interchangeability, but from my personal observation they didn't carry that out. In the beginning, when I was rebuilding Coventry-Climax engines, most of the problem was in actually making the new parts good enough to fit the old engine. The old FPF twin-cams, in particular, were real "knife-and-fork" jobs.'

Weslake's V-12 rival to the DFV

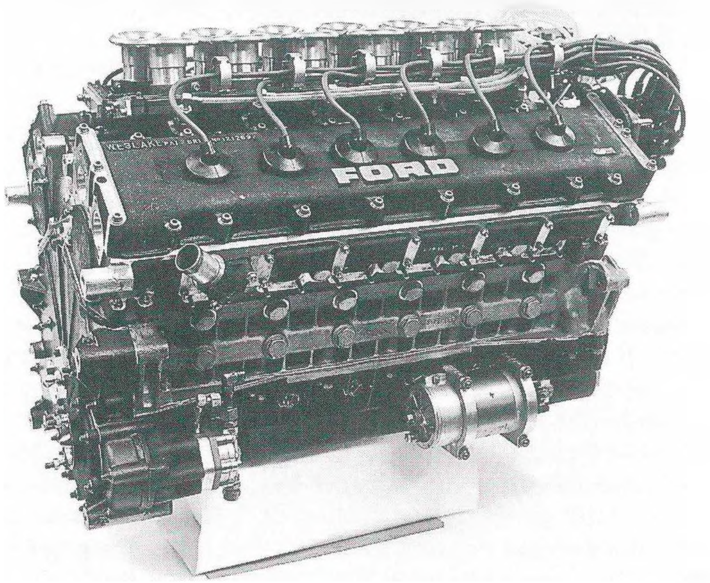
Walter Hayes confirms that although he was completely happy with the performance of the Cosworth DFV:

'When I was involved in the Ford GT40 project, I got to know Harry Weslake very well. He did some amazing work on GT40 cylinder heads when the team was in trouble. Soon after that, Harry Weslake tried to sell me the idea of a new F1 engine, which was a 3-litre V-12. Well, I didn't really want to set up a competitor for Cosworth, we didn't need that, and as we had a very happy relationship why should I want to break it?'

Weslake, helped along by his consultancy agreement with BRM, and Aubrey Woods, had produced similar V-12 engines for Dan Gurney's AAR Eagle team in the 1966-68 period, for which 410 bhp-plus was claimed. Although there were several engines, all were hand-built with virtually no interchangeability, unit to unit. There was one major success for the Eagle-Weslake V-12 – the Belgian GP of 1967 – but Dan Gurney became disillusioned, and pulled out of the project in 1968.

In 1970, however, Walter Hayes and Stuart Turner of Ford encouraged Weslake to design another 3.0-litre V-12, ostensibly for long-distance sports car racing, though it was always understood that if it *was* to be competitive in output, then Ford might consider it for use in a Grand Prix car.

The new Weslake-Ford V-12 used the bore, stroke, crankshaft and other details of the Eagle unit. The 4-valve, narrow-



included-angle, pent-roof combustion chamber looked superficially like that of the DFV, though this time there were swirl-inducing lobes in the chamber profile, a Weslake favourite, as also used in the famous BMC A-Series engine (and as distrusted, on 'masking' grounds, by Keith Duckworth). The initial power target was 440 bhp, which would have made it immediately competitive with the DFV.

The engine ran for the first time on 20 December 1971, and according to Weslake's own test bed it actually produced 460 bhp, with a later engine working up to 470 bhp, which was 20 bhp more than that shown by a current-spec Cosworth DFV on the same bed. Tests in Gulf-Mirage prototypes were encouraging, but all manner of problems – financial, political, and development – meant that it was never raced. Legal action followed, with Weslake being awarded damages against Gulf-Mirage. John Dunn, of the Cosworth-controlled Swindon Racing Engines concern, also tested an engine and recorded 465 bhp, thus proving Weslake's claims, but it never seemed to deliver the goods in a racing car. In 1973, BRM tried one in a P160, while Brabham also fitted one in a BT39, but neither installation was a success.

During 1974 the Weslake V-12 project was cancelled completely, having cost £150,000 to develop to that stage, and Weslake had nothing to show for it. The problem seems to have been two-fold – a lack of reliability, and a lack of mid-range torque.

Keith Duckworth's race engine design philosophy, once again, was completely vindicated – there was no point in having record-breaking peak power if the engine was not also flexible further down the range.

'Bill Brown was the proponent of this straightforward approach. We rarely upset people in this way, or over delivery dates. We rarely quoted delivery dates, but on the other hand we always said we "would use our best endeavours" to get things ready.

'We always decided we would be dead honest about our power outputs. If we said our engines were going to give "this much", *every* engine we sold was going to have to give that much on our test beds. We stated a figure that, in general, we thought it would be fairly easy to achieve. Because of the scatter we didn't want to have too much aggravation – but sometimes we needed rebuilds of engines that didn't quite make the targets. When we had a real demon engine, we often tried to find out why it was so good, but we never made it.'

This, of course, was an astonishing breakthrough for what had become the 'Grand Prix industry'. New customers took time at first to accept what they were told, and because the figures quoted were minimum ratings, rather than average ratings, a few people thought they were being honoured by extra-special units. In truth, Cosworth rarely set out to build screamers, and in a few cases actually delivered top-rated engines to the customer without telling him! On the other hand, Cosworth – Keith in particular – expected customers to be honest with them:

'We must have had one of the best experiences of low bad debts, of any firm, ever. We did insist on getting paid promptly for new engines. New engines didn't leave the place until they had been paid for. But we could be fairly generous, by not pressing too hard for prompt payment from customers who we thought were struggling hard, but honest – we were always as reasonable as possible to people like Frank Williams. Frequently, we got paid somewhat late, but we usually got the money in the end. We *always* got paid by Frank.

'If payment tended to be rather late, and rather slow, we could often fall back on the fact that another of that customer's engines was in for a rebuild. It tended to be fairly difficult to get those engines back to them if they hadn't paid their bills.'

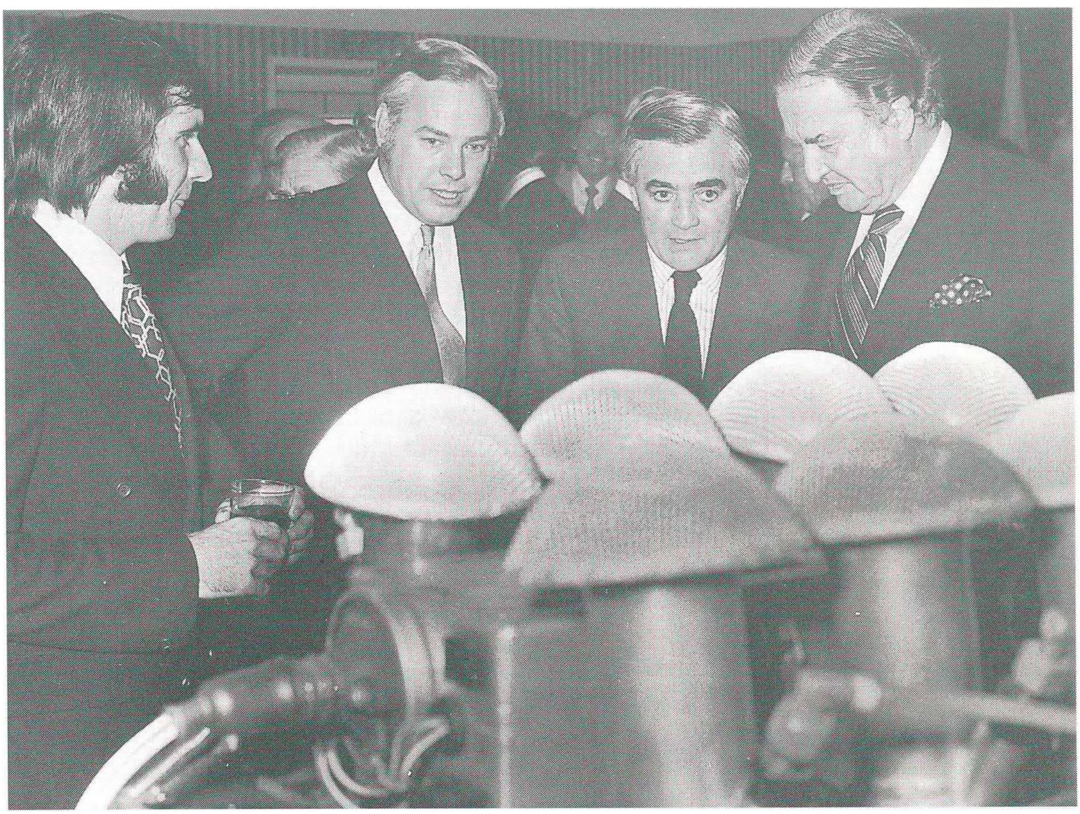
'We didn't approve of people going broke on us. Actually there have been teams which went strategically broke, but we've seldom been caught by those people. In a lot of cases they would want to start up in business again, and therefore they could do well without having us as creditors!'

In the early years of the DFV project, although the engine powered a lot of race-winning cars, the DFV was not always as reliable as Keith and Mike would have liked. The engines were always as powerful as claimed, but from time to time breakages occurred. The oil circulation problem was soon solved, but the two most irritating failings were to timing gears, and to crankshafts.

'We had very few DFV problems, really,' Keith recalls, 'but solving the gear train torsional problem took us a long time. It was a pure torsional, which we chased from one end of the engine to the other. We eventually found that the torque causing our timing gear failures was far higher than the output torque from the crankshaft. So it wasn't surprising that the fairly flimsy gears failed under it. I had to get more material into a very limited amount of space, so that existing engines could be converted. It was nearly an impossible problem – I was aiming to reduce the instantaneous torque to about an eighth of what it originally was.'

In the end, and after a great deal of the 'withering concentration' for which Keith had become noted, the famous multi-quill shock-absorbing gear was developed.

In 1972, Ford celebrated the 50th victory in GP racing by a DFV engine. The actual win was by Jackie Stewart's Tyrrell in the Canadian GP. Here, at the party are (left to right) Emerson Fittipaldi, DKD, Walter Hayes, and Henry Ford II.



Henry Ford II presents an award to Keith Duckworth, to commemorate the 50th GP win by a Ford-Cosworth DFV engine — the occasion was in 1972.

It looks flimsy, it looks complex, and it looks fussy – but it works. [Significantly enough, when Mario Ilien and Paul Morgan left Cosworth to set up Ilmor Engineering, their DFY 'clone' engine was unreliable for the first two years of its racing life. The trouble, they say, was all connected with torsional vibrations in the timing gears, which had no quill absorbing feature . . .]

There was a short period when crankshafts repeatedly broke, but this was soon traced to a mistake in detail machining. The problem was not to solve the problem, but to get new supplies of unmachined forgings to replace the broken items.

By the early 1970s the DFV had come to dominate F1 racing. DFV-engined cars helped Graham Hill, Jackie Stewart (three times), Jochen Rindt and Emerson Fittipaldi (twice) win the World Driver's Championship between 1968 and 1974. Ferrari then fought back, with its flat-12, but James Hunt (1976) and Mario Andretti (1978) went on to show that the DFV was not finished.

The F1 World Championship race successes mounted, as did the number of engines built. Here is a summary of the 1960s and 1970s:

Year	No of victories	Year	No of victories
1967	4	1974	12
1968	11	1975	8
1969	11	1976	10
1970	8	1977	12
1971	7	1978	9
1972	10	1979	8
1973	15		

Ilmor

By 1983 Mario Ilien and Paul Morgan were respected and responsible Cosworth engineers. At the end of that year they left abruptly and set up Ilmor Engineering in Brixworth.

The objective, quite simply, was to use Penske/Chevrolet finance to develop an Indy-racing engine – specifically to rival the Cosworth DFX. This caused a great deal of bitterness at Cosworth, and one can see why. Nothing like this had been seen since a Shadow F1 chassis design suddenly reappeared as an Arrows in 1978. Ilien had designed racing engines in Europe before he undertook formal engineering training, and while at Cosworth he had designed the DFY 'conversion' to the DFV, and initiated work on the Sierra RS Cosworth production car engine. Morgan had been involved with the DFX, as a race engineer, since the early days.

In November 1983, no doubt somewhat frustrated by Cosworth's policy of deliberately 'under-employing' people, so as to minimize mistakes, the two decided to branch out on their own. The result was an approach to Roger Penske of the USA, who soon assembled a financial package to allow them to set up shop a few miles from Northampton.

If the Ilmor engine had been innovative, or significantly different, from anything which Cosworth was designing, everyone would have wished them well. It was not, and everyone I have spoken to mutters deeply about the way the years of experience were directly used in the new engine. For obvious reasons, I cannot name the personalities who talked to me, but here is a selection of what was said:

'The Ilmor engine was a near copy of the DFY, with the same head, but turbocharged. It was built to fit the same monocoques as the DFX. Most engine pieces were exact replicas of ours, or "borrowed" from new designs which Cosworth was considering. Really, it's a straight clone.

'People are going to leave any company, nobody feels hurt about that. If they'd gone off to do a V-6, or a totally different V-8, Keith would have wished them well.

'I'm sure the Ilmor was just a turbocharged DFY. But they missed out the compound gear with the quills. *The* cleverest feature of the DFV – and they didn't copy it!'

Instead Ilmor relied on a train of timing gears going up from the flywheel end of the engine, which had a lower torsional component. This was an idea which had been discarded by Keith in view of the tiny flywheels which were being used.

'It took them two years longer than they promised, to make the engine work. Making a slightly up-dated version of the DFX was a bigger challenge than they had expected, wasn't it?'

The Ilmor engine, however, persuaded Cosworth to drop the 'no-development' agreement it had had with the Indy-racing authorities. Once the Ilmor started winning, Cosworth began to look at new DFX features. The result, for 1989, was the DFS, and the successful new XB followed in 1992.

The whole thing, as Walter Hayes quipped, was getting 'bigger than Ben Hur', and:

'It really wasn't necessary for Keith to do more than sit at home and enjoy it, but he couldn't keep away. I don't think he actively courted this, but in spite of everything he soon became famous. Before the DFV he had really been Professor Brainstorm, in his own simple workshop, creating his own toys, but all of a sudden he was in big business, he *was* big business.'

Never before, in the history of F1 racing, had so many engines been built by one concern. As the doyen of Formula One history, Doug Nye, once wrote:

'. . . the greatest compliment that can be paid them is that they put a Grand Prix racing engine into quantity production and kept it at the top of the class for much more than a decade.'

By 1973, with the build total of DFV engines well past the 100 mark, the walls were bulging with work. Some changes had to be made. Whereas Jack Field had originally been able to keep track of every engine, and also accept them all back for rebuilds, it was clear that the quality of work would go down unless some work (but not all) was farmed out:

'Until the Nicholsons, the Judds, the Hesketh s and the Swindons came along, we used to rebuild every engine. Then we decided that we needed to encourage people outside of Northampton to service all these engines, and that was how they got started.'

Swindon was a special case, as founder/managing director John Dunn told me:

'I had been in the States for seven years. I used to be the

Fuel flow limits in F1 – the Cosworth solution

When the Cosworth DFV arrived in 1967, it produced more than 400 bhp, and set new standards in F1. Ten years later, Cosworth had found another 100 bhp, while Ferrari's best flat-12s were also nudging 500 bhp. Surely it was time, the pundits said – and wrote – that this 3-litre power race should be stifled?

But how? Some sort of restriction would be needed – but should it be on engine air flow, or fuel flow? No-one really thought it through except, need I say it, Keith Duckworth.

'Fuel is the thing you pay for, not air, so it only made *technical* sense to leave air flow alone, and put a limit on fuel flow. As far as I could see, it didn't even matter what size the engine was, as long as the fuel flow was limited. If you restrict air entry you must run the engine rich, so that you use every scrap of air. If you are in fact fuel-limited you must use a surplus amount of air – that's lean burn – to guarantee you use every bit of fuel.

'Therefore your engine would be more efficient if you chose a fuel/second, rather than an air/second, formula. In any case, you could argue that as air is everywhere, and you can't sell it, to ration it would be illogical. Incidentally, I once calculated what size of sonic-flow aperture (F3 style) would do that trick – something like 2.1 inches/53mm rings a bell.

[Keith's rooted objection to the type of F1 racing which eventually followed in the 1980s now comes through]

'It would be totally unsatisfactory to have racing based on so many gallons for the race distance, so the only sensible alternative was to limit the maximum instantaneous power. Therefore, some sort of flow-limiting valve, calibrated in fuel/second, was needed. When I thought this through, I calculated that 27 cc/second was enough to produce 500 bhp, and that this ought to be allowed. In fact if someone developed a two-stroke to use the same amount of fuel, but developing more power, then such an engine should be allowed to win.

'Ideally, you could produce a bigger engine, running slower, because that's the best way to get efficient combustion. The point was that the car would never need to run out of fuel – the car could carry as much fuel as necessary, and the limitation would only be on the *rate* at which the fuel could be used.'

It took a lot of talking, but in the end Keith got the authorities to listen:

'FISA actually invited me to make a device, a valve. I did a lot of work, produced a prototype, and somewhere at Northampton it still exists. Then FISA demanded that I make up to fifty of these valves that would all flow at 27 cc/second. I said that I couldn't guarantee that – I could guarantee that they would all flow within one per cent of one another, but no nearer. FISA couldn't understand that, and therefore I had to abandon it. To have a valve flowing at exactly 27 cc/second, in all temperatures and at all heights, well it just wasn't practical, you would have needed National Physical Laboratory standards of testing kit.'

Did FISA pay for all this?

'Certainly not, we – Cosworth – had to pay for it. By the way, I think it would have been possible to cheat, a bit, too. Someone, somewhere, would have found ways of storing some of the fuel flow downstream of the valve, to get more instantaneous power for a very short period.'

Keith is adamant, however, that the fuel flow valves would have worked, and would have produced good racing, if all the constructors, and FISA, had really wanted to see it happen.

'I showed the device to my main rival, Ferrari, and I still have a letter which agrees that it was theoretically sound, but that there was no way that FISA was competent to calibrate it.'

engines engineer at Shelby American, building V-8s, then I went into partnership with a guy called Falconer, setting up Falconer & Dunn Racing Engines.' I looked after Keith when he came over to the USA for a week – I remember that we paid a visit to Hughes Helicopters. When I came back to the UK, I wanted to start my own business, so I went to see Keith. He asked me to give Cosworth a proposal, which I did.

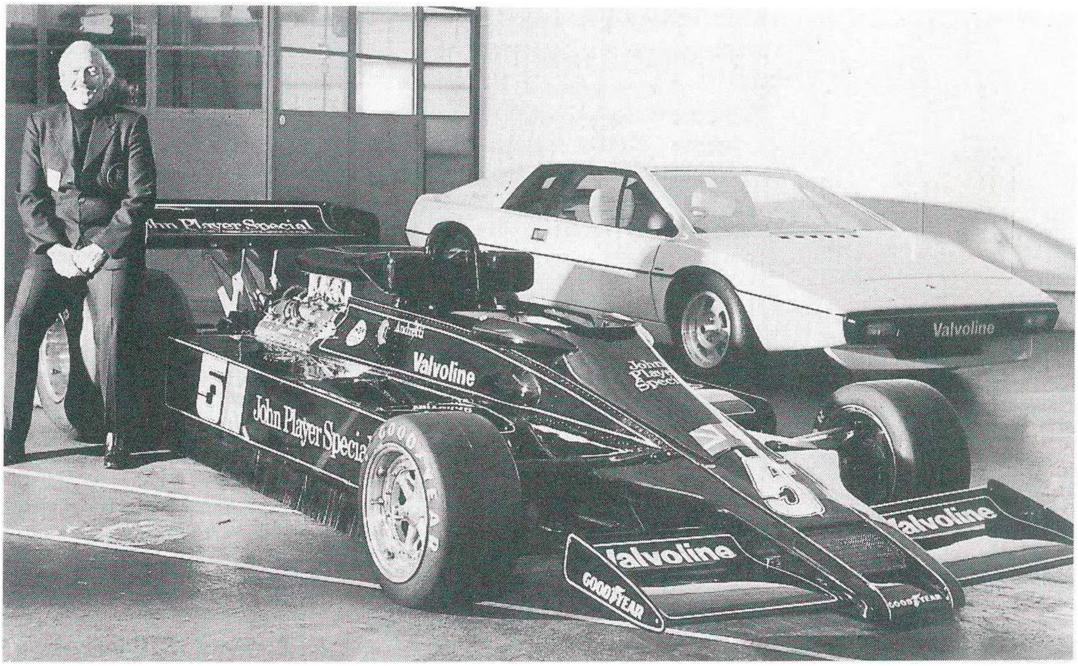
'The result was that Swindon Racing Engines was set up in 1972, a new company and a new building in Swindon, the prime purpose being to service and rebuild DFVs.'

The deal was that Dunn and Cosworth directors would set up a new company, with Dunn running the business, but with Messrs Duckworth, Costin, Brown and Rood all holding shares in the limited company. In later years Alf Vickers also took a small share. John Dunn made it clear however that Swindon was never a part of Cosworth although all Cosworth's directors were directors of his new concern. None of this was broadcast, but neither was it kept secret. The motor racing industry soon came to know about the Cosworth-SRE connection, and the Cosworth directors' share interests appear in the annual records deposited at Companies' House.

'It was a completely "hands off" arrangement. Keith Duckworth has never even been to Swindon – though he told me he had once looked in at the windows as he was passing. There was never any pressure. I used to see quite a lot of him at Northampton, but I was always encouraged to do my own thing. As far as I recall, there wasn't ever an annual board meeting!'

SRE was up and running even before John Nicholson's competing London-based business got under way ('We tested his engines, for him, initially'), not only with the job of rebuilding engines for major teams like Tyrrell, but with specific contracts such as the development of a Formula Atlantic 'package' for the BD Series units, and the building of Formula Super V engines based on the VW Golf engine.

Not only did Swindon prosper by the rebuilding of DFVs, but also from the servicing of other engines such as the Cosworth-developed Opel Ascona 400/Manta 400 rally car engines. Although none of the rebuilders was encouraged to do its own ongoing development, this naturally took place, and some teams stuck closely to one rebuilding concern, keeping their little manoeuvres secret from everyone else. John Dunn is proud of the fact the SRE developed the short inlet trumpet package which sud-



Colin Chapman, and Lotus, were the first to use DFV engines, and even in 1977, when this picture was taken, the combination was successful. The car is a Lotus 78, the first 'ground effect' car to run in F1. It was in this year that Mario Andretti won four GPs, and when the DFV passed the 100 GP victories mark.

denly added horsepower to the DFV in the 1975 season ('In South America, Shadow blew everyone into the weeds. By the next race everyone had them.'), Nicholson was the first to try an enlarged bore/shorter stroke system, while several tried different cam grinds before Cosworth came back with the definitive DA12 profile of its own.

The various DFV rebuilders were not encouraged to co-operate, each having to pitch for its own contracts, and individual tweaking and development was discouraged. In any case, there was a great deal of routine, but profitable, work to be done. John Dunn told me that although a DFV rebuild occupied 120 man-hours, his SRE concern once tackled 130 such jobs in a year.

In the early 1970s, then, Cosworth was happy to let the DFV coast along on the tidal wave of its own success, not needing to do too much work to make it more powerful, only making sure that the orders could be met, and reliability achieved. Graham Dale-Jones is sure that between 1970 and 1977 (when he finally moved on) there were no changes to DFV ports, valve sizes, or cams though 'we changed the trumpets, and gradually we came to let it run faster.' Eoin Young, writing in *Autocar* in 1969, summed up the DFV's dominance in this way:

'I have been wondering what Cosworth planned to do when their 3-litre engine starts to get overhauled by more

Autocar: 4 June 1977

In my survey of the DFV's career to that point, headed 'Duckworth's Decade', I opened the piece:

'"I don't think the DFV is at its limit yet, and I *do* think it should be possible to get 500 bhp from it. Anyway it looks as if we've got to try!". That is a typically trenchant remark from Keith Duckworth, and followed by a lengthy pause for thought.

'. . . how else can one summarize an engine which is – quite literally – the most successful Grand Prix design of all time? It has raced more times, won more races, been used by more constructors, been built in far greater quantities, and won more World Championships, than any other engine.

'At one point, too, Keith Duckworth confessed his own limitations:

"Of course I'm surprised and delighted that the DFV has been so competitive for so long. I certainly didn't plan it that way in 1966, and I certainly didn't design the engine to reach 500 bhp eventually. I'm *far* too ignorant to lay out a design with power improvements locked inside".'

These words were written, and spoken, at a time when the DFV was celebrating its 100th GP win. But there was a lot more to follow – between 1977 and 1983 the DFV family won another 55 World Championship GP races, while the turbocharged DFX became *the* engine to use in North American CART/Indy racing.

exotic creations from Ferrari and BRM, but Mike Costin doesn't see any immediate problem.

'He idly checked the figures on a slide rule as he talked, and said: "If we raise the engine limit from 9,500 to 10,000 rpm, we should get just over 450 bhp.".

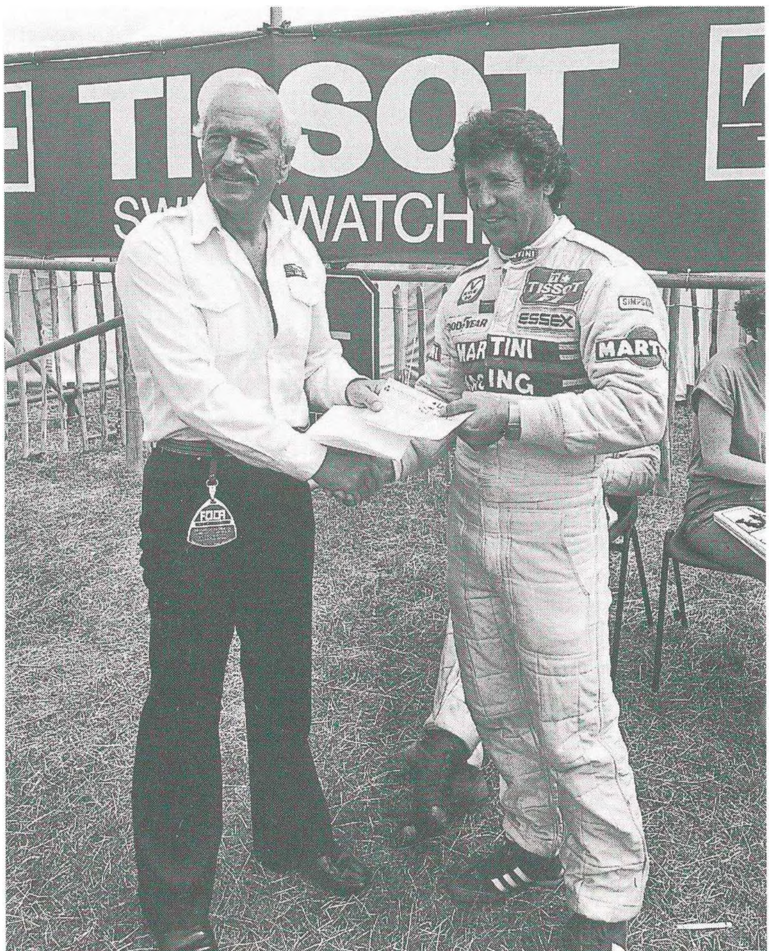
By mid 1970, most DFVs had 430 bhp, but a few had more than 440 bhp at 10,000 rpm. If the limit was raised to 10,500 rpm, more than 450 bhp would be available, and at 11,000 rpm this would ease ahead to 470 bhp. Even so, teams could put 600 racing miles on an engine before a rebuild was needed, after which a £500 rebuild, and a £200 test-bed check would follow.

By 1974, with inflation biting hard into the British economy, a new DFV cost £9,266 (including VAT), and by 1977 it was priced at nearly £15,000 (including VAT).

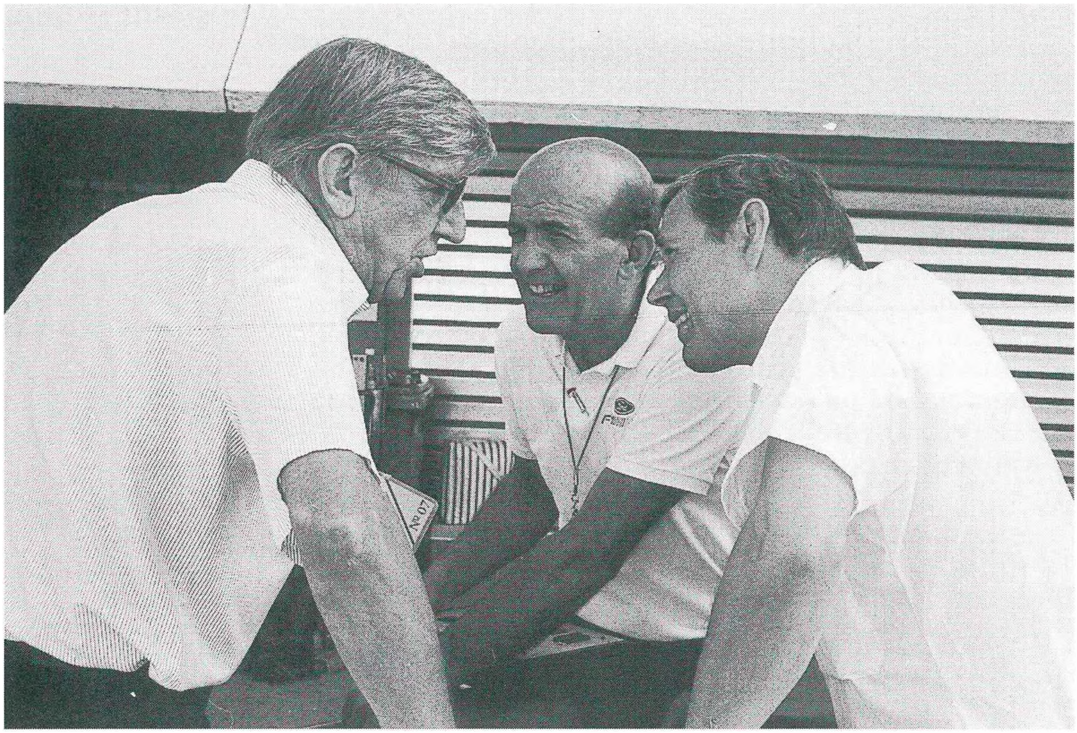
In the meantime, Ferrari had caught up with Cosworth in the horsepower race, for no DFV changes were made from 1973 to 1976 inclusive. The Ferrari flat-12 engine, first raced in 1970 with a claimed output of 460 bhp, was rated at 495 bhp by 1974, and passed the 500 bhp mark by 1976. No-one doubted those peak figures, though the 'boxer' engine was by no means as torquey in the mid-range as was the DFV. Nevertheless, the Ferrari-Lauda combination was winner, claiming three victories in 1974, seven in 1975, and six in 1976. As Keith Duckworth so succinctly told me, in an *Autocar* interview at the beginning of 1977:

'I don't think the DFV is at its limit, yet, and I *do* think it should be possible to get 500 bhp from it. Anyway it looks as if we've got to try!'

The first effort was to produce a much lighter DFV, by using magnesium castings for the heads and the cylinder block. This produced a 44 lb weight saving, but there were innumerable problems over differential expansion as the engine warmed up – if the crank bearings were too loose the oil pressure dropped, if they were too tight, then the power would be 10 bhp or more down on a nominal figure.



Colin Chapman of Lotus (left) and Mario Andretti, an amazingly successful combination, powered by DFV engines, in the late 1970s.



Still trying to wring the last few bhp out of a Cosworth V-8 — (left to right) Ken Tyrrell, Brian Hart and Cosworth's Dick Scammell (*Maurice Hamilton*).

Next Keith and his team turned their attention to the internals of the engine, to reduce windage, and to the re-packaging of the accessories, to make it more suitable for one of the new-fangled 'ground-effects' cars. Geoff Goddard, who was later to be responsible for the overall design of the GB (turbocharged V-6 F1 engine) and the HB (new-generation 75-degree V-8 F1 engine for 1989), carried out most of the 'ground-effect' DFV work, listing it as one of his first major projects. Geoff Goddard recalls how Keith used to worry away at any aspect – *every* aspect – of race engine design, and tell his designers what was needed:

'He used to supply me with one-phrase headings on paper, then a written discussion – "Valve Gear", "Pumps", or whatever. Below those headings would be the "first epistle from the mountain". I can show you books and books of these. They are fabulous. Keith never throws anything away, and he never forgets anything, either . . .

'Then he would keep coming in, and saying "I've just thought of . . .", and sometimes he would have thought a thing through in total detail. In most cases he would have three avenues he would like explored.'

As the 1980s dawned, however, the DFV was under attack from all sides, not least by the increasingly powerful *and* reliable turbocharged engines from Renault, Ferrari and BMW. Keith had fought against the turbo revolution (and lost his case – this is explained in depth in the next chapter), but had set his face against designing such a unit. Instead he authorized one final re-design of the faithful DFV, into the short-lived DFY. This design job, carried out for him by an ambitious engineer called Mario Ilien, involved the use of a large bore/short stroke configuration, the latest camshaft profiles, and entirely new cylinder head castings, with an extremely narrow valve-included angle of 16 degrees. Not only this, but it was 44 lb lighter than the DFV.

By that time the DFV was rated at 495 bhp, and the DFY came to the line with 520 bhp at 11,000 rpm. It was an improvement, and very worthwhile too, but it was not enough. The F1 industry in general was turning its attention towards turbocharged engines, and the DFY had only one win – at Detroit in 1983.

DFX – 'blowing' the DFV . . .

In 1975 a turbocharged version of the DFV – later known as the DFX – first appeared at practice for the Indianapolis 500 race in 1975, won its first major CART/Indy race at Pocono in 1976, and went on to become the standard-setting Indy-car race engine for the next decade. Yet this engine, more than any other in Cosworth's armoury, was evolved by a customer first, and by Cosworth afterwards.

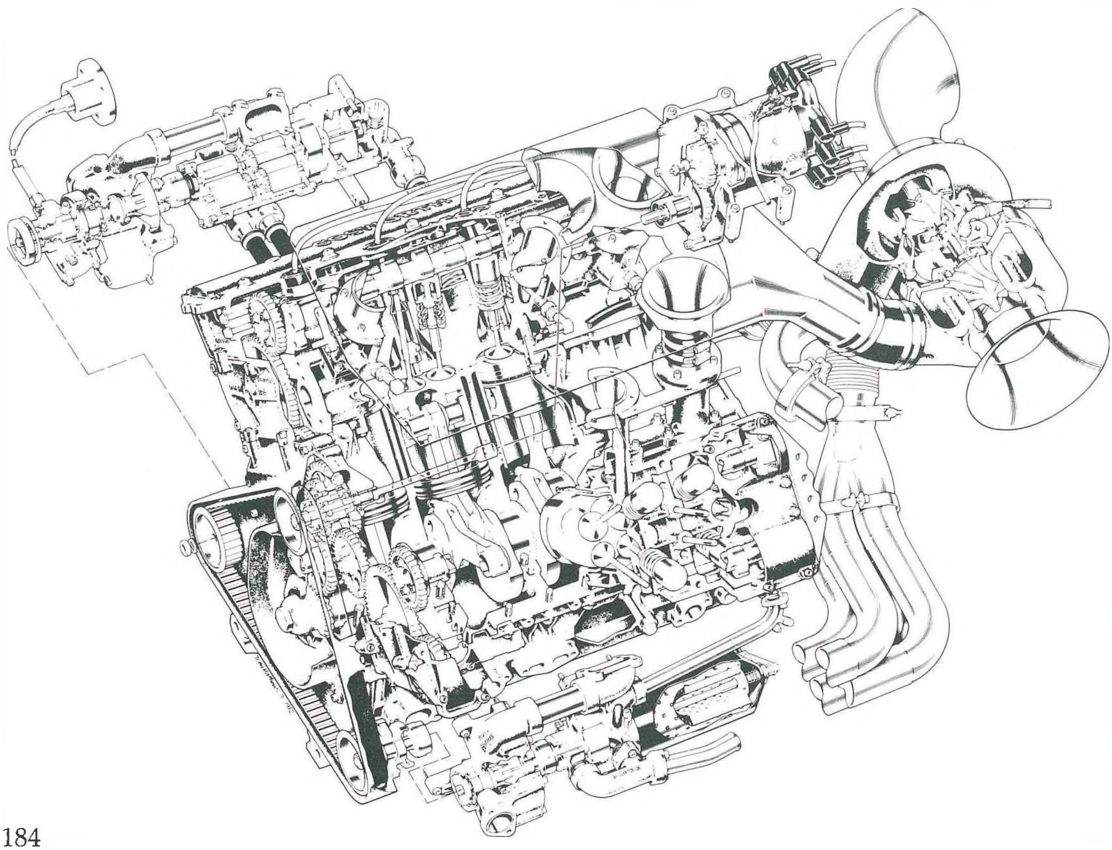
CART/Indy racing, in the USA, had specified 2.65-litre turbocharged engines for some time, and there was no pressure for this to be changed. Once the DFV had settled down, Roger Penske persuaded Cosworth to design and build new short-stroke engines, so that he could produce turbocharged versions but later he changed his mind, and the project languished. Then, in 1974, the Vels Parnelli Jones team started to develop F1 cars *and* CART/Indy cars. By using the new short-stroke cranks, and developing its own turbocharging arrangements, it had prototype engines running before the end of the year. As the regulations allowed 80 in turbo pressure (equivalent to 4.5 Bar boost over atmospheric pressure), and the early engines were pushing out 750 bhp, it took time to keep the early units in one piece.

The breakthrough came when Cosworth – which is to say, Keith Duckworth – took an interest. Keith, however, told me that there was an elment of chance in this. It was a time when the combination of Ferrari's flat-12 F1 engine, and Niki Lauda as driver, had started to beat the Cosworth-engined cars:

'I was in one of my "Well, we don't want to expand" periods. We only went into Indy racing because I thought that our F1 business might be dying. So we produced the DFX. Then, instead of dying, our F1 business stood up well, the DFX engine took off like a rocket, and that caused us to expand rapidly once again.'

Several of Cosworth's well-known 'names' got involved in the DFX – Geoff Goddard designed a new top end, Graham Dale-Jones had already designed the crankshafts for the original Penske project, Paul Morgan became the DFX project engineer, and later Malcolm Tyrrell took up that job. In the early days of the DFX engine, Cosworth actually built up DFXs as low-compression normally-aspirated units, then shipped them out to the USA for conversion and completion. In later years, however, it set

This beautifully detailed 'exploded drawing' shows all the technicalities of Cosworth's Indy racing DFX, which was a much-modified, and turbocharged, version of the DFV.



up a new company – Cosworth Engineering Inc, at Torrance in California – to build, service and rebuild Indy car engines.

As with the DFV, the DFX went through several stages during its competitive life, notably the introduction of larger bore/shorter stroke versions, different fuel injection and different maximum boost settings. It was also sold as a 'Cosworth' rather than a 'Ford' engine, that fact being emphasized by the different badging on the cam covers. Walter Hayes tells why:

'I actually suggested to Keith that he call it a Cosworth in the United States. There were people in the United States who wanted to run it, but who had contractual arrangements which precluded them from going with a Ford engine – for example it would be very difficult for a Chevrolet dealer to do so.'

Never-ending development

One of the last 'secret' development programmes which Keith initiated for the DFV engine family was to investigate desmodromic valve gear. Desmodromic? This is a 'buzz-word' indicating ways of opening *and* closing valves by mechanical means, without using valve springs. Mercedes-Benz used such methods on its F1 and racing sports car engines of 1954-55, but at the time no other concern tried to follow suit. Keith told me why:

'We seemed to spend most of our time in valve spring trouble – surge trouble, breakages, and other valve gear malfunctions all due to spring problems. To go to desmodromic valve gear looked to be a way of getting out of this trouble. However, we then found that instead of having valve spring trouble, we had trouble with all the new pieces, and a fairly difficult manufacturing set-up . . .

'We got a programme going in the early 1980s, it didn't copy anyone and it was an original concept and layout. We built parts and tested them on rigs. But I stopped the programme, and I made myself fairly unpopular. I thought it was all going on for too long, and after I had worked out all the sums for the stressing, I came to the conclusion that we couldn't actually build something of this type that would be strong enough. It kept on failing, and I felt I was vindicated, but some of the engineers thought they could make it work. I thought that my analysis of the problem was reasonable. Either it was never going to work, or it was going to require too much development and redesign to make it work. It was going to need a fundamental redesign, which would throw it right back in time. I wasn't prepared to sanction that . . .'

The DFV family, in fact, steadfastly refuses to die. After winning in F1 it blossomed as an endurance engine (the DFL), then from the mid-1980s it suddenly became *the* engine to use in F3000. In 1988 Cosworth made more DFV-based engines than ever before, an astonishing come-back when the slump of 1985 is considered. Richard Bulman, Cosworth's managing director since that slack

DFZ – an 'instant' F1 engine

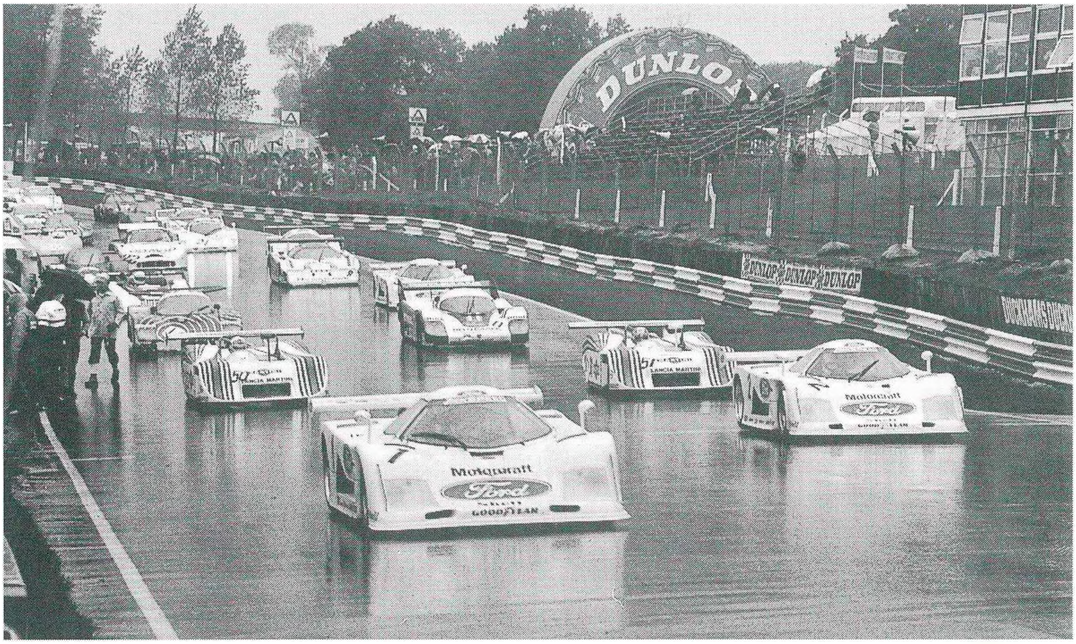
On 3 October 1986 FISA made sweeping changes to Formula 1 engine regulations. Turbocharged engines were to be emasculated by the imposition of turbo-boost 'pop-off' valves, while a new normally-aspirated 3½-litre engine alternative was to be introduced for 1987.

As ever, several manufacturers turned to Cosworth for help. Before the first race of 1987 – the Brazilian GP on 12 April – Cosworth had supplied a new type of engine, the DFZ to Tyrrell, AGS, and March. By mid-season Lola had also joined the fray. Using DFZs, Jonathan Palmer (Tyrrell DG016) won the 'normally aspirated' World Championship.

The DFZ had been produced in about six months – it was a remarkable achievement, even by Cosworth's own standards. In fact Cosworth, Geoff Goddard, and John Hancock, had been lucky, for there was a great deal of 'stretch' in the DFV layout. Over the years, a series of 'endurance' versions of the versatile DFV had been built, along with a big bore/short stroke development programme for F1 applications, and capacities varied from 2,491 cc to 3,955 cc. Along the way, the bore had gone out, from 85.67 mm to 90.00 mm, while the stroke had varied between 54 mm (DFW) and 77.7 mm (3.9-litre DFL).

When the time came to develop a 'DFZ' in a hurry, a few minutes' calculation showed that the largest cylinder bore (90 mm – as used in DFLs) could be mated to a new 68.6 mm crankshaft stroke. At the cost of designing a new crankshaft, the use of DFX connecting rods, and making changes to the cylinder heads, ports, and valves, the 'instant engine' was made available very speedily indeed.

Geoff Goddard subsequently called the DFZ a: 'reliable customer engine, to fill the grid'. In reality, it was more than that. It was good enough for Tyrrell to dominate the 1987 'normally-aspirated' categories, and it was the engine which allowed no fewer than eight under-financed teams to feel their way back from the dizzy (and expensive) heights of turbo power, to the more sensible 1989 levels. Not only that, but the DFR (the most successful normally-aspirated F1 engine of 1988) was a direct descendant of it.



In the early 1980s, Ford started a Group C racing sports car project, the C100, which used 'endurance' long-stroke DFL engines. Here are two of the cars, on pole, at Brands Hatch in 1982.

time, was quite unprepared for that:

'I didn't anticipate the F1 explosion, with normally-aspirated engines coming back, and with F3000 becoming so popular, but we were soon in pole position to take advantage of the situation. We went in for a lot of re-organization of the machine shops – we simply couldn't have met the demand without doing so. In three years we doubled our output of V-8 engines, and I believe it cost us no more than £50,000 to make those changes. We were only just in time. Quite a few of the staff were becoming frustrated by having to use the old machining methods, but as everyone had kept on saying that the old engine was going to die out the changes had never been made.'

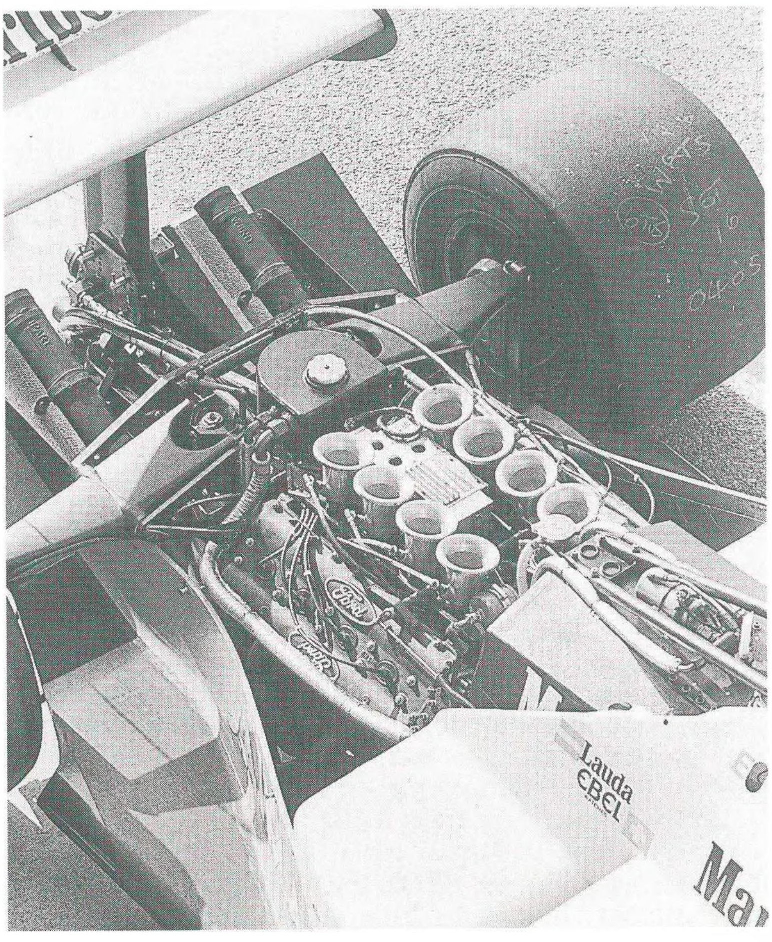
In that process, Ben Rood's machine shop was able to cut the machining time of a V-8 block down from twelve weeks to less than a week, and the casting would need to be on only three different machines, rather than the original thirty. Even though opposition to the DFV family continued to appear – Ilmor engines for Indy racing, Mugen engines for F3000, Judd engines for F1 – the engine was still alive, kicking, and successful at the end of the 1980s. As Jack Field told me, in the spring of 1989:

'At the moment we are still building 110 DFV-family V-8 engines a year, or kits of parts to build engines, in four basic forms: DFVs for F3000, the DFRs for F1, the DFX as a "customer" engine for Indy racing, and the DFS [DFX

"Evolution"] for just two teams in the States. I am building 52 DFRs for 1989 F1 – and I turned down 33 orders! If you ordered an engine today, I would have to say that delivery would be in eight months time, so you've already missed the 1989 season completely. I would immediately want an £8,000 deposit to make sure you were serious.

'If you insisted that Cosworth build the engine, well, I would try to do that for you, but a lot would depend on our work on the other F1 engines [the HB, for Benetton]. Otherwise I would have to supply a kit of parts for you to nominate assembly at a company like Mader, Brian Hart, or Swindon Racing. And I couldn't do rebuilds, not at all . . .'

There will, of course, be an end to DFV sales one day, but no-one is about to forecast the date. Cosworth has been caught, that way before.



Right Marlboro McLaren began a long series of 1980s F1 wins with Cosworth DFV-powered cars. This was one of the 1983 types, as driven by Niki Lauda.

Far right Cosworth's DFV celebrated its hundredth F1 GP victory in 1977, which Ford thought was a good excuse to pose most of the Cosworth workforce behind two of the engines. This picture is full of personalities. Keith Duckworth, naturally, is in centre stage, with Ben Rood to his right, and Mike Hall, Alf Vickers and Mike Costin to his left. Dick Scammell and Geoff Goddard are behind Mike Costin's right and left shoulders, respectively.

DFV – the Dynasty

Over the years, the DFV family has grown and grown. Type has followed type, success has followed success, and the total delivered horsepower has reached a phenomenal figure. The first DFVs were delivered to Lotus in 1967, and during 1989 the latest DFVs, DFRs and DFSs were going to F1, F3000 and CART/Indy teams all round the world. In *April 1989*, Marketing Manager Jack Field provided me with some fascinating statistics about sales of the various types:

DFV (The classic 3-litre F1 engine, and its development, the F3000 engine)
Cosworth built up to engine number 421. The first seven engines for Lotus were out of the numbering system, and 88 complete engine kits had also been supplied for outside engine builder assembly. 421 + 7 + 88 = 516 total engines and kits.

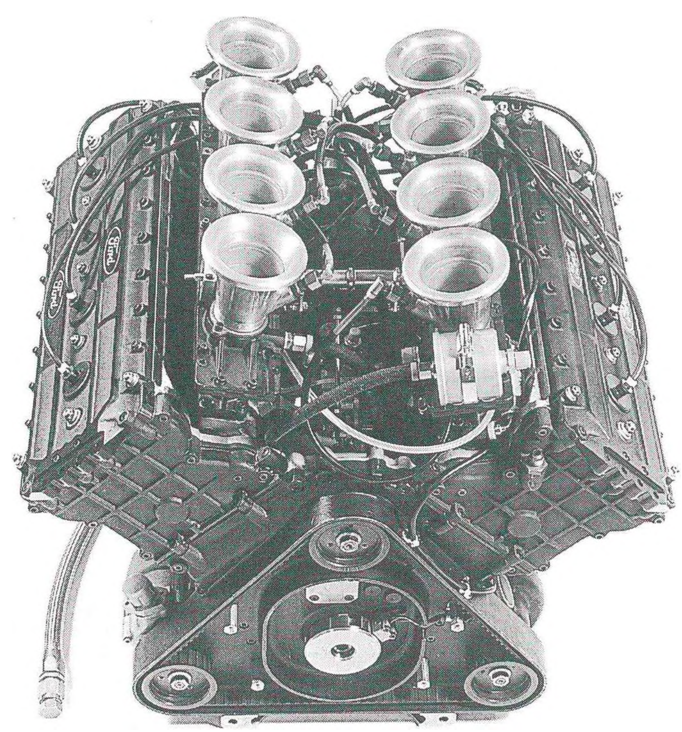
DFW (The 2½-litre 'Tasman formula' engine)
These were all converted DFV engines, having been F1 engines in the F1 season, and Tasman engines in the winter.

DFX (The 2.65-litre turbocharged engine, for CART/Indy racing)
Cosworth built 347 engines, 7 of which were later listed as DFS, plus 110 kits, 6 of which were DFS kits. 340 + 104 *true* DFX = 444 engines and kits.

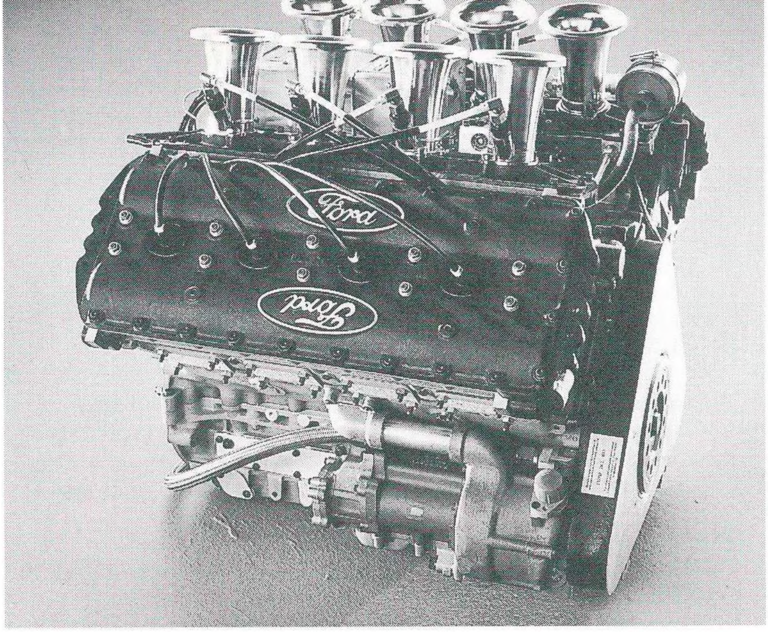
DFY (The early-1980s development of the 3-litre F1 engine)
Engine numbers 2 to 21 were really short-stroke DFVs. Engines numbered 1 and 22-27 had different heads, the integral cam carrier, and different valve angles. Designated as DFY = 27 engines.

DFL (The 'endurance' or 'sports car' engine)
36 engines were built, none of them as kits. These engines were both 3.3 and 3.9-litres. Quite a number of DFVs have also been converted to DFL 3.3s by their owners. Designed as DFL = 36 engines.

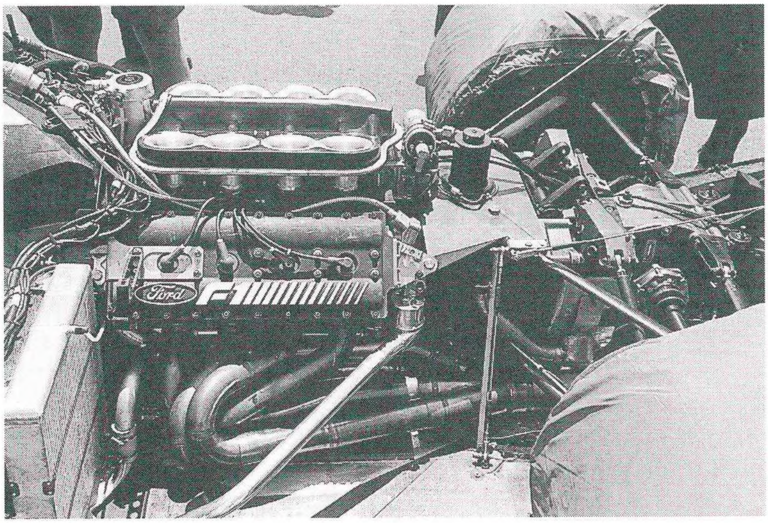
DFZ (The 3½-litre version of the DFV, for late 1980s F1 cars)
Cosworth built 5 complete engines, and supplied 75 kits = 80 engines and kits.



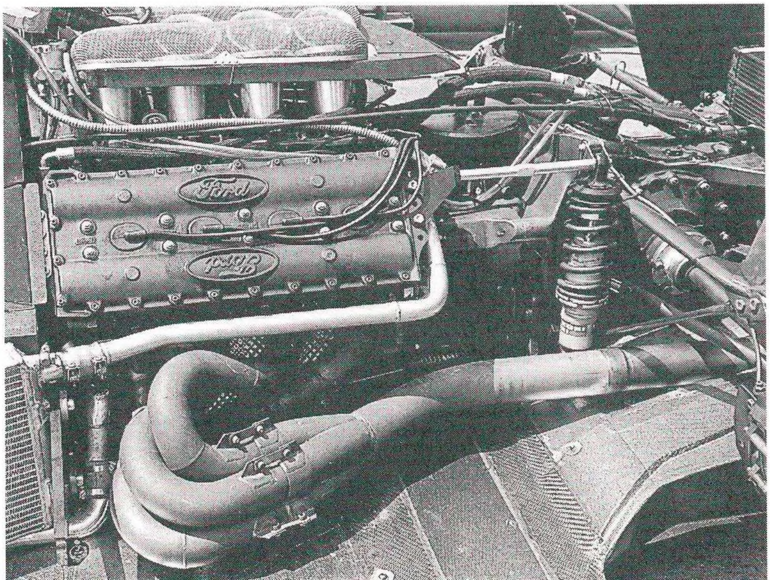
The DFY came along in the early 1980s, as a further development of the DFV family, complete with a narrower-angle cylinder head, and many other detail refinements.



Only a Cosworth connoisseur could 'pick' this from many other types. In fact it is a long-stroke 'endurance' derivative, the DFL of the early 1980s.



When Yamaha's 5-valve head design proved to be a failure, Cosworth then developed the DFR for the exclusive use of Benetton's F1 team in 1988. It was approximately 30 bhp more powerful than the DFZ (*Maurice Hamilton*).



Another neat Cosworth engine installation, this being a DFZ as used in a Tyrrell 017 of 1988 (*Maurice Hamilton*).

DFR (The 'ultimate' re-design of the DFV family, 3½-litres for F1 racing, used only by Benetton in 1988, but by other customers in 1989)
So far 23 built-up engines, and 37 kits = 60 engines.

DFS (The 1988-1989 development of the turbocharged DFX)
So far, 7 engines, and six engine kits = 13 engines in all.

That makes the astonishing total of 1,176 complete engines or engine kits, not to mention the enormous number of major components supplied for rebuilding, over the years.

Jack was anxious to point out, however, that this was not a complete or final story.

'If I were you, I should "date" the information on the DFV, the DFX and the DFR. We are still working on the 1989 season order book, and the numbers are a moving target!'

Prices, too, have changed considerably over the years. In 1968 the original price of a 'customer' DFV was £7,500. The first DFVs provided for F3000 cars cost £25,000 (plus VAT). The April 1989 price for a built and tested DFR was £46,010, plus VAT. The original price of the turbocharged DFX, in the late 1970s, was $25,000. Where will it all end?

Turbocharging in F1 – the Ford V-6 project

'To my mind, the use of turbochargers was always against the rules in F1.'

'A turbocharger is a gas turbine which shares its combustion chamber with a piston engine . . .'

The new era in Grand Prix racing was born in July 1977, but it made no immediate headlines. The world's first turbocharged Formula 1 car, Renault's V-6-engined RS01 model, qualified twenty first on the grid for the British GP of 1977 – and no-one thought it significant. Why should they? At the time, the car was thirsty, slow, and dreadfully unreliable – surely the normally-aspirated establishment had nothing to fear?

Not yet, for sure, but the message soon got through. The Renault scored its first points in 1978, its first 'Pole Position' after practice in March 1979, and its first win (the French GP, at Dijon) in July 1979.

Even so, it took time for other designers to follow suit. The first turbos from Ferrari and BMW followed in 1981, after which everyone joined in. Even though it had already developed a turbocharged engine for racing in the United States, however, (the DFX) Cosworth was in no hurry to follow the fashion. The DFV kept on winning races – lots of them – and the first-generation turbos kept blowing up. Not only that, but Keith Duckworth was convinced – and is *still* convinced, that the concept of turbocharging was 'illegal' according to the regulations governing F1:

'I made myself clear when accepting the RAC's Diamond Jubilee Trophy in 1978. That was the point where I stood up and said that turbocharging was all wrong, and I also took the limit of compounded two-stroke engines, which could have produced any power figure that you wanted.'

'Actually, as a result of that, the authorities banned two-stroke engines, but they didn't ban the turbocharger. To my mind, the use of turbochargers was always against the rules in F1, and in any case the "equivalency factor" [3.0-litres normally aspirated, but 1.5-litres with forced induction] was grossly unbalanced.

'What happened, when the rules were being written for 1966, was that 3.0-litre engines were going to be allowed, and the existing 1.5-litre engines of 1961-65 were going to be made obsolete. There were all kinds of complaints – "We won't be able to get new 3.0-litre engines" – so some bright spark in Paris then said: "OK, now we're specifying petrol, to give people with 1.5-litre engines a chance to compete in the new Formula, we'll allow them to fit superchargers."

'Don't forget that between 1946 and 1953, 1.5-litre supercharged cars had been expected to compete against 4.5-litre normally-aspirated machines, though alcohol fuel was allowed in those days. In fact, I don't think anyone ever produced a supercharged 1.5-litre engine – I know that Coventry-Climax were asked to do one, but they refused.

'When the rules were written, and published, only the word "supercharging" was used, and "turbocharging" was not mentioned at all. At that date, turbochargers were really only for diesel trucks, though I believe GM had fitted them to a few Corvair cars too.'

Keith is adamant that there is a vast difference in operation between the supercharged, and the turbocharged, engine:

'In a supercharged engine you can affect the weight of charge getting into the cylinder, albeit at the cost of taking work off the engine to drive the compressor. Then you only have the stroke of the piston to do expansion work, which brings its own limits. On the other hand, a turbocharger is an air compressor driven by a turbine, and the turbine itself is an expansion motor. Therefore a turbocharger not only allows you to "fiddle the books" on the weight of charge, but it allows you unlimited expansion capacity as well – and that can be a virtuous *or* a vicious circle. It means that the effective capacity of a turbocharged engine has an entirely different meaning from that of a supercharged engine.'

'You could also say, as an another aproach to it, that a turbocharger is a gas turbine which shares its combustion chamber with a piston engine. That means that you have *two* engines, which is illegal, and by the way the rules also state that gas turbines are *forbidden*.

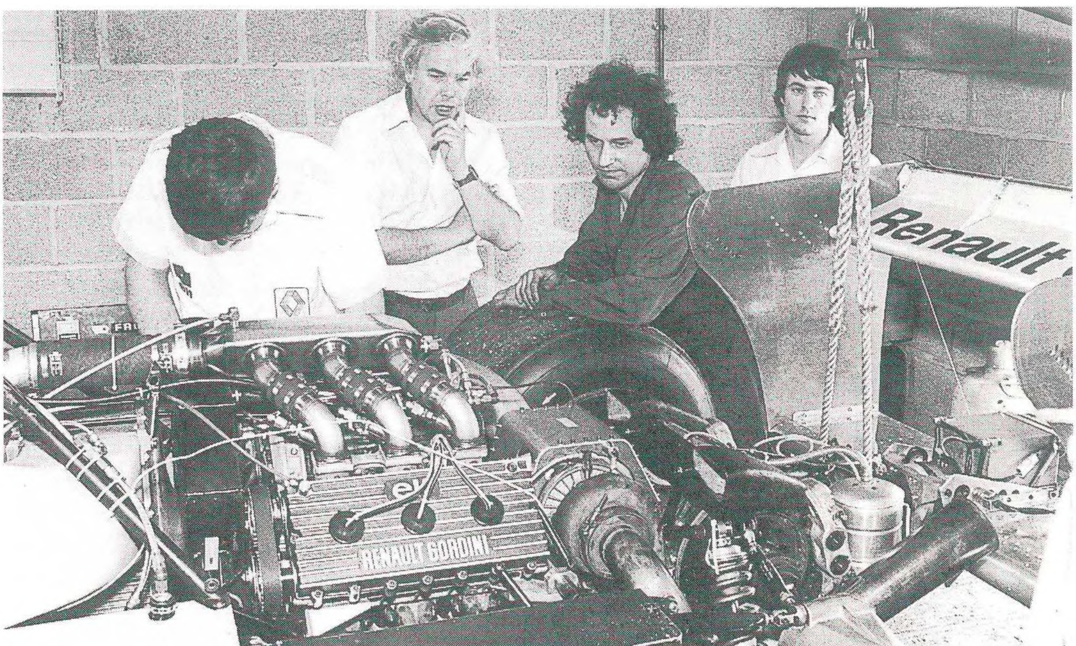
'At one point Ferrari was actually injecting fuel into the turbocharger, to make it speed up quicker and kill the lag, which rather proves that they were treating their installation as two different engines.'

It is no wonder that at this point in an interview Keith collapsed into gales of laughter, unable to come to terms with what he saw as the stupidity of motor racing's administrators:

'The limits of the turbocharged engine, therefore, are connected with mechanical strength and thermal problems – the capacity of the engine is virtually meaningless'.

Walter Hayes told me that he believed Keith always to be a purist as far as race engine design was concerned and that Keith always regarded the turbocharger as an unnatural and nasty thing, because it was not really an improvement to the engine, but really a crude way of force-feeding it. In the late 1970s Keith argued, long and loud, that turbocharged engines should be banned, but in most cases he could not even get people to understand what he was saying, never mind to agree with him:

'The telling part of the FIA appeal court, on legality, was that it [turbocharging] was accepted by taxation auth-



Right from the start of the turbo era in Formula 1, Keith Duckworth (centre) kept a careful eye on what rival engine manufacturers were doing. This was Silverstone 1977, where mechanics were working on the 1½-litre turbocharged Renault engine (*Phipps Photographic*).

orities throughout the world, that the fitting of a turbocharger did not change the capacity of an engine for taxation purposes. Of course, the *real* stupidity of it all is that it is the world's taxation authorities which are wrong!'

It is easy to see why Keith, Mike, and Cosworth Engineering were anxious to get turbocharged F1 cars banned – their future business, after all, was at stake. No-one, surely, could blame Keith for wanting to preserve F1 as a normally-aspirated formula, when his DFV engines were so dominant? In the Renault turbo's first race for example 20 of the 26 starters used DFV engines, these being shared between 11 teams. For Cosworth, F1 was a good business to be in – and the company wanted it to stay that way. Keith lost his fight to ban turbochargers. Being a man of principle, who was not about to change his opinions, it was years before he could be persuaded to see a new Cosworth turbo engine designed for F1:

'I thought it would all lead to a great escalation in cost and complexity, and I did not think it would be very useful technology for production cars. This problem became worse and worse as soon as we came to special fuels, which compounded the problem.

'If people aren't worried about costs, then I am totally in favour of useful technology, preferably with commercial value, being derived from racing. In fact I don't think that diesel engines, two-stroke engines, turbochargers, gas turbines or even Wankel engines ought to be banned from racing if there is to be a technological challenge. The only thing I object to is to try to equalize everything with equivalencies which are totally meaningless.

'I thought it was against *everyone's* interests to allow turbocharged engines to continue. There was a lot of talk about motor racing becoming too expensive in the 1970s, and the chances of F1 dying out were regarded as high. Everyone, or so they said, wanted to make racing cheaper, and I was under the belief that this was the serious opinion of the governing body.

'I wasn't totally alone in my views. The whole of British motor racing got together and fought their battles – this being the whole basis of the FOCA/FISA split of the early 1980s. FOCA wanted to ban turbos, but Renault, Ferrari and BMW didn't. It nearly split F1 racing right down the middle. Now we have the Concorde Agreement, as a compromise. It all ended in a very bloody draw, and some fairly daft agreements.

'The only meaningful basis on which all types of car could be made "equivalent" would be to impose fuel consumption limits. It needn't matter how efficiently each engine uses its air (in other words it needn't matter how large, or small, the capacity is), but how it uses its fuel. Fuel is the thing you pay for, and if you are forced to make an engine – *any* engine – fuel efficient, then that really is a technological challenge I relish.'

By the early 1980s, however, the 'illegal' turbocharged engines had become reliable, and the turbo cars had started to win a lot of races. This was the four-year trend:

1980	15 races, 3 turbo-car victories, 11 to the Cosworth DFV
1981	16 races, 5 turbo-car victories, 8 to the Cosworth DFV
1982	16 races, 8 turbo-car victories, 8 to the Cosworth DFV
1983	15 races, 12 turbo-car victories, 3 to the Cosworth DFV/DFY

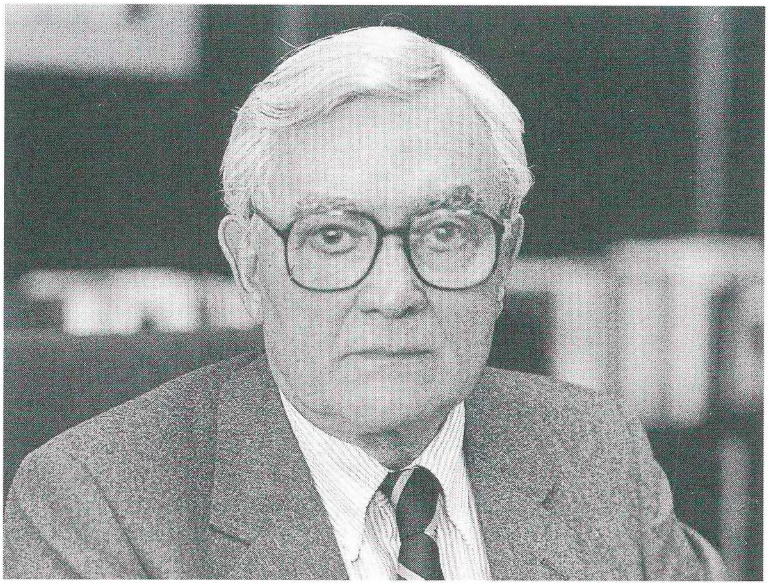
The last normally-aspirated Cosworth victory came in the Detroit GP of June 1983, and after that the Cosworth-engined runners were struggling. Yet, even at that time, Keith had not begun to think about a replacement. Walter Hayes, meanwhile, had become vice-president of public affairs at Ford-USA, and thinks he knows why:

'I concluded that Keith genuinely thought that he had produced one masterpiece, and he was reluctant to drag himself up to go and do it all again. After all, if you have painted the Mona Lisa, or you have built the Eiffel Tower, it's difficult to repeat yourself.

'By designing the DFV, Keith had already created the one perfect thing in his lifetime, and although it was still a great engine, it had been hit hard by regulations, and by the activities of other people. I honestly think that he was resentful, that although he had probably designed the finest engine in the world, he was going to have to try again. Make no mistake, it *was* the finest, and if the formula had stayed at 3.0-litres it would probably still be unbeatable today.'

'Once we got a World Championship race in Detroit and I was much involved in that, lots of people were persistent about the need for Ford to do another Grand Prix engine. It seemed to me that the time was ripe to start talking to Cosworth about a new turbocharged engine. But Keith still wasn't having any – whenever I raised the question, he would immediately change the subject!'

That last Ford-Cosworth victory in Detroit, it seems, was an important occasion:



Walter Hayes listened carefully when he was told that Keith Duckworth didn't want to tackle a turbocharged F1 engine, then spent hours discussing the project with him. The silver-tongued Hayes got his way in the end . . .

'After Tyrrell had won that race, I took Ken and his wife back to my home in Ann Arbor, where we gave them a special dinner in honour of the win. I thought that this was the time to start pumping. I actually said to Ken Tyrrell: "I can't persuade him to do a turbo engine, in fact I can't even persuade him to think about one. See what *you* can do". Later on I had a call from Ken, who said: "I think he's ready to talk." I wasn't at all convinced, but I invited him out to Detroit, and we started from there.'

At which point a clever bit of Hayes psychology helped to change things:

'I know enough about Keith, to be able to pull his leg, to get him into the right mood. The way to do it was not to go to fancy hotels, but to have him at my home, where my wife would cook him things like toad-in-the-hole, Lancashire hot-pot and other Northern dishes.

'When I was in the States, and he came over to see us, at first we used to go to dinner in hotels. But my wife tumbled to the secret very quickly. She said to me: "If you really want to know what Keith's thinking, then you're doing it all wrong. You automatically pick up the wine list, but what you really need to do is to get some beer into him!"

'She was right. Also, at home, we would give him real cups of tea, and offer him as much lager and good British beer as he could drink – after a few glasses of lager, the inspiration really began to flow. *Then* we would start to have long conversations on the subject . . .'

The problem was that although Keith was confident that Cosworth could produce a race-winning F1 turbo engine, he still objected to the whole philosophy, and the doubtful sporting 'legality' of such engines. In any case, the Cosworth company of 1983 was very different from that of 1966, when the original DFV had been designed. As Chapter 11 makes clear, Keith had sold out to United Engineering Industries (UEI) in 1980, the company was vastly larger and less flexible than it had once been, and it was just about to embark on heavy investment in the turbocharged YB-Series Sierrra engine. Keith, as usual, was looking further ahead than almost anyone else in motorsport:

'There was already so much talk of doing away with turbo engines that it seemed unlikely that they would carry on for long. There was talk about charging engine capacities, banning turbos, everything. I really couldn't imagine any one really settling down to a fuel consumption formula. The entrants were talking about too much power, there were drivers' campaigns as well. *Everything* looked as if it was about to change.'

The pressures, from all sides, eventually paid off:

'There was a lot of internal pressure, to the effect that Cosworth couldn't afford to be out of F1 racing, without a turbo engine. In the end, I said: "OK, we will have a go at doing a turbo engine. We will need financial support to do this, so I will approach Ford, to get that support".'

Walter Hayes, in fact, had already persuaded his fellow directors in the United States to provide the backing. Along with Mike Kranefuss, who had moved to Ford-USA at the beginning of the 1980s to rejuvenate the motorsport effort:

'I went along to a *much* more formal meeting than in 1965, and presented the proposal for a new Cosworth-designed engine, thinking that regulations stability had been achieved. This time, though, it was to be a Ford-USA project, financed from Detroit. The numbers were *much* larger than last time.'

In the meantime FISA's controversial president, Jean-Marie Balestre, had visited Ford's policy makers, and assured them that its turbo engine investment would remain valid until the end of the 1980s. Mike Kranefuss then hatched a 'Five Year Plan' – two years of design and testing, followed by three seasons of racing. Even so, at this time Keith was sure that Kranefuss would favour his fellow-countryman Erich Zakowski (of Zakspeed) for any new engine work, and said as much to Walter Hayes in a transatlantic telephone conversation which Kranefuss (in Hayes' office) overheard!

Keith's decision to go ahead only came after a lot of discussion:

'Mike, Geoff Goddard and I spent a lot of time trying to plot which way the rules were likely to go. Every week, when we had actually decided what was favourite, and what was the sensible concept for an engine, it looked as if the rules would change again. FISA was proposing to change the engine size, they were talking about orifice limitations, fuel limitations, progressively less fuel year by year and boost limitations – all these things were discussed.

'This was all very well if someone already had an engine – then they would have no option but to do the best they could, with what they had. But to start off, to design an engine, to rules that you didn't really think had much chance of still being the same rules when the engine was finished – well, that was bloody impossible.

'In the end, we had to design an engine, and *hope* that when it was running, that the rules wouldn't have changed to mess it all up. Well, in the end, that's *exactly* what happened – by the time our engine was on the pace, FISA chopped the boost, twice, to 4.0 Bar, then to 2.5 Bar.'

At first, therefore, Keith and his chief racing engine designer, Geoff Goddard, agreed that they needed an engine to be optimized for strict fuel limitations and that, according to Keith's analysis, favoured very small cars, with a four-cylinder engine:

'If we were going to have to run relatively slowly, and with modest power outputs, there was nothing wrong with a four cylinder engine. So at the end of 1983, that was how we started. We didn't go for an all-new engine, because I thought the aluminium block of the BD, with Nicasil coating for the bores, would be sufficient. We started with the same basic castings for head and block, as with other BDs, but it wasn't long before we re-did the head.'

It was not, however, a simple conversion, and was certainly not a specially-prepared version of the BDT which later powered the Ford RS200 model:

'We had just one turbocharger, with a view to it being a divided housing component. At that stage we were proposing to drive it through the crankshaft as well, so that we could cure the response problems. In the end, after an extensive evaluation, we decided to use an infinitely variable drive gear, using the Ford CVT belt from the nose of the crankshaft, along with an electronic engine management system to control everything. We even thought it would be useful as damper for the torsionals.'

We were thinking that horsepower was going to be restricted to about 650 bhp – by fuel or by air restrictions – and that's what prompted the choice of a four-cylinder. We thought that our compounding arrangement would help the response *and* the fuel efficiency. I'd actually thought very deeply about compounding, which wasn't specifically banned by the regulations.

'However, if there was to be a problem with the regulations, I thought we could always fit an over-running clutch in the drive system, so that we couldn't transmit power back to the crankshaft. Now, although all this might sound heavy, the alloy block allowed us still to have a very light engine, all in all.

'We'd actually schemed out a 180-degree six-cylinder engine – a flat-six engine – as well, which also lent itself to turbo-compounding, for we could have fitted this on top of the engine between the intakes . . .'

And so it began. Cosworth built the variable speed drive, made epicyclic gearboxes to drive the turbocharger, rig-tested the variable-speed drives and their control systems, and tested driving from one turbocharger to another. Then came the first major setback – the Ford CVT belt was suddenly withdrawn as the programme slipped. This had been a false dawn for Ford, for Van Doornes were having great difficulty in making suitable belts.

Although test bed engines of 1,497 cc, which ran in 1984, used most, but not all, of the complex turbocharger control gear, original runs, in fact, were done with the aid of an external compressor to provide boosted air.

But there was worse to come. In a series of test-bed breakdowns, so graphically caught in Patrick Uden's Channel 4 TV documentary, the new four-cylinder engine kept breaking its crankshafts when running 3.0 Bar boost at 11,000 rpm. Cosworth, however, traced this to the rear of the crankshaft, which failed in bending. The crank was re-designed along with the flywheel, and they were on the way to solving all its difficulties.

Stuart Turner, affectionately recalling the work he had done with Keith, thinks that Cosworth under-estimated the difficulty of getting back 'on the pace' in the mid-1980s:

'I think you could say that Cosworth had got a bit complacent, and maybe expected to come back in [with a new engine] and resume their lofty stature. But if this was meant to be a Royal Return, they found that there were other royalists already on the scene.

'Cosworth, too, had changed since the late 1960s. Keith commented on this to me at 25th anniversary time – he called in every member of the staff to give them a present, individually, and found that it took him all day to complete. Maybe, in the mid-1980s, they were just a bit slow to react.'

For many reasons, however, Keith decided to cancel the four-cylinder project completely, and start again:

'We had foreseen which way the rules would go, and we were wrong. Power outputs were well above 650 bhp, and rising towards 800 bhp, and I didn't feel that our siamesed-bore block would do the job.'

Geoff Goddard, who claims not to go to motor races to see what the opposition is doing in case it confuses him, now thinks that Cosworth set its sights too low in the beginning:

'People were probably already racing with more than 700 bhp when we started the project, but at that sort of figure, in the first place, the life of our crankshafts could be measured in minutes, not hours. Incidentally, we always worried that if our turbo-compounding worked, and we won races with it, that it might have been banned overnight.'

Keith decided on a new approach:

'It was time to start again, and therefore we decided that we would make a coventionally turbocharged V-6, very small and light. We had a few early cylinder block problems, but otherwise it was always remarkably reliable.'

Even then, the decision wasn't simple, for at the time FISA was still trying to decide whether or not to impose a 1.2-litre limit for 1986. Ford-USA finally gave the go-ahead for a completely new design in September 1984, and this was where Geoff Goddard really came into his own. Geoff now had enough design know-how to tackle almost all the work himself, for he had rarely ignored anything which he had seen, and experienced, since he had joined Cosworth in 1971. Walter Hayes summed up Geoff's character admirably:

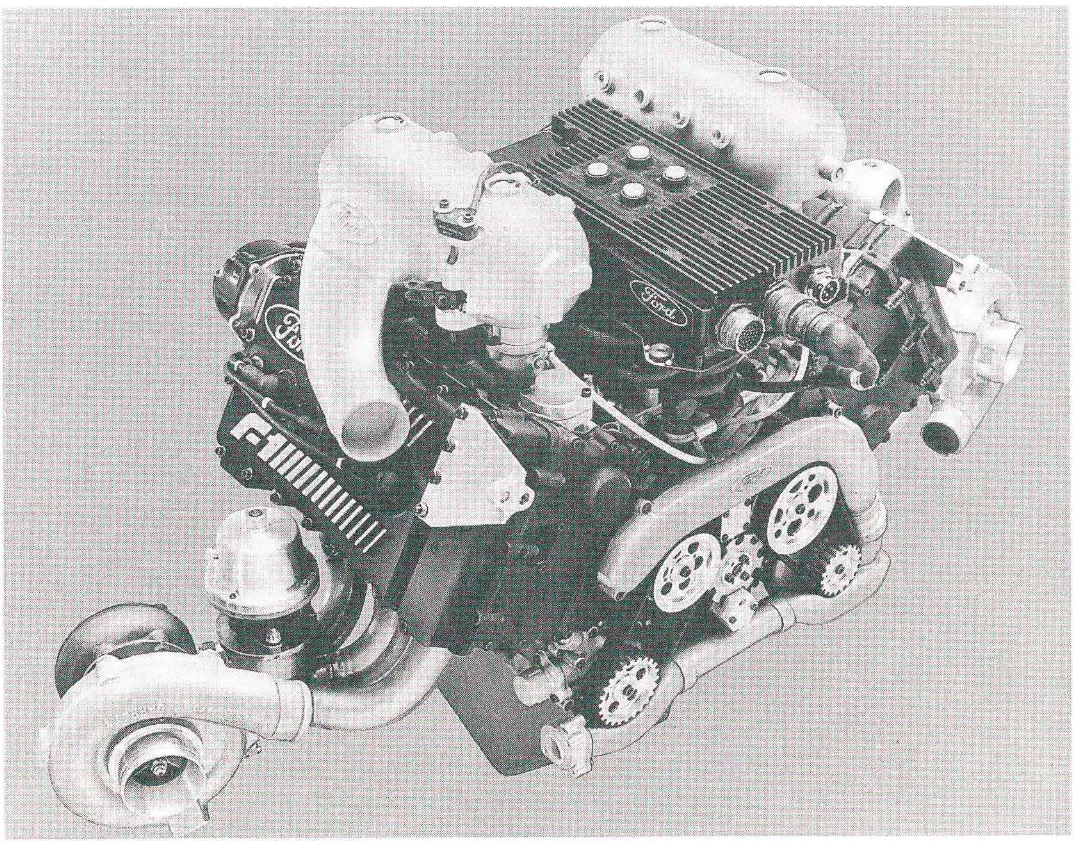
'There are several people at Northampton who walk like Keith, talk like Keith, and who behave like Keith! Geoff Goddard is one of them. My wife once spied him at a party and said: "Who is that chap?". I told her, and she responded: "I was looking at him from the back, and I thought it was Keith Duckworth." I thought for a second, then replied: "Well, it probably is, actually."

'If you are a successful leader, a succesful genius of that kind, then people will clone themselves from you; the manner is adapted. In a way, with Geoff Goddard, Keith reproduced himself.'

The new approach yielded the quirk of two project titles – Ford called it the 'TEC Turbo', while Cosworth decided to call it 'GB'. The Ford acronym stands for Turbocharged Engine, Cosworth. The choice of GB, by Cosworth, had nothing to do with national pride, but was much more prosaic. The *original* Cosworth-designed V-6, for Ford, had been Mike Hall's GA series. What could be more logical, therefore, than to use the next in the sequence – GB – for the next V-6 for Ford!

This time, it was decided to produce a conventionally turbocharged engine, one turbo to each bank, and well out at the side where they could be properly packaged in a chassis. Cosworth, as usual, produced the first engine very rapidly indeed. Keith was spending more and more of his life at home, Geoff Goddard would visit him every week or so to discuss concepts, or agree on layouts, but

Cosworth's first turbocharged F1 engine, the 1½-litre GB project, was a 120-degree V-6 unit. It ran for the first time in 1985, was used in the Haas-Lola cars in 1986, the Benetton cars in 1987, and was regularly producing 1,000 bhp by the end of that period. 25 engines were built, and most were later stored away at Northampton.



essentially the TEC/GB was a Geoff Goddard, and not a Keith Duckworth, design.

'The first actual component drawings were released in December 1984, that was the cylinder head, and we first ran the engine on 1 August 1985. We had been doing layouts for a month or so before that, so it took about ten months to design the engine. The only thing we got wrong at first,' Geoff Goddard told me, 'was in deciding what power to go for. We aimed for a power level, which we instantly got, we then turned up for the first race, found everyone else disappearing into the distance, and decided that we hadn't been very bright.

'The problem was that we had designed it to run on pump fuel, and we were gazumped right at the end of the design when people started using "rocket fuel".'

Mike Kranefuss agrees – and disagrees:

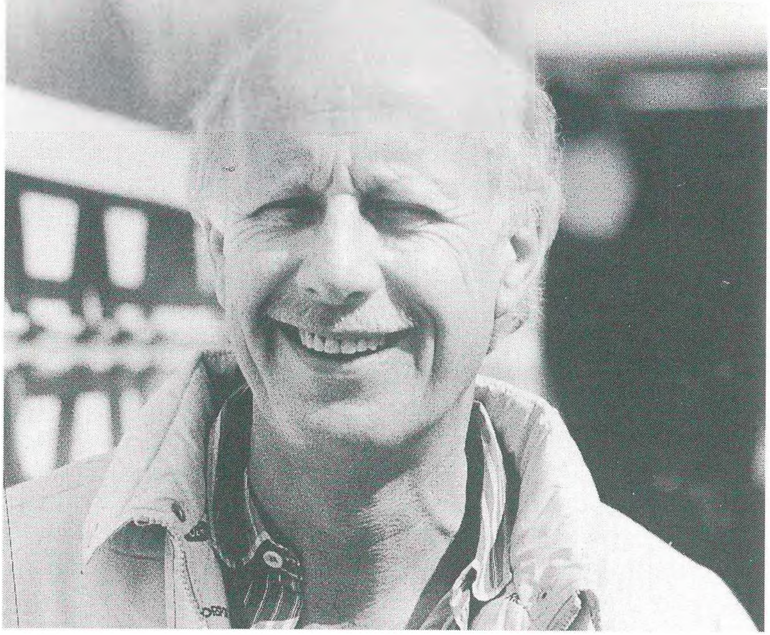
'I think there was a degree of ignorance about the opposition at Cosworth. The Honda engine was only on the horizon, the Renault engine didn't produce a threat enough to frighten Keith, and I think Cosworth *should* have been sending people out to the races to get a feel for what was happening. Cosworth thought they knew it all by that time. People had started, but only just started, using funny fuels, though the idea had been around for some time.'

The difference in potential between ordinary fuels and special fuels was immense, this allowing F1 engine power outputs to double, from 600 bhp to more than 1,200 bhp, in about four years. Cosworth had no say in the choice of team to use the tiny new 120-degree V-6, this being a Ford-USA decision influenced right from the top, as Mike Kranefuss confirmed:

'I had already talked to Carl Haas about F1, but I had also talked to Bernie Ecclestone, Frank Williams, and Lotus too. But at first I didn't want to go with Haas – the *last* thing I wanted was to go with a new team. Then one day the Chairman of Ford, Don Peterson, called me – he was a very staunch supporter of motor sport – and said he had just taken a call from Jim Dutt of Beatrice. Dutt, he said, was going to support Haas, and since Beatrice was not only a big company, but it also controlled Avis, the car hire people, which meant business for Ford *and* a ready supply of Goodyear tyres for the F1 team.

'Peterson said it was my decision . . .' [but, in effect, that decision was being made for him] '. . . and in the end I signed with Haas, with Beatrice sponsorship.'

'Well, it didn't help that the Beatrice thing dissolved



Ford's motorsport supremo, Mike Kranefuss, was smiling happily in 1986, when the Cosworth turbo F1 engine was new, but he soon became extremely frustrated by the failings of the Lola team. Mike thinks Cosworth was not ambitious enough when designing the V-6 turbo engine.

when Dutt was ousted from Beatrice, and that was before the Ford engine even ran in a car.'

The new car was designed by Lola, and was sometimes called a Haas-Lola, sometimes a FORCE (after the name of the new F1 company), sometimes a combination of all three. Cosworth really didn't mind what the name was – the fact was that the car was not competitive! The team was established near London, with ex-McLaren managing director Teddy Mayer running the team. When the new Cosworth V-6 turbo first ran in the car, the drivers (Alan Jones and Patrick Tambay) commented on its smoothness, but that it lacked power, in the order of 700/750 bhp. Only three engines were race-ready by that time. When Alan Jones gave the car its racing debut at Imola in 1986, it was embarrassingly slow:

Mike Kranefuss: 'We were way, way, off the pace. It was devastating for me, because I knew there couldn't be an answer overnight – you couldn't just crank up the boost and get more power. We were in dire straits. For Keith it must have been a tremendously painful situation. I would have wished I could be in Alaska. The race was a total non-event.'

Keith Duckworth: 'We had designed it to run on petrol, with a 6.5:1 compression ratio, but that was miles away from what we could run on special fuels.'

For the record, on that occasion, the fastest practice lap, at Imola, was by Ayrton Senna's Lotus-Renault turbo (1 min 25.05 sec), while Jones's Lola lapped in 1 min 30.087 sec, and started 21st in the grid. Patrick Tambay was 2.8 seconds quicker in the 'interim' Hart-engined car. In the race the car circulated as high as ninth place, but broke its gear linkage, and suffered a split water radiator.

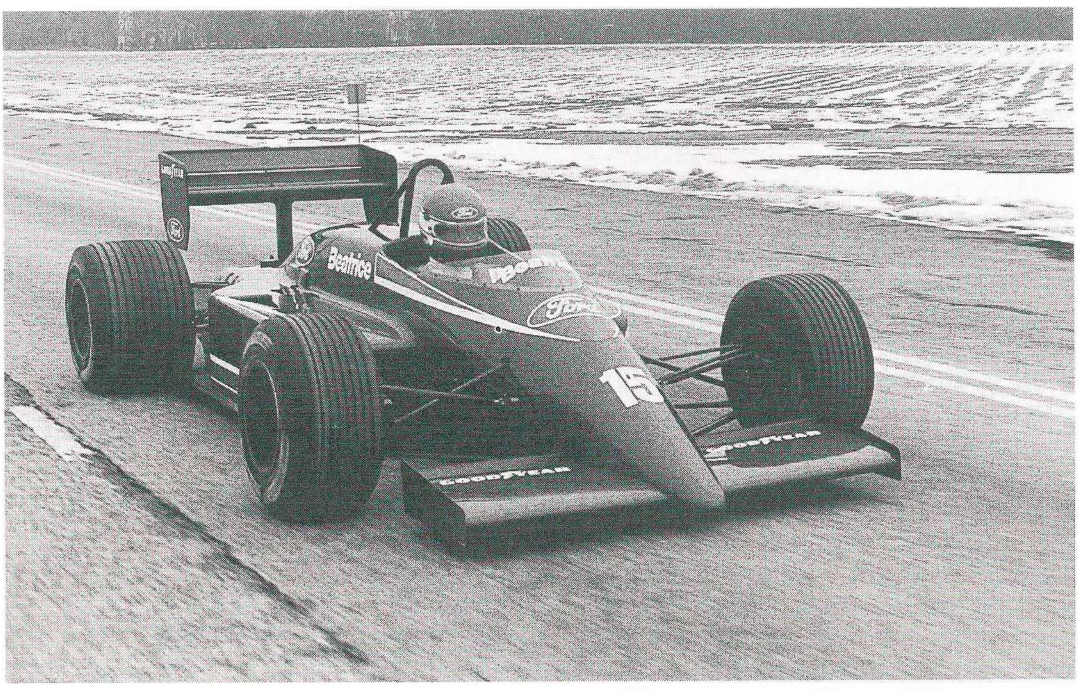
No-one was impressed by this early showing – Mike Kranefuss described it as Cosworth's '****-up' and suggested they should do something about it, straight away, whereas Keith was critical of the car's preparation. For the rest of 1986 Cosworth pressed ahead with improvements – higher compression ratios, different fuels, modified cylinder heads. The first 7.5:1 compression engine appeared in July, the first 8.0:1 engine in September. By the end of the year the engine was producing up to 1,000 bhp in race qualifying trim – an improvement of about 300 bhp in less than a season. Even Keith was surprised by this:

'It was all a big multiplying game. For every half ratio [on compression] we went up, the exhaust temperature dropped a fair lump, and the engine went 25 bhp better. But it wasn't easy – we needed different pistons and quite a lot of setting-up time every time we made a change. We were feeling for detonation all the time. The peak pressures went up and up, and so did the mechanical loadings.'

'As we went on, it was almost all good news, because the structure was strong enough – every time we went up on compression, the fuel consumption stayed the same, the inlet temperature to the turbocharger turbine dropped, and we could actually run leaner . . .'

By 1987, after less than one year's racing, Cosworth was

The V-6 turbo Cosworth F1 engine made its very first run at Ford's Boreham test track, on a very cold day early in 1986. The problem, then, was to keep everyone warm. The car looked better than it went, for unreliability was always a problem in 1986.



able to run at the 4.0-Bar boost limit which FISA had applied, and although several engines were lost due to failings in the special fuel supplied, at the end of the season it was a reliable 1,000 bhp engine, as competitive, and sometimes ahead of, the Honda unit. Not only that, but individual engines were running for up to 600 miles between rebuilds. A pool of 25 engines, all owned by Ford-USA, was available to service one team.

The Haas/Lola team, on the other hand, had never been able to produce properly reliable cars, the loss of Beatrice sponsorship had been a severe blow to the team's finances, and the result was that Ford decided to switch teams. Geoff Goddard summed up, rather bitterly:

'The first year was almost wasted, because it was such a poor team that could never run the car, and we were never able to do much work.'

Mike Kranefuss told me how complex the first few months then became:

'Things went sour for Carl Haas. He had been well-funded by Beatrice, then he had to start looking for other sponsors. He started being a bit stingy with the F1 operation. I decided that we had to move the engine to another team. Many of them thought that Cosworth could make the engine competitive, but others wanted money as well as free engines, if given the chance. Keith wanted Cosworth to have the choice of teams for 1987, but politically that wasn't possible.'

Then there was the case of Bernie Ecclestone buying the Haas/FORCE operation. Did he really think he could buy the rights to the Ford-Cosworth V-6 turbo in that way? Mike Kranefuss heard about this, in a roundabout way:

'It was in Portugal, when relations between Carl Haas, Teddy Mayer and myself were really bitter, that Bernie Ecclestone told men that *his* driver, Riccardo Patrese, was going to drive *our* car the very next day! Nobody had told me – not Carl, not Teddy, nobody. I was really pissed off, the car was still breaking things, and I just didn't want that to happen. I found out, later, that they had started talking to Bernie about selling the team as early as May 1986.

'I had already got to know Peter Collins, at Benetton, and he then told me that Bernie had told Luciano Benetton that he would soon control the Ford V-6 engine. I liked Collins, and I liked Benetton, so I recommended to Ford in Detroit that we either pulled out of F1, or that we looked for a new team, and that it should be Benetton.

'Keith was very good. Although he was very unhappy

A contrast in designs. This was the Cosworth GB V-6 installed in the Haas-Lola of 1986 . . .

. . . and this was the further-developed engine fitted to the Benetton B187 of 1987. Cosworth pushed up the GB's peak power from 750 to 1,000 bhp in little more than a year, even though FISA's compulsory 4-Bar blow-off valves (seen on top of the engine) had to be fitted in the latter year. Compared with its rivals, the Cosworth GB engine was very small indeed.

Edsel Ford Junior, keeping up the family's interest in motor racing, attended the 1987 Detroit GP, hoping to see a good performance from the GB-engined Benettons. On that occasion Boutsen's qualified fourth fastest, and Fabi's car eighth.

with what had happened in 1986, he told us that he wanted Cosworth to stay in F1 with this engine.'

The last few months of 1986 were traumatic for many companies, teams, and individuals. Haas had a three-year agreement with Ford, which had to be dissolved (and in the end, Ford had to make a financial settlement), Ford's 'top-brass' had to be mollified, while Mike Kranefuss and Keith Duckworth had to rebuild a relationship which had gone wrong.

Keith had been disappointed, and very vocal, about the failings of the Haas-Lola team, while Mike Kranefuss says that he had found Keith, at various times, cynical, sympathetic, cold, supportive, and enthusiastic. Keith, in fact, was a normal, warm-blooded, human being who could not accept the way that his designers' best efforts were at times being negated by failures at the race track.

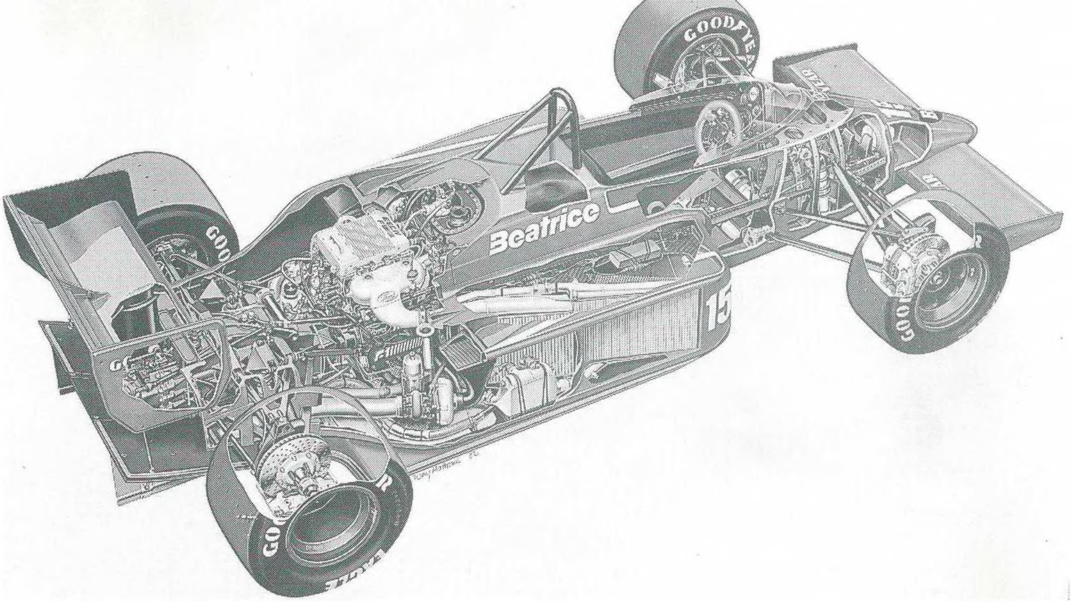
By mid-1987 the Cosworth-engined Benetton B187 was almost on the pace, regularly qualifying on the second row of the grid, and (in the hands of Thierry Boutsen and Teo Fabi) regularly finishing in the points. The problem was that although Geoff Goddard is now sure that in 1987 the Cosworth engine was racing with the same horsepower as the omnipotent Honda V-6 turbo, if not slightly more, the Benetton car itself was not as finely honed, or as effective, as the all-conquering Williams-Hondas.

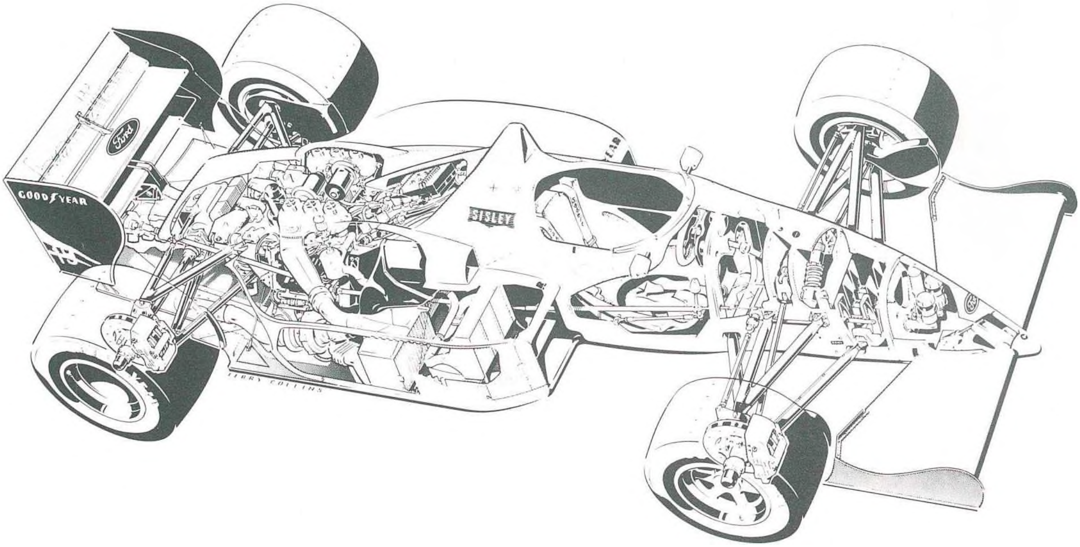
The engine, which had started life in 1986 with a 10,500 rpm limit, was now regularly running to 12,000 rpm, but if drivers missed gears when changing down for corners, read-outs sometimes exceeded 16,000 rpm, and according to Goddard no engine ever dropped a valve.

Then, late in 1987, FISA broke yet another of its promises about technical stability, performed yet another of its somersaults, and issued two decisions. One was that turbocharged F1 engines were to be reduced to 2.5-Bar boost in 1988, and the other was that turbocharged engines would be completely banned from the end of that year. Just as the Cosworth V-6 turbo had made its reputation (and, make no mistake, there was a queue of hopeful customers forming at Northampton at this time), FISA proposed to kill it off.

This was a body blow to Cosworth, where spirits had been rising as the engine showed its worth. Was it worth re-developing the engine? Ford, frankly, was not happy to finance another upheaval, as Mike Kranefuss told me:

'By this time the F1 programme had less than total support from my management. We had two alternatives for 1988 – either to continue with the V-6, spend a lot of


Beatrice
15
GOODYEAR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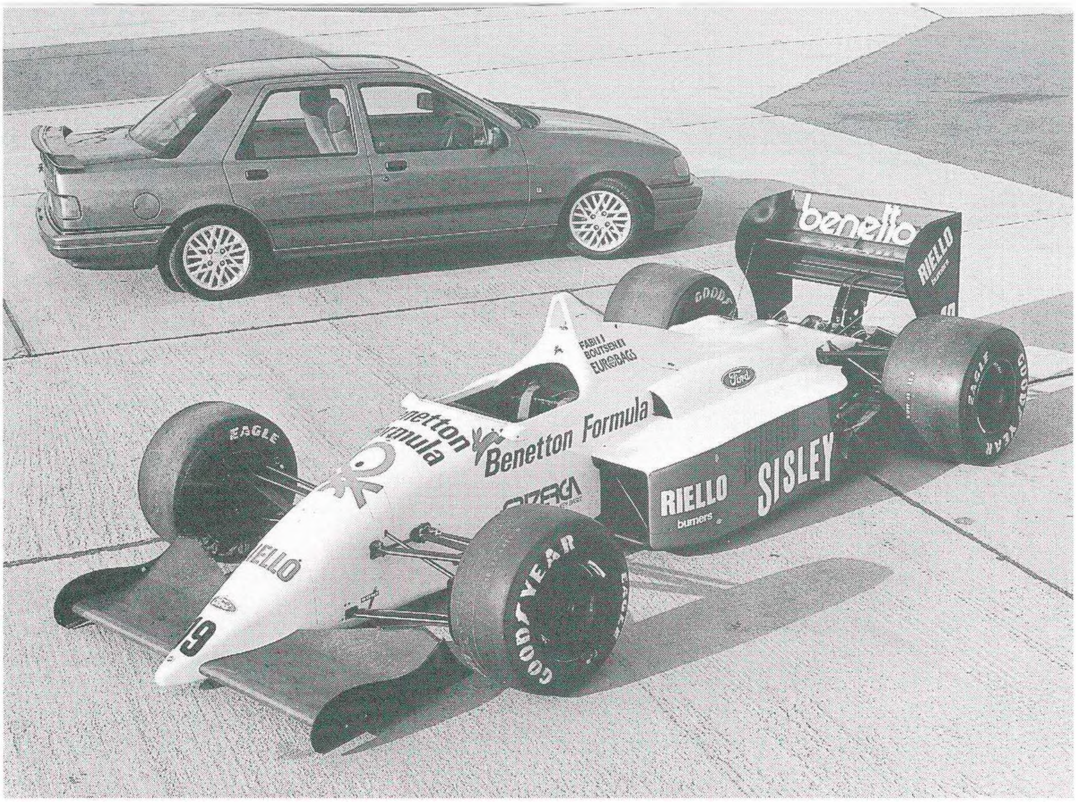


In 1987 Ford emphasised the Cosworth-Ford-Benetton connection by posing a new four-door Sierra RS Cosworth alongside the V-6 GB-engined Benetton B187 (*Maurice Hamilton*).

money, and use all available engineering and design capacity, or we could start again with a normally-aspirated engine.

'With the Cosworth V-6 turbo, we could certainly match the Honda, but the total picture was that we didn't have the best total team. We would probably have been on pole a few times, maybe even won a race or two, but we would not have been able to focus on the future.

'At that point we thought that we had a viable 5-valve Yamaha alternative to the DFZ. So we had discussions with Benetton, asking them what they wanted to do. Some of them wanted to continue with the turbo, especially as we had made such great improvements towards the end of 1987, but others were saying, let's get on with the future.'

Cosworth's managing director, Richard Bulman, reminded me that Cosworth's commitment to the V-6 turbo was, in any case, as heavy as the company could bear:

'We were very stretched with the V-6 turbo. It was a very demanding programme. At peak we had more than 100 people working on that project *alone*, to catch up on the years of lost development, and that was just to supply one F1 team. That was to keep up with just 25 engines. Honda, at the time, was reputed to have 400 people to supply two teams, their budget was ten to twenty times higher than ours, and we know they built 135 engines in that last year!'

Keith Duckworth was happy to kill off the turbocharged F1 engine:

'We were not big enough to waste further techonological effort on a dying art, on something which I did not think had any relevance. It was a waste of scarce mind-power, to do something as frivolous as that. In any case, if we had tried to drop the boost to 2.5-Bar, the engine needed to run faster, but our engine wasn't designed to run faster. I simply didn't want to do it.

'Even so, among the designers there was a vast enthusiasm for keeping going, a frustration that the engine had been designed, but not actually proved. Let's face it, we had come up, on a par, with the Honda in less than two years. Someone had a half-hearted go at making one run with 2.5-Bar boost, but it was never a serious effort. By the end of 1987 it was all over, really.'

Cosworth, therefore, repossessed all the engines, and stored them away in Northampton, where most of them still remain. As far as I know, no-one outside Cosworth has ever seen an engine stripped out, and all knowledge of vital details like bore/stroke ratios, port shapes, cylinder head fixing arrangements, and all other structural details, remain secret. Richard Bulman takes an upbeat view of the programme which was, let's not forget, totally funded by Ford:

'I think we learned quite a lot from it. In the end, we had the best turbo engine in F1, I don't think there's any doubt about that. The engine was extremely sound, though we simply didn't have the man-power and the budget to meet Honda head-on.'

Mike Kranefuss, practical man though he is, certainly didn't want to see the engines locked away for ever:

'It would be stupid to throw them away. I gave a couple to Ford's Engine Design/Engine Engineering divisions in the USA and in Europe. Bernie Ecclestone wanted one or two for the Haas-Lola cars he bought in the takeover, and Peter Collins of Benetton would like one or two.

'One day, maybe, there will be a formula which suits them, or maybe we could use the block and the heads . . .'

One day, who knows . . .

CHAPTER 10

Company into Group – Worcester, Wellingborough, UEI and Carlton

'It was Alf who originally said to me: "We'll be in a hell of a mess if you die".'

By the mid 1970s, Cosworth was still expanding rapidly, and before long it was to open a new high-technology foundry at Worcester. In the 1980s a large production and assembly plant was to be erected at Wellingborough, and before the 1980s were over both these facilities were being doubled in size.

An independent Cosworth company might have been able to finance such a massive expansion, but it would never have been as simple as it looked, especially as Keith and Mike were not obviously grooming a successor to take over from them when they retired. In the late 1970s I asked Keith why he had not begun to expand Cosworth into a broadly-based consultancy concern, effectively as a British-based rival to Porsche, which was doing the same thing at the same time:

'I don't think that's possible, at this stage. There aren't enough really bright people around, in England, for us to do that.'

Mike Costin later countered this statement, in the down-to-earth way that has balanced Duckworth so much in thirty years, by suggesting that:

'The geniuses, like Keith, can't do all the work. Most of it has to be tackled by lesser mortals. There is usually a supply of what we might call lesser mortals. Young British engineers are knocking on our door all the time.'

Later Keith would modify his views, as Cosworth took on more and more work on engines, though neither he, nor UEI, was tempted to move into other automobile-based activities. There was quite enough to learn, Cosworth decided, and quite enough business to be won, by concentrating on engine work.

There seemed to be little doubt that Cosworth was much the most capable engine design company in Europe, and arguably in the world. As one seasoned Cosworth-watcher told me, Honda would need 200 people (and probably *had* 200 people) to get the results regularly achieved by ten designers at Cosworth. The ever-confident Geoff Goddard, when asked where a customer would go if he didn't like the look of Cosworth, quipped: 'Well, you're in big trouble, aren't you?'

One ex-employee, who had better not be named, remembers one significant occasion, at Northampton, in the 1970s:

'There was one time when the staff wanted to get a union into Cosworth. Keith heard about this, gathered everyone into the canteen, and calmly stated: "If the union comes into Cosworth, I'm leaving, I'll close it down", and that was the end of that little episode!'

From the first twenty years of its existence, Cosworth was purely a design, development, machining and assembly concern. Its premises were always full of work, its facilities overcrowded, and it relied, to a great extent, on its suppliers. The suppliers did their best, but by Cosworth standards this best was often not good enough. In particular, the company suffered badly from the variable quality of castings and forgings which had to be bought in.

The forgings problem was solved, eventually, by setting up a forge in Northampton. This was needed to produce pistons, and the problem was eventually solved by purchasing redundant plant from Hepworth and Grandage.

Cosworth is famous for many reasons, but it is not generally known that the company shares with Mahle of West Germany a peerless reputation for piston manufacture, in all sizes, all types, and for all manner of cars. Annual sales are measured in tens of thousands, with Cosworth pistons being supplied for engines as diverse as TWR Jaguar V-12s, Austin-Rover Metro 6R4s, NASCAR V-8s, and as replacements for almost every competition engine in the business – Toyota, Nissan, Mazda, Yamaha, Susuki, Honda among many others. But initially the casting problem was difficult to resolve, as Keith confirmed:

'Our experience of purchasing complicated castings, like 4-valve cylinder heads, was variable to say the least. Some batches would be good, and others would be seriously porous. The foundry we were using – Aeroplane & Motor – was very good, but they couldn't control the porosity. Sometimes we'd be well on with machining something when we struck trouble, and unless we had large reserve stocks we would then be in terrible trouble with deliveries.'

'It was the early DFX heads – those where the engines which were boosted to 80 in of mercury – which gave most trouble. If there was any porosity around the valve seats, we used to get heads back looking as if they had been flame-cut. We were getting a bad name for having heads which could hardly survive. I was fed up with that. My view was that if it was possible to supply good castings some of the time, it must also be possible to supply good castings all the time. There must be a set of circumstances which would guarantee good castings.

'Foundries would admit that they had a "housekeeping" problem, and that a lot of "black art" methods had to be employed. These were old skills, and as the old craftsmen retired those old skills were dying out; supplies were getting progressively worse. Therefore, I decided to set up a foundry, to prove that it was possible to cast such things. If, by rigorous measurement, and control of the parameters, we could cast something right, we ought to be able to do it the following week, the following year, or whatever.'

What followed was a typically enterprising Cosworthian manoeuvre by Keith and Mike, which confounded the rest of industry. Not only did they decide to start it without expert foundry people ('Otherwise they would convert it back into a black art situation again . . .'), but they decided it had to be remote from Northampton.

Keith and Mike wanted it to be far enough away from Northampton for it to be an awkward trip, so that no-one from Northampton would have a good excuse to: 'just nip over to the foundry for a while.'

'We consulted experts, and this produced the name of Dr John Campbell, who had spent his time researching into porosity and other things in foundries. He struck us as having a fair idea of the problem [that is Duckworth-speak, to say that he was impressed . . .], he said he had a cure, and he introduced us to zircon sand and a few other features.

'I then made one of my own contributions: "There is this pump that appeals to me, it looks right to feed metal from the furnace to the moulds, it allows you to fill how you want, and it should be programmable because it is electronically controlled. We should be able to fill up from underneath, to hold the "head", and that looks like what we need. John Campbell had an urge to live in the Worcester area because he loved the Malverns, so that is where we set up shop. John installed a pilot plant, gathered a few research people round him, and started out. Alf controlled it, and we hoped it would produce good castings.'

Cosworth looked afresh at every aspect of casting technology, not least that of correctly assembling and designing the cores:

'In those days core locations were too sloppy. You got highly individual castings, therefore a lot of averaging had to be done at the machining stage. It was always a big problem, and very time consuming. We decided we had to get core locations absolutely right, and we also wanted repeatability. We also wanted to turn Worcester from something of a "boffin" establishment to one which could produce a pile of heads. This meant that Mike [Costin] had to spend a lot of time over there.

'The problem was that soon it was eating its head off financially and there was a limit to how much money I could afford to lose there. We were already into electron beam microscopes, research laboratories and a lot of kit, but we weren't actually making many heads. It needed a real energy pill . . .'

This, then, was the point at which Keith and Mike looked round for a managing director to turn round the Worcester operation. It was typical of Keith and Mike that they chose 'brightness, rather than experience', which is where Bob Smith came in:

'The foundry had been set up in the late 1970s, but I arrived in November 1982. I didn't have *any* previous castings experience, in fact I had been running my own printing business. I already knew Peter Michael [UEI's chairman], and coincidentally I also knew Alf Vickers.

'When I arrived at Worcester, there were thirty people on the payroll – four of them having PhD degrees – but we were making almost nothing. Just a few castings for the racing team and the Rolls-Royce Gem helicopter air intake (they used it in Lynx helicopters) – but the Alvis gear box casting we were tackling was a bit of a fiasco.

'Alf wanted to get management and he wanted to get system into Worcester. The Mercedes-Benz head contract was looming up too. All in all, it took nearly three years, a big struggle, to get the business working properly. The problem was that we couldn't get many outside contracts at first as the whole of the motor industry was in deep recession there were old established foundries going out of business everywhere, and others were selling at cost.

'In addition, the company was still called Cosworth Research and Development Ltd, and it had absolutely no track record at this time: it was absolutely unknown. The final problem – the critical problem – was that we still had an extraordinarily high cost base. The new process worked in concept, but it was only a research facility, extremely cumbersome and very slow. This was what we now call Foundry 1. There was no flow line that we could show customers; in terms of commercial exploitation it still had a long way to go.'

Cosworth then decided, not only that it would take the 'brave pill' and install a medium-sized production foundry (Foundry 2) at Worcester, but that it would like to licence the process to companies around the world. Foundry 2 was to be capable of making about 30,000 cylinder heads every year. A deal was struck with GKN Contractors, whereby they would inject capital, and that they would sell the process all round the world. They would help with the production engineering, and their money would help to produce the production process at Worcester.

In the next couple of years their small team must have generated up to 200 serious enquiries, but in the end only one of these – from Austin Rover – looked as though it would lead to a licencing agreement and this finally disintegrated. Even that led to all manner of disagreements, both financial and commercial. Until the large expansion to build Foundry 2 was complete, it was impossible to convince customers that the slow process demonstrated in Foundry 1 was ever likely to be commercially viable. Then, in 1983, at exactly the wrong time for the development of the business, GKN re-appraised its entire business strategy, and decided to close down its 'Contracts' division. As Bob Smith recalls:

'It was "deep breath" time. Suddenly we were on our own. We employed two of the GKN engineers who had been made redundant – Simon Wilkins and David Tomlin – and with UEI finance we set about spending £750,000 to build the serious foundry, Foundry 2. The submission for finance went in for approval in May 1983, we began commissioning in July 1984, and it was formally opened in September 1984. We started making Mercedes-Benz heads, in numbers, even before Foundry 2 opened, then started using Foundry 2, and things started to get better after that.'

Although the evolution, and the expansion, of the Worcester foundry facility was never straightforward, from 1985, when the Sierra YB heads began to come on stream, it began to fill up, and then became a profitable part of the Cosworth scene. In spite of the heavy spending originally needed on Worcester, Cosworth's finances stayed healthy. In 1976 turnover was £1.9 million, in 1978 it had risen to £3.46 million, and in 1980 it rushed ahead to £5.36 millions. After-tax profits, in the same years, leapt ahead from £152,000 to £329,000, and then again to £1.02 millions. By 1980 the company's capital reserves stood at no less than £4.17 million.

In 1980 with DFX sales leaping ahead, and with other overseas work also adding its contribution, the balance of Cosworth's business was changing. In 1976 only 20 per cent of Cosworth's sales were to export territories, but by 1980 this figure had risen to 42 per cent. These commendable figures, by the way, had been achieved with a very limited workforce. In 1976 the workforce totalled 155 people, which rose to 184 in 1978, and to around 200 in 1980. Boring statistics? Not at all. They all bear out two of Keith Duckworth's most famous remarks:

'Over the years we've been doing things with a standard of reliability which is totally non-human. I'm one of those people who would rather do a few things very well – extraordinarily well – than what I see at the other extreme, in other companies, of making an average mess of doing a lot of things. It takes an enormous effort to get the last little thing right.'

To the outside world, and measured by any sensible standards, Cosworth was on the crest of a wave as the 1980s opened. The DFV engine was still supreme in Grand Prix racing, North American motor racing had taken the DFX to its heart, and the Cosworth-produced Ford BDs, Opel KAs and Vauxhall Chevette engines powered hundreds of competitive race and rally cars. Keith, on the other hand, was looking ahead in a rather pessimistic manner:

'Obviously Alf Vickers was fairly old, and I was petrified as to what might happen if he died, because I didn't want to have to run the place again. I certainly didn't like the thought of running a company of the size we had then become. But then it was Alf who said to me: "We'll be in a mess if *you* die", because I held 85 per cent of the shares. That made me think. I wasn't being morbid, but it made me think. The family would have been in a forced sale situation, and the death duties problems would have been awful. By the time death duties had been settled, quite a lot of the company's shares would have had to be sold off, into odd hands, or there would be an enormous amount of debt to service. Quite simply, Cosworth couldn't have gone on being run by the family. I decided, therefore, that the best thing for all concerned was for Cosworth to be sold into the hands of somebody who looked sensible, and ongoing.'

As I continued my research to write this book, I found that statement astonishing. Earlier, I had been certain that I would uncover any number of takeover approaches for a prestigious concern like Cosworth. Amazingly enough, there appear to have been none.

In the early days, for sure, Ford had every reason to bid for Cosworth. Walter Hayes, indeed, certainly considered this in the early days of the DFV, but:

'I decided that you must be very careful of taking over anything which really depends on one or two men. Taking over Cosworth, from our point of view, would have been to take over Keith and Mike. On that basis I felt sure it should never happen, because it seemed to me that Keith, without his freedom, would lose his edge.'

Walter Hayes, who retired in 1989, must now know that all those fears were justified in the 1980s:

'When we started to get into high volume production with Cosworth, Ford certainly had discussions about controlling Cosworth. I talked both to Keith and to UEI. Ford's concern was not our wanting to own them, or to take them over, but to ensure the integrity and security of Cosworth. We felt that if they belonged to us, then nobody else could take them over.

'We are now satisfied that this cannot happen, even though UEI has sold out to Carlton. We have an adequate agreement with them, which gives us all we need, and secures their independence.

'Even so, in the 1970s – and especially after his first heart attack – I talked to Keith about the necessity of him establishing a "going concern" that could operate without him, and which in future years would talk with reverence about "our founder". You always have to hope that what you've built will be better after you've departed. We've all seen examples of firms that disappeared when the founder was gone – Lotus was a very good example, and I would argue that Jaguar would have faired better if Sir William Lyons had prepared it for life after him.'

Keith Duckworth decided to sell out, to UEI, in 1980, to secure the future of Cosworth. 'We'd be in awful trouble if you died', Alf Vickers once told him — and he took the message to heart.

Although Keith thought a lot about his company's future, he had never troubled to talk to other and larger companies before the end of the 1970s. Nor had he been more than mildly tempted to 'go public':

'All that happened was that Alf Vickers began looking around for a suitable company to sell us to. It was felt that the City of London wasn't really interested in people who were involved in racing engines. I'd already had some fairly weird financial advice – setting up companies in the Bahamas, that sort of thing – but the fundamental dishonesty of most the tax schemes I was shown, well I didn't like that. I thought one was always likely to come unstuck, somehow. [This was the occasion for Keith to launch into one of his celebrated tirades, this time against the strange methods which have been developed for keeping money out of the hands of central government]

'I really did object that the government, while appearing to be hard on those who were earning a lot of money, with taxation very high, always seemed to leave loopholes – so that providing people had minds that were warped enough, they didn't actually have to lose their money.

'It was those years, of course, which encouraged such ethics, and the death of the morals of the City of London. It was the 98 per cent taxation on investment income that caused crookery, that caused an irreversible change in the mentality of the people who operate those systems.

'It was the high taxation system which caused Cosworth to expand, by buying machinery instead of paying out profits as dividends. We kept on stirring the money back into the pit. The planners may say that that is what they intended – but they *might* say all sorts of things.

'It was crazy to pay high dividends, because that would have been called "unearned income", and we had 98 per cent taxation on such earnings in the 1970s. The great advantage of having just one bloke – me – running a company, and not primarily being interested in money, is that any money that was made was just ploughed back. That way, we generated our own capital, and bought a lot of capital equipment – we kept Cosworth going as a self-financing, self-expanding, outfit, and nobody could argue about that.'

'I am still staggered by what other people get up to. I do still speak, occasionally, to wealthy people who, I would have to say, are guilty of fraud. But they cannot understand that they are guilty, because they're only repeating something that has been done many times before.'

Mike Costin, after he became Cosworth's chairman in 1988, commented that Keith had put in a systematic search for companies of the right type to purchase Cosworth. The object, Mike says, was to find a Group which would not indulge in asset stripping, but which would understand the company and let it carry on being run by the people who were already running it.

Richard Bulman, who became managing director in 1985, in succession to Alf Vickers, said that Keith simply wasn't interested in 'going public', to dilute his shareholding, and to get a USM (Unlisted Securities Market) quote. Except to his fellow directors, Keith kept his thoughts to himself and nothing leaked to the public. Suddenly, in February 1980, the deed was done. *Autocar* reported it thus:

'Cosworth are to be taken over by UEI [United Engineering Industries], a Manchester-based engineering firm. The change will in no way affect the supply and servicing of Cosworth racing engines – but it does show how lucractive this business has been. The deal comprises £3.4 million in UEI shares, £2.4 million in loan bonds, and a further £425,000 in loan bonds at the conclusion of a satisfactory year's trading.

'Keith Duckworth, whom many people have been surprised to find owns 85 per cent of Cosworth shares [But why should they? It, was, after all, his company, and he had founded it . . .], will be the main recipient of the purchase.

'He will now be left alone to concentrate on the design of new components . . .'

In fact Keith had rarely done anything other than design new engines. For the first few years he had had to do almost everything in the business, but Bill Brown had been a very able general manager until the mid-1970s at which point he drifted away and Alf Vickers had been a very effective, and pragmatic, managing director, since then:

'Alf did a great job running the place on the basis of a few conversations with me from time to time, and odd joint meetings until about 1985. He was responsible for the total running, the administration, and he produced the methods of working out the strategy that he and I devised between us.'

Early in 1980 Keith was happy to sell Cosworth to UEI, though in later years he came to realize that he might have got a higher price:

'We sold ourselves for what turned out to be a very modest figure, at a not particularly good time to sell, to an outfit which looked like a club of entrepreneurs, with the board consisting of the founders of those companies which had joined it. It looked like quite a good environment. In the end, I'm positive that we sold out too cheap, and I reckon that Cosworth is one of the best firms, for the money, that has ever changed hands. As we were consistently under-employing people, our latent competence and our capability for expansion, meant that we were really worth a bomb. There were *no* skeletons in the cupboard for the new owners to discover.

'But I still don't want to be seriously rich. I'm still quite amazed that some people who have some money actually seem to want a lot more. I do not think that it is a great measure of one's life to have made a lot of money.

'Self-esteem, yes, that does come into it – it's really the *only* thing that comes into it. Incidentally, neither am I interested in external honours, or prizes, or being given fellowships. However if someone pushed them on to me, it would be unreasonable to refuse. Having had a go at beating the world by building racing engines, and having managed to be responsible for the design and engineering of engines which have been successful, world-wide – I do like that. That's a reasonable accolade.'

With the takeover by UEI, all manner of personal and financial upheavals became necessary. [Motor sport enthusiasts, not interested in this, should skip the next few paragraphs!]. All the original directors of Cosworth were obliged to sell their interest in Swindon Racing Engines, which left John Dunn with the tricky job of financing the loans he needed to buy them out:

'We'd never made a lot of money, and I certainly wasn't rolling in it. I paid off the others very quickly, but Keith's holding took longer. Keith, personally, still owns the building *and* the one next door, but the actual business is now my own.'

Soon after the takeover, Ursula Duckworth (Keith's first wife) and Bill Brown resigned from the Cosworth board, and at the same time the nominal share capital was raised from a derisory £1,000, to a more sensible £100,000. Two UEI board members joined the Cosworth board at the time, Harvey Fox joined them a few months later, and naturally enough Keith also became a member of UEI's board.

In the next few years Keith gradually, but perceptibly, began to distance himself from front-line management at Northampton, while becoming more and more closely involved in the activities of the parent company. Eventually Richard Bulman, whose family once owned a company making exotic tunnel boring machinery, who had known Alf Vickers for many years, and who had spent some years at Hawker-Siddeley, joined Cosworth to become managing director. Along the way the company had effectively been split, with Alf Vickers running the operations side, and Keith the engineering and racing side. By this time Keith was visibly less happy working in a larger company, though Mike did not show as much impatience with the way their little company was growing so large, so quickly. Keith, in particular, was having to deal with more and more 'big company' men whose habits irritated him:

'They all speak in a particular way. They all speak like politicians. It is a characteristic of me, and proper Cosworth people, in general, that if you ask something, then there ought to be a certain amount of delay before anyone replies. The next best thing would be for people to admit that they did not have an answer, but that they would find out, or that they would think about it. To me that's a perfectly satisfactory response. In a big company, as far as I can see, that *last* thing you can afford to do is not to start replying immediately. People must start saying something, anything, immediately, words vaguely connected with the question, hoping that this might constitute an answer. What those people do is to learn to waffle. It is actually known in the dictionary as "equivocation" – the use of misleading words to conceal the truth. I actually feel mentally ill when people state things that have no meaning. It completely buggers me up, I have to follow it, and worry about it. I've lost the next ten sentences. I don't think I should be paid to suffer the company of people who are waffling!'

[A set of crisply stated opinions which then led Keith to recall one of Ben Rood's most famous Cosworth moments.]

'Ben once listened carefully to a visitor, then said, "You and I understand English, and therefore I know the meaning of every word you use. Unfortunately, when you string more than two of them together, to me they become entirely meaningless".'

In the meantime Cosworth, its future, and its finances, thoroughly underpinned with the backing of UEI, was gradually growing larger, and larger. From the outside, growth looked unstoppable. Cosworth was allowed to go ahead, freewheeling, with little influence from above. There was no attempt, fortunately, to send in teams of grey-faced accountants, to milk Cosworth's name for what it was worth.

By 1984, and ahead of the public announcement of the cylinder head assembly contract from Mercedes-Benz, annual turnover was up to £8 million, and a new engine assembly factory, at Wellingborough, was already partly built. Details of this major project, which was closely linked to the Sierra engine programme, are included in the next chapter. Two years later, in 1986, turnover had doubled to £16.1 million, and in 1988 it had doubled yet again, this time to £33.3 million.

Richard Bulman admits that the company has grown even faster than he expected, much of it due to the way Sierra RS Cosworth engine assembly has gone ahead. He also insists that motor racing was, is, and will remain, a very important part of Cosworth's activities:

'Racing is a superb vehicle, a great catalyst, for really stretching the technology. The time scale forces the issue like no amount of R & D, trials and endurance testing can ever do. We want to sustain the racing position, in several areas, as key players. I'm absolutely determined about that. Look what happened to Coventry-Climax, look at Aston-Martin, which was bailed out by Ford.'

By the 1980s, perhaps, it was high time that Keith began to think seriously about his personal future. Whereas his co-founder, Mike Costin, always appeared to be affable, relaxed, and well able to float calmly over the stresses of running a fast-growing concern, Keith was visibly serious, and closely involved, in everything which he tackled.

Mike seemed to rise above all the increased 'politicking' which crept into the much expanded company. He had never been unhappy at Cosworth, he told me in 1989, and he had never been tempted to leave, for another firm – 'maybe because nobody thinks I've been worth poaching!'.

Ben Rood, too, was still running all the machine shops with obvious enjoyment. It was rarely possible to pin him down to talk about his past, as he was too obviously tied up with the future developments. He was always, he said, 'thinking six machines ahead' of the last one he had designed. He also admitted that:

'I don't think I will know when to stop, that's going to be the disastrous undoing of me. I'm a bit worried about the day which may come when I've got nowhere to go in the mornings. I hate going on holiday, and I'll tell you why – I'm pretty sure that I could get to like it!'

The traumas surrounding the design of the new turbocharged engine, the break-up of Keith's first marriage, and the sheer size of the Wellingborough/Sierra engine project, all clearly had an effect. Perhaps his heart attack of 1973 had been too lightly shrugged off. Suddenly, in 1986, the old trouble flared up again. Three years afterwards, Keith was more cheerful, when describing an awful period in his life, than he must have felt at the time:

'Generally speaking I was feeling very fit, and I felt that I might get my helicopter licence back. I went to Harley Street for a check, and there didn't seem to be a lot wrong at first. Then he suggested that I should have an angiogram – great sport, that was, they gave me a great shot of heroin – but the results of that were terrible. I had partial blockages in two of the tubes. As a reasonable plumber, who had been dealing with fluid flow all my life, I was rather offended. Not only that, but there was no way I could get my helicopter licence back! The specialists suggested that I have heart surgery, but I ignored that advice. I said "Sod that, I'm not going through with it".'

Walter Hayes was really rather angry with him about this vacillation. It was no good, he said, for Keith to carry on acting as the Founding Father of his company if, one day, he might no longer be there to be the Father. Then came the first, embarrassing, race debut of the new turbocharged F1 engine at Imola, in 1986:

'After the race, I had to run through the paddock to catch the Ford helicopter, and I was out of breath, and in a fair bit of pain. So I thought I should get Harley Street to

What is Keith thinking? How about: 'I suppose we'd better listen to this bloke, Mike, he used to drive our DFV engined cars quite quickly . . .' This was 1988, and Jackie Stewart had just opened Cosworth's new office block, in Northampton. Note the name — Costin House, which the irreverent workforce has already given several different nicknames . . .

have another look at me, but I wasn't in a hurry, and I did nothing until the beginning of 1987.

'Then I think I must have had another, very mild, heart attack, at home in bed. The following day I went for a check up, was put on a monitoring machine, and it was suggested that I should have another angiogram in Oxford. That was *terrible* – much worse than the last time. I saw the records, and I sat there, and thought that was Heap Bad News. They said, "Well, you're lucky still to be with us", and I said that I thought I could see that. By that time I had decided that I would only settle for Magdi Yacoub and a transplant, but when they then told me that a team could be assembled in Oxford, for the following day, I decided to be gracious and accept their kind offer.'

The result was that early in 1987 Keith endured major by-pass surgery, not without many problems, and he told me that he still felt thoroughly let down by his own body. He also admitted, incidentally, that his surgeons told him that there was no point in their carrying out by-pass surgery if he carried on smoking:

'I'd tried to stop smoking before. This time I stopped – *immediately*!.'

Although he eventually returned to work and married again, to Jill, Keith soon retired to 'The Folly', his comfortable house on a hill top, not far from Northampton, where he continued to dabble in F1 engine design, and : 'any technical problem that made me really sit down, and *think*.' Times, and his company, had moved on too far to interest him any more in Cosworth:

'When I was chairman, I felt that I had to be responsible overall for what was going on. I had to be in charge. That had now become unreasonable. I'd always taken the view that any job we took on should have been with my knowledge. If the worst came to the worst, if an engineering job got into the mire, I felt that by abandoning other things, I could apply myself and dig it out of the mire.

'We needed someone like Richard Bulman, to impose some discipline, to watch over all the finances, to implement the strategy. Someone with a normal large-company approach. It was beyond me. As the company got bigger, this became more unrealistic.

'I think I am, always was, unsuitable, to be in charge of a larger company. The whole of my nature, anyhow, was that I wanted to do a few things very well indeed, rather than doing a lot of things only fairly well. Mike is far more capable, by his nature, of assisting in little ways, generally to uplift the standard. I would like to lift *all* the standards to an *unrealistic* height. I am really not very good at just assisting things. The problem in life, for me, was that there never seemed to be enough time to do everything right.'

'The Folly' was the sort of house you might expect of a 'Professor Brainstorm' (to use Walter Hayes' apt phraseology), with not one, but two, helicopters in the hangar, a microlight kit being built up, a Sierra RS Cosworth in the yard, son Roger's Sierra Cosworth-engined Escort rally car nearby, and a large and rather untidy study into which Keith regularly disappeared to think out a particular problem.

He had already split Cosworth into two major activities – one centred around the racing engine business, the other larger one being bound up in production engine design and manufacture – but was no longer connected, at ground level, with either. His old friend and confidante, Alf Vickers, died in February 1988.

Slowly, but definitely, the atmosphere at Northampton changed – not deteriorated, but changed. The pressure-cooker, high-technology, university-of-engineering atmosphere dissipated, and a more conventional atmosphere took over. To some of his designers, Keith had been too long-winded, too anxious to argue every technical conundrum, however, minor, to its ultimate conclusion. There were people, let us be honest, who would try to avoid him when that 'let's have a discussion' gleam came into his eyes – life, they said, was too short for that. To others, the crackle in the atmosphere had gone. As one ex-designer told me:

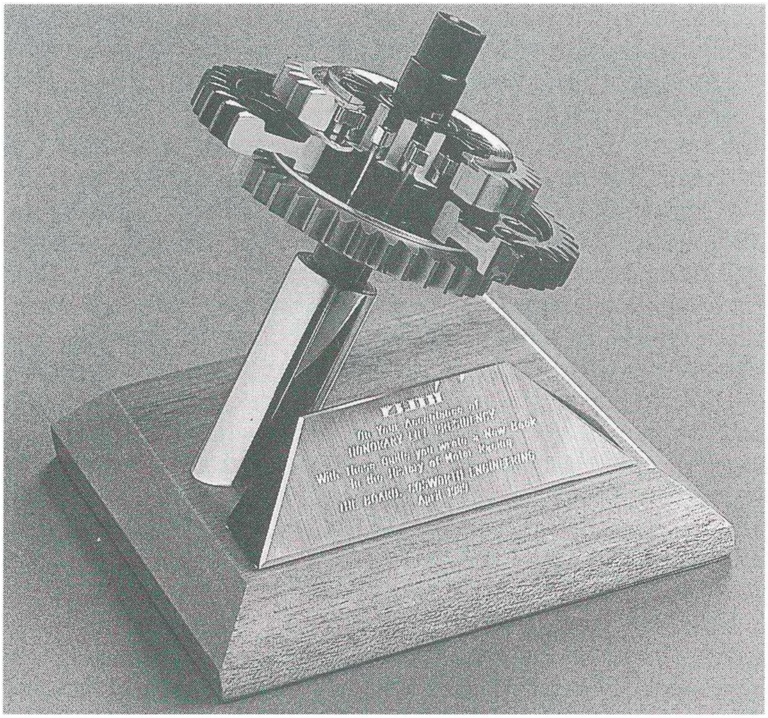
'He was always a very exciting bloke to have around, he had so many ideas, all the time. If that made you tick, it was a happy atmosphere. After he had been with me, at my drawing board, I ended up being quite inspired for the rest of the day.'

Mike Costin thinks that what followed was inevitable:

'He gradually lost interest in the company which he had founded, because he could no longer control *all* the engineering which was going on. In the end, really, he said "Stuff it", and retired. On the other hand, he is still going on consulting especially on the race engine side.'

By 1988 Cosworth had grown to employ 570 people,

Thirty years after Mike Costin became the co-founder of Cosworth in 1958, he took over as chairman. But don't chairmen usually wear expensive suits, and look stern and reassuring? Not if Mike Costin can help it, they don't . . .



The caption says it all: 'Keith. On your acceptance of Honorary Life Presidency. With these quills you wrote a new book in the history of motor racing. The Board, Cosworth Engineering, April 1989.' This was to be Keith's memento of his famous DFV engine, the complex timing gear of which solved all the vibration problems in the DFV F1 engine.

none of whom were involved in useless, or esoteric, activities. Keith, following his second heart attack, had mellowed, and decided that there was more to life than killing himself in the pursuit of technical excellence.

Mike Costin once quoted from a note which Keith had jotted, after a particularly difficult time: 'I have decided that I will join the human race and take no thought for the morrow, let the morrow take care of itself.' Or (as Costin quipped, eyes glinting behind his glasses): 'He's decided that he can't rebuild the world – stuff it, he'll join it.'

'The records show that Keith stepped down from the Chair, which he had held since 1958, on 30 August 1988, and that Mike Costin took his place. It was 29 years and 11 months since Cosworth Engineering had been incorporated. His enormous contribution to everything achieved by Cosworth was formalized in April 1989 when the 'new regime' presented him with a mounted version of the famous DFV multi-quill timing gear, and the following inscription:

'Keith. On your acceptance of HONORARY LIFE PRESIDENCY. With these quills, you wrote a New Book in the History of Motor Racing. THE BOARD, COSWORTH ENGINEERING. April 1989.'

Even while the first edition of this book was being drafted, the surprises, and the commercial manoeuvrings, continued. No sooner had UEI announced record profits for 1988 (26 per cent higher than in 1987), with group turnover up by a similar amount, than UEI itself agreed to be taken over. The report in 25 May 1989's *Daily Telegraph* summarized the attitude of the City:

'Carlton Communications, the ambitious television services group led by Michael Green, took its shareholders by surprise yesterday, with an agreed £492 million offer for the UEI electronics-to-engineering company.

'UEI will significantly add to Carlton's strength in the world market for advanced television technology.'

There was, however, a rather disturbing paragraph, later on:

'UEI has two other major divisions – including the Link Scientific and Cosworth motor engine businesses – which Carlton admitted yesterday are not an obvious [business] fit. However, Mr Green insisted that : "No companies are for sale".'

The Times took this on board without much comment, except to suggest that : 'Cosworth is likely to attract offers, particularly from suppliers to the motor industry.'

In the autumn and winter of 1989/1990, in fact, Britain's 'rumour factory' decided that Cosworth *was* for sale, and linked its future with several different concerns. For

After Keith Duckworth retired from Cosworth in 1988, Mike Costin became the company's chairman. This was the ideal opportunity to pose Mike (in sports jacket), his managing director Richard Bulman, and a Ford Sierra (Sapphire) Cosworth in front of the famous logo, at the Northampton factory.

The Hart-Cosworth partnership

Brian Hart set up his own engine building business at the end of the 1960s, designed the aluminium block for the BD engine in 1971/1972, and went on to produce his all-new Hart 420R F2 2.0-litre engine, which was announced in 1975:

'I spent a complete winter designing it, and there was only one proviso. Stuart Turner, of Ford, wanted to be sure that it would fit into the engine bay of a Ford Escort, just in case it might be turned into a road car engine!'

The 420R started winning F2 races in 1977, first won the F2 European Championship (with Toleman) in 1980, and was then converted to 1.5-litre turbocharged power (as the 415T) for Toleman in 1981. In normally aspirated, 2.3-litre, form, it was also put forward as an engine project for use in Ford's still-born RS1700T rally car.

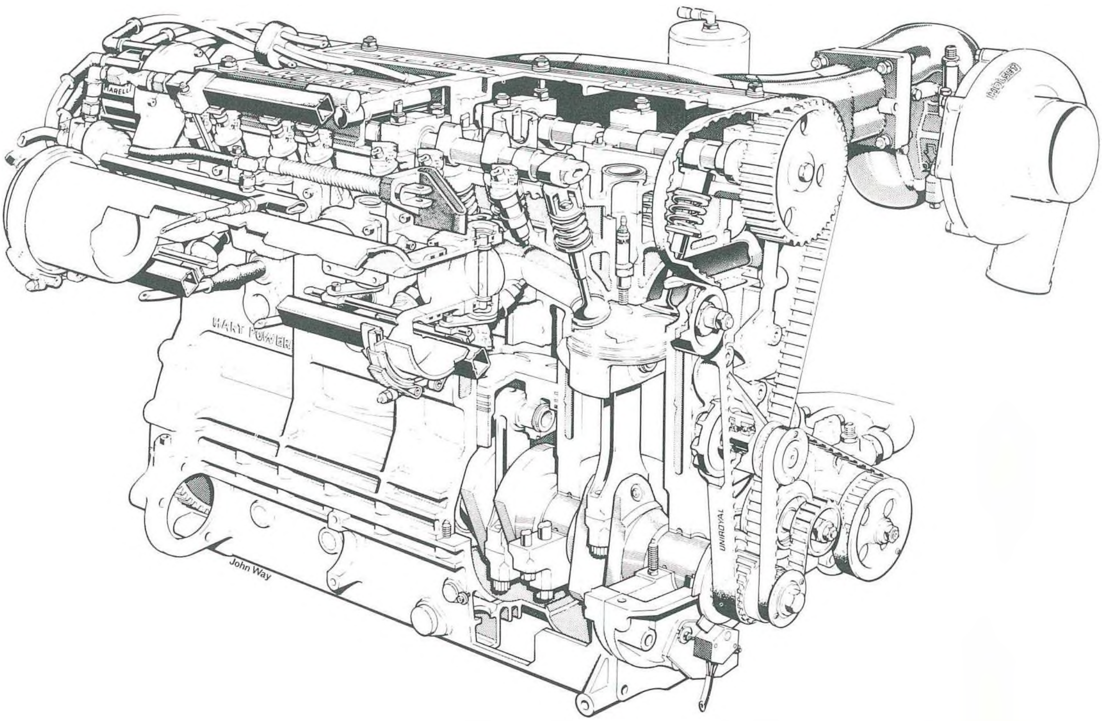
For the next few years, the small and admittedly under-financed company struggled to make the 415T engine competitive and reliable against the might of Renault, BMW, Ferrari and TAG-Porsche. It was a losing battle. At best the 415T could race at 4-bar boost limits with 800 bhp, which wasn't enough. The last team to use Hart F1 engines, as a temporary measure, was Beatrice/Lola, prior to the delivery of its Cosworth GB V-6 turbocharged units.

The F1 programme cost Brian Hart Ltd a great deal of money, and he was only able to stay in business because of the other work which came his way, not least the Ford 'BDT-E' RS200 project. When that engine, too, was killed off by a change in regulations, Brian felt very downhearted. His design staff, after all, consisted of himself and his brother Tony, with John Lievesley working on a consultancy basis, and there was also a 29-man workforce to feed:

'We were then approached directly by Keith Duckworth in November 1986, wanting to take us over. At the time Cosworth had more work on racing car engines than it could foreseeably cope with. We, on the other hand, had designed a very promising twin-cam conversion of an established road-car engine, but were not capable or interested in putting it into production.'

'Since we had already said to the client: "Look, we're only small, we can only build prototypes, you'd better go to Cosworth for production engines, there's no-one else in Europe who has the same kind of facility", I suppose the solution was obvious. Of course, Ford *and* Cosworth already knew this, because they had just got the Sierra engine into volume production.'

In Richard Bulman's own words: 'We were so stretched with the turbocharged F1 engine that we couldn't look at anything else. We both needed each other.' The result was that Keith had a close look at the projected road-car engine and wanted to acquire it, offered a great deal of racing design



Early in the 1980s, Brian Hart designed a turbocharged F1 version of his well-developed four-cylinder engine. Cosworth later considered designing a four-cylinder turbo-4, and later actually controlled Brian Hart Ltd for a time, but there was no technical link between the two projects.

and development work for BHL's future, and made a bid for Brian Hart Ltd. Brian, who was the sole shareholder of BHL, sold 75 per cent of his holding, and his company then became a subsidiary of Cosworth Engineering. The road-car engine project was moved to Northampton, was redesigned, developed and tooled for production, and was due to go into a fast and prestigious car in 1990.

The deal was made public in February 1987 when it was suggested that BHL: 'will take an important role in the design and development of the 3.5-litre Ford engine for F1'. Unhappily, the fine words were never translated into worthy actions. Within a year the relationship between Cosworth and BHL had soured, for neither party found that it was gaining any benefit. BHL had been given very little design and development work on the interim DFR, and had not been consulted on the layout of Geoff Goddard's all-new HB V-8 F1 engine for 1989. Cosworth, on the other hand, was not content with the profits earned by its newest sudsidiary. Cosworth managing director Richard Bulman puts it this way: 'We found that the opportunities for BHL in F1 were, to a certain extent, inhibited by Cosworth, because teams felt that their particular technology would be spewed around within Cosworth.'

Brian Hart is more direct:

'In a word, we didn't get the work in exchange, that we had been promised. We were never asked to give an opinion on the 5-valve/Yamaha dilemma, in fact we were never taken into Cosworth's confidence over that. Two things then happened. Dear Alf Vickers, who had done all the negotiations with us, died. Keith had his heart operation, and for a long time in 1987 that prevented work coming to us. When Keith stepped down from the chairmanship of Cosworth, Richard Bulman came to see us, and it was fairly clear that Richard thought we were something of a corporate irritation. He wanted us to be much more profitable, and told us so.

'Soon after Mike Costin took over as Chairman, he came down to see me, and we discussed various solutions. It was clear that we weren't going to get any new design work from Northampton, so one of the alternatives – that we dissolve the marriage – seemed to make sense. So, we accepted that, and after a protracted period, I bought back my 75 per cent. Now we operate on a purely commercial basis – supplier to customer – with Cosworth, no more and no less than that.'

After squeezing even more power out of DFRs, DFZs and DFLs, Hart then designed a completely new F1 vee-10 engine of his own, a compact and powerful 3.5-litre unit which was used by the Jordan team in 1993 and 1994. Further F1 3-litre engines were promised for 1995 and beyond.

Brian is the chairman, the chief designer, the chief development engineer and – on the evidence of a visit I recently made to Harlow – the storeman and marketing chief as well. Which, I suspect, is what he prefers to be . . .

obvious reasons Ford, General Motors and Daimler-Benz were all quoted as possible buyers, with Fiat also thought to be a strong contender. Since Cosworth's 1989 profits had reached £14.2 million, the company was obviously very attractive to predators.

In March 1990, however, almost everyone was surprised when Carlton agreed to sell Cosworth to the Vickers Group, the deal going through with the minimum of disruption. Vickers, which already owned Rolls-Royce Motor Cars, agreed to pay £163.5 million for Cosworth.

There was a brisk re-shuffle of names before Cosworth settled down under new ownership. Mike Costin vacated the Chairman's post, stepping down to become Deputy Chairman for a time, as Vickers appointed Rolls-Royce Engineering Director Mike Dunn as the new (part-time) Chairman.

A few months later Dr Peter Nevitt became Cosworth's new Chairman in place of Mike Dunn, and Mike Costin finally retired. Cosworth, under new direction, faced up to major expansion in the 1990s.

The Sierra project – a quantum leap into the future

'We think there's a market for 200 conversion kits a year so we thought we'd do one.'

'You know, we could put that engine into a Sierra, with a turbo, and there's no way anything would beat us on the track.'

When a new project is successful, any number of people are happy to take credit for it. Cosworth's famous turbocharged YB-series Sierra engine is a case in point. Not only did it become a race and rally-winning unit in the late 1980s, but it was also the main influence behind the company's huge expansion. Consider these simple facts – in 1982, before the YB was designed, Cosworth's annual turnover was £5.2 million, and its after-tax profit £943,000. Five years later turnover had rocketed to £33.4 million, and profits to £3.3 million.

The story of this phase of growth really began in the early 1980s, when Keith and Jack Field began to study the needs of the specialist manufacturers, and the 'engine kit' market. The BD series, they decided, was getting old, block supplies could not be guaranteed for ever, and in any case the cylinder head was too expensive to produce. In a private venture, they decided to use Ford's long-established T88/'Pinto' cylinder block and bottom end, and to develop a new *normally-aspirated* 16-valve twin-cam cylinder head conversion. Mike Hall recalls that: 'It could have been a bolt-on goody for private owners. We even thought we might sell a few to Ford RS dealers.'

Cosworth was not the first company to try a 16-valve/

Pinto combination. Holbay had attempted a more basic conversion in the 1970s and Ford had actually commissioned Brian Hart Ltd to produce an engine at the same time, but neither came to anything. By 1983 the first Cosworth-Pinto engines – what we now know as the YAA types – were built, but no serious testing had begun.

It was at about the same time that Ford's European Motorsport division experienced an upheaval. Karl Ludvigsen, who had been running things, moved out, while Stuart Turner returned from a long sojourn in the Public Affairs division. Within days Turner had killed off the C100 sports car project (complete with its 3.9-litre DFL engine) and the Escort RS1700T rally car (complete with its BDT engine). He needed new projects to take their place. The coincidences then began to build up:

'The week after I came back, in March 1983, Walter Hayes and I went to a Silverstone touring car race, and watched the Rover Vitesses winning. I recall saying something like "It would be nice to see something of ours that could beat them." Jim Capolongo and Ed Blanche, who were president and chairman of Ford of Europe, were discussing the "Shall we design a new F1 engine" question at the time, and felt that they should visit Cosworth.

'I took them both to Cosworth in Northampton, and as we were walking round, there was this T88 block, with a 16-valve head on it. I asked Keith what it was, and he told me: "We think there's a market for about 200 conversion kits a year, so we thought we'd do one".'

'Then we all went to the local pub and had a ploughman's lunch. Over lunch I distinctly remember saying: "You know, we could put that engine in a Sierra, with a turbo, and there's no way anything would beat us on the track." Really, it all began to roll from then. Make no mistake, we were incredibly lucky with our timing, just to see that engine there, at the right time. Don't run away with the idea that Ford is all about computerized planning.'

One famous document produced by the dynamic Turner in his whirlwind return to Motorsport, was that listing a 'Ladder of Opportunity' for the division. It started, at the bottom, with 'Posters for Motor Clubs', and finished, at the top, with 'New F1 engine?' Near the top were three other queried projects – 'Escort Turbo for rallying?', New Group B car for rallying?', and 'Turbo Sierra for Group A racing?'. Stuart asked for all three projects to be approved, expected at least one to be refused, and was astonished to see all three go through.

The project was formalized in 1983, the prototype Sierra

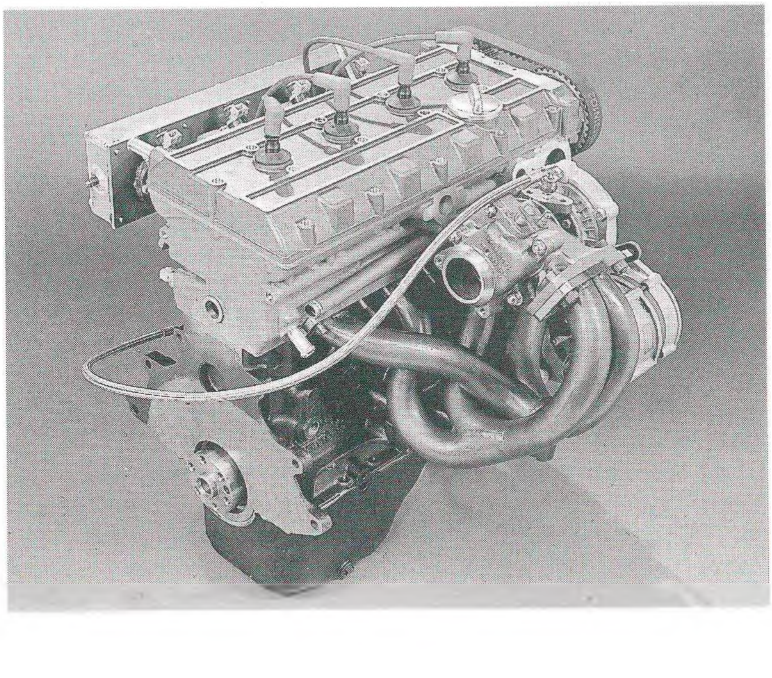
RS Cosworth was unveiled in March 1985, and engine deliveries to Ford began before the end of that year. It was necessary to build 5,000 engines to achieve sporting homologation, and the initial production contract was for 15,000 YBs of all types. Stuart thinks the gods were on Ford's side in 1983:

'Had we had to start by creating 16-valves, then turbo-charging, it would have taken too long. It was only because Cosworth had already designed the engine as a private venture that it could be done so quickly.'

These things are never quite as cut-and-dried, or as romantic, as they seem. One experienced engineer, with Ford SVE connections, assured me that Cosworth had already offered the normally-aspirated YBA engine to Ford for appraisal before Capolongo, Blanche and Turner saw it, and that Cosworth had been told: 'it will need turbocharging to be competitive'.

The vagaries of FISA's new Group A regulations had to be taken into account. The new engine needed a steel crank and steel rods, the camshaft profiles were carefully drawn so that a revision for Group A events would be feasible – the result being that the cylinder block was the only standard Ford item left over. Mike Hall, too, of Cosworth, also told me that:

'Ford originally talked about taking several thousand of these, but in normally-aspirated form. I think it was a bit of a surprise to us when they came back and said they



Cosworth produced prototype YB-type engines for the Sierra in 1984. At that time the engine had fabricated tubular exhaust manifolds, and a unique type of cam cover, neither of which featured on the production cars.

wanted a turbocharger.'

Mike can also remember, now, with a smile, that it was work on this new project which caused him to have a heart attack:

'We were terribly busy, but I didn't think I had so many hassles that it would affect my health. We were right up against it with the Opel [GM 16-valve 2-litre] job, and I was also having to pick up the Sierra YB work. Mario Ilien had actually done most of the design, but he had just left to set up Ilmor, and soon after he had gone one of our best draughtsmen, Geoff Oliver, also left. So suddenly, I was right in the thick of it, I had too much on, and my body let me know about that.'

The new engine, when built at the end of 1983, worked well straightaway. As Keith once commented, on another matter:

'There's one major difference between Cosworth and anyone else. As far as we can see, we're the only people who expect a prototype to go together straightaway, and definitely I think that disgust is felt when the pieces don't actually go together.'

Geoff Goddard also makes the point that: 'With road engines, we're actually able to dial in, within the odd horsepower of what was requested. With the Sierra though, well we didn't get the 200 bhp as requested, we just couldn't get the engine *down* to that!'

The YB project was to be much the biggest that Cosworth had ever tackled, and much of the liaison work was carried out by project engineer Paul Fricker. If the company had still been privately owned, perhaps the offer would never have come – for Ford not only wanted an 'homologation special' engine designed and developed, they also wanted to see Cosworth manufacture the production engines too. Because Ford's own prestigious new product was involved, it gave a great deal of help to Cosworth in planning the project, to make sure that its finances were always on an even keel. A huge multinational company like Ford could visualize itself building a handful of engines every year, or building hundreds of thousands a year, but would have found it difficult to build just 5,000 to 8,000 engines a year. For a company of Ford's size, it didn't make economic sense.

On the other hand, there were very few companies, in Europe, which *would* be comfortably set at those sort of rates. To meet all the targets, the engines had to be built quickly. Cosworth, for sure, was an ideal candidate. For Cosworth, indeed, the offer came at exactly the right time.

Keith Duckworth agrees that 'it wasn't worth my time even going to a drawing board unless I could see an end product to keep my own machines busy'. Once Alf Vickers had explained the problems, and the possibilities, UEI, Cosworth's parent company, gave enthusiastic support. A new assembly plant would be needed, but this would become necessary soon anyway to look after Mercedes-Benz and GM 16-valve cylinder head assembly in the years to come.

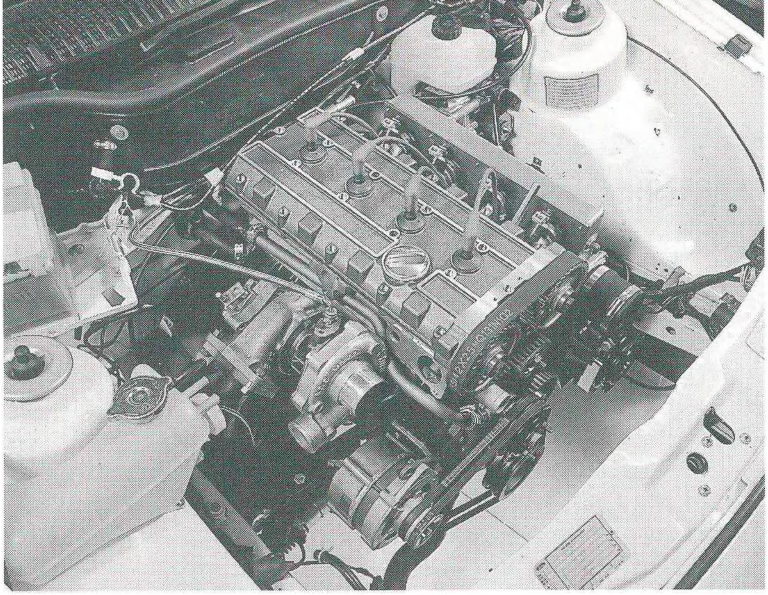
As YB development got under way, Alf Vickers looked around for a site to build a factory to assemble the engines. There was no space alongside the Northampton or the Worcester facilities and, in any case, Mike Costin reminded me that it was desirable that the plant should be situated away from corporate HQ: 'so that people don't always have the excuse to nip off and get involved in production problems'.

Fortuitously, because there was an unemployment problem at Wellingborough, with the local authority offering financial incentives and plenty of space for firms to set up shop on the north of town, Cosworth decided to build a new plant, just ten miles from Northampton. Building work started in 1984, and the first engines were built before the end of the following year.

The old hands – Alf Vickers, Ben Rood, and Mike Costin – all had much to do with the layout of the Wellingborough facility. The original consultants' report suggested such a high capital cost of installing machinery that Cosworth 'would have gone broke trying to set it up'. Ben Rood then suggested ways of doing the job, and although his original ideas were partially rejected, the late-1980s re-equipment and expansion saw several pure 'Rood' machines installed.

It was Ben, who brought so much machining know-how to Cosworth, who enabled amazing machining feats to be done on machinery which looked as if it should have been ditched years ago. A closer look, however, reveals that most have been extensively re-designed by Rood, originally in his head, then practically, and robustly, on the ground.

'The most I ever paid for a secondhand machine tool was £3,250, and the cheapest was just £200. But some of them had solid casting beds which had aged for thirty years, had stopped creeping about – and we could have them reconditioned, and modified for our "machining between centres" methods for less than £4,000. We also work to extremely tight tolerances these days. The limits



The very first Cosworth YB engine being fitted into a Sierra in 1984 — this shows the prototype cam cover, the tubular exhaust manifold, and the very neat turbocharger mounting.

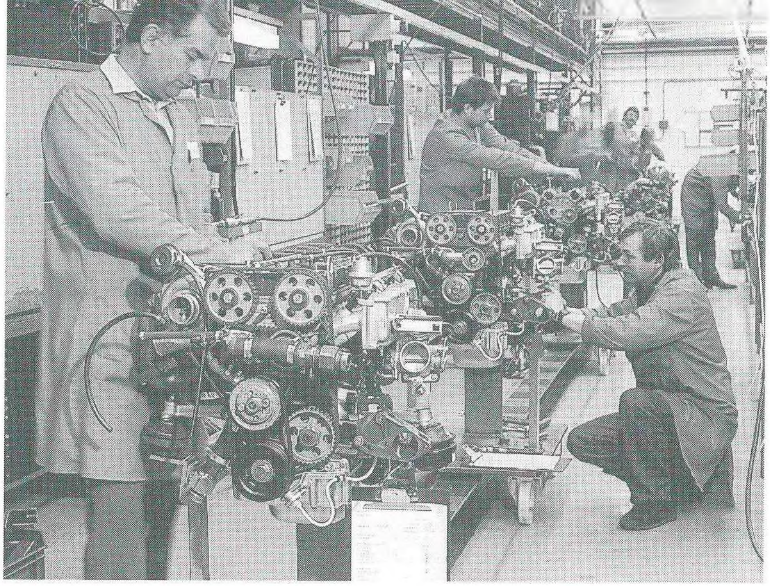
on production heads, such as for the Mercedes-Benz and the Sierra, well they're tighter than ever we imposed on the racing engines! Other people may specify tighter tolerances on their drawings, but we keep to ours. I think we probably *work* to tighter tolerances than anyone else in the motor industry.'

The Sierra, too, was significant for being the very first Ford car to carry the name of 'Cosworth' in its badging. Mike Hall, who had been through the politics of this on previous occasions, told me why:

'It was only because we had done the entire project, from drawing to production, testing to delivery, that this was entirely our own engine. It was the first time we had ever manufactured the entire engine for a road car. If we had just done a head for someone else to assemble then Cosworth wouldn't have allowed its name to go on the car.'

In business terms, however, Cosworth had to go out on a limb, and teeter, out there, for some time. Stuart Turner reminded me that the Sierra RS Cosworth car, in its original stages, had a very charmed life, that the big rear spoiler on the tail of the three-door car didn't help some of Ford's bosses to like it, and that Walter Hayes 'had it on a life support machine at least twice, before it was finally born'.

Mike Costin told me that it was the most cliff-hanging project ever, while Richard Bulman pointed out that even after Ford unveiled the prototype car in 1985, it had still not finally committed itself to go ahead. Mike, cheerful but exuding false modesty for his company, reckons that if Cosworth had made a *really* professional study of the Sierra project, then it would never have built the factory because:

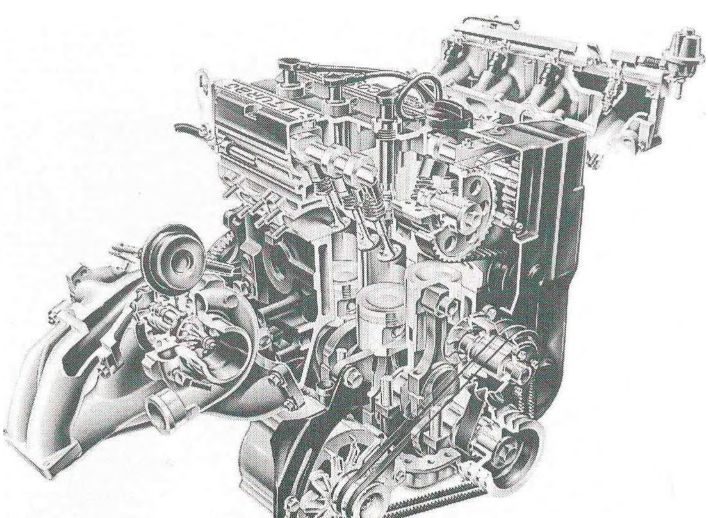


YB-Series (Sierra RS Cosworth) engine assembly at Cosworth's Wellingborough factory. The engine nearest the camera is almost ready for hot testing, complete with temporary (for test-bed use) water pipes. One very compact assembly line completes more than 30 engines in a day, if necessary.

'There is a world of difference between building 100 BDs a year, and 5,000 Sierra engines a year. Assembling heads was one thing, but this was the first engine that we had to manufacture, in total. This time we had to machine, assemble, test and validate everything.'

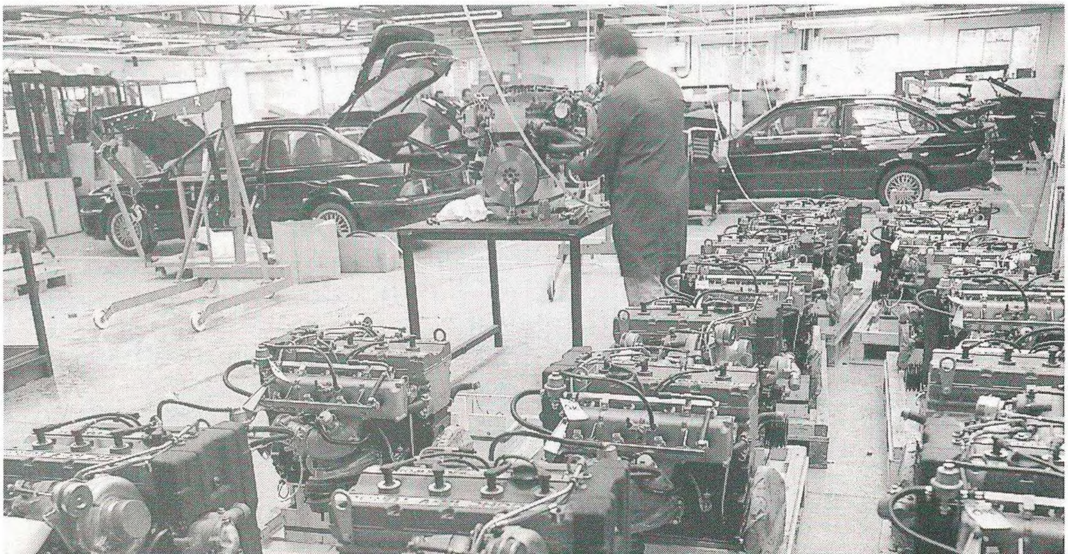
Cosworth's Wellingborough factories (there were two adjoining plants from 1985, and a massive new block, for a still-secret new assembly project, was completed during 1989) were brand new, and built without technical compromise. A plaque in the sparsely furnished office entrance reveals that the original 29,000 sq ft factory was formally opened by the Duke of Kent in November 1985, by which time it was already building the first 'off-tools' engines for delivery to Ford in Belgium.

There were delays in getting the Sierra RS Cosworth into the showrooms, none of them due to any hold-ups at Wellingborough. By the beginning of 1986, more than twenty cylinder heads were being cast at Worcester every day, with all the machining being done on multi-purpose



Ford's official cutaway drawing of the Cosworth YBB engine used in the Sierra RS Cosworth of 1986. By this time the engine had been given a two-piece cast exhaust manifold, the thermostat position had been changed, and Ford's design department had requested a more distinctive cam cover.


QUALITY
CONTROL



tools at Wellingborough. T88/Pinto cylinder blocks arrived, in batches, from Ford, Cosworth machined many other components in its Northampton shops, and final assembly was carried out along one side of the Wellingborough premises.

Even before the public got its hands on the Sierra RS Cosworth, the engine looked remarkable, but once the car's 150 mph top speed, and the engine's great flexibility, had become known, it was seen as phenomenal. There had never been a 2-litre engined car like this before.

Ford wanted the Sierra to be a race winner, and its targets had been set very high. Originally it had asked for 200 bhp, and Cosworth came back with a guaranteed output of 204 bhp. This made the Sierra RS Cosworth the first series-production road car to be sold with an engine offering more than 100 bhp/litre – 200-off 'Group B' specials like the Audi sport Quattro were not really series-production machines, and don't qualify.

But there was more, much more, to come from this remarkable statement of Cosworth's art. In fully-tuned Group A racing form, the YBC version of the engine produced up to 340 bhp. Even so, Ford was not satisfied. Group A Regulations allowed 'evolution' versions of cars to be produced – with 500 identical extra cars to be built. One of Paul Fricker's tasks was to produce a development of the 'ordinary' engine for such cars, with a lot more power potential locked inside.

Ford had been planning ahead, and actually built not 5,000, but 5,500 of the original 'whale-tail' Sierras. 500 cars were then carefully stored for a few months, then shipped to the Aston Martin Tickford factory at Bedworth, near Coventry. Among the many changes made to convert an RS Cosworth into an RS500 Cosworth, was the removal of the original engine, and the craning into place of the YBD 'Evolution' version of the Sierra engine.

The engines were built at Wellingborough in one continuous run in 1987 around a much strengthened version of the cylinder block, and with larger turbochargers and two, rather than one, row of fuel injectors. In standard form, for road use, the YBD produced 'only' 224 bhp, but when fully-tuned for circuit racing (and running at the sort of boost which DFX and BDT tuners would be proud of) more than 500 bhp was on tap. Remarkably, little of this power tuning was ever carried out at Cosworth, though much of hardware, and the expert knowledge, was based at Northampton. Jack Field explains why:

'We did a rally spec, and got that off the ground, but

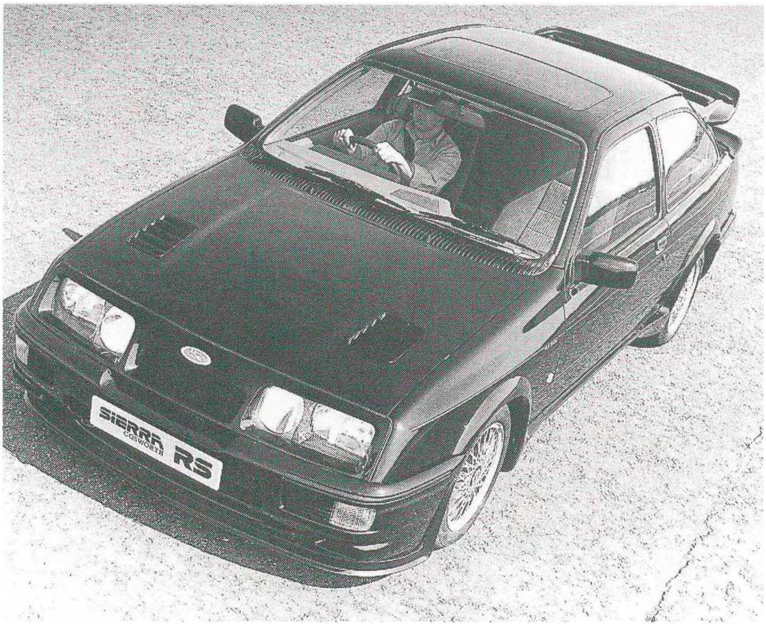
The Sierra RS Cosworth — the first Ford production car to carry the 'Cosworth' name — was previewed in 1985, then put on sale in 1986. This was one of the first 'whale-tail' models, captured at the press launch in Spain. The high performance of the car — top speed was 150mph — caused a sensation. Exactly 5,000 such cars were built, plus an extra 500 for conversion into RS500 models.

When Ford produced the Sierra RS500 Cosworth as an 'homologation special' in 1987, the work was carried out at the Aston Martin Tickford factory at Bedworth, near Coventry. There was controlled bedlam as exactly 500 Sierra RS Cosworths were re-engined, and fitted with modified aerodynamic items.

This was the scene at the Aston Martin Tickford factory at Bedworth when the 500 Sierra RS500 Cosworths were being produced. Cars in the background are awaiting engine fitment. The engines in the foreground are RS500 (YBD, in Cosworth-speak) units, complete with eight fuel injectors, and an enlarged turbocharger.

As Ford's motor sport director once said, in a public speech: 'The Sierra won the World Touring Car Championship, so FISA cancelled it. The Sierra then won the European Touring Car Championship, so FISA cancelled that too . . .' The Eggenberger team was responsible for both those successes, with 2-litre engines producing up to 500 bhp.

other engine builders took over, and some now say that everything is of their own manufacture. In fact we do nearly 100 per cent of all the special pieces used in YBs – everything except the electronics – but don't trumpet this. As far as the RS500 racing engine is concerned, we did some development, but much of the work was done by people like Eggenberger, Hoyle, and Andy Rouse. We have tried to work closely with them. The engine builders all like it that way. They're in the business of preparing, and rebuilding engines. They need a ready supply of good pieces, but the last thing they want is to see Cosworth building engines. It's far better if they can buy a full kit



Externally, the Ford Sierra RS500 Cosworth looked almost identical to the 'ordinary' Ford Sierra RS Cosworth, except that it had an even larger front spoiler, and two spoilers instead of one on the tailgate. These were the cars which became completely dominant in motor racing in the next three seasons.

from Cosworth – and they can.

'We like to keep abreast of what is going on out there at the engine builders – but you'd be amazed, some can be very difficult, very secretive. I don't know why: The last thing *we* want to do is to build engines which compete with those produced by our best customers.'

Leading engine builders like Terry Hoyle Ltd, however, do a lot of their own work. The relationship with Northampton is open, and relaxed, but partner Graham Dale-Jones is not anxious to pay Cosworth's consultancy rates on too many occasions.

By 1989, on the other hand, Jack Field thought that there was a great deal of scope for the Sierra engine to take over from other, older, Cosworth units. Among his on-going projects was a normally-aspirated derivation:

'I could offer a much cheaper engine, offering similar performance, to some of the BD types. I'd be able to kill off the BDP, except for supplying spares. The Sierra engine already has the steel crank and rods, as built at Wellingborough, which makes it much simpler than with the original BDs.'

The challenge to turn the super-high-perfomance Sierra engine into an environmentally friendly, 'green' unit, was achieved with almost contemptuous ease in 1987 and 1988. The pundits who knew little about Cosworth suggested that the Sierra's teeth would be well-and-truly drawn by the need to meet clean-exhaust rules, and the need to run on lead-free fuel. Instead, the job was completed without any major design, and an engine which was not less, but actually more, powerful than before. Even when using 95 Octane petrol instead of 99 Octane, the engine produced 207 bhp instead of 204 bhp. Geoff Goddard, who was involved in the original camshaft profile design of this remarkable engine, told me why:

'We had been designing F1 engines for some years which had extremely efficient combustion. To go "green", all that was necessary was to know what octane number was going to be available, to decide what compression ratio could be used, then look at valve seats and valves, and the job was nearly done. The Sierra's burning was so clean, in any case, that we were almost there at the start.'

Cosworth's people seem to have retained that amazing 'can-do' attitude of its founders that other less-accomplished firms do not even approach. Keith Duckworth told me, rather fondly, of one of his design engineers:

'He always sees things as simple, he seems to know so

Having beaten the world in motorsport, Ford then re-developed the Sierra Cosworth concept, to produce the four-door saloon 'executive express'. This car went on sale early in 1988, and led to an even more exciting derivative in 1990, which had four wheel drive.

much, and he always promises speedy deadlines for anything. His ability is colossal, even though some such things are *not* simple to other people.'

The company, on the other hand became progressively besieged by the motor industry, some existing customers, and some old and new. By the end of the 1980s the original Worcester premises was bursting at the seams, for Cosworth had started to make 4-valve cylinder heads for the Chrysler TC-Maserati turbocharged engine, cylinder blocks for Mercury Marine outboard two-stroke V-6 engines, and several mysterious prototype block and head castings for destinations which I was not encouraged to discuss. All this with a workforce of 125 people, and a wastage of the precious Zircon sand of only one per cent. Meaningless? In that case, consider that the sand can be used up to 100 times – how many of the world's other foundries can achieve that?

By 1989 Worcester was sending 450 cylinder head castings to Wellingborough every week, and another 120 heads to outside customers, in addition to another 40 castings for miscellaneous customers. With a doubling of Cosworth's engine assembly planned for the early 1990s, the castings facility needed to be expanded, so a brand new factory block was built, in Warndon, at the other side of Worcester. Cosworth, of course, would always use 'own-make' castings to machine and build into its own engines, but why shouldn't other companies, some of them rivals, do the same? Bob Smith had a ready answer:

'We're so much more accurate than most people, and our consistency allows us to cut down on spare metal, and therefore on machining. This is more important as castings (such as for a 4-valve head) get more and more complex.'

He was delighted to confirm, too, that both Ilmor and Judd had approached Cosworth to have major castings done at Worcester, but that Keith Duckworth had emphatically turned them away. Just as Worcester was getting larger, so was Wellingborough. By the early 1990s, instead of being instructed to go round the eastern ring road, and 'to look for Mothercare's factory, we're just beyond that', it was possible to see a massive new factory block, some distance away, well before one reached it. This time, perhaps for the first time in Cosworth's illustrious thirty-year life, there was more than enough space for the next phase of expansion.

But where would the limits be? Was there a lot more to come in the next few years?

No whale-tail, no wheelarch extensions, no bonnet louvres, but still an exceptionally fast road car — this was what became known as the 'Sapphire' Cosworth of 1988 and 1989.

A new 'atmo' engine for the 1990s

'I sent a Fax back to Japan saying: "Please arrange a search party, we appear to have a leak on our dyno, there must be a big puddle of horsepower on the floor" . . .'

'The first time they put an HB engine together, and took a power reading, we got *significantly* more power than the DFR . . .'

Cosworth's last F1 victory had been recorded in 1983, and normally-aspirated engines were totally banned from the end of 1985. Had the 1.5-litre turbo engine won the war? Keith Duckworth was adamant that an all-turbo formula was a mistake, and within two years he was vindicated. By 1986 FISA, horrified to see the way that turbo horsepower, in 'race trim', had leapt to more than 1,000 bhp, turned one of its well-known credibility somersaults. For 1987 normally-aspirated engines of 3.5-litres would be allowed, and for the 1989 season these would be compulsory once again!

Having been double-crossed, maybe even triple-crossed, over engine stability regulations in Grand Prix racing, Cosworth could have made excuses for turning its back on the tight little world of F1. Managing director Richard Bulman, a businessman with no died-in-the-wool experience of motor racing, thought this would be ill-advised:

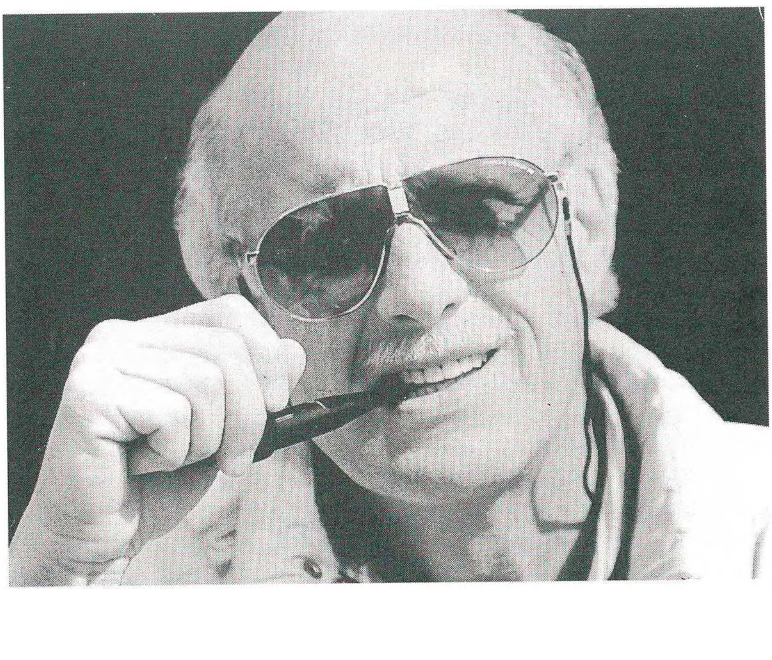
'Although F1 sales volumes are low, the race engine side is a very significant side of our business. We're unlikely to get any larger, in proportion to the whole of the business, but it is the "driving force" of our innovative technology. We *need* to keep on racing, to protect our reputation.'

In 1987, therefore, Cosworth decided to shrug off the short-lived V-6 turbo programme, and try again. This time, at least, it would be with a normally-aspirated engine, a type of which Keith Duckworth and his disciples thoroughly approved. As already recounted in Chapter 8, Cosworth was able to produce the 3.5-litre DFZ at very short notice, a 565 bhp engine which at least allowed many teams to stay in Grand Prix racing, but this was only a very short term project.

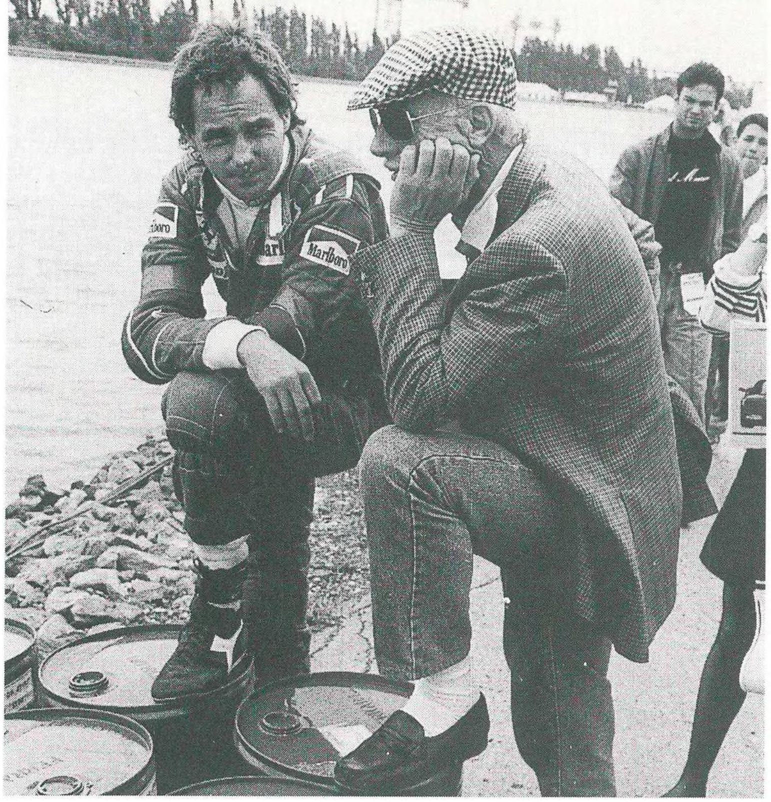
Ford-USAs motorsport director, Mike Kranefuss, weary from the double-talking, the cynicism, and the disappointment of his first two seasons in F1 racing, gained approval for a new Ford-financed programme, with engines originally to be supplied only to the Witney-based Benetton team. There would be two phases. Just over the horizon – or so it seemed to Mike Kranefuss and Cosworth, at the time – there was the promise of a powerful 5-valve/cylinder version of the DFV, by Yamaha, and this was the project which Ford approved for 1988. As the choice of 'DFZ' had dropped the naming sequence off the end of the alphabet, Cosworth was forced to jump back further along the scale, and chose DFR for its identification.

For 1989 and beyond, however, Cosworth would be encouraged to design a completely new normally-aspirated engine, and the DFR would then become the current 'customer' F1 engine.

The Ford-Yamaha connection was first made in the USA, when the Japanese company (hitherto only famous



Even though the turbo V-6 programme had been cancelled, Ford's Mike Kranefuss could smile. The early-1989 performances of the new -atmo' V-8 were very encouraging.



Mike Kranefuss (right) talking to Formula 1 driver Gerhard Berger at the Canadian GP in June 1989. The new HB engine had not yet raced, but was Kranefuss trying to attract the Austrian to Benetton for 1990? (*Maurice Hamilton*).

for building successful road *and* racing motorcycles) was contracted to produce high-performance versions of Ford's road car engines. To follow this, Yamaha decided to get into F3000 racing in Japan, where the main battle of the normally-aspirated engines was between Cosworth's ageless DFV, and the new Honda V-8. Geoff Goddard (who, with Martin Walters, would be responsible for the design of the next two Cosworth F1 engines) clearly recalls what happened next:

'Yamaha asked our permission to put their new 5-valve cylinder head, which was totally their own design, on to a DFV bottom end. It seemed to be promising, but it was no more powerful than a 4-valve DFV.'

Five-valve cylinder heads, with three inlet and two exhaust valves, are theoretically able to pass up to 10 per cent more air through their cylinders than can a 4-valve head. Because F3000 engines are limited to 9,000 rpm by regulation, this advantage never showed up. Mike Kranefuss confirms that Yamaha then proposed that it should supply cylinder heads to Cosworth for use on the interim 1988 F1 engine:

'They discussed a deal with Cosworth. The horsepower numbers they gave us were absolutely convincing – if the engines came out anywhere near close to the predicted figures we would be in good shape. The DFZ had produced 565 bhp, we were looking for 600 bhp, but they said that 630 bhp shouldn't be a problem.'

Yamaha had projected their F3000 figures upwards, to horsepower ratings which looked very attractive. For the moment, at least, Ford was convinced. Yamaha was already an important commercial partner, and eventually Keith Duckworth was persuaded that this was the interim way to go. Geoff Goddard, who swears that there was no jealousy involved on his part, was never convinced, and actually wrote a discussion paper arguing that the 5-valve head should not be used. It wasn't long before Mike Kranefuss was very nervous about the whole project:

'Yamaha took a DFZ away, and kept coming back with complaints about the block, that this was flexing, that that was wrong. Cosworth kept on replying "Yes, we know about that, just keep concentrating on the cylinder head, and the power." Then, of all things, Yamaha were late. Instead of running engines in August and September 1987, they were months late. It wasn't until just before Christmas 1987 that Cosworth ran up an engine at Northampton. It was disastrous, no power, a very erratic curve, all kinds of things were wrong.'

Yamaha, in fact, had built five engines, and all were disappointing. Geoff Goddard, who was itching to get started on an all-new design, was appalled by what he discovered when the Yamaha-developed engine went on to a Northampton test-bed:

'It wasn't even competitive with our own 4-valve engine, never mind ahead of it. I sent a Fax back to Japan saying that: "Please arrange a search party, we appear to have a leak on our dyno, there must be a big puddle of horsepower on the floor".'

Cosworth worked away on the engine until the middle of January 1988, then cancelled the project. Mike Kranefuss remembers receiving a 'phone call from Keith ('It must have been 3.00 am in England') stating, quite firmly, that the 5-valve project had been abandoned. Mike then told me, with a fond smile on his face, about the speed of Cosworth's reponse:

'This convinced me that the basics at Cosworth are still there, and alive. Within a few weeks, all their resources were behind the 4-valve engine, and they soon came up with some pretty good figures, considering the time wasted on the 5-valve engine.'

[Yamaha, incidentally, were still convinced that their head was a definite improvement over anything that Cosworth had ever done, and set out to prove it by supplying new F1 engines to Zakspeed for the 1989 season. Unhappily, by mid-1989, no Zakspeed had even qualified to start a race, so the claims were still not proven!]

Whenever I mentioned 5-valve heads to Cosworth personalities, while preparing this book, a fair amount of bristling, injured pride, and a dismissive 'Well, *I* was never convinced . . .' attitude surfaced. Keith, however, talked all round the subject, and was not prepared to write off the layout, while Geoff Goddard sagely admitted that there were 'certain advantages, certain disadvantages', but also told me with a grin that Cosworth has kept on working, has continued to look at everything in detail, and has continued to test . . .

Aston Martin Tickford's engine development division, led by no less a personality than ex-Cosworth engineer Alistair Lyle, has produced its own 5-valve heads for the rival Judd engine, but as these featured not two, but three, camshafts, there was yet another factor to be considered . . .

Early in 1988, Geoff Goddard was finally unleashed on the definitive DFR, which he had in any case been studying throughout 1987. While admitting that what Ford really needed was a newer, and altogether smaller, engine, he 'went through the whole engine and looked at everything hard, in detail'. He was not impressed when I suggested that it had been a routine re-development job.

'This was a good example of a major new design that doesn't look like it. The DFR was developed from the old DFV, but we did over 400 new drawings for the new version – that's about 80 per cent of the drawings involved in an all-new engine.'

The DFR, as raced by Benetton in 1988, produced 595 bhp at 11,000 rpm as soon as it ran, with occasional engines just creeping above 600 bhp – this latter figure representing 171 bhp/litre, which was slightly *less* than the DFY had achieved, way back in 1983. It was good, but in a year completely dominated by turbocharged Honda engines, it was never good enough to win a race. Nevertheless, the Benetton-DFR cars were far and away the most successful of the normally-aspirated runners that season. During the year, Benetton drivers Thierry Boutsen and Alessandro Nannini took eight third places and another eight points-scoring positions, while the team finished third in the Manufacturers' Championship, behind the turbocharged McLaren-Honda, and Ferrari teams.

Even so, it was not until the DFR was up and running, and already proving itself to be a very satisfactory normally-aspirated V-8 – the best of the current bunch – that Cosworth could even turn to the idea of building a new engine. The new unit, coded HB by Cosworth (but stubbornly *not* named by Ford when revealed in 1989!), only existed in the mind of its creators – Keith Duckworth, Mike Costin and Geoff Goddard – until Geoff took a drawing board home in May 1988, and started the drawing process. Only seven months later, the first engine ran on a test bed in Northampton!

[You want a reason for the use of the HB title? There really isn't one. The *previous* new F1 design for Ford had been the V-6 turbocharged GB, so maybe HB was a logical progression from that? Why not HA instead? Had there been a secret HA project, once? Cosworth wouldn't tell me, though Jack Field did admit that: 'Sometimes we design "belly-flops" that we don't want to admit to.']

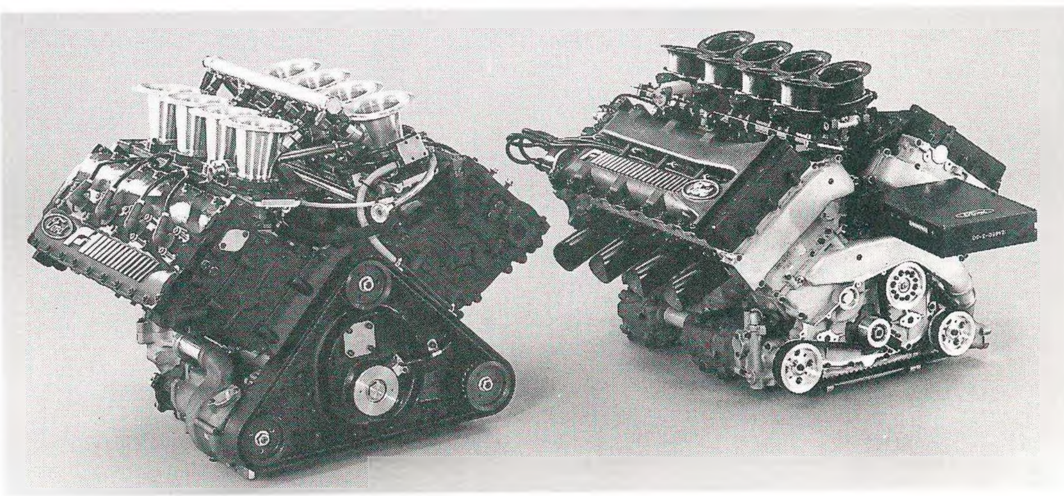
Mike Kranefuss was encouraged by the new engine:

'The first time Cosworth put an engine together, and took a power reading at 10,500 rpm, which was by no means the peak at which it was to be raced, it produced *significantly* more power than any DFR had ever done.

'I was surprised. Maybe the whole process of going through the difficulties of the V-6 turbo project after so many years of success with the DFV, then the disaster with the Yamaha engine, which never really worked made it unexpected. Probably this could be the turn-round for Cosworth Engineering, into getting back to the forefront of F1 racing engines again.

'Martin Walters is very cynical, and he thought we'd be lucky if we got the same power, at first, as a DFR. Geoff Goddard, who is a racer at heart, and always very enthusi-

1989-specification HB (right) directly compared with 1988 specification DFR (left). Clearly the HB was more compact — slimmer and lower — this mainly being due to the use of a 75-degree V-angle in place of a 90 degree angle. The horsepower difference? No-one at Cosworth, or at Ford, was admitting to anything . . .



astic, was always saying that the new engine was going to work well.'

Since Keith Duckworth designed the original DFV in 1967, the Formula 1 engine business has become much more specialized, much more competitive, and the various companies have become more secretive. For that reason, neither Ford, nor Cosworth, has released bore and stroke dimensions, valve sizes or valve angles, compression ratios, power or torque figures. What follows, therefore, is merely a summary of what Mike Kranefuss and Geoff Goddard were prepared to tell me. Since the 1960s and 1970s there has also been a fundamental change in the design process at Cosworth. Mike Costin told me that Keith was finding it more and more difficult to design anything because:

'His experience was such that it was becoming impossible to get him to make decisions. The more he understood about the subject, the more he saw the impossibility of it all.'

Mike Kranefuss agrees:

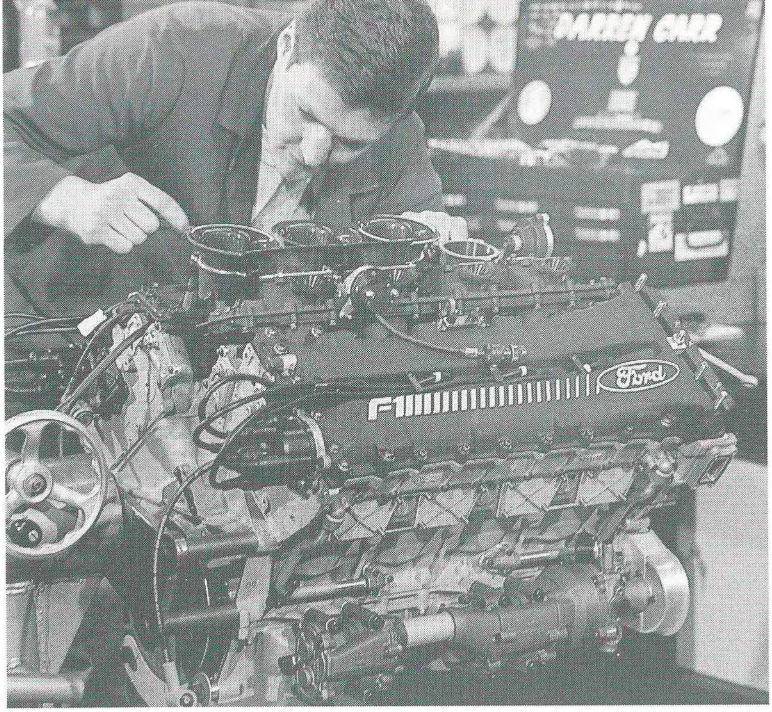
'Keith reached a point where he could talk through a programme, analysing it in detail, which in my opinion is his greatest capability. Then he goes on talking, and analysing, and starts talking about solutions, and problems. Eventually, he then talks himself out of the solutions! He got to the point where he could always see the next mountain of problems.'

Keith Duckworth reluctantly agreed with that, and that he had almost nothing to do with the new engine:

'I think I have got over the hill, as a designer,' he told me in 1989. 'I know too much nowadays, I try to design too many things out. I could see all the problems that weren't necessarily going to occur, or not be serious, and I would try to design them out.'

Two examples of what Goddard calls the 'theoretically impossible problem' to solve are that DFV cylinder blocks weave by up to 0.022 in, while connecting rod compression loads are sometimes as high as 12 tons. Not only that, but something like 50 lb ft of stab torque is needed to open two valves.

'But I'm still a good lateral thinker. These days I tend to write great treatises on head gaskets, cylinder head to block joints, and great elastic diagrams to show how the cylinder block behaves. I worked out what should be a fundamentally reasonable head and block structure. Someone like Geoff can then translate from these principles into something which embodies the principles into



The new 75-degree HB 3.5-litre engine was even more compact than its predecessors.

the detailed design. I think I'm still very good at concepts, and at the fundamentals of a thing, but nowadays when I get down to the details, I start worrying. I'm now too slow, because I'm still trying to do things too well. There's no doubt that this has got worse over the years.

'Never mind. Geoff Goddard is very good and so is John Hancock, who has now moved over to road-car engine design with a project of his own. They are both quite capable of designing a whole engine on their own. In both cases, if I have to explain some very complicated thing, they understand.

'It's when I have to do something which is different from the normal that I have had difficulty in finding people who understand. John Hancock and Geoff Goddard, well they're both very bright . . .'

['Bright', let's not forget, is the ultimate accolade from Duckworth . . .]

Keith then confirmed the way in which the 1989 HB came to be laid out:

'Geoff was responsible for the total mechanical layout, from concept, to principles of the bank angle [which is 75 degrees, not 90 degrees as one might expect], to decisions on the crankshaft and the balancing systems. Quite a number of the conceptual things were mine, though, and structurally the V-8 HB is really the "son of GB vee-6 turbo". Martin Walters did the electronics and the fuelling system, using Ford's system and was helped a lot by Ford's people.

'The HB was essentially a two-man job – Geoff and John

Hancock – the major components being shared almost equally. Incidentally, it's always important to get people to appreciate the importance of detail – engines usually only go wrong in detail – but Geoff and John know all about that.'

Geoff Goddard confirmed the arrangement:

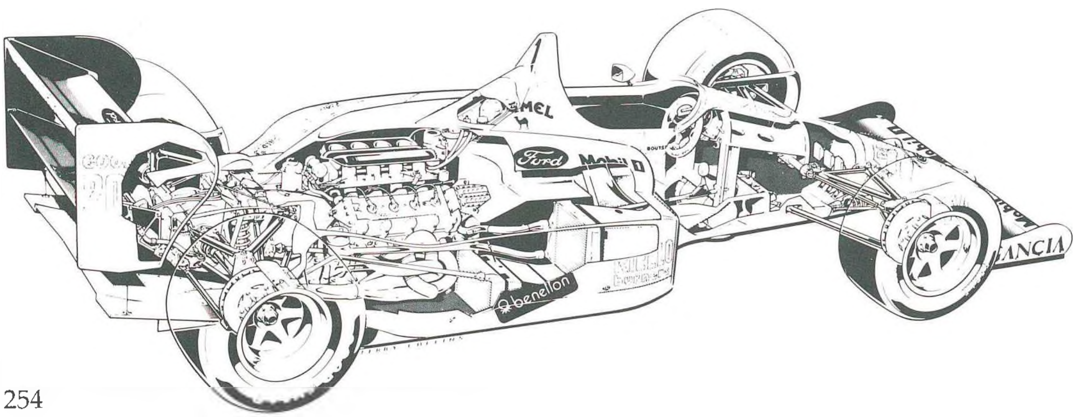
'In 1988 the racing design office was only seven people. Keith and I had been talking about the engine for some weeks before I started drawing the engine on 12 May. It ran on the testbed for the first time in December 1988. That was only achieved by people spending up to sixty hours a week on design work.

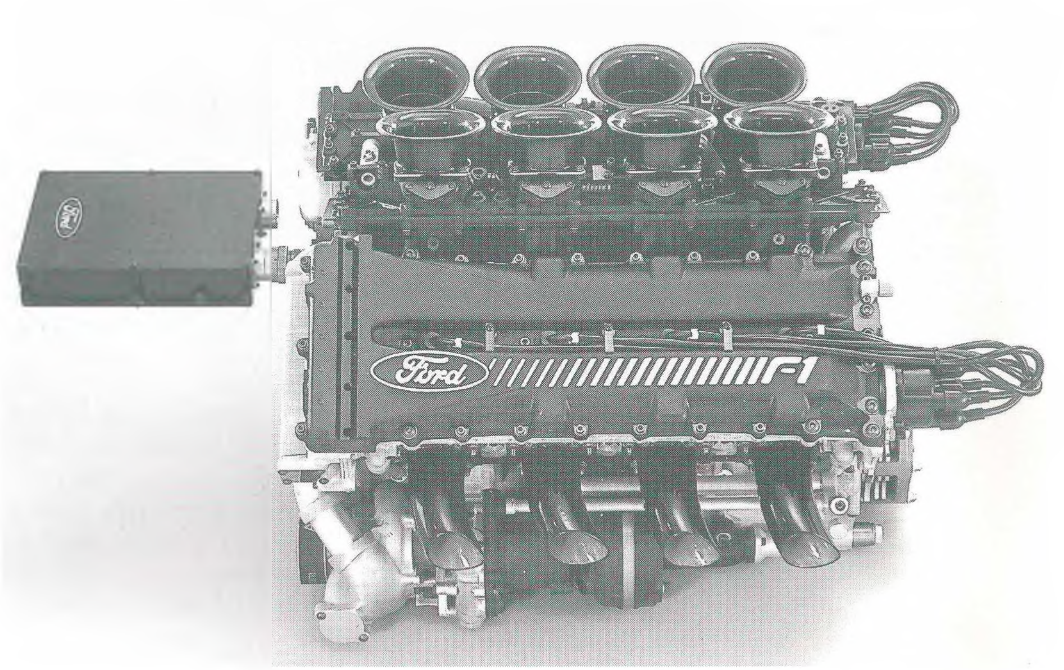
'We don't learn much by looking at what other people were doing. All you can really see, in any case, is installations – fuel systems, electronics, and how you might package things. The *really* important bits are always hidden away. You never read, in the magazines, of what is going on *inside* an engine, do you? If someone gave us – say – a complete Honda engine, and invited us to have a look inside, that would be wonderful, but I doubt if we'll ever get the chance.

'If you pick up the motoring magazines, they will all tell you that a 12-cylinder engine is needed, because it can run the quickest, and breath the most. But when, with Benetton, we started to look at the package, the weight, the fuel consumption, this led us to look at several different types. Benetton wanted the car to be as small and light as possible – down to the weight limit, if possible.

'When we started talking, and thinking, we oscillated between several different layouts. The "12" perhaps, was going to be the best for ultimate power, but fuel consumption was going to count against that. In deciding what

There was a contrast in Cosworth engines, and in the Benetton F1 cars which used them. The 1988 car, with the very complex exhaust system, used the hastily (but successfully) developed DFR engine.





The 1989 HB F1 engine was actually slightly longer than the DFR which it replaced. No internal dimensions were released, but it was assumed that the engine had a larger cylinder bore than ever before used on a DF-series V-8.

engine to make, we also projected what we thought the different engines would be able to achieve, if they were all done to the same standards – you can't argue 10s against 12s against 8s unless they're all designed by the same people, to the same standards.'

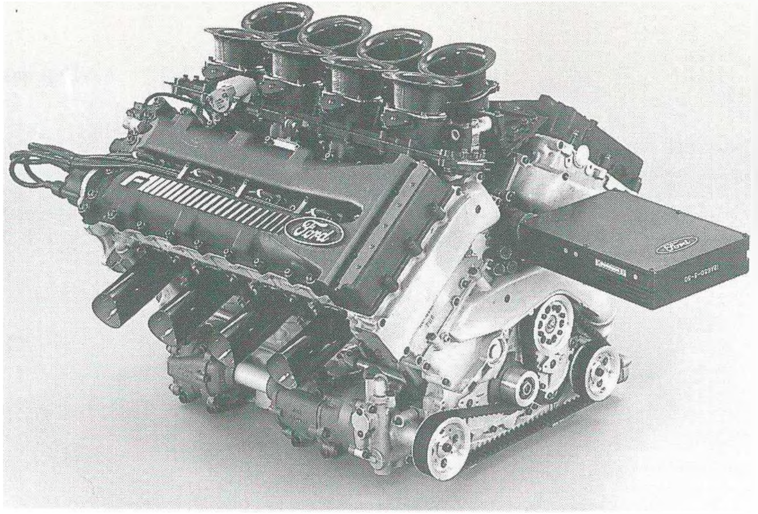
Mike Kranefuss agrees, entirely, with the way that the concept was settled:

'We all talked to each other. We looked at a 12, but thought it would be bigger, a bit more thirsty, and would need a bigger car. A V-10, well, no-one could really warm to the idea. Cosworth then said, "Well, we know a lot about V-8s, we can do a new one very fast, we can do one lighter, smaller . . ." Rory Byrne of Benetton agreed, that the V-12 would probably be too large, the V-10 was a "maybe". Cosworth also thought that they had never ever gone for the "ultimate DFV", and now here was a chance.

'I said I wanted a new engine for just one team, two later, maybe. Later on, perhaps Cosworth could supply engines to ten teams if they wanted to. Right now, I said, I want to win some races.'

Geoff Goddard, in the meantime, was backing up this process with lots of 'paper engines':

'We sketched several package shapes in several months – Vees, flats, tens, eights, 12s – showing them all to Rory Byrne at Benetton. Did we need a flat engine now that



Ford, and Cosworth, were very sparing with information about the new HB engine for 1989. The 75-degree V-angle is not obvious in this shot, but the compact pumps layout, and the very stubby inlet trumpets are noticeable.

there were no "ground effect" structures, or would that get in the way of the "Coke bottle" body profile – that sort of problem.

'In the end we homed in on a 75 degree V-8, a very compact package which hides behind *any* other engine, from any angle. The difference between the HB and the old DFV, was not only twenty years of development but the fact that the DFV eventually went out to almost 4.0-litres where the 3.5-litre HB is almost impossible to stretch.'

Compared with the launch of the DFV in 1967, the launch of HB in March 1989 (or, as Ford insisted on calling it, 'the new Ford Formula One' engine) was a very muted affair. Mike Kranefuss made a very short, humorous, and downbeat speech in which he gave nothing away, while the written information was sparse in the extreme. Except that we knew that it was to run on a 12.0:1 compression ratio, and that 'in excess of 600 bhp' was claimed, almost nothing else was revealed. A side by side picture of the DFR against the HB was more instructive, for the new HB was clearly narrower and lower, but at least as long. The inference was that it had a larger bore and a shorter stroke than the DFR, and that every millimetre of unnecessary size had been squeezed out of it.

Right from the start, it seems, the new HB exceeded its own immediate targets, and on my visits to Northampton I often heard the most exhilarating 12,000 rpm wails coming from the test beds at the back of the original factory block. But how much? These days, perhaps, we will never know. Some people laughed off ideas of a 650 bhp peak though talk of 635 bhp was thought to be reasonable. Geoff Goddard, exuberant, confident, and secretive all at the same time, suggested that:

'Limits are only set by a lack of knowledge. The key measure, the BMEP in the cylinder head, is now very hard to shift – we're only talking of crawling up half of one per cent at a time. The secret is to keep the BMEP curve up, and to make the engine rev faster than ever. All the time, these days, we are scratching around for little improvements – and don't forget that for this engine one per cent is 6 bhp!'

Before getting the HB into F1 racing, there were many frustrations. First the Benetton B189 car was completed a few weeks late, and on an early test the first car was crashed. Lengthy tests then uncovered an engine problem which resulted in crankshaft breakages after considerable test-running in cars. The puzzle for Cosworth was that the same problem could never be reproduced on the test bed.

It was not until June that the first race-length tests were satisfactorily completed, and it was not until July that the B189/HB combination first appeared in a race. One new Benetton B189, driven by Alessandro Nannini, started the French GP. On the first day of practice it was way off the pace, but on the second day the chassis matched the engine's potential, and Nannini was fourth fastest, just 0.934 sec behind pole-sitter Alain Prost. The Benetton was on the second row of the grid, behind the two 10-cylinder Hondas, and alongside Nigel Mansell's V-12 engined Ferrari. [The 5-valve Yamaha-engined Zakspeeds, as usual, had not qualified – they were three seconds slower than the B189]

At Paul Ricard, where the race was held, there is a long drag down to the first corner. After the lights turned green, the Benetton made a fine start, outdragging the Ferrari, and jinking around behind the two Hondas. Then Gugelmin's crash caused the race to be stopped.

No matter, the HB's power was proven, once again, at the restart, and before long Nannini was sitting comfortably in second place, behind Prost's Honda-engined McLaren. No other car, and no other engine, could keep up with the HB-engined Benetton. For half the race the Benetton howled around the fast Paul Ricard circuit until, suddenly, a rear suspension link failed at high speed, and the car hurled off the track, to retire. It was a let down – but at least the engine had proved its point. The Benetton had set the second fastest race lap too.

The second outing, just a week later, came in the British GP. This time Nannini qualified the car ninth fastest, but right from the start he tucked in behind the Hondas, Ferraris, and Williams cars. An early pit stop for tyres dropped him off the leaderboard, but in a spirited drive he soon regained fourth place, spent much of the race catch-ing, then passing, Nelson Piquet's Judd-engined Lotus. The Benetton, and the new HB, took third place in the end, its first 'podium finish', and an encouraging beginning for the team.

Neither Benetton, Ford, nor Cosworth could have been completely happy with the rest of the HB's first season. Although the engines were almost completely reliable (and it was soon clear that they produced at least as much power as every engine except the Honda V-10, and possibly the V-12 Ferrari), the cars, and sometimes the drivers, let the side down on many occasions.

Many observers, not only among the pundits, but among the rival teams, observed that the 1989 Benetton did not handle as well as the 1988 car – with more than one writer suggesting that it was one of the season's worst-handling cars. Ford, however, was soon happy to confirm that the HB would not be made available to other teams in 1990 and beyond. Clearly if the car could achieve so much with such mediocre handling, then the engine must be quite outstanding?

In Germany, Emanuele Pirro got up to third place behind the two McLaren Hondas, then went off under braking, in Hungary Nannini's gearbox let him down, in Belgium Nannini finished fifth in atrocious conditions, while in Italy both cars retired. Pirro spun off in Spain, when lying fourth, apparently due to fatigue. In the same period team manager Peter Collins (who had been the inspiration behind the signing of Johnny Herbert, who was then dropped from the team in favour of Pirro) walked out of his job.

Then, towards the end of the year, it all began to come right, and the HB recorded its first World Championship win. Nannini finished fourth in Portugal, and then was all set to finish third in Japan – when the two leading McLarens suddenly tangled with each other. He then took the lead as marshals sorted out the chaos, and although he was later re-passed by Senna's hard-charging McLaren, the Honda-powered car was later disqualified for a variety of offences.

This first outright win for the HB, though unexpected, was none the less welcome – and it represented a huge 'loss of face' for the Japanese Honda concern. Nor had Nannini anything to apologize about, for he had backed off the racing pace well before the end of the race, when secure in third place. Without this precaution, he would certainly have recorded an undisputed victory.

The last event of the year, the Australian GP, was pure farce, for the weather was appalling, and many drivers simply spun off and crashed in the awful conditions. Alessandro Nannini had qualified fourth and, driving with his head as well as his heart, managed to stay between the walls, settled into second place (behind Boutsen's Renault-engined Williams) at quarter distance, and stayed there to the end. Pirro's car took fifth place – the first time both HB-engined cars had been on the leader board in the 1989 season.

In its first half-season, therefore, the V-8 HB had recorded one victory, one second place, one third, one fourth and two fifth places. Compared with 1967, it was a modest beginning, but in the super-competitive Formula 1 of 1989 it was a solid start. Not only that, but Geoff Goddard's team had already developed an HB 'Mark 2' tune (officially called the 'development engine') which had more power and torque, and which would form the basis of the 1990 engines for the Benetton team.

At the end of 1989, however, it was clear that many people had great confidence in Benetton's future, which was also a real compliment to the performance of the new Cosworth HB engine. There were two totally unexpected moves – one was the appointment of John Barnard as Technical Director, the other was the signing of three-times F1 World Champion Nelson Piquet to drive one of the cars.

John Barnard had made his name as McLaren's principal designer earlier in the 1980s, but had later set up the 'satellite' Ferrari business – GTO – at Guildford. It was Barnard's expertise which had transformed Ferrari's chassis performance with a new structure built in the UK, along with a revolutionary seven-speed semi-automatic transmission. Although Ferrari wanted to keep him, Barnard was attracted to Benetton to work on new cars for the 1990s.

His appointment was always likely to make the relationship with Benetton chief designer Rory Byrne rather prickly, especially as the pundits suggested that the 1989 car's chassis had not been as competitive as the HM engine which powered it. Clearly two top men could not remain together for long – this being confirmed during 1990 when Byrne resigned and moved to another F1 team.

Even before the end of 1989, too, Ford's Mike Kranefuss had started getting requests from other teams, for supplies of HBs for the 1990 season. Tyrrell wanted to know if HBs could replace their DFRs? Lotus asked if HBs could replace their Judds? Ligier made approaches – and there were others.

Mike, for sure, listened politely to everyone, but turned them all down. For 1990, at least, Ford and Cosworth's HB engine would remain available to only one team.

The signing of Nelson Piquet (to replace Emanuele Pirro) was a real surprise, for the Brazilian's 1988 and 1989 record in the Lotus F1 team had been disappointing, and there were those who suggested that he was past his best. Benetton, Ford and Cosworth, however, were all convinced that the problem had been with the cars, and not with Piquet .

Nelson was known to shine when the cars encouraged him to do so, and perhaps to switch off when there was nothing to be gained by grappling with uncompetitive equipment. For 1990 he was given an extra incentive to get results; his contract reputedly included huge extra payments for each World Championship point notched up.

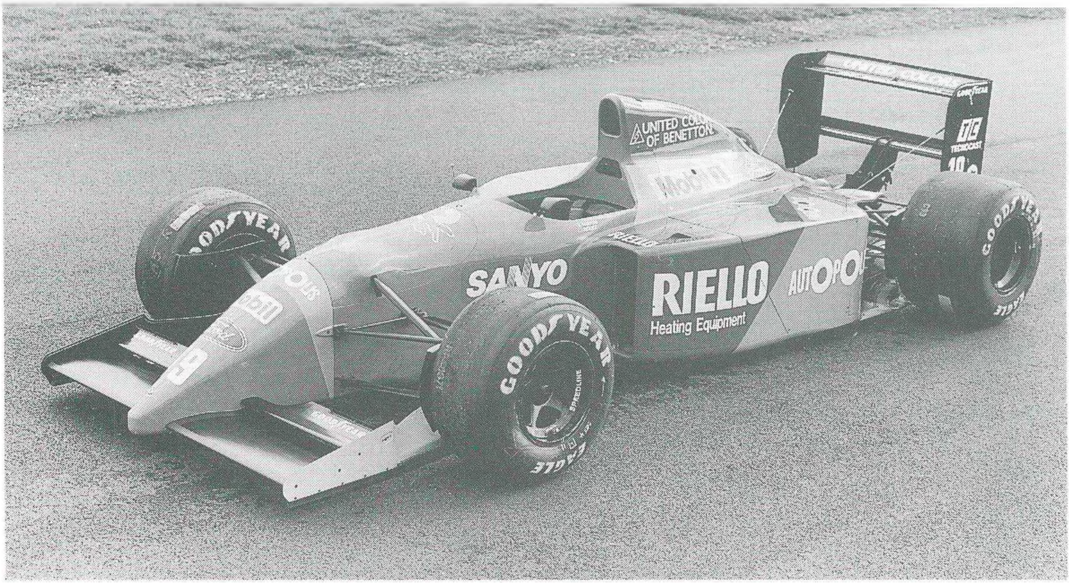
For 1990, therefore, Cosworth's still-developing HB engine was matched to yet another Rory Byrne chassis, the Benetton B190, and to the new driving team of Nelson Piquet and Alessandro Nannini.

Cosworth's race engineers, led by Dick Scammell and designer Geoff Goddard, worked hard on the HB all through the winter, ensuring that the *original* 1990-spec. HB engine was more powerful than the last of the 1989 types – and an even bigger improvement was already being promised for mid-season.

In any case Cosworth *had* to keep on improving the HB, merely to keep up with the opposition, for technical progress in F1 was as rapid as ever. At the end of 1989 Honda reported that it had squeezed a lot more power from its successful vee-10 F1 engine during that year *and* revealed a new vee-12 unit to be used in the 1991 season. In addition Judd and Ilmor were known to be developing new vee-10s while Porsche was designing a vee-12 . . .

Quite independent of the Cosworth factory, by the way, Brian Hart had been working away on the development of the venerable DFR engine. Somewhere from inside that long-established layout he found more power, and for 1990 guaranteed a peak rating of 612bhp instead of the 595bhp of the 'standard' DFRs of 1989. That brought the specific output of the old design up to 175bhp/litre – better than Cosworth itself had ever achieved with the 3-litre DFY of 1983!

As is usual in this modern security-conscious F1 era, neither Ford nor Cosworth said much about the internal changes made to the HB; certainly there were no obvious visual changes to be seen on the engines during 1990. The



For 1990, Cosworth's 75-degree vee-8 HB engine powered the Benetton B190 F1 car. The B190 was smaller and neater than the B189 had been, and had a high-mounted fresh-air intake for the HB's engine behind the driver's head. Evidence of Ford (and therefore Cosworth) involvement was surprisingly limited – the only Ford ovals were on the nose cone and either side of the engine cowling.

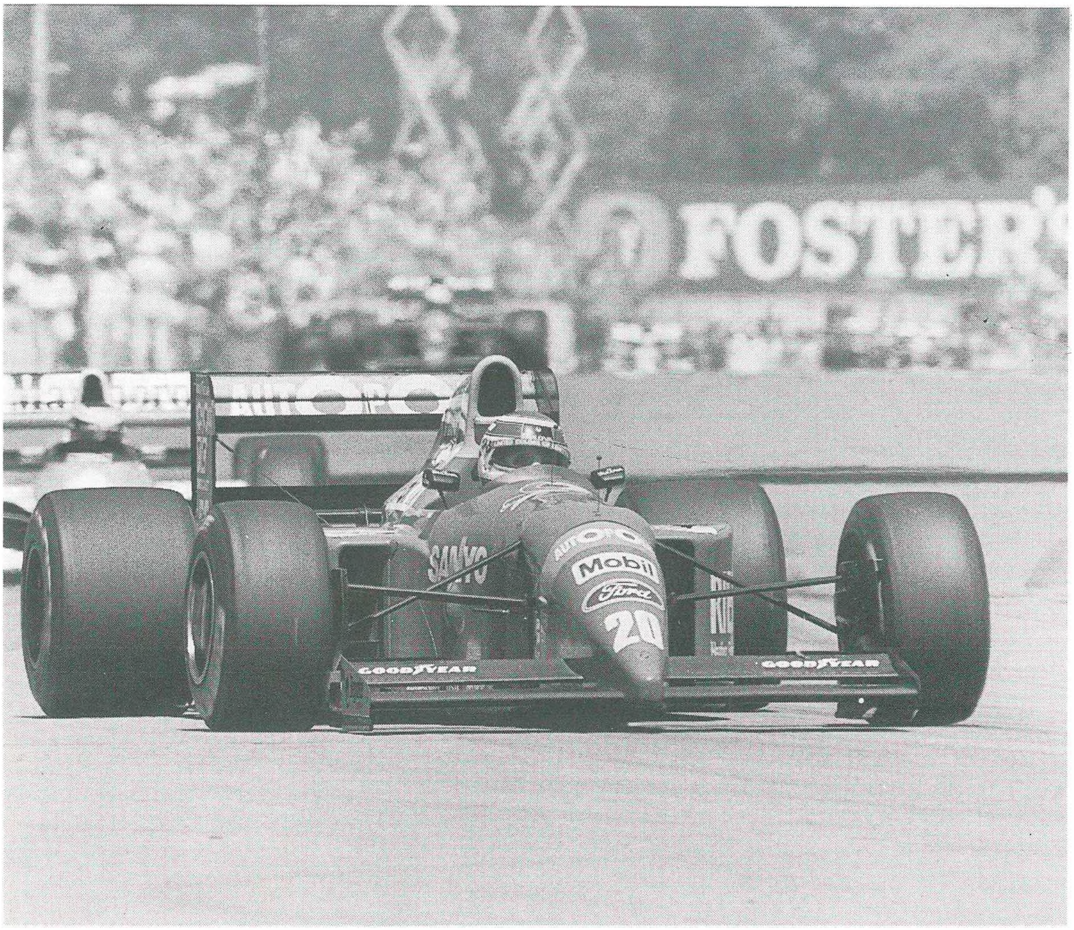
only clues we ever had were that the engines seemed to rev faster and faster – and they were usually extremely reliable.

Benetton started the 1990 season with the 1989 cars, and were outqualified at Phoenix by Jean Alesi's DFR-equipped Tyrrell! Alesi then went on to lead the first half of the race, finished second, beating Piquet's B189 into fourth place. The new Benetton B190s were ready for Imola, in May, where Alessandro Nannini finished third and Piquet fifth, and the HB engines could be spun up to 12,500rpm.

Benetton, and the still-improving HB engine, was getting better all the time. Piquet picked up second place in Canada (though Nannini wrote off *his* car), Nannini was fourth in Mexico, and Piquet fourth in France. Before the British GP, where the 13,000rpm Series IV HB engine was available, Nelson Piquet was so confident of victory that he placed a bet to back himself; everything then went wrong however when he was forced to start from the back of the grid, and he could only finish fifth.

By this time the resurgence of the team was a big talking point in the F1 'circus' The Benettons usually qualified immediately behind the Hondas, Ferraris and Williams-Renaults, but in race trim they were often fastest in a straight line, and gradually they were beginning to beat the vee-10 engined Williams cars in the races themselves.

Benetton's philosophy was to avoid mid-race tyre changes if at all possible (Keith Duckworth with his 'opti-



Nelson Piquet's 'No. 20' HB-powered Benetton B190 in full cry, ahead of one of the McLaren-Hondas. This combination won the last two World Championship F1 GPs of 1990.

mum use of rubber' philosophy would have approved of that), which meant that their late-race performance was sometimes marginal. Out on the circuits, though, only the shrill vee-10 Hondas and vee-12 Ferraris had their measure, and Benetton was closing the gap. Not only that, but Nelson Piquet's return to form – a rejuvenation, no less – was quite remarkable.

At the end of 1990 Ford admitted that the Series IV HB engine produced 'more than 650bhp' (which was already 50bhp more than it had claimed for the original HB in 1989) though pundits reckoned that it probably peaked at around 680bhp or even more. Certainly Geoff Goddard's statement that: 'the secret is to keep the BMEP curve up, and to make the engine rev faster than ever' was being borne out. Cosworth was still using conventional valve springs, yet the engine was happy to exceed 13,000rpm – no other F1 racing vee-8 could match this.

Benetton's real charge came in the second half of 1990, and the sturdy Series IV HB engine had a lot to do with this. At Hockenheim, in the German GP, Nannini's Benetton took the lead at pit-stop time, and held off Senna's Honda until nine laps from the end. His second place was a truly storming result.

Then came Hungary, and one of those bursts of controversy for which F1 had become noted. Nannini and Piquet qualified seventh and ninth, yet Nannini had moved up to second place by two-thirds distance. Eight laps later, when shaping up to pass Boutsen's Williams, and take the lead, his Benetton was literally shunted off the circuit by Ayrton Senna. As Nigel Roebuck's *Autosport* race report pointed out: 'On lap 64 Nannini and Senna touched at the chicane. Which is to say that Senna touched Nannini, in a move which had no place in the repertoire of Formula 1's fastest driver . . . Nannini's car was pitched high in the air and off the circuit'.

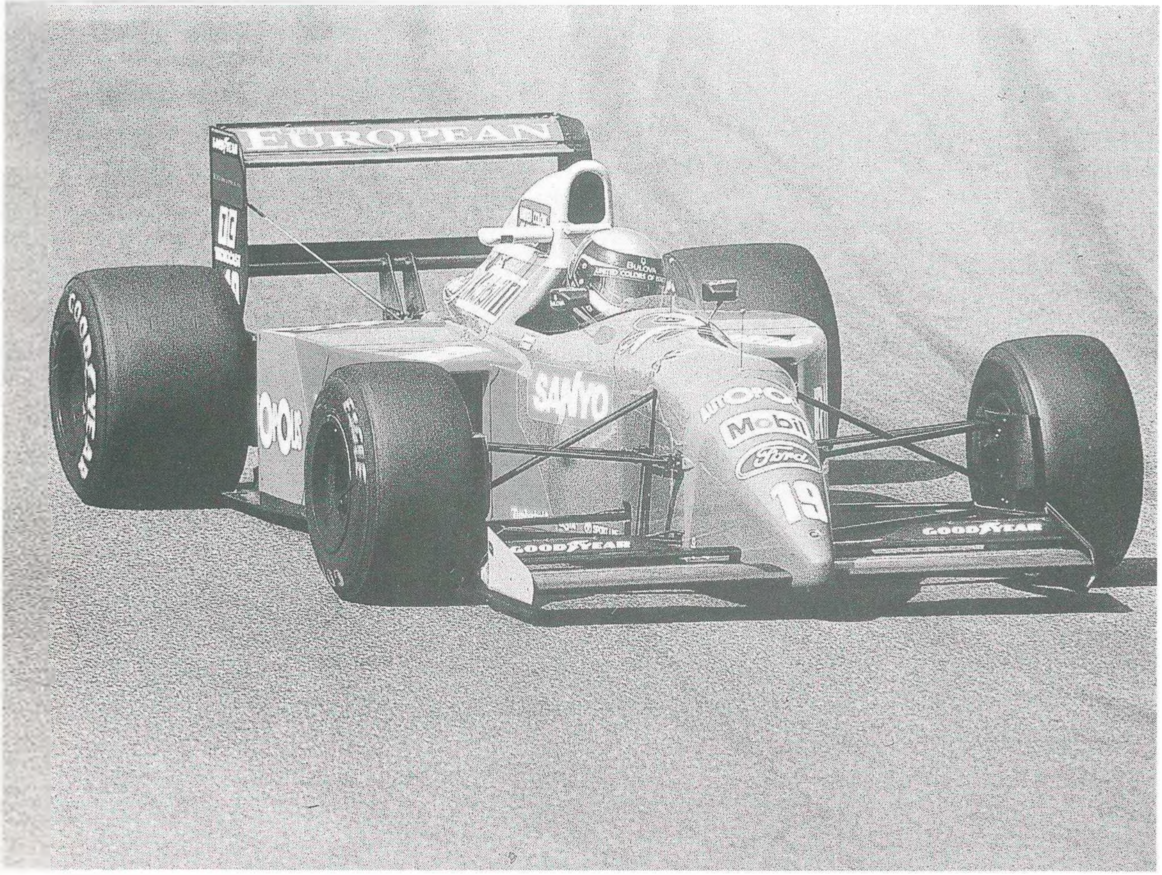
Feelings ran high, and Senna, saintly as usual, protested that it wasn't his fault. Nannini, Benetton and the whole world knew, though, that this should have been Benetton's first victory of 1990.

Two weeks later, in Belgium, the Benettons finished fourth and fifth, while at Jerez, in Spain, Nannini's car took yet another third place after Piquet's car had briefly led the race at mid-distance. All the time this was going on the two drivers were piling up points and the team was creeping up in the Manufacturers' standings.

In October, everything went wrong – then dramatically right – for Cosworth and Benetton. The likeable Alessandro Nannini was dreadfully injured in a helicopter crash at his parents' home in Italy, and Roberto Moreno had to be drafted in to the team for the last two races of the year. The Italian was not thought likely to be able to drive a racing car again.

Even so, in the wake of this sadness for Benetton there was a splendid finish to the season. In Japan, at Suzuka, both McLarens and Prost's Ferrari were eliminated by early crashes, which allowed the Benettons to slot comfortably into second and third places. Suddenly, at half distance, Mansell's Ferrari broke its transmission, which left Nelson Piquet's Benetton in the lead and his new team-mate Roberto Moreno behind him in second place.

That was the way it stayed, with Benetton notching up its first-ever one-two finish, repeating its great success of precisely one year earlier, and once again, humiliating the Japanese manufacturers on their home territory. Not only



Alessandro Nannini's Benetton B190 was allocated No. 19 for 1990. Connoisseurs of detail will see the 'European' decals on the rear aerofoil – which places this shot in the second half of 1990 – and the tiny on-board TV/video camera pod (to the right of the air intake) which was carried by all F1 cars from time to time during the season.

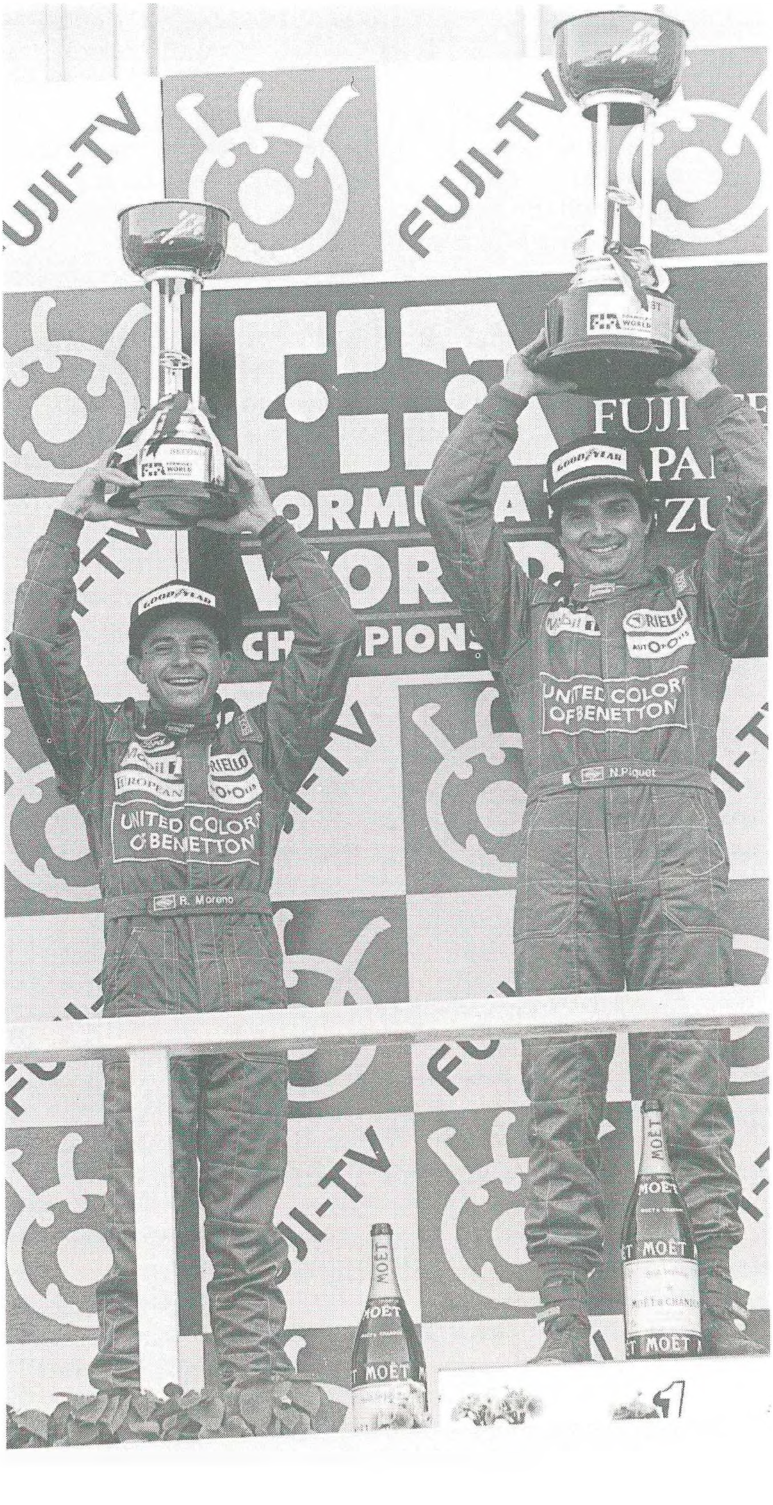
that, but Benetton moved firmly ahead of Williams-Renault in the Manufactuers' Championship, headed only by McLaren and Ferrari.

For Nelson Piquet it was a triumphant return from the depths of 1989. He had not won an F1 GP since 1987, so it was not surprising that, with an impish grin, he re-introduced himself to the world's media at the post-race press conference!

Two weeks later, at Adelaide in Australia, Benetton did it again. The two Benettons qualified in their customary seventh and eighth positions, once again the cars were seen to be very fast in a straight line, and once again they planned to go through non-stop, in the 81-lap street race.

Nelson Piquet surged into fifth place on the first lap, moved up to fourth two laps later by passing Alain Prost's Ferrari, annexed third place from Gerhard Berger's McLaren-Honda six laps later, then calmly set about reeling in Nigel Mansell's Ferrari to take second place on lap 46.

Was there more to come? Could the beautifully-balanced



For Benetton, Ford and Cosworth, the prize-giving at Suzuka, Japan, in 1990, was a sweet and satisfying moment. Not only did Nelson Piquet (right) record his first F1 victory since 1987, but his new team-mate Roberto Moreno (to Nelson's right) took second place in his first-ever drive for Benetton. Piquet repeated the trick in Australia in the next race.

Benetton overtake Ayrton Senna's McLaren-Honda? We may never know that – what we *do* know is that Senna was pressured so much that he missed a gear and crashed the McLaren.

Piquet's Benetton, with HB engine singing away at up to 13,000 rpm on the main straight, surged into the lead and, in spite of a last-minute excursion, kept that to the end, defeating both the Ferraris, both the Williams-Renaults, and the surviving McLaren-Honda.

In the meantime Ford – and Cosworth – had decided to increase its F1 involvement for 1991, and to build more HB engines. While Benetton would continue to get every priority, especially with new developments, this meant that it would be possible to supply engines to an extra team.

Even though Judd, Ilmor and Porsche were also bringing new F1 engines to the scene, once the word about HB availability got around (and rumours travel *very* fast in the Grand Prix business) there was another rush to contact Mike Kranefuss, and all manner of deals were proposed.

In the end, almost everyone was surprised when Ford decided to supply engines to the newly-formed Jordan team. Who? If you had to ask, you obviously hadn't been looking at F3000, where Eddie Jordan's DFV-engined team cars had usually been front runners, and race winners.

The persuasive Eddie Jordan, who was also the personal manager for several up-and-coming F1 drivers, had clearly offered an ambitious package to Ford, who obviously expected his cars to be better than any of the other long-established teams which were using Cosworth DFR, or Judd vee-8 engines.

Yet more fascinating HB developments were promised for 1991. One was that Cosworth developed a Group C (World Championship Sports Prototype racing) version for Tom Walkinshaw's Jaguars.

A 'Ford' engine in a Jaguar would have been quite unthinkable in previous years, but after Ford had completed the takeover of Jaguar in November 1989, anything was possible. For 1991 there was to be a new Group C formula, which required the use of normally-aspirated 3.5-litre engines, so with the Ford HB and the XJR racing Jaguars now all under the same umbrella this was an obvious marriage.

It was typical of Cosworth, of course, that it insisted it had not originally designed the HB for endurance races, but, as the modern type of Group C events were much shorter than before, this made a re-working of the 75-degree vee-8 more sensible.

For Cosworth – and for Ford and Jaguar – 1991 was going to be a busy and varied season.

New business in the 1990s . . .

'My mission is to grow the company. We already have a vision – the management team has a vision – for Cosworth until the year 2000.'

'I don't feel that anyone else in the Western world can approach Cosworth's expertise in doing what it does.'

As the 1990s unfolded, Cosworth changed considerably. The reticent, if not to say reclusive, company of old gave way to a more open business. In the 1960s and 1970s the company had seemed to expand almost against Keith Duckworth's wishes, but in the 1990s it positively looked round for growth, and new business, at every opportunity.

The master-plan, if that is the way to describe what happened, was formulated by the parent company, Vickers. After it gained control, Vickers installed Dr Peter Nevitt [who later authorised the Zetec-R] in the chair. To quote a colleague:

'I think Vickers brought in Peter because he could provide good links, and a good understanding of the Ford mind. [As ever, Ford still provided Cosworth with a lot of its business, especially on the road-car engines side]. But he had already retired from Ford, so this was always felt to be a medium-term appointment.

'They were then looking to replace him with a career executive, someone with the ability to look at Cosworth as a business. Vickers was anxious to preserve all the good things of Cosworth, then grow the business. Vickers is a great boss. They sign off an operating plan every year, and a three-year business plan. Generally they give us a lot of autonomy.'

Seasoned Cosworth-watchers were astonished to see the changes that followed. For the first time, regular factory tours were started, and new race-engine launches took place at Northampton. The company – which had once positively recoiled from public relations activity – now appointed a PR manager, who was immediately inundated with requests for facilities – tours, visits, photographs and interviews.

'In fact, the Cosworth brand name is quite difficult to market,' Chief Executive Chris Woodwark admitted. 'Our best and most famous product today is the Ford Zetec-R F1 engine, which isn't badged as a Cosworth – it's a Ford engine. Because some of our customers want secrecy we can't talk about the excellence of Cosworth without hurting those customers! But for them our ability to preserve secrecy and integrity is vital, and important. For all of them, we have to preserve individual expertise, integrity and knowledge within the group.'

Most significant of all was that archivist Valerie Given collected together so many historic old engines and artefacts, and that space was found for a small, neatly detailed company museum. By 1994 relatively unknown race engines such as the JAA motor cycle unit had gone on display, along with previously secret engines such as the AB Chevrolet vee-8 conversion – and even an example of the still-born VB vee-12 F1 engine of 1991/1992.

Chris Woodwark, who became Cosworth's CE in 1993, explained that: 'In recent years Cosworth had been on a plateau. It made reasonable profits, and had reasonable revenues, but the company hadn't been moving forward. The management team then developed a growth strategy – which is new because there was no aggressive strategy before! The shareholders want to see the company grow. Cosworth has to react to the fact that it is now owned by a PLC [Public Limited Company].'

Although it was going to take years to revolutionise the company, by 1994 Woodwark knew what he, and Vickers, wanted to do:

'My mission is to grow the company. We already have a vision – the management team has a vision – for Cosworth until the year 2000. I've worked in British manufacturing all my life, starting in 1964, and never have I seen engineers having such a say as they do here. We want to give them authority, let them lead, and develop the company against that background, its desire to win.

'Cosworth's strategic intent is to win wherever it competes – in any of the four operating divisions – racing, engines engineering, manufacturing and castings. I've tried to give people room to operate, and to give them authority.

'Next we want to expand a fifth division, to gain new business in other areas. We're trying to do that: we've just opened an office in North America, and then we're

Chris Woodwark

After working within the Rover Group and its ancestors for 22 years, Chris Woodwark took over as Cosworth Engineering's Chief Executive in 1993. His mission, to expand Cosworth's horizons, would only become obvious to the public in the later 1990s.

Born in Surrey in 1946, he gained a BSc Economics degree at the Polytechnic of Central London, before joining Rootes in 1964 as a Trainee. Like many others who worked there he decided to move after Chrysler took control of its British subsidiary, and in 1971 he moved to British Leyland on the marketing side.

By 1978 he was Sales Director of Land Rover, Africa, became Sales and Marketing Director of Leyland Trucks in 1982, and took over as Managing Director, Land Rover-Leyland International Holdings, in 1985. Because Austin-Rover (later Rover) liked to shuffle its pack at regular intervals, he then held down seven top jobs in the next eight years, latterly running Austin-Rover Cars of North America, Land Rover, and Rover International.

'Then I was approached by headhunters. I wanted to get back into the heart of the motor industry, in engineering, to create something. At Cosworth I have to lead the company, to give it a strategic framework . . .'

Not only was Woodwark a formidable manager (his career record proves that), but he was also demonstrably a motoring enthusiast too. From the start Cosworth's racing heritage seemed to be safe with him: 'It is terribly important, there is a history of success, and a huge body of expertise in the company'.

And he was determined to make it more visible, and more accessible, to the public and the motor industry: 'I want to open Cosworth up. I'm very proud of this company. People are now understanding much more about what Cosworth is all about, and how broadly based it is . . .'

In spite of a punishing schedule – in 1994 he completed 70,000 miles in a Scorpio 24V, spending a lot of time working alongside his driver, while being whisked from his Buckinghamshire home to the various Cosworth, Vickers and customers' factories – he exuded the sort of enthusiasm with which every young Cosworth employee could identify.

When I met him once again at Cosworth, his enthusiasms shone through – so much so that I was taken on a whistle-stop tour of the design offices, to the consternation of watchful engineers who were busy finalising the new 3-litre F1 engines and the next generation of Indy car units . . .

'I'm very proud of this company . . .'

Woodwark was appointed Chairman of Cosworth Engineering, and Chief Executive of Rolls-Royce Motor Cars on 1 January 1995, and is a Director of Vickers PLC.

Chris Woodwark became Cosworth's Chief Executive in mid-1993, his mission 'to grow the company' into the 21st century.

concentrating on the Far East.'

Woodwark's view was that the company had been ripe for change, and that the original founders – Keith Duckworth and Mike Costin – had been very graceful about it when they retired. From time to time they still visited 'their' company in this period, and realised that Cosworth had become very different:

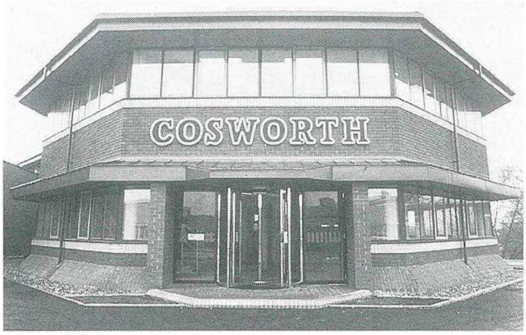
'A lot of the heritage and ethos they brought to Cosworth is still here, still being developed and built on. I think one of the nicest things is that they understood what had to happen, wished the company well when they retired in the late '80s, and still take an active interest in how it prospers.'

Compared with the 1960s and when the DFV F1 engine was designed, and when there were fewer than 50 people in the entire workforce, Cosworth in the mid-1990s had changed completely. There were almost 1,000 people on the pay roll – putting it into the top five per cent of British engineering companies – in more than 250,000 square feet of factory space on five sites (including Torrance, California); these figures, in any case, were set to rise again by 1996 when the large new castings factory in Worcester came on stream.

In 1990, when Vickers took over, the balance at Cosworth between road-car engines and motorsport was just about half-and-half. Once Wellingborough Two was up and running, with the FB vee-6 engine in series production, that all changed. Even though growing numbers of world-class race-winning vee-8 race car engines – HB, AC, XB, and Zetec-R – continued to pour out of Northampton, the shift to road-car work was noticeable.

By the mid-1990s there was evidence all around. Wellingborough Two, the large road-car engines factory, had taken over from Wellingborough One, whose lease was ready to be released. The second castings factory at Worcester (in Warndon) was already bursting at the seams, the original Hylton Road castings factory was set to be sold off, and a massive 'Worcester Three' building was being built to produce major components for a brand-new Jaguar vee-8 engine. In Windsor, Ontario (Canada) Ford was already using the patented Cosworth castings process for new generations of engines, and in Northampton more vee-8 race engines were being built, serviced and developed than ever before.

More was already on the way. On a visit to Northampton in 1994 I saw that the facade of the original (1964) factory building had been enlarged and redeveloped, and that a non-Cosworth business (Bullers), once surrounded by Cosworth buildings in the 1980s, had finally been absorbed,



Above left Building work, and modification, never seems to end at Northampton. This executive office extension was blended in to the original 1964 building in 1992/93. In 1994 the race engine design offices were on the upper floor of this building, and the 'works' F1 and Indycar engine build shops were alongside it. In 1995 the full building was occupied as the race engine design offices.

Above As the 1990s opened, Cosworth was producing more and more engines for fast and capable road cars. This was the Mercedes-Benz 190E 2.3-16.

and integrated, into the business.

Diggers and bulldozers had already moved on to an adjacent site (the Emissions and Driveability Centre) to prepare the ground for yet another high-tech facility, where the Duke of Kent had just laid the foundation stone. I also saw a Crewe-registered Rolls-Royce Silver Spirit in the car park, which was clearly a development car.

Road car engines

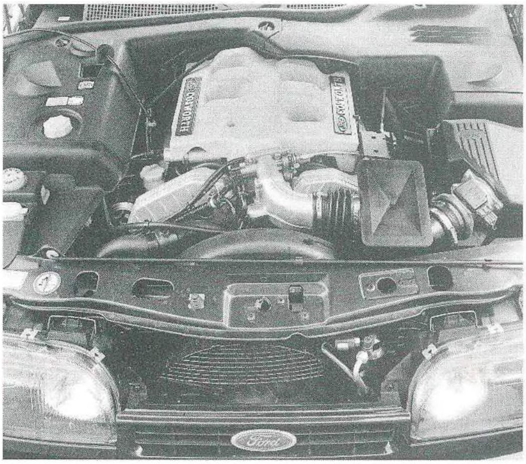
By 1990 Cosworth's principal road-car engine-building project was the YB-Series for the Ford Sierra Cosworth 4x4. Almost at once this was joined by the manufacture of Ford Scorpio 24-valve vee-6 (FB) engines, while work for Mercedes-Benz and General Motors gradually tailed off.

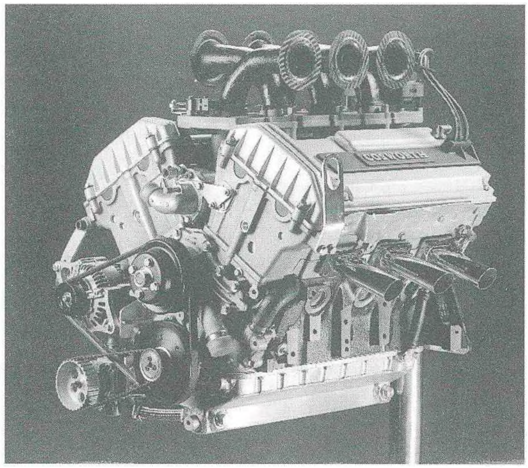
Mercedes-Benz, having relied on Wellingborough to produce cylinder heads for the 190E 2.3-16, later embraced four-valve technology for its own mass-produced units. GM, having shared KB-type assembly with Wellingborough at first, later began making many more engines in its own plant. Where high volumes are concerned, transfer line production is more cost-effective than Cosworth's unique abilities.

Mark Hunt, Manufacturing Director, now takes up the story: 'We had tremendous expansion in two years, but in 1991 we were then hit hard by the British and then the European recessions. Volumes went down to about one-third of what they had been. But it wasn't only the recession – the Escort RS Cosworth was a different class of car from the Sierra, and didn't sell as fast. Even when Scorpio volumes came back, the straight-four [YB Series] volumes didn't come back with them.'

The result was that all activities were consolidated into the new site – Wellingborough Two – which was then offering about 30,000 square feet of space:

'We then went out to get new business . . . We now do





Above The FB vee-6 engine fitted neatly into the engine bay of Ford's Scorpio model, and was very conservatively rated at 195 bhp, and mated to four-speed automatic transmission.

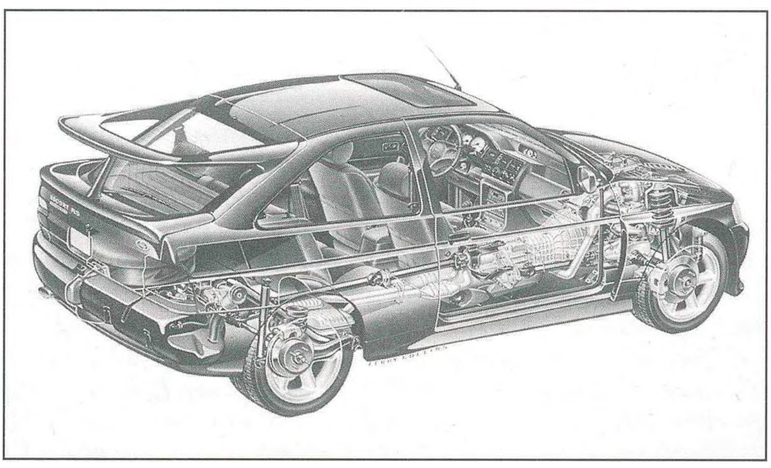
Above right For use in specially-developed racing sports cars, Cosworth produced the FBE engine, a 300 bhp version of the FBA which usually powered the luxuriously equipped Ford Scorpio road car.

Right Ford's most capable of all road cars – the Cosworth YB-powered Escort RS Cosworth. Having owned two of these marvellous machines, the author has fond memories of the performance, the roadholding – and the turbolag of the original models. . .

some sub-contract machining of heads for Ford, and [by 1994] we were fully utilising the new factory and looking to expand again. We actually have a 6-acre site of which we occupy only about one-third.'

At that point Wellingborough was operating round the clock – three shifts, and employing about 120 people – but there was certainly an ambition to tackle even more. At its peak Wellingborough was certainly very profitable, and there were signs that clients wondered if they could do the same sort of job themselves, in house. Even though the 'between-centres' machining system which Ben Rood had devised could not be patented, Cosworth – Woodwark, Hunt, *et al* – were convinced that there was new business out there, waiting to be won.

Commercially there was a significant difference between the two Wellingborough sites. The original, brand new in 1985, had only ever been leased, and was now redundant.



Wellingborough Two was always owned by Cosworth, and was to be expanded, long-term. By 1995 'Two' was producing YBs and FBs – each with its own dedicated assembly line – plus spares requirements for many obsolete Cosworth engines; it was also manufacturing and assembling complete overhead-valve 12-valve pushrod engines for the Ford Scorpio.

This last was the venerable 'Ford-Cologne' vee-6, which was nearing the end of its life. Ford, having done its sums, concluded that it made more sense for this old engine to be built by Cosworth in limited numbers, for in Cologne this released valuable space for a new generation of ultra-modern engines to be installed instead. The move was made in 1994 (after assembly was closed down in Cologne, it took only 12 weeks to re-start production in Wellingborough), but was not expected to be a long-term project.

Although the grey iron pushrod heads of this design could not be machined by Cosworth's celebrated 'between-centres' tools and fixtures (the cutting forces were too great), this facility nevertheless made Cosworth almost uniquely capable in Europe's motor industry. When I asked Hunt (and one of his colleagues, Rob Oldaker) about this, both claimed that Cosworth was pre-eminent, but that they rated 'one or two competitors in Germany and Italy' extremely highly.

The founders, Keith Duckworth and Mike Costin, would certainly be proud of the way their company has developed. Their ruthless ambition to be the best was always evident – as was the policy of not dabbling in fields where unique technology could not be deployed. This may explain why Cosworth, still Europe's most famous specialist piston supplier, has never been tempted to expand into other forging activities (crankshafts, for instance). Gear cutting was once considered, but rejected – Hunt, with previous transmission engineering experience in an earlier job, thought that it would have required a new building, different machinery, and a step change in technology.

Cosworth methods continued to be exported to other customers. In Britain the re-born Triumph motorcycles business at Hinckley used Cosworth 'between-centres' methods to make its engines: 'Mike Costin and Ben Rood went in to their factory to advise them.'

By this time Cosworth was so flexible that it began to advertise its ability to deal with other companies' 'peaks and troughs' problems. Mark Hunt confirmed that the combination of Wellingborough and Northampton could take on the building of mere hundreds of cylinder heads, right up to a maximum of about 60,000/70,000 a year. In a clearly delineated diagram in a brochure, Cosworth proposed a solution to the 'problem zones' – that it could tackle pre-production, the run-in and run-out phases, and to take on what it called 'peak-lopping' contracts, of which the Ford-Cologne vee-6 was an ideal example. Even so, there was still time – sometimes – to make parts for older 'heritage' Cosworth engines:

'The racing season is very peaked,' Hunt reminded me. 'So if someone wants a part for a 20-year-old engine, we certainly wouldn't be producing that between November and March. But we would certainly consider doing that in the summer. We still produce BD parts, and some DFV parts.'

To make sure that there would be a steady flow of new work into the workshops and assembly buildings, Vickers encouraged Cosworth to expand its road-car strengths. Engines Engineering, which had developed the YB and FB types, carried on selling itself to the world's motor industry, and from 1993 Rob Oldaker (ex-Rover Group, where he had been running the entire Chassis Engineering operation) arrived at Northampton to take over from Ron Nicholls. Rob's Chief Engineer, John Hancock, had already moved over from the racing side.

Because work on the Mondeo and Calibra Touring Car racing projects involved the modification of road-car units, Engines Engineering also took development responsibility for them:

'They are good learning projects for the road engines side – and vice versa – though there's very little true technology transfer from racing to road engines. However, because we've learned a lot about manufacturing, engines like the latest Zetec-R are a lot quicker and easier to build than the HB.'

Under this new regime, it was logical that Geoff Goddard, who had featured strongly in the design of the HB F1 engine, should be involved in the design, development and proving of the Ford Probe vee-6 engine for use in the 'works' BTCC Ford Mondeo race cars. Recognising the limits imposed on them by BTCC rules, and the need to use castings from standard road-car engines, Goddard's small team speedily produced a race-winning 290 bhp 2-litre unit, that could have revved to 10,000 if authorised to do so.

'My job is to grow this division some more,' Oldaker told me. 'We have an interesting list of clients . . . [at which point he smiled secretively, and would say no more . . .].

'We have a reputation for being able to do things quickly, we are flexible and responsive. I guess another big selling point is that we do our own castings at Worcester.

'In 1994, for the first time, I put a man in to an office at Dearborn, near Detroit. His job, at first, was to put together a business plan, to see how we can proceed in North America. We're already doing a job for Ford-America . . .'

'That man', incidentally, was none other than Paul Fricker, who had been Cosworth's project engineer on Sierra RS Cosworth YB development, and was once famously described as 'having forgotten more about the YB than most other people had ever learned . . .'

Woodwark sees the Dearborn operation becoming very important:

'I can see the company growing in North America: that's why we have moved to new premises in Torrance. I believe we will eventually replicate Costin House in Detroit, or we may enter a strategic alliance, with a company out there. From there we could service Japanese customers on the West Coast too, and obviously we have to talk to Mercedes-Benz and BMW, who are opening up new factories on the East Coast.

'Our next stage is to see what we can gain in the Far East.'

By motor industry standards, Oldaker's claim about 'doing things quickly' meant taking an engine from concept, through testing and calibration to mass production in about 3½ years. When the new Northampton EDC facility is in use (construction began in 1994) this is expected to fall by at least three months.

Prototype engines could be running in cars only six months after design work began, which meant that a team of 80 people ('That's from me down to the office cat . . .') and an increasing back-up from Computervision's CAD (Computer Aided Design) equipment were working very efficiently:

'We tend to recruit selected people from outside to do project work. We're expanding our own operation right now, and we've started to grow the business – in advance of getting the orders!

'We do tend to get a lot of graduates knocking on our door, wanting jobs – Italians, Danes, Germans, Chinese, Americans as well as Brits – and we're trying to build up a long-term strategic plan.'

Chris Woodwark confirmed that for every 100 graduates who applied for a job, only one of them was taken on:

'We set a first class honours degree, or an upper-second, limit on entry. Yes, there's a lot of interest.'

Oldaker also confirmed that, as larger manufacturers made their own operations more flexible than before, projects like the Ford YB and FB engines might not come along in the same way again:

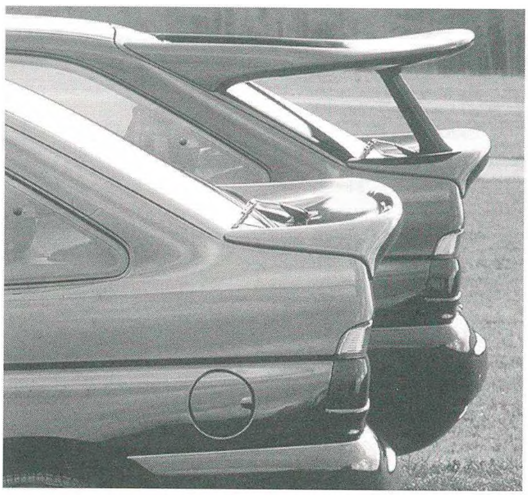
'What we are now seeing more of is smaller projects, which means the design and development of a cylinder head, or a complete engine, but not necessarily a manufacturing agreement.'

So, with so many clients, what happens if one particular innovation is produced for one of them? Could it be offered to their rivals?

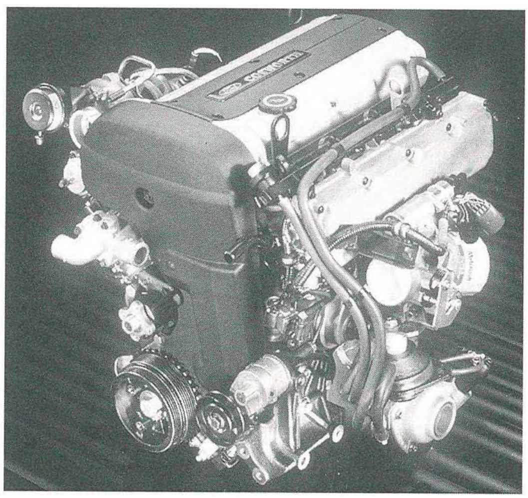
'It depends. We do, indeed, have to build "Chinese walls" between teams, and every client has to rely on our integrity. If we developed a new "widget" – well, it all depends on the contract with the customer. Certainly we would not exploit a novelty with someone else unless we were cleared to share it. When clients come to us, they expect Cosworth to be at the leading edge, and they expect to get something which is perhaps different from what they can do themselves.'

By 1995 the small-turbo/EEC-IV version of the YB engine had gone on sale in the Escort RS Cosworth, and the up-rated (210 bhp) 2.9-litre FBC was being used in the radically re-styled Scorpio. But what was due to take over in the mid- and later-1990s? Let's just say that there always seemed to be areas of the factory which were out of bounds to me when I made a visit, and that there were photographs on file with very significant company logos on cam covers, which I was asked to ignore 'for the time being'.

Cosworth celebrated 30 years of life at Northampton at the end of 1994, though most of the staff were too busy to notice. It looked as if the future would be just as interesting, just as exciting, as the past.



Below By 1994 Escort RS Cosworths came in two shapes – with or without the rear spoiler – and by mid-year a smaller-turbo engine, no less powerful than the original, had also been standardised.



Below right In 1994 the YB production car engine was further modified, and given a facelift, for use in the latest Escort RS Cosworth road cars. Compared with the original 'blue top' engines, these units had smaller turbochargers (for better low-speed response), and more rounded camshaft covers.

Coscast – still world leaders

The first time I ever visited Cosworth – in the 1970s – Keith Duckworth's frustration with the British castings industry was at its height. Subsequently he encouraged Dr John Campbell to set up a research facility in Worcester, and by the mid-1980s the revolutionary Coscast process had been unveiled.

[I nearly called Coscast a 'mould-breaking' achievement, then realised that was precisely, and absolutely, the wrong thing to do, as Cosworth castings don't need 'breaking' in the same way as everyone else's . . .]

By the end of the 1980s the Worcester factory had become a highly efficient operation, producing tens of thousands of cylinder heads and cylinder blocks every year. In the meantime a new site – in Warndon, on the outskirts of Worcester – was built, at first to support a major contract with Ford at Windsor, Ontario, Canada, where the company was shaping up to build brand new four-overhead-cam vee-6 and vee-8 engines.

By the early 1990s Ford of North America had invested US $150 million in new plant, and had a ten-year operating licence; both engines were in mass production, with the unique Cosworth 'roll-over' casting process providing up to 1.5 million castings a year. The vee-6, in fact, is the smooth, high-revving 2.5-litre unit found in the modern Ford Mondeo 24V model.

'Things then moved on,' says Geoff Tupman, the Managing Director of Cosworth Castings. 'We then transformed the Warndon factory into a product development centre – it was opened in September 1993 by Sir Richard Lloyd, the Chairman of Vickers – and put in a small amount of plant, the object being to use it for very low production runs, to do a lot of process development, and to develop our customers' product.

'It was the forerunner to what we wanted to do – we wanted to build a new site. That accelerated even beyond what we expected. We negotiated a deal to produce several new major castings for the new Jaguar vee-8 – that was in May 1994 – and immediately we had to start provisioning a new site.'

Months, and many meetings, later (along with a great deal of investment from Vickers, the parent company) a new 10-acre site was found, half a mile away, near the M5 motorway. Prototype Jaguar castings were already flowing from Warndon in 1994, but before the new site could be erected a nearby pond had to be relocated, so that a particular rare

Geoff Tupman

Once Bob Smith retired from Cosworth Castings in 1992, Geoff Tupman took over, to direct the massive expansion scheduled for Castings in the mid and late 1990s. Although he claimed to be a manager rather than an engineer, most of his earlier experience had been with engineering concerns.

Having run his own management consultancy for some years, he joined Vickers in 1979, and began running subsidiary companies, or divisions of companies, in 1981. Having moved to Vickers' corporate offices on Millbank in 1989, originally as PA to Chief Executive Sir Colin Chandler, he then took on the job of monitoring investments – business investments – around the Vickers empire.

'Then, very rapidly, Vickers moved in to an acquisitions programme, so I became the leader of that, and a prime target was Cosworth. I spent a couple of years "shadowing", learning about it, and became very interested. But it was always difficult to get to know anything – I had to gather information from the public domain.

'I was involved in the Cosworth acquisition, then became the man who helped integrate Cosworth into the empire. For two years I was a non-executive director of Cosworth . . .'

Geoff confirmed Vickers' modern attitude to its subsidiary businesses:

'Vickers saw a world-class engineering company which would fit in nicely with Vickers' own engineering companies, not necessarily tightly integrated. From a brand point of view – Vickers is very much into brands – Cosworth was seen as a great brand, very high profile, very high quality.

'For Cosworth, the link with Vickers was to give real stability – it was always going to be more appropriate being linked with a group concentrating on high-class engineering, than in TV or whatever. It was the right type of home.'

That was the businessman talking, but there was a glint in his eyes while it was being said. Tupman, like most of the top management at 1990s Cosworth, clearly enjoyed his job.

breed of greater crested newt could be preserved. No, I am not joking . . .

By 1996, when series production of Jaguar vee-8 castings was due to begin, Tupman expected to see the original downtown Worcester site closed down and sold off ('It's quite a cramped site, and it's no place to have a foundry any more . . .'). Several hundred new jobs would eventually be created at the new site, which would easily make up for this closure.

In the meantime, Hylton Road and Warndon continued to deliver an amazing variety of castings – mainly cylinder heads and cylinder blocks – some so carefully and intricately detailed that very little machining would need to be done by the customer. It was this, Tupman claimed, which made Coscast components so easy and economical to work.

A typical week's output would feature much more than quantity production parts to Wellingborough Two for Ford assembly to go ahead. F1, Indycar and F3000 work would be scheduled alongside cylinder head castings for Triumph motorcycles, for Maserati, for Aston Martin, for Mercury Marine [engines for power boats], and for high-tech aerospace products. Prototype work was always being carried out: when I spotted unfamiliar shapes and configurations and commented, these were studiously ignored by my guides . . .

Although the early castings patents weren't as strong as Cosworth would have liked, later developments, particularly related to the 'roll-over' process, were well protected. Mainly for that reason, Cosworth still claims to be well ahead of the rest of the world's castings industry: 'There have been several attempts to copy our roll-over process – and most of them don't work! All the other systems, gravity die and so on, have major problems, and fundamental flaws . . .'

So, what would happen next? Tupman could clearly see a path ahead, and Tupman insisted that: 'We have a phased expansion programme. We hope we will have more new orders, new products coming in, even before Phase 1 [the Jaguar facility] is up and running.

'Then we're going to go back to look at magnesium, which we did some work on ten years ago. Aluminium to magnesium? Yes, there's a weight saving, and it's worth doing. Also there's now a huge trend in Europe to go over from iron blocks to aluminium blocks.

'There was once quite a trend away from metal, to ceramics, but that trend now seems to have been reversed.'

Research projects

When it was revealed at the Detroit Society of Engineers' show in March 1991, the new MBA vee-6 engine seemed to pose more questions than it answered. Was it all-new and all-Cosworth? If so, did it have a customer? What was its purpose? Was it a race engine or a road-car unit? What was new about it, and would Cosworth tell anyone?

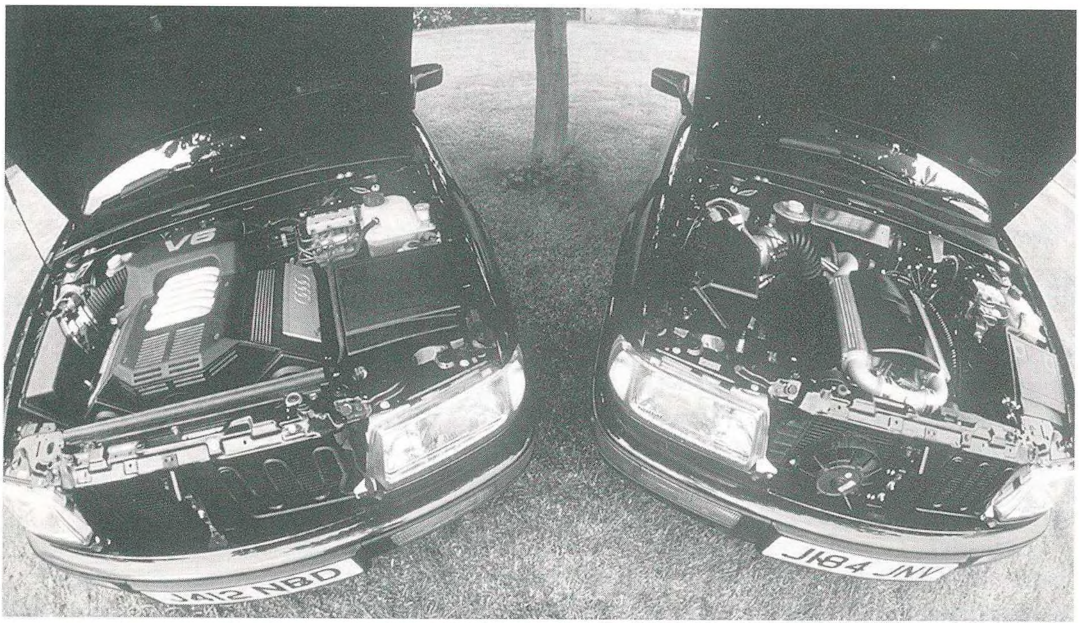
Although Cosworth, as usual, was modest rather than drum-beating on the subject, it rapidly became clear that this was probably the company's most ambitious research project to date, for it was the very first Cosworth road-car engine to use its own cylinder block. Rob Oldaker, Engineering Director, Engines Engineering, since 1993, told me that: 'MBA was always going to be the first of a family of engines should anybody want it, though it was really built as a concept engine to show off our technology.

'It was meant to achieve a platform for displaying a number of advanced pieces of technology, particularly the use of port-located barrel throttles (which was coming direct from the racing programme), which in this case were being used to control exhaust gas recirculation, as well as allowing high overlap cam timing in conjunction with a primary throttle to allow a very wide spread of torque as well as high power and an unusually high rev. range.

'It was a high-revving engine, it was light, it was small, and it did show anybody else that they too could use a very small high-powered vee-6. Three years on we're still using it as a demonstrator of technology. We're not trying to sell the *engine*, as such, to anybody. The view, today, is that it demonstrates technology. We can say: "Look Mr Customer, you could have a three, a four, a six, an eight, or a 12-cylinder incorporating a lot of things that are in here". There are one or two patents in that engine which we can exploit . . .'

Features like the hollow balancer shaft which doubled as a crankcase breather, removing oil by centrifugal force, were all steps forward. John Hancock and Darren Cairns led the project, which was producing full power within 12 months

To demonstrate the qualities of the new MBA vee-6 engine, Cosworth installed it in an Audi 80 quattro in 1992. In this nose-to-nose comparison, the MBA engine is fitted to J184 JNV (right), while J412 NBD (left) retains its own standard 2.8-litre vee-6. Clearly the MBA was more compact than the Audi unit, but with 225 bhp it was also lighter and gave higher performance.



of work starting, but it was not until a prototype was installed in an Audi 80 Quattro 'slave' that the real advantages were proved.

Compared with the Audi's 2.8-litre vee-6, the MBA was 80 lb/36 kg lighter, and was demonstrably smaller than the unit it had displaced. It was 50 bhp more powerful, too! Performance – acceleration and top speed – was up, fuel consumption was improved, and, with a tickover of 500 rpm allied to peak revs of 8,000 rpm, is was clearly a totally versatile road-car design.

But if MBA was research being carried out in public, with the intention of capturing interest – and orders – from the world's motor industry, co-operation with Rolls-Royce was much more discreet. It was surprising indeed that the two Vickers-owned companies had not appeared to get together often. One reason, perhaps, was that until the 1990s Rolls-Royce was widely seen as technically arrogant, even though features like its chassis platform dated from the 1960s, and its vast alloy vee-8 engine had been conceived in the 1950s.

It was only after Chris Woodwark and Peter Ward got together in 1993 that the companies began to work together. This led to the most intriguing, and most secretive, road-car project of all, unveiled at the Geneva Motor Show in 1994. Rolls-Royce showed a new compact prototype, a sleek coupé or convertible named the Bentley Java.

Styled by Roy Axe's Warwick-based Design Research Associates concern, this was more mock-up than running car – *Autocar & Motor* described it as 'a model looking for a platform' – this concept car was never seen with the bonnet open.

Both companies – Rolls-Royce and Cosworth – were very secretive about the actual engine used. Rolls-Royce described it simply as a 'twin-turbocharged vee-8, conceived in conjunction with Cosworth Engineering. With four valves per cylinder and a capacity of 3.5 litres, giving it 0–60 mph in 5.6 seconds and a 0–100 mph capability of 14.2 seconds, this new engine could provide the best solution. A theoretical top speed of 170 mph would be electronically governed to 155 mph . . .' To produce that sort of performance, something like 350 bhp, with a wide torque band, was going to be needed, not a requirement which was likely to make Cosworth's engineers lose too much sleep.

Autocar & Motor's description suggested that the engine had its roots in the Ford-Cosworth XB Indycar unit, which seemed to be very unlikely, and the picture Rolls-Royce released of the engine showed what was certainly only a mock-up of a likely power unit! Rob Oldaker denied any connection with XB *or* HB:

The Rolls-Royce connection

No sooner had Cosworth merged with Vickers, which already controlled Rolls-Royce, than the know-alls gave voice:

'Well, of course, it's obvious. Cosworth will design the next engine for Rolls-Royce. You wait and see.'

That was in 1990, and five years later there was still no sign of that engine. Further, in the interim period Rolls-Royce had conducted well-reported talks with BMW *and* with Mercedes-Benz, all the news eventually being that BMW engines would appear in the next generation of cars from Crewe.

Vickers, it seemed, had a more subtle approach to mergers, and to integration. Although Cosworth began to consult with Rolls-Royce almost at once, this was on a more general basis. Cosworth designed a four-valve/twin-cam cylinder head conversion for the existing 6.75-litre Rolls-Royce vee-8 engine, saw the head briefly shown at a trade show, then consigned it to history. [When I asked Rolls-Royce for pictures, I was politely, but firmly, rebuffed . . .]

Chris Woodwark confirmed that there were no formal links between the two Vickers subsidiaries until 1993, after which: 'Peter Ward and I made it our job to see what synergies there can be . . .'

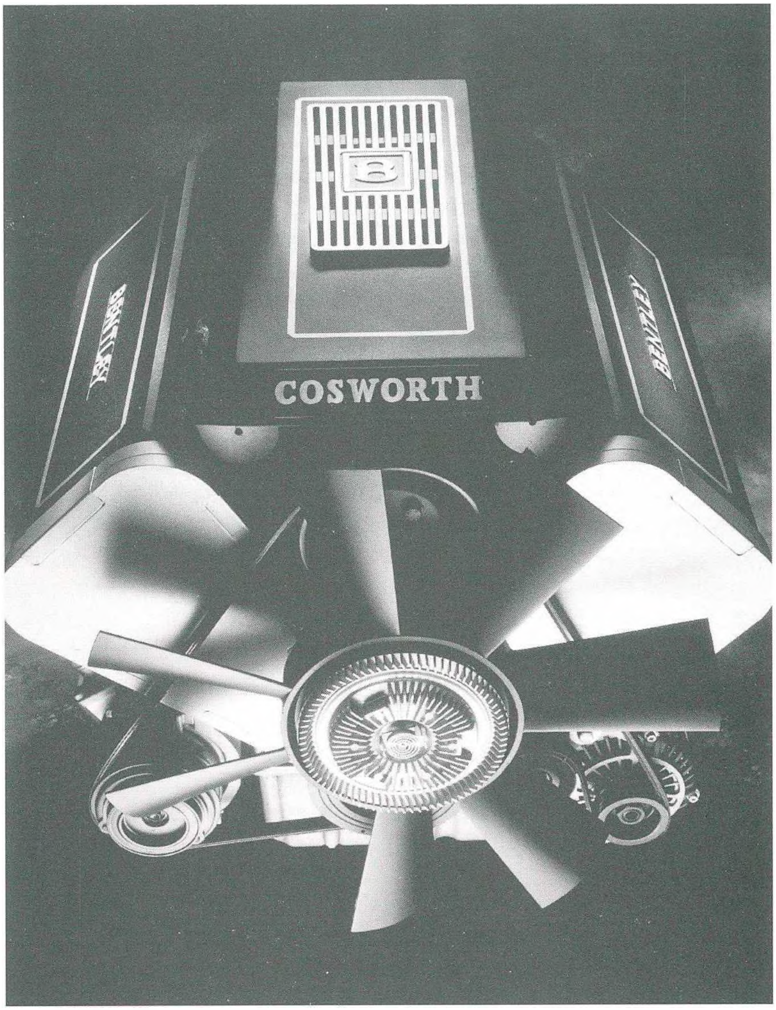
Development work, of an entirely secret nature, then began again, but to no greater priority than for other divisions. By the end of 1994 'Rolls-Royce engineers are working here,' Woodwark admitted, 'on a project we're undertaking for Rolls-Royce.

'But we do other things for Vickers – including helping the Vickers Medical Division – and we did an audit on a gearbox in the Vickers battle tank! I'm developing this cross-company fertilisation . . .'

'The engine for Java was based on our MBA, but was a vee-8. It draws on some racing developments but it's not a racing engine. The porting and throttling are shared with the XB; throttling developed on the MBA V6 project enables us to run with a camshaft overlap, which fills in the torque curve and gives high top power. It also harnesses our latest thin-wall cylinder block techniques . . .'

Further, when I discussed the car with Roy Axe, he twinkled, bristled his moustache, admitted that an engine *had* been in place, but that he was not about to tell me what it was.

All of which led me to conclude that Java was more mock-up than motor car, and that there was more wishful thinking than firm engineering in what we were allowed to see. In 1994, whatever it was meant to become, Java was at least five



When Rolls-Royce unveiled the Bentley Java project car in March 1994, it released this engine picture – of a 3.5-litre 75-degree vee-8 unit. But don't get too excited. My spies tell me that this was merely a good-looking mock-up – and that the actual car was powered by another type of engine! We would have to wait and see what happened next. . .

years away from production – if, that is, it ever got the nod from Vickers.

The future

By the late 1990s, as Mark Hunt admitted to me, Wellingborough Two was likely to be producing several different – new – products. The famous YB-Series Sierra/Escort engine would be beyond its tenth birthday, the long-lived Scorpio platform would also be moving into retirement – but Woodwark and his colleagues were confident that new projects would then take over.

Woodwark: 'I hope and intend to build another new factory at Wellingborough – Two has got an identical piece of land next to it. As we are opening the company up, and getting far more visitors, people are understanding much more about what Cosworth is about, how broadly based it is, and the fact that it's quite capable of doing business with other customers as well as Ford. Ford are important, much respected and loyal customers of ours: they want to see Cosworth grow outside that relationship.'

Oldaker pointed out that he didn't think anyone else in the Western world could match Cosworth's expertise in doing what it did, and Chairman Chris Woodwark summed up like this:

'My vision for Cosworth's future is that our team will remain at the forefront of engineering excellence, around the globe, and continue to succeed across all its racing and business activities.'

In the meantime, there had also been a revolution in the company's racing activities. So much had been tackled, and so many victories had been achieved, that these deserve a chapter to themselves.

Motorsport – winning all round the world

In the early 1990s Cosworth's race engine design strategy changed considerably. After years of getting by with a small design team, and the ability only to develop one all-new engine at once, the company took a corporate deep breath and changed its ways. By the mid-1990s several brand-new engines – for F1, Indycar and Formula 3000 – had all appeared, and all of them were winning!

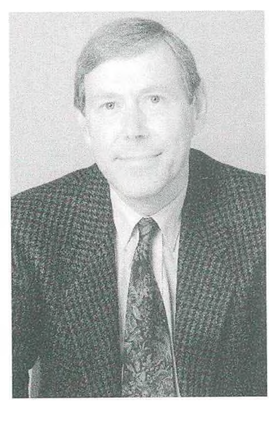
New designers, new customers – and intense competition from rival companies – had all seen to that. Encouraged by Vickers, Cosworth wanted to be winning, preferably dominant, in every category it contested. Ten or especially 20 years earlier, that might have been straightforward enough – but not in the 1990s. Big money was needed to finance the development of new engines – if, that is, they were to be produced quickly, and if they were to be competitive from Day One. Cosworth was now confronted by big spenders like Honda, Renault, and GM (later Mercedes-Benz) backed Ilmor, and had to match their methods – and their results.

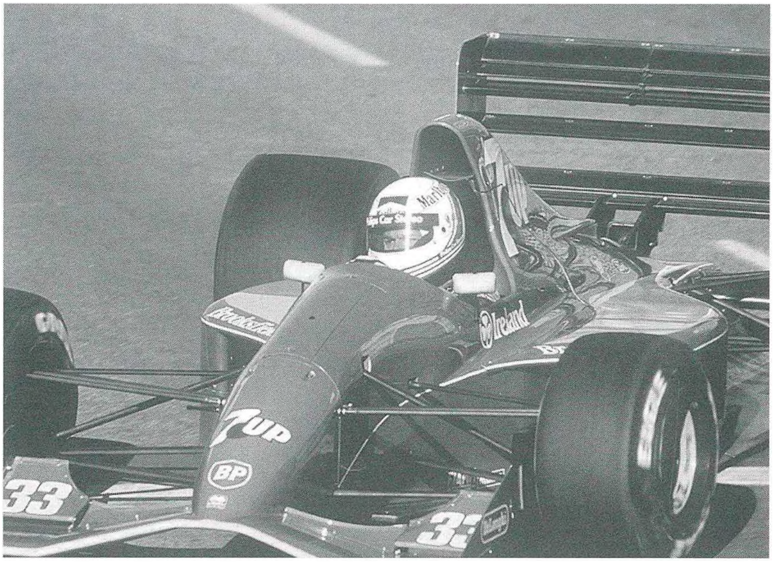
In 1990 the only truly modern Cosworth race engine was the HB – and even that high-revving vee-8 unit had been around for three years. The DFS (a turbocharged but lineal-development of the 1960s-generation DFV) was not a winner, and in Formula 3000 the rev-limited DFV seemed to have reached its limit.

For the time being, though, Ford encouraged Cosworth to carry on developing the 75-degree HB F1 engine. Benetton stayed on as the 'works' team for 1991, while Jaguar got the use of HBCs for sports car racing in XJR14 models. There was general surprise when Jordan, a new F1 team, also got a supply of recent-specification HBs, but this was a new and thrusting team whose results soon made everything worthwhile.

Even at that point, though, there were hints of new engines from Northampton. When Benetton's high-nose B191 was launched at a London hotel, in the usual flurry of strobe lights and clouds of dry ice, Technical Director John Barnard agreed that: 'We will be using the latest Ford vee-8

By the early 1990s Racing Director Dick Scammell was looking after more all-new engine design programmes than ever before. The Zetec-R, the XB, the AC, and the still-born VB vee-12 unit were all developed in a short period. Dick's team then got down to the study of new 3.0-litre F1 engines, new 2.2-litre Indycar engines, and a whole lot more. . . He was awarded an MBE in the 1995 New Year honours list for services to motor racing.



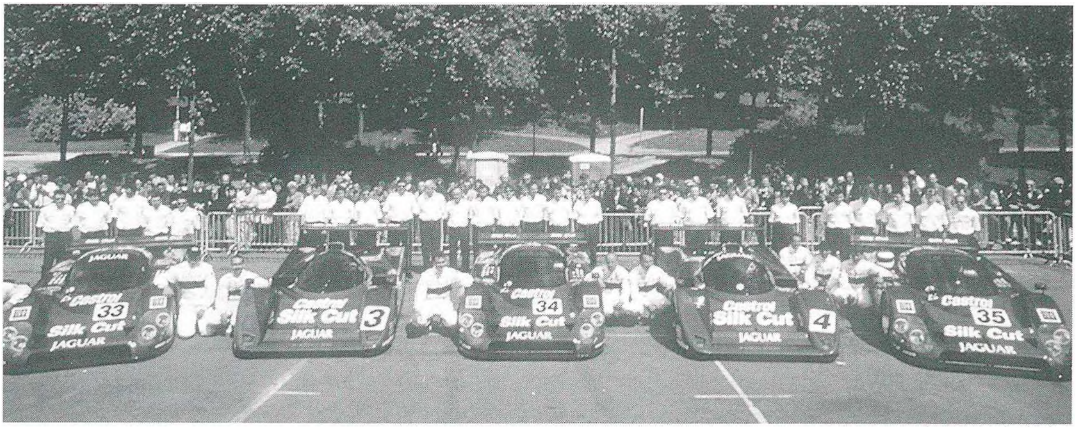


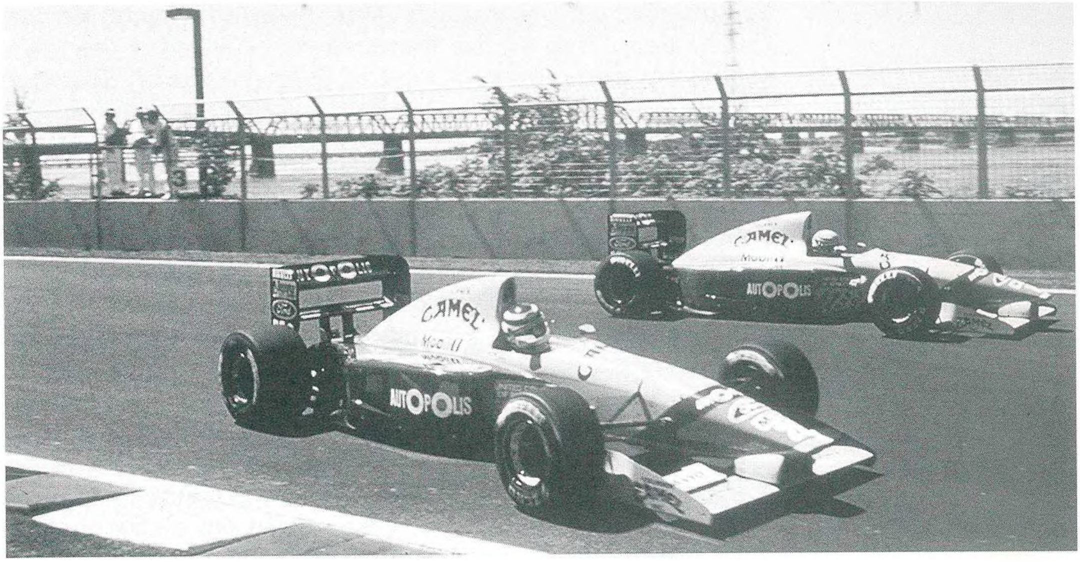
Jordan was a new F1 team in 1991, chose HB engines, and put in some remarkable performances with what was an attractive car with a most effective chassis.

engine "for the moment" '. Nothing more was said – and no amount of probing made him add to that comment, but everyone assumed that another Ford-Cosworth engine was already on the way. They were right, and they were wrong. Cosworth had already started work on an advanced new vee-12 – but in the end it would never be raced! John Barnard, incidentally, was to leave Benetton before the end of 1991, his ego bruised by the number of high-profile bosses and influences with whom he was obliged to interact . . .

Benetton's B191 was once described as 'one of the ugliest F1 cars ever built' (it was certainly no beauty), whereas the Jordan was often praised for its lissome lines. For Benetton in that year, there was a single F1 victory (by Nelson Piquet, in Canada), while Jordan's best finish was fourth,

The HB F1 engine was only ever applied to one two-seater racing sports car – the remarkably successful Jaguar XJR14 of 1991. Tom Walkinshaw's Silk Cut-sponsored team won the World Sports Car Championship in that year.





Using the latest version of the 3.5-litre Ford HB vee-8 engine, Nelson Piquet (Car No 20, foreground) won the 1991 Canadian GP. Confounding uninformed criticism from some reporters, this vee-8 was always remarkably effective in the Benetton chassis.

also in Canada, but the most significant event of that year was the arrival of Michael Schumacher on the F1 scene. Scoring championship points in only his second race, he soon proved that he was the fastest HB driver on the F1 scene.

That was also the year in which Jaguar's HBC-powered sports racing cars won the World Sports Car Championship, where the cars were heavier, and the races were longer, but not that much longer, than an F1 GP. This, though, was a single-season programme, for with the World Sports Car Championship in disarray at the end of the year, Jaguar withdrew from the sport. Once again a great Cosworth engine's career was cut short by motor racing politics. Jaguar publicity quoted the 3.5-litre HB's power output as 730 bhp, which didn't sound credible. Cosworth, when asked to confirm that figure, merely smiled and refused comment.

All-in-all, the HB was proving to be a remarkable engine. Racing Director Dick Scammell later told me that: 'There was no pre-conceived idea as to how long we could keep using it. We never had a long-term strategy for it – we would keep it as long as we could carry on developing it . . .'

There was a further breakthrough for 1992. Not only did Benetton have Michael Schumacher to prove that he was a potential World Champion, but the B192 was a better car than the B191. With Tom Walkinshaw now on board at Benetton, the team finished third in the Constructors' series (behind Williams-Renault and McLaren-Honda), while

Schumacher and team-mate Martin Brundle were always on the pace. Tom Walkinshaw was once asked if the team would be trying to sign Ayrton Senna: 'Senna? No, why would I want Senna? I've got Michael Schumacher!'

As *Autosport* reported in its annual GP review: 'The B192 was one of the most sinfully ugly racing cars ever built – but none could deny it went like hell . . . Cosworth continued to do a wonderful job for Benetton . . . this lone V8 often showed its strengths, in torque and fuel consumption. Nothing went to the grid lighter than a Benetton-Ford. And not much went faster either . . .'

Michael Schumacher won one race, and took a total of eight podium finishes, while Martin Brundle finished second or third five times.

The final HBs were known as Series VIIs or Series VIIIs (there were many detail differences, especially in torque characteristics) and they were known to rev all the way to 13,500 rpm. Clearly something remarkable had been achieved:

'The problem with the original engine,' Dick Scammell says, 'was that we couldn't run it fast enough because of the wire valve springs. Therefore we sat down quite early to make some air valves, and they opened up a whole new prospect. Before then we ran the HB to 12,800 rpm after which we lost control of the valve gear. Once we started using the air valves, we could run to 13,500 rpm. But then we started to have problems with other parts of the engine – you go round and round the engine looking for the next weak link. We had problems with the bottom end, and we also struggled with the pistons . . .'

Dick insists that the pneumatic valves were totally a Cosworth concept. Because the engineering of F1 engines is now such a secretive business, Cosworth never gets a chance to see inside its rivals' products, or to study them, so there was no foreknowledge of other people's technology.

'We had looked at air valve springs right back when the 3.5-litre formula came in,' Scammell confirmed, 'we knew the valve gear would be the Achilles' heel to us, and we had been developing it for some time. It was a very big development exercise.'

Not only was this an intricate design and development job, but manufacture and assembly was extremely ticklish. Observers who have been walked through the Cosworth F1 engine build shops (where cameras are strictly forbidden!) always comment on the clinically clean environment – where valve gear is assembled, there is talk of tweezers and other medical-standard equipment being used.

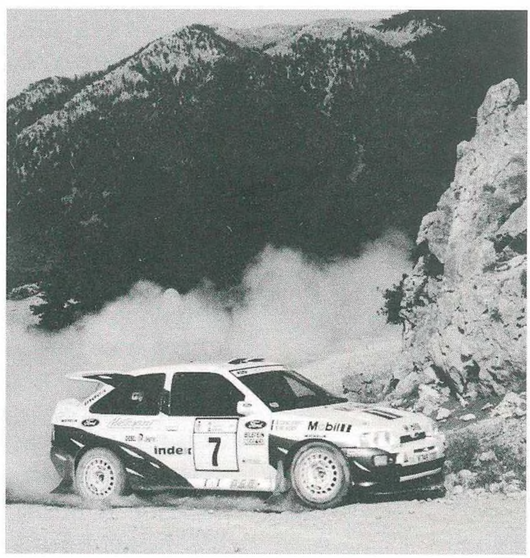
It was in this discussion that Scammell confirmed that Cosworth never allowed its HB-users – not even Benetton – to look inside the engines, even after a major problem at the circuits:

'That's why we now lease engines. We started leasing in 1989, and that way we know where all the engines are, all of the time. We have to keep the technology in house. We never see the insides of other teams' engines, and they don't see inside ours. We were more open once, but all that ended with the last DFs – DFY and DFR – and ever since then we have had Cosworth people supporting the teams at the circuits, whether they're customers or the "works" teams, and we rebuild all the engines ourselves. Other engine manufacturers operate in the same way these days.

'We'd all love to see inside other peoples' engines, wouldn't we, but we can't!'

Although the HB had become a truly remarkable vee-8 by the end of 1992 (Cosworth never quoted peak power outputs, but unofficial estimates were that a Series VIII HB could produce well over 700 bhp, maybe 730 bhp or more), there was still little official news of the much-rumoured VB vee-12 design which was meant to replace it. During 1991 Ford and Cosworth had circulated a sketch of what the new engine might look like, but that was all. By 1993 the engine had not been seen in public. Nothing official was ever said, but eventually it became clear that the project had been

Below left Miki Biasion won the 1993 Acropolis rally in this 'works' Escort RS Cosworth, using a Mountune-prepared version of the YB engine. Peak power output, officially quoted as 300 bhp, was probably in excess of 350 bhp. . .



Below Ford's 'works' Motorsport department began rallying the Escort RS Cosworth in 1993, and many World Championship victories were gained. The most publicity-worthy of all, no question, came when Francois Delecour won the Monte Carlo rally in January 1994.

abandoned. So, what happened, and when?

The initial thrust for a compact vee-12, to take over from the HB, came from Ford's 'works' team, Benetton, which by 1990 was convinced that a vee-12 was the way to improve on the HB vee-8. Once Ford approved the investment, Cosworth quickly got to work, and produced a 70-degree (note the intriguing vee-angle, which is not one normally associated with vee-12s, for which 60 degrees is often considered normal) during 1991.

It was an extremely compact design, really quite astonishingly so for what must have been a very complex unit. Only about 2 inches longer than the HB, it pushed Cosworth's knowledge and application to new extremes. The final version of the VB, now on display in Cosworth's own museum in Northampton, confirms this.

'Possibly we went too far in the steps of trying to make progress,' Scammell told me. 'We really "hung it out" in a few places, one of them being the bearing sizes. The engine was very small, so the bearings were also very small. We just overdid it – we went too far in trying to scratch for performance.

'To overcome some of the deficiencies during the development, we ran it with an external oil supply – the idea was to develop the engine with a slave oil system, and then when we'd worked out what we really wanted to do, to re-design it, and produce a "Mk 2" vee-12.'

By that time, though, F1 regulations were changing, and the architecture of the cars was changing to suit them. Soon after Benetton came back to report that the position of the driver had to be pushed back, and that the radiators really needed to be moved, all of which would affect the position of the fuel tanks, which would therefore cramp the space available for the engine. . .

'In any case,' Scammell explained, 'because the vee-12 was set to use more fuel, the car would have needed a bigger fuel tank, and bigger radiators. So we all had to reconsider – should we design the definitive "Mk 2" vee-12, and what would the ideal cars look like in a year or two? In the end we cancelled the project.' It was a clean break.

Almost immediately after work on the VB was killed off, project work began on yet another F1 engine, which proved to be enormously successful – the World Championship-winning Zetec-R.

By that time about half-a-dozen prototype vee-12 engines had been built, at considerable cost in time and material. Prominent Ford personalities once told me that the VB was the best thing that ever happened to the HB, for it promoted healthy 'in house' competition at Cosworth. Scammell insists this was not the case, as some technicians were involved in both engines, but agrees that the HB continued to improve throughout 1991 and 1992.

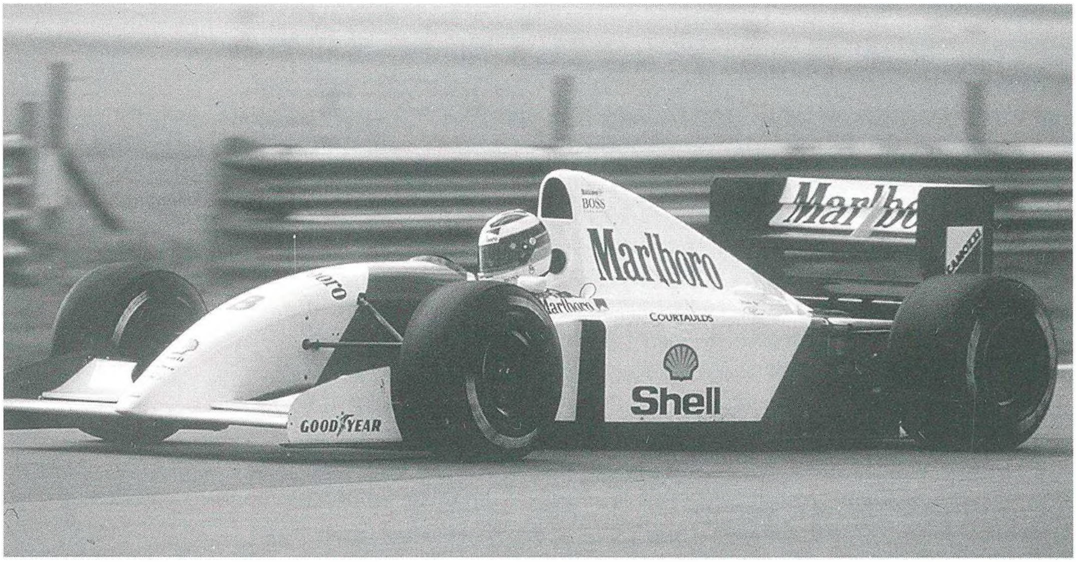
'By the end, in fact, the VB was producing more power than the HB. It would obviously have gone on from there . . .'

Accordingly, after a long development period, several vee-12 VBs were, quite literally, scrapped, and the example on show in the museum is now modestly labelled as a '1991/1992 Development Project 3.5-litre V12'. The only alternative, as with the 1,000 bhp turbocharged GB Formula 1 engines of the mid-1980s, would have been to loan the VBs to museums and technical organisations, but because the VB was such a modern design, Cosworth decided not to do that.

Cosworth insists, though, that much of what was learned on the still-born vee-12 was applied to the next F1 engine, the ultra-successful Zetec-R which followed it, and that it allowed design work to be completed more quickly, and more surely.

In the meantime the HB carried on, enjoying a real 'Indian Summer' in 1993, when the top teams all had cars with semi-automatic transmission, traction control and computer-controlled active suspension. Because traction control operated by cutting the power of the engines as the wheels started to spin, even the best-prepared and tuned F1 units sounded awful at times, but not the HB, for which more sophisticated electronic control of the engine was developed . . .

Not only did Benetton have the use of 'works team' engines, but McLaren also became HB users, first as customers for recent-spec (but not up-to-the-minute) engines, then after mid-season with the same spec. as Benetton. The end-of-season scorecard showed that HB-powered cars won six of the 16 World Championship F1 events – but only one of those victories went to Michael Schumacher and Benetton. McLaren finished second in the Constructors' Championship, Benetton third. In each case Cosworth set up separate build and development teams, keeping a float of 25–30 engines for each team, which looked after a full race programme and on-going development. 'Customer' teams such as Lotus or Footwork would use about 15 engines each. Cosworth has heard of major engine builders talking of running pools of more than 100 engines (Honda was supposed to have more than



For 1993 McLaren chose Ford HB engines for its F1 effort, the result being five World Championship victories for Ayrton Senna. This is test-driver Mika Hakkinen, shaking down one of the first HB-powered cars at Silverstone.

200 F1 vee-12s in play for McLaren in 1991 and 1992!), but simply cannot see the need for it. Many of those engines, it thinks, would never even have been installed in a car during their lives . . .

In spite of what seemed like continuous friction between McLaren and their lead driver, Ayrton Senna, the brilliant Brazilian won five races in 1993, one of them the prestigious Monaco GP. Better yet, for those with short memories, he won the last two races of the season – in Japan and Australia. Perhaps McLaren would never admit it, even afterwards, but the MP4/8-Ford/Cosworth HB combination was eventually far more competitive than they could ever have hoped, even though Ayrton Senna was often out-qualified by Michael Schumacher's B193 Benetton.

For those of us addicted to fair reporting, the antics of those pundits trying to explain away all those victories while claiming that Cosworth's HB was 'underpowered', was enough to turn the stomach. Cosworth engineers themselves have no idea how much power their opposition's engines produce – so how could the press know any better?

These days, in Formula 1, an engine's reputation can only be made by its results. Dick Scammell confirms that Cosworth never revealed power outputs or power curve. 'No, that would be another useful piece of information to the competition. We would tell people "ball park" figures, but in fact it would have to be "sold" on the basis of its performance elsewhere. If a team decided to leave its supplier to come to us, it was because they had seen the way the Benetton had run with an HB in it.'

When teams come to make a choice of F1 engines, there is always another factor – money. Well-drilled by founder Keith Duckworth's Northern business ethic, Cosworth has never set itself up as a benevolent society. Every team using HBs had to pay leasing charges, and were not allowed to renege on a deal at a later date. In the early 1990s Cosworth resorted to law to oblige Jordan to settle their 1991 programme, while Lotus's plunge into administration in 1994 was not helped by its inability to pay Cosworth's bills from 1992 and 1993.

Money, secrecy, and good old-fashioned F1 politics goes a long way to explain why HBs were taken up, then dropped, by several F1 teams over the years. Why did McLaren dump the HB in favour of a new Peugeot engine in 1994 (both of which were supplied free!) – a major error? Why did Jordan, so promising with HB power in 1991, use Yamaha engines instead of HBs in 1992, with dismal results? Why was the Mugen-powered Lotus of 1994 such a disappointment after the promise of the HB-powered cars of 1992/93?

How, on the other hand, could the HB-powered Footwork of 1994 be so effective compared with its previous Honda/Mugen-powered cars? Most amazing of all – how could Benetton, for whom Michael Schumacher won the 1994 World Championship with Ford Zetec-R-powered cars, discard such a magnificent engine for 1995 – and how could Cosworth then find itself struggling to find a race-winning partner for 1995?

1994, however, was an F1 season to be savoured. For Cosworth, Ford, Benetton and Michael Schumacher it revolved round the amazing new Zetec-R vee-8 engine, which took over from the HB as Ford and Cosworth's front-line F1 power unit. Against all the sneering forecasts of the motoring press, here was a remarkably successful power unit. Not a vee-10, not a vee-12 – but a classic vee-8, which did everything very well, and most things superbly.

Immediately the VB vee-12 project had been cancelled, a team led by Martin Walters started project work on a new F1 design which was initially called the EC. Well before release, however, the EC designation had been dropped, and Ford's publicity-inspired 'Zetec-R' name took over instead.

By 1993 the HB, a remarkable vee-8 by any standard, had reached its limits. On my assumption (mine, only, please note), the most powerful HBs probably produced about 210 bhp/litre, but Walters and Scammell were not satisfied:

'We felt the cylinder bore should be bigger,' Scammell admitted. [How much bigger? We were never told . . .] 'But we couldn't do this within the confines of the HB block. So we had to design an all-new engine, to carry on the developments which were indicated to us. The HB gave us a lot of clues about the way to go, and fortunately those signposts were good ones.'

Work started on layouts in October 1992, detail drawing and CAD (Computer Aided Design) began at the end of the year, and the very first engine ran on the test beds in October 1993. The first engines were delivered to Benetton for in-car testing in January 1994 – and duly won their first race in March 1994. Even Scammell, the died-in-the-wool realist, admits with pride that this was very rapid progress indeed:

'A lot of what we knew from the "works" HBs went into the Zetec-R,' Dick told me. 'There was a lot more than a bigger bore, a shorter stroke and a longer cylinder block in the design.

'But it wasn't reliable straight away. We did, in fact, have a problem with pistons. That was reasonable [there's that famous Duckworth description again . . . (AAGR)] because we had bigger pistons, and one of the engine's design parameters was that this new vee-8 had to run up to 14,500 rpm. During the first four months of the engine's life, we probably used 15 different piston designs . . .'

Once again this justified everything Cosworth has ever tried to do at Northampton, for the piston forging plant was just 50 yards from the design offices, and when Martin Walters wanted to make changes, he had only to cross the road to consult the technicians in the forge.

'By the time the Zetec-R engine got to Brazil, we had got it to run a race distance on the dyno, but we certainly weren't out of the woods. We were still working on the pistons – and have done so since then – and now it's reliable.'

Right away, even on early test bed runs, the original Zetec-R was better than an HB. Naturally no peak power figures were ever published, but if Cosworth's philosophy of keeping up the BMEP while letting the engine rev faster was achieved, that alone must have been worth an extra 40–50 bhp: it certainly looked like that out on the tracks.

There's no doubt that the 14,500 rpm figure was achieved, without affecting Cosworth's quite astonishing low-speed torque and flexibility, for Ford often allowed the Benetton B194's telemetry readings to be superimposed on the TV pictures published worldwide throughout the 1994 F1 season.

The Zetec-R's most remarkable performance was not a victory, though. In Spain, Schumacher's Benetton gearbox stuck in fifth gear, but the driver elected to keep going. TV-published telemetry showed just how far down the rev range the engine continued to work well – so it was not surprising that Jim Brett sprinted to the team's electronic centre and hastily pulled the plug . . .

In future years, when we look back on the 1994 F1 season, more attention will be paid to the personal tragedies, the technical changes which followed, and to the extraordinary political wrangles which affected the motor racing. A season which opened with the enthralling prospect of head-to-head battles between the Schumacher/Benetton/Ford-Cosworth combination and the Senna/Williams/Renault, was suddenly shattered at Imola when Senna's Williams crashed, and the driver was killed.

Although Schumacher's Zetec-R-powered Benetton had already won the first races (in Brazil and Japan), this was no way for him to become the sport's leading driver, and later events made it more controversial still. Throughout the year the Benetton was dominant, but there were more traumas to be suffered. For ignoring a black flag at Silverstone, Schumacher was disqualified, and obliged to miss two further races, while his Benetton was disqualified after winning the Belgian GB after the newly-introduced compulsory 'plank' under the monocoque was found to be worn below regulatory limits. Even in the final race of the year, Schumacher's Benetton and Damon Hill's Williams hit each other, eliminating both cars.

As an understandably bitter Schumacher later commented, he was being asked to win a 16-event World Championship by competing in only 12 events. It says a lot for his character, and for the resources of his team, that in the end he won eight of those 12 races, and became a truly worthy World Champion. After such a successful season, few outsiders could understand why Benetton then walked away from a supportive long-term agreement with Ford and Cosworth, choosing Renault engines for their future.

Worse, how could it then be that Ford, and Cosworth, found it so difficult to link up with an established front-line team for 1995? Scammell, Martin Walters, Nick Hayes and their team had already spent months working on a 3-litre up-date of the Zetec-R theme before they knew that it would be used in the Sauber chassis. Formula 1 is truly impossible to understand at times . . .

XB: A new generation of Indycar engines

Although Cosworth had produced the world's most successful CART/Indycar race engines in the 1970s and 1980s, by 1990 and 1991 the final member of that generation – the DFS – had been out-gunned: the Chevrolet-backed Ilmor vee-8, designed by two ex-Cosworth engineers, was totally dominant in this unique type of racing, where engines had to be turbocharged 2.65-litre units running on Methanol. The time had come to fight back.

Totally at Cosworth's own cost, a new and specialised engine, the XB, took shape at Northampton. But there was more. All previous Indycar race engines had been Cosworths, with no overt Ford backing. Now, for 1991, Ford helped to fund the XB unit. When Ford-USA and Cosworth launched the programme at a function in the Indianapolis Motor Speedway in November 1991, they made the point that they were returning after a gap of more than 20 years, and that in 1992 this would be the first time that Ford and General Motors had ever clashed on Indycar race tracks.

Even before starting work, Cosworth made it clear that to make any sense, this had to be a multi-season programme. It likes to produce engines for a minimum life cycle of at least three years ('You need to have it around long enough to learn what's good and bad about it, and to develop it to know where you want to go next . . .').

For the XB that was a minimum requirement, especially as a 'works' team test, development and engine building department would have to be set up in Northampton, along with other facilities for the customer teams at Cosworth Inc in California. As with the HBs, all engines would be leased, not sold outright, and customers were forbidden to open them up at any time.

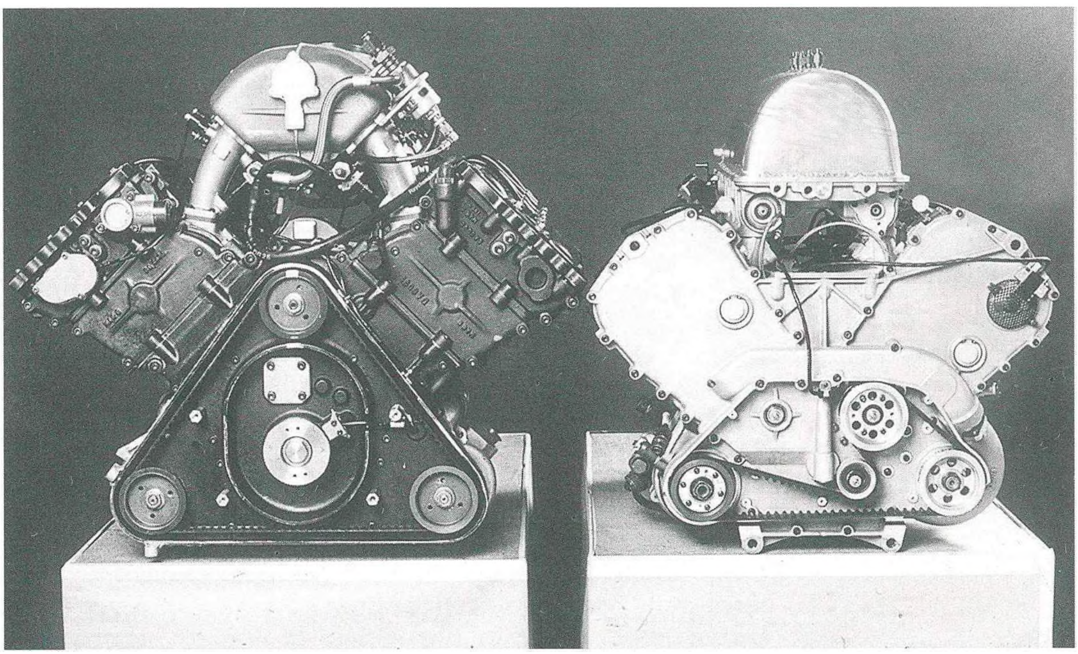
By any standards this was a very serious and ambitious programme. Not content with getting modestly back into the swim, Michael Kranefuss and Steve Miller surveyed the Indycar field, courted, seduced, then won the most successful of all teams – Newman-Haas racing, in which Carl Haas's partner was Hollywood superstar Paul Newman. Newman-Haas, whose star drivers were Michael Andretti and his father Mario, had won the 1991 Indycar series outright in Ilmor-powered Lola T91s, so when the team agreed to defect to Ford, General Motors was not best pleased.

If it had chosen to back any other engine design than the new Cosworth XB, this would have been a high-risk strategy for Ford. Other major engine-builders, like Alfa Romeo, Porsche, Buick and Judd, had all tried to beat Ilmor – and failed. This, however, was about to change, for when previewed in 1991 the XB looked to be lighter, more compact, and more carefully and delicately engineered than all of its rivals. The new 'works' team facility was up and running in Northampton by 1992, and there never seemed to be any problems caused by the transatlantic chasm between Newman-Haas and Cosworth. Which says a lot for Cosworth engine reliability, and for the efficiency of modern airline freight services . . .

Unlike the successful old DFX, the new XB Indycar engine was not, repeat not, a conversion of the modern HB Formula 1 engine. Even so, for a time there were people who heard the denials and chose not to believe them, noting the same 75-degree vee-angle and compact layout – but in fact there was virtually no common ground. By 1994 this was always clear to Cosworth visitors, for HB and XB engines stood side-by-side, on display stands, at Northampton in the company's reception area.

Dick Scammell succinctly outlined the thinking behind the new XB unit:

Not only was the XB Indycar engine (left) a lot more powerful than the DFS (right) which it replaced, but it was smaller, lighter, and had a great deal of potential. Unveiled at the end of 1991, it began winning races the following year.



'Obviously, because Indycar engines have to be 2.65-litres – a lot smaller than the 3.5 litres of the F1 engine of the day – they can be more compact. We designed the XB to take maximum advantage of the rules. We designed it from the ground up, as a turbocharged engine.

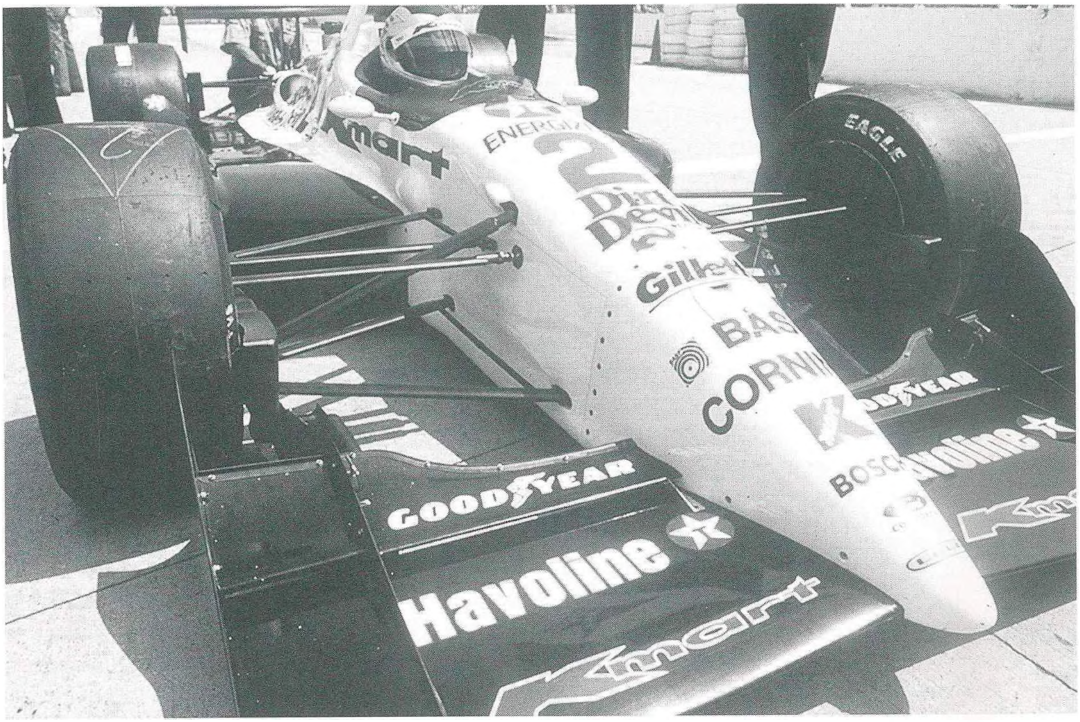
'The competition is now so great that unless you optimise the engine totally you lose out. These days this always impels us to make new engines for different formulae – and we run the place deliberately set up with different teams of people.'

It was typical of Cosworth's approach to original thinking that it also decided to fuel the XB in a novel way. Not only were there conventional fuel injectors near each cylinder trumpet/port at the base of the inlet manifold, but there was also a further injector at the outer, upstream, face of the turbocharger compressor. Naturally Cosworth's rivals, Chevrolet-Ilmor, did not like this (they had not thought of it first . . .), but officials eventually declared it race-legal. This was yet another instance of the way all Cosworth engineers are encouraged to think, to innovate, and to push technology to its limits. It was also classic proof of that old dictum, 'The competition starts when the regulations arrive . . .'

Although it was always too much to ask Newman-Haas to win the Indycar series in 1992 with a brand-new engine, they came mighty close, for Michael Andretti finished second – very close behind Bobby Rahal's Ilmor-powered car. Along the way, though, XB-powered Lolas won six of the 16 races, Michael Andretti won five events (more than any other individual), led all but two of the season's races at one point or another, and led more race laps throughout the season than any other driver. Mario Andretti finished sixth in the series.

Then came 1993, the year in which Michael Andretti moved to F1 (and McLaren) with dismal results, while F1's new World Champion Nigel Mansell took his place in the Newman-Haas Indycar team, with quite sensational results. Although Mansell was the 'rookie' in every sense, he soon mastered the cars. After winning the season's first race, at Surfer's Paradise in Australia, he then suffered a high-speed testing crash on the Phoenix Oval. After recovering rapidly from a back injury, Mansell then won at Milwaukee in June.

By the end of the season, with five victories from 15 starts, along with five other podium finishes, the Englishman had won the Indycar championship, with team-mate Mario Andretti winning one race and yet again taking sixth place in the series. It was an astonishing



Nigel Mansell, with whom the famous racing number 'Red 5' was so strongly linked, raced XB-powered Newman-Haas Lolas in 1993 and 1994. In his first-ever Indycar season he became Indycar Champion, and the XB proved itself to be the most powerful engine in that series.

performance in every way. Mansell was known to be brave, the Lola chassis was fully competitive, but above all it was clear that Cosworth's latest XB was the most powerful Indycar engine in existence. General Motors, in fact, was so demoralised by this that it withdrew its backing from Ilmor, which smacked of the old British schoolboy adage, 'If I can't win, I'll take my bat and ball away . . .'.

For 1994 everything looked set for another Ford-Cosworth triumph, which merely goes to prove that one must never make assumptions in motor racing. Although the XB was on top of its form, still acknowledged to be the best Indycar engine, the Lolas used by the Newman-Haas team struggled against the Ilmor (now Mercedes-Benz backed)-engined Penskes. Nigel Mansell did not win a single race, rapidly fell out of love with the Indycar circus (and they with him . . .), and returned to F1.

During that season, too, the Indycar establishment shocked the engine builders by announcing major changes to be imposed for 1996. Developed versions of the XB would be allowed one more season – 1995 – but thereafter Indycars would have to run with 2.2-litre engines. If the Indycar law-makers thought that this would merely mean the modification of existing engines, they were totally misguided.

Even in 1994, therefore, Steve Miller's Indycar team had to start designing yet another new unit. Dick Scammell confirmed that it would be entirely new, smaller and more advanced than the XB itself. There would also be a 'customer conversion bit' for the XB – reducing it to a 2.2-litre unit, to ease the transition for them.

'Everyone talks about costs, about saving costs, but one of the biggest cost-savers of all time is stability, so that the same equipment, or modifications of that equipment, can have a reasonable life span.

'Every time anybody changes anything in motor racing, it often means changing the engine to suit. It isn't always changing the engine regulations which we worry about.'

Although Scammell was smiling as those remarks were made, he could have been excused for being cynical about the whole process. Faced, in any case, with the busiest race-engine design period which Cosworth had ever known, his engineers were now being obliged to meet yet another unasked-for, unexpected, challenge. It was exciting, and it was enthralling, but I could see that Cosworth would rather have concentrated on other things.

Other formulae, other successes . . .

By this time, however, Cosworth was so resourceful and so quick to respond to new opportunities that it had also found time to have another look at Formula 3000, and at the same time to get back to its roots, as an ace-modifier of other peoples' engines. In 1993, for instance, not only was there a brand-new F3000 engine – the AC – but Cosworth also got the task of optimising Ford-Mazda and GM vee-6 production car engines for Touring Car racing in Britain and Germany.

Originally set up in 1985, F3000 single-seater motor racing had always been seen as the final step towards F1 competition, with engines limited to 3-litres, and to not more than eight cylinders and a maximum of 9000 rpm. At first this was almost tailor-made for the venerable DFV, which was chosen by most chassis builders. Although it was always the most successful engine in this series (DFV-powered cars won eight out of ten International races in 1992), the DFV was by no means the optimum design – and according to Cosworth's design ethic this was not desirable.

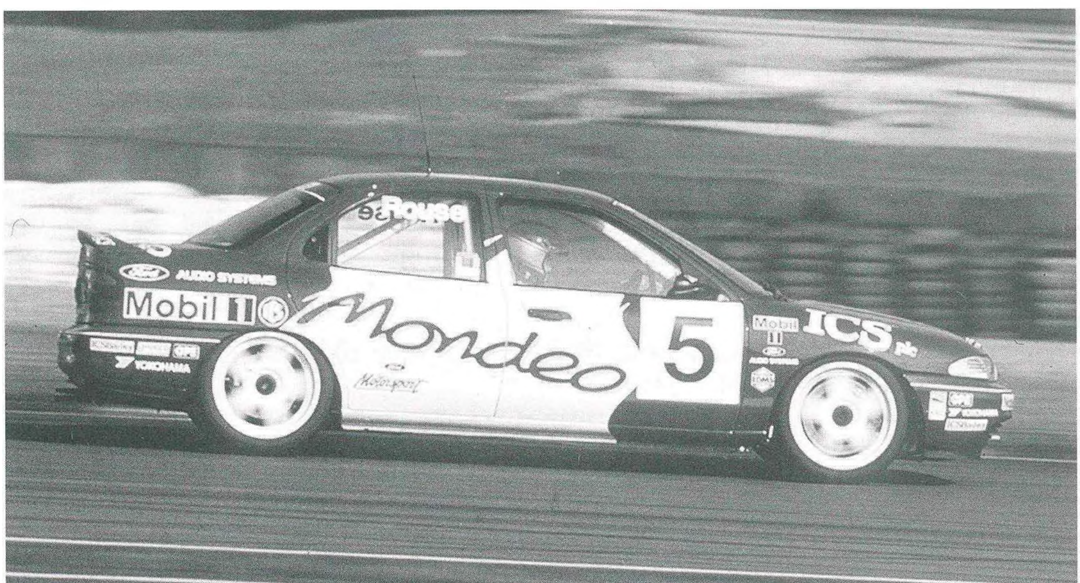
As the company's promotional literature made clear: 'Sales of the old DFV were stagnating, and Cosworth decided it needed to reinforce its dominance by introducing an engine designed specifically for the requirements of Formula 3000.'

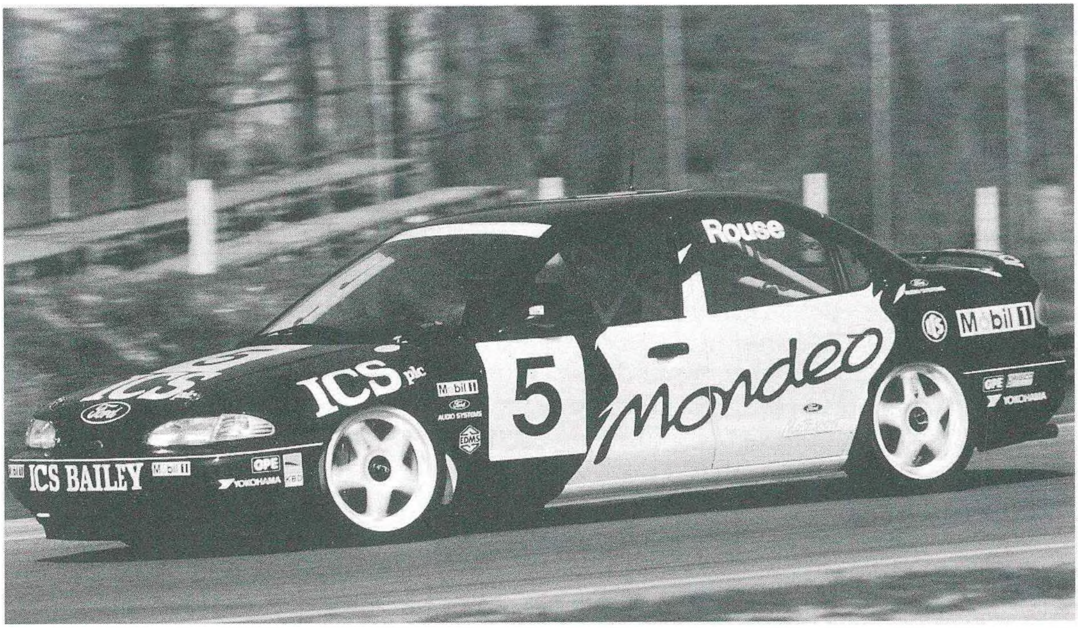
For 1993, therefore, the company launched yet another all-new racing engine to take over from the DFV – the AC – which was a purpose-built 3-litre 90-degree vee-8. Cynics who suggested that this was no more than a re-vamped DFV were speedily re-educated. At 282 lb/128 kg, Cosworth claimed, the AC was 10.4 per cent lighter than the old DFV, was smaller and more compact, and (very important, this) featured a lower vibration level than before.

It was typical of Cosworth that neither bore and stroke, nor peak power output figures, were released – all that was guaranteed was that race engines would be ready by April 1993, that they would fit into existing chassis, and that they would be competitive. All of which came true! AC-engined cars won seven out of nine F3000 races in that season (the other two races being won by DFV-engined cars . . .), while there was also total domination in 1994.

By this stage Cosworth-prepared cars seemed to winning everywhere once again. The opportunity to prepare engines for Ford's British Touring Car Championship programme (Mondeos using 2.0-litre vee-6s from the Probe model, which was based on the chassis of the Mazda MX-6) and for Opel's German Touring Car Championship (Calibras with new-type vee-6 engines) meant having to modify rather

For 1993 Andy Rouse Engineering was commissioned to develop Ford Mondeo cars to compete in the British Touring Car Championship, and opted to use Ford-USA vee-6 engines. When further developed by Cosworth, these 2-litre units turned the cars into race winners. Driving Mondeos, New Zealander Paul Radisich won the World Touring Car Cup in 1993, and again in 1994.





The Ford Mondeos used in the British Touring Car Championship made their debut in mid-1993, and within six weeks had won their first race. Andy Rouse's Coventry-based team (Andy is here, at the wheel) prepared the cars, but the Ford-USA vee-6 engines were developed, and made race-reliable, by Cosworth at Northampton.

than innovate, and to make production castings stay in one piece when subjected to much-higher-than-planned stresses. For Cosworth it was almost like old times, though few of the 1990s-breed of engineers could recall the 1960s period when a much smaller Cosworth company did little else!

To make the most of these projects, Cosworth gave Geoff Goddard his head, to liaise between race and road-car engineers and to wrap his own particular expertise around the various, sometimes conflicting, regulations. In the BTCC, for instance, the 2.0-litre engines needed to produce 290/300 bhp to be competitive. By Cosworth standards this was not difficult – except that they also had to be rev-limited to 8,500 rpm, a regulation which was strictly and ruthlessly policed by the organisers. All had to use production castings, though in some instances, project leader Len Newton told me, these were really not very suitable for the job.

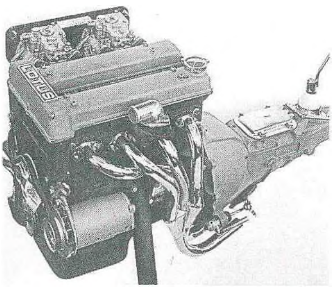
Goddard, operating a very different programme from that of an F1 engine, rapidly turned the original Rouse-tuned vee-6 into an even more powerful unit, and only weeks after the Mondeos first raced, New Zealander Paul Radisich won at Brands Hatch (an occasion, incidentally, which notched up Ford's 200th BTCC victory, most of which had been achieved using Cosworth power). More Mondeo wins followed – including victory in the World Touring Car Cup races of 1993 *and* 1994 – and yet more developments were promised for the mid-1990s.

Keke Rosberg's vee-6-engined Calibras, complete with four-wheel-drive, had to compete against expensively financed Alfa Romeo and Mercedes-Benz cars. Three cars were powered by 450 bhp 2.5-litre engines built and developed at Northampton, but there was only one race win to report in the original season; Opel was hoping for much more in 1995 and beyond.

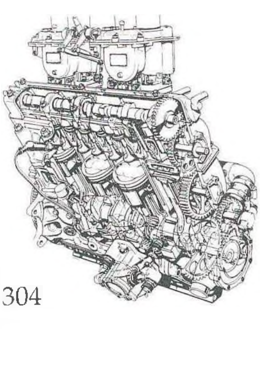
By the mid-1990s there was never any let-up in Cosworth's race-engine design and development areas; if anything, the pace of change increased. Just so long as the investment made sense, Chief Executive Chris Woodwark encouraged this with great enthusiasm, and looked forward to new engines, new successes, and new partnerships all being made public in the years to come.

Cosworth engines from 1960

Cosworth contributed a lot to the final design of the Lotus-Ford twin-cam engine, announced in 1962. The engine shown is the standard 105 bhp design, though Cosworth's Mk XII was a 140 bhp version of this.



The SCA of 1964 was Cosworth's very first 'own-design' cylinder head, featuring a single-overhead-camshaft layout, in line valves, and the combustion chamber in the crown of the pistons.



Although this Appendix is based on that provided by Cosworth Engineering Ltd, it is not the usual bald list of types, and dates.

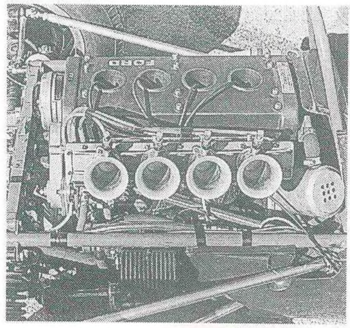
On this occasion I have tried to collect the various engines into groups, and to indicate the chronology and relation of one engine to the other. Here goes:

Modified Ford 105E ohv engine family

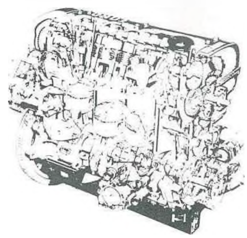
Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1959	Mk I	997	—	Purely experimental, and never put on sale. The original Cosworth-Ford, on which Keith's radically new ideas of camshaft design were developed.
1960	Mk II	997	75	The first Cosworth production engine, designed specifically for Formula Junior. This was the first Cosworth engine to start winning races, and it also established the Lotus-Ford-Cosworth connection.
1960	Mk III	997	85/90	A developed version of the Mk II, with a different (A3 instead of A2) camshaft profile, a stronger bottom end, and with optional dry sump lubrication.
1961	Mk IV	1098	90/95	A bored-out version of the Mk III, still for use in Formula Junior cars.
1962	Mk V	1340	80	The first-ever Cosworth engine for a road car, a lightly-modified (109E) Ford Classic unit for use in the Lotus Seven of the period.
1962	Mk VI	1340	105	The most powerful Cosworth engine so far, a racing version of the Mk V, but because of its swept volume not really suitable for any racing formula. Very few made.
1962	Mk VII	1475	120	Yet another 'most powerful so far', a bored-out version of the Mk VI, to take it nearer to the 1.5-litre class limit

				for sports cars. Still a 3-main-bearing engine.
1963	Mk VIII	1498	90	Like the Mk V, a simply-specified engine based on the 5-main-bearing 116E unit, as used in the Ford Cortina, also for road-car use in the Lotus 7. A large number were built.
1963	Mk IX	1498	125	A racing version of the Mk VIII.
1963	Mk X	1498	—	A one-off experimental development version of the famous Lotus-Ford twin-cam engine, which had a cylinder head designed by Harry Mundy (*not* by Cosworth), as later used bored out to 1558 cc for use in road cars such as the Lotus Elan, Plus 2, Europa, Ford Lotus-Cortina and Escort Twin-Cam. Also see Mks XII/XIII/XIV below. (This engine was unveiled by Lotus in 1962)
1963	Mk XI	1098	110	An up-dated version of the Mk IV Formula Junior engine, the first-ever Cosworth unit to produce 100 bhp/litre. Very successful, and sold in large numbers.
1963	Mk XII	1594	140	Racing version of the Lotus-Ford twin-cam engine, enlarged to the 1.6-litre class capacity limit. Dry sump lubrication, but standard rods and crankshaft.
1963	Mk XIII	1594	140	Developed version of the Mk XII, this time with steel rods and crankshaft, to allow for (eventually) higher rpm, and higher power outputs.
1963	Mk XIV	1498	100	A developed version of the Mk VIII, for road car use in the Lotus 7.
1963	Mk XV	1594	140	Also a racing version of the Lotus-Ford twin-cam engine, this time with a wet sump (as required by some regulations), for use in the Lotus-Cortina. Closely related to the Mk XIII.
1963	Mk XVI	1498	140	Lotus-Ford twin-cam based, with tune like that of the Mk XIII. Specifically developed for use in Australasian racing of the day, where a 1.5-litre capacity limit applied.
1964	Mk XVII	1098	120	A special development of the Mk XI Formula Junior engine, with specially-modified cylinder heads incorporating downdraught inlet ports. Only a few engines made, due to difficulty (and expense) of brazing inlet passages into modified cast-iron Ford cylinder heads.
1965	MAE	997	100	A very successful further develop-

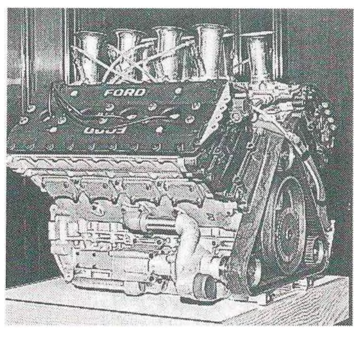
The sensationally successful FVA F2 engine, as installed in a 1966 Brabham (*Phipps Photographic*).

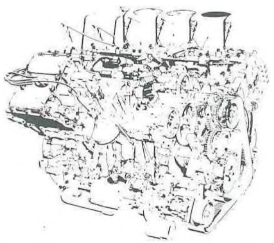


Cosworth's first 4-valve/2-ohc engine was the FVA unit, laid down in 1965, raced successfully from 1967, and in general layout the direct ancestor of the famous DFV V-8 unit. Note the gear drive to the camshafts.

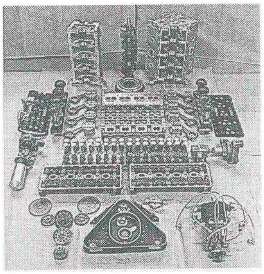


The original Ford DFV V-8 F1 engine was launched in 1967, when it was rated at 405 bhp. In the next fifteen years that peak figure was pushed up to no less than 520 bhp.

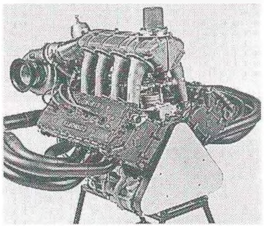




This Theo Page cutaway drawing shows all the hidden details of Keith Duckworth's magnificent DFV design. How times change – when the HB unit was launched in 1989 there was no cutaway drawing, no bore/stroke dimensions, no valve angles, and virtually no technical information!



Cosworth prided itself in machining just about every component which went into the DFV V-8 F1 engine. After the late 1970s, too, Cosworth also produced its own castings (*Phipps Photographic*).



By turbocharging the DFV, and redeveloping every aspect of its design, Cosworth produced the DFX engine, for Indy racing, in the 1970s. It dominated this branch of the sport for more than a decade.

ment of this Ford-based family, for use in the new 1-litre Formula 3 of the mid-1960s. Formula 3 replaced Formula Junior, with regulations requiring one single-choke carburettor. Many MAEs were sold as kits, rather than as complete engines.

Single-overhead-camshaft SCA family

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1964	SCA	997	115	The first Cosworth engine to use a Cosworth-designed cylinder head, in aluminium alloy, with vertical valves, and a single overhead camshaft. Based on the Ford Cortina-type 116E cylinder block, with five main-bearings, and with bowl-in-piston combustion chamber. Designed for the new 1-litre Formula 2 of 1964. Power output eventually pushed up to nearly 140 bhp.
1964	SCB	1498	175	A 1.5-litre derivative of the SCA, made only for experimental purposes.
1965	SCC	1098	135	An increased-bore SCA, designed for use in a North American sports car racing Formula. Many SCAs, redundant from F2, were later converted to SCC by new bore, pistons, and other details. The camshaft was chain driven.

Twin-cam/16-valve FVA family

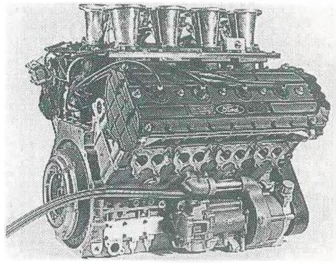
Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1966	FVA	1598	218	*The* first Cosworth-designed twin-cam engine to go into production, which established the successful twin-cam/narrow included-valve-angle, four-valves-per-cylinder, pent-roof combustion chamber. Based on the 5-bearing Ford 116E cylinder block, and with gear drive to cams. The dominant engine in the 1.6-litre Formula 2 of 1967–1971, and the direct ancestor of the legendary DFV V-8.
1967	FVB	1500	200	A purely experimental version of the FVA, made to speed development, and to examine the problems and possibilities for the DFV V-8 before that engine actually ran.
1969	FVC	1790	235	A long-stroke version of the FVA,

				produced for use in current European 2-litre sports-car racing, which it won twice. Nevertheless, an 'interim' engine.
1973	FVD	1975	275	An experimental version of the FV family, using the enlarged bore/stroke dimensions of the BDG.

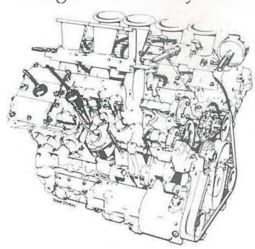
V-8 DFV family – all types

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1967	DFV	2993	405	All previous Cosworth engines had used a proprietary (Ford) block, so this was the first engine to be designed totally by Cosworth. The legendary and enormously successful Formula 1 engine, which won 155 World Championship GPs between 1967 and 1983. A 90 degree V-8, with four valves per cylinder, twin overhead camshafts per bank, and fuel injection. Power output eventually pushed up to *circa* 500 bhp.
1968	DFW	2491	358	A short-stroke version of the DFV, used by Lotus in Tasman Series racing. Engines converted from DFV, later re-converted.
1975	DFX	2645	840	A short-stroke turbocharged version of the DFV, for use in CART/Indy racing in the USA. Limited by regulations to a maximum turbo boost (in USA measure) of 80 in.
(1986			700	Regulations later changed, and with a maximum of 48 in of boost pressure, 700 bhp was available. This was the enormously successful Indy engine of the 1980s).
1981	DFL	3955	540	Much-enlarged 'endurance' version of the DFV, developed for use in Group C sports cars, with larger bore *and* stroke dimensions. Originally intended for Ford's own C100 project.
(1981	DFL	3298	490	A short-stroke version of the 3.9-litre DFL was also produced for Group C2 racing)
1982	DFV short stroke	2993	500	Combining the larger bore of the DFL, with a short stroke crankshaft, to give a higher revving, slightly more powerful, version of the DFV for F1 racing.
1982	DFY	2993	500/ 520	Further derivation of the short-stroke DFV, with new and narrower-valve-included-angle cylinder heads. For use only in F1 racing.

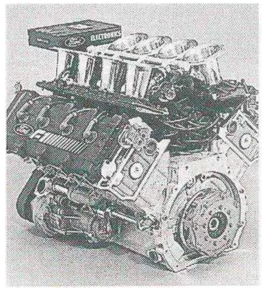
In the early 1980s the top end of the DFV was redesigned with a new cylinder head and narrower valve angles, the result being the 520 bhp DFY unit. Only seven such engines were built.

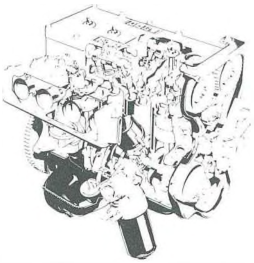


This cutaway drawing shows the DFY of 1982. Compared with the DFV, many details of the original design had been changed in fifteen years.

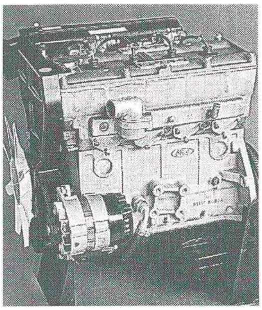


Geoff Goddard produced the DFR for the 1988 F1 season in double quick time, when the Yamaha 5-valve cylinder head project proved to be ineffective. Used only by Benetton during 1988, it was taken up by several F1 teams in 1989.

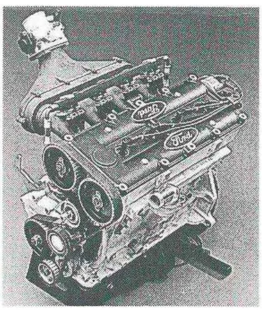




Mike Hall's four-cylinder BD engine was the first Cosworth to have belt-driven camshafts. Launched in 1970, it was still being built, in developed form, at the end of the 1980s.



The original BD engines had cast iron cylinder blocks, but in 1972 Brian Hart designed a light-alloy block derivative, which Ford soon adopted for the Escort RS1600 model.



This final version of the basic BD design – the BDT-E – was a turbocharged engine designed *and* manufactured by Brian Hart Ltd. It was a 2.1-litre unit which produced 500 bhp, but could be tuned to deliver 650 bhp!

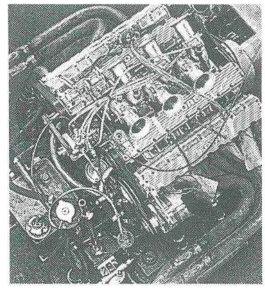
1986	DFV (F3000)	2993	420	Specially developed for F3000 single-seater racing, rev-limited (by regulation) to 9,000 rpm.
1987	DFZ	3495	560	An enlarged version of the definitive DFV/DFY, for use in F1 racing from 1987, where normally-aspirated engines could be enlarged to 3.5-litres.
1988	DFR	3495	595+	A thoroughly modernized version of the DFZ, for use in Formula 1, with new cylinder heads and four valves per cylinder. Five-valve cylinder heads (initially designed by Yamaha) tested in 1987/1988, but never raced. Used only by Benetton F1 team in 1988, but widely available in 1989.
1988/9	DFS	2645	not quoted	A modernized version of the turbo-charged DFX, for CART/Indy racing in the USA, drawing on DFR experience.

Twin-cam/16-valve BDA family

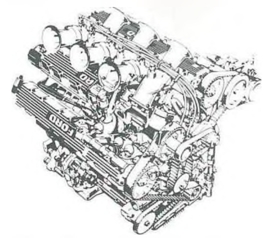
Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1969	BDA	1601	120	Same basic cylinder head breathing layout as four-cylinder FVA, and V-8 DFV, but based on taller Ford 'Kent' block, and with toothed-belt drive to twin overhead camshafts. As with other engines, four valves per cylinder.
1970	BDB	1700	200	An engine developed for Ford for use in the Escort RS1600 in rallying (where engine enlargement was allowed). Used an enlarged cylinder bore, different pistons, cam profiles, etc. All but one engine sold in kit form.
1970	BDC	1700	230	A fuel-injected racing version of the BDB (see above), developed with Group 2 saloon car racing in mind, for the Escort RS1600. As with BDB, all but one sold in kit form.
1971	BDD	1600	200	Developed specifically for use in Formula Atlantic single-seater race cars. All but one sold as kits.
1972	BDE	1790	245	For use in the 2-litre Formula 2, which came into force in 1972 (but not yet close to that class limit). With larger cylinder bore and fuel injection.
1972	BDF	1927	270	An improved development of the BDE, with larger cylinder bore (and oversize liners brazed into the standard (cast iron) cylinder block. Also for the 2-litre F2, and very successful in 1972 itself.

1973	BDG	1975	275	A further enlarged, and improved, version of the BDF, used in F2 in 1973, but later used by many Ford Escort RS cars in rallying. Originally with a cast iron block, later with an aluminium block.
1973	BDH	1300	190	A 1.3-litre version of the BDA design, using a short-stroke crankshaft, and using the shallower 1.3-litre version of the Ford 'Kent' cylinder block. For Group 2 saloon car or sports car racing. Considered by Ford for use in an Escort RS1300 road car, but the project was cancelled.
1974	BDJ	1098	150	Another short-stroke version of the BDA design, using a shallow Ford block. For use in American SCCA Formula C single seaters.
-	BDK	-	-	This acronym was reserved for a development project which never matured. No-one at Cosworth can now remember what it was!
-	BDL	-	-	An experimental turbocharging evaluation. Never put on sale.
1975	BDM	1599	225	A further-developed version of the 1.6-litre BDD (Formula Atlantic) engine, with larger valves, and fuel injection.
1977	BDN	1600	210	A serialized version of the BDD Formula Atlantic engine, for the Canadian FA Series. The series organizers sold all engines and components.
-	BDO	-	-	Not allocated
1984	BDP	1975	245	Specially developed by Cosworth's USA subsidiary, for use in USA 'Midget' single-seater racing. It combined the latest light alloy block/crankcase, the 1975 cc size of the BDG, fuel injection, and the use of methanol fuel.
-	BDQ	-	-	Not allocated
1983	BDR	1601	120	Closely based on the BDA, but sold as kits, for building of engines for the Caterham (one-time Lotus) Super Seven sports cars. Also built in 1.7-litre form, in 150 bhp and 170 bhp tune.
1981	BDT	1778 (RS1700T) 1803 (RS200)	200 250	Turbocharged version of light-alloy block BD engine, evolved by Ford for Escort RS1700T. 200 engine kits built by Cosworth, assembled by JQF; same engines re-designed, rebuilt, and slightly enlarged for use in Ford RS200.
1986	BDT-E	2137	500	Enlarged, 'evolution' version of BDT engine, developed by Brian Hart Ltd,

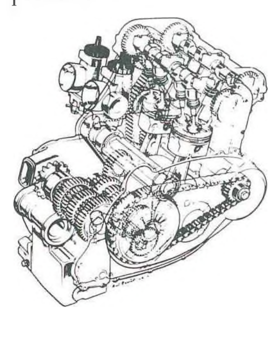
Count the trumpets and you will see that this is a V-6 engine, actually the Ford-based GA unit. Mike Hall designed it as a 'conversion kit', for use in Capri RS3100 cars in Group 2 production touring car racing.

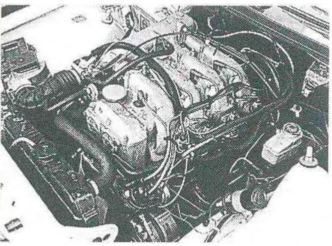


The 60-degree V-6 GA engine was ready for the 1974 touring car racing season, in 3.4-litre form. It produced 440 bhp at first, this eventually being boosted to more than 460 bhp for F5000 single seaters.

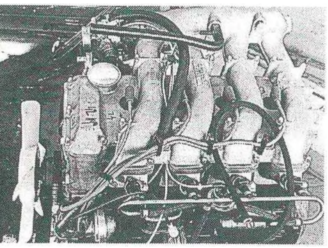


A real rarity – the twin-cylinder motorcycle engine, designed by Cosworth for Norton to use, both in racing and in a road machine. Norton's financial troubles killed this off before it could prove itself.

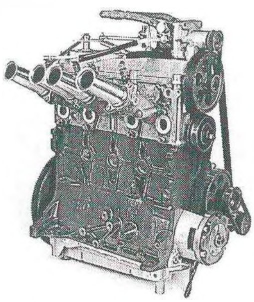




Cosworth carried out redesign and development work for GM on a 16-valve engine, eventually producing the successful 2.4-litre KA-series Opel Ascona/Manta 400 unit of the early 1980s. This was the 'road car' engine, with inlet passages swept up and over the cam cover.



The road-car version of the KA-Series Opel Ascona/Manta 400 engine. On competition cars the inlet manifolds and injection system were discarded, the head was machined back, and dual-choke Weber carburettors were used instead.



The OA-Series Formula Super Vee engine for VW was partially successful, but soon sidelined in favour of more important projects.

for use in RS200'E' models. 25 engines built, and many more parts.

Chevrolet Vega engine family

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1972	EAA	1995	275	Based on the USA Chevrolet Vega light-alloy cylinder block – the first Cosworth 'stock-block' engine *not* to be based on a Ford cylinder block: 16-valve cylinder head of similar layout to current BD-series, also with belt-driven twin overhead camshafts. Designed for F2 and Sports Car racing, but only successfully used in Sports Cars. Let down at first by a lack of cylinder block strength. Later productionized, producing 122 bhp, built by Chevrolet, for use in the Chevrolet Cosworth Vega of mid-1970s.

Ford 'Essex' V-6 racing engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1973	GAA	3412	440	Based on the existing Ford Capri/Granada V-6 block, but with light-alloy 4-valve, twin-cam cylinder heads, and cogged belt drive to the camshafts. The original engine was a 2994 cc unit: the GA was a bored out version. For use in Group 2 touring car racing in the Ford Capri 3100, and later used in F5000 single seaters. 100 kits produced, and sold through Ford Motorsport.

Twin-cylinder motor cycle engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1974	JAA	750	65	A parallel-twin water-cooled motor cycle engine, with twin balancer shafts, designed for Dennis Poore of Norton Villiers. Effectively using the 'top end' of the DFV engine, with two camshafts and eight valves. For projected use in a production motor cycle. Norton Villiers struck financial trouble, and the project was cancelled after about 30 engine/transmission units were built.

1975	JAB	750	95/ 110	A racing version of the JAA, at first with carburettors, later with fuel injection. Interest in this engine revived in the late 1980s!

Opel Ascona 400/Manta 400 engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1978	KAA	2410	240	Based on the existing Opel diesel cylinder block, and an existing Opel design, this 16-valve, twin-cam unit was developed for the Group 4 Opel Ascona 400 'homologation special'. In road-car tune, with injection, it produced 140 bhp, but for rallying, twin dual-choke Weber carbs were used. From 1982 it was also used in the Manta 400 which replaced the Ascona 400, and up to 275 bhp was available.

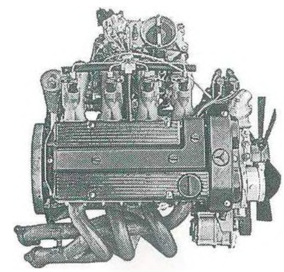
VW Formula Supervee engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1979	OAA	1600	170	This design was based on the single overhead camshaft four-cylinder VW Golf design, and was developed purely for the one-engine Formula Supervee racing formula.

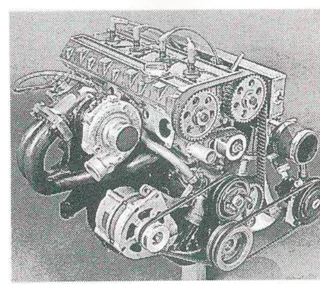
Overhead-cam Chevrolet vee-8 conversion

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1983	AB	-	Not quoted	Early in the 1980s, with racing in North America in mind, Cosworth completed the re-design and conversion of the 'Big Block' Chevrolet vee-8 engine, using that company's cylinder block, but providing single-overhead-camshaft cylinder heads. This block, which had already been raced very successfully over many years in overhead-valve 'pushrod' form, could have been built in sizes up to 7.5 litres, and would have been immensely powerful. By the time the engine was being tested, more important priorities had intervened in Northampton, and the engine was never put into production.

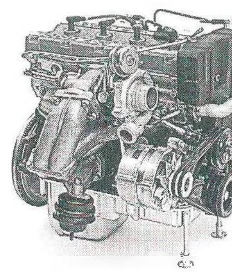
Cosworth produced a very neatly-detailed 16-valve twin-cam engine for Mercedes-Benz, this being the WA-Series engine fitted to the 190E models, in 2.3-litre and 2.5-litre form.

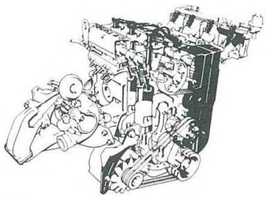


The original Sierra RS Cosworth engines – the YBA prototypes of 1984 – looked like this, with tubular exhaust manifolds, sideways-facing thermostat housings, and a different style of cam cover . . .



. . . whereas series-production YBBs had a camshaft cover designed by Ford, cast exhaust manifolds, and a relocated thermostat position.

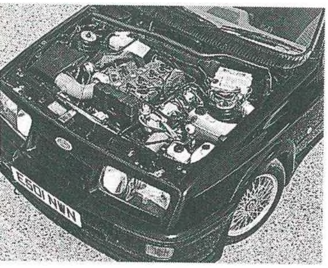




The Sierra RS Cosworth (YBB) series engine laid bare.

Mercedes-Benz engine

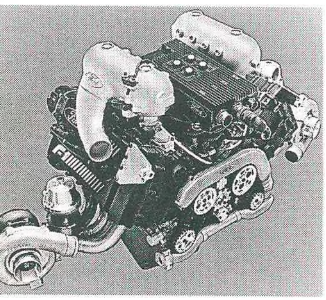
Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1984	WAA	2297	187	Like several Ford engines, a twin-over-head camshaft conversion of an existing engine, this time for Mercedes-Benz on the M102 four-cylinder unit. Originally conceived as a competition engine, then re-developed for use in a road car, the 190E 2.3-16 model. This was Cosworth's largest-quantity project to that point, with completely assembled heads supplied to West Germany at the rate of 5,000+ units per year.
1988	'WAB'	2498	195	The 16-valve Mercedes engine was enlarged to 2.5-litres for the start-up of 1989 model-year production.
1989	WAC	2463	201/330	'Evolution' short-stroke version of 'WAB' engine, for Group A racing use in 2.5-16 model in German touring car racing.
1990	WAC	2463	235/330	



Compared with the original YBB type, the Sierra RS500 engine (the YBD type) had a larger turbocharger and air passages, plus an eight-fuel-injector inlet manifold – this filled the Sierra's engine bay almost completely!

The Ford Sierra road-car engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1984	YAA	1993	Undisclosed	Originally a privately-financed Cosworth project, with 16-valve, twin-overhead-cam, cogged-belt camshaft drive, on a Ford T88/'Pinto' block. Intended to be normally-aspirated, for sale to small specialist manufacturers. Three engines built.
1984	YBA	1993	200	Prototype version of later YBB production engine. Ten engines built.
1985	YBB	1993	204	The turbocharged version of YAA, as commissioned by Ford for use in the Sierra RS Cosworth road car 'homologation special'. The first-ever Cosworth road car engine to be totally built at the new Wellingborough factory. More than 5,000 made in 1986 so that Group A/Group N homologation of the Sierra could be achieved. From 1988, used in the Sierra (Sapphire) RS Cosworth four-door saloon.
1986	YBC	1993	280/ 300	Group A Rally engine, based on the YBB, gradually with more power extracted.
1987	YBD	1993	225	The uprated 'Evolution' version of the YBB, used in the 500-off Sierra RS500 Cosworth hatchback model. Com-



Cosworth's most powerful engine – so far – has been the 120-degree 1.5-litre twin-turbo Type GB F1 engine, as produced for Ford in the 1986 and 1987 seasons. In final form, it produced more than 1,000 bhp, or more than 666 bhp/litre.

				pared to the YBB, there was a larger turbo-charger, eight instead of four fuel injectors, and the car itself used an enlarged intercooler and inlet passages. Capable of more than 500 bhp racing tune, making the Sierra *the* dominant Group A race car of the late 1980s (see YBF, below).
1987	YBE	1993	-	Engine for Ford Industrial Power Products, identified by black 'Non-Cosworth' cam cover. Built to purchasers' specification, but only fitted in Ford-approved installations. The Panther Solo used a YBE derivative.
1987	YBF	1993	400+	Race version of YBD 'Evolution' engine, with 400+ bhp nominal, though much more regularly obtained.
1989	YBG	1993	207	Later version of YBB, certified for 83US emissions, and capable of running on 95 octane unleaded fuel.
1989	YBH	-	-	Not yet disclosed
1989	YBJ	1993	207	Similar to YBG, this time certified for 15.04 emissions, and 95 octane unleaded fuel.
1990	YBM	1993	300+	Motorsport derivative of the YB series. Rally use for Escort RS Cosworth, etc.
1992	YBT	1993	227	Escort RS Cosworth road-car engine, with T35 turbocharger, Weber-Marelli engine management and 'blue top' cam covers.
1994	YBP	1993	227	For revised Escort RS Cosworth road car, with T25 turbocharger, Ford EEC IV management, and reshaped 'silver top' cam covers.

- other YB derivatives have been developed, but not yet publicised.

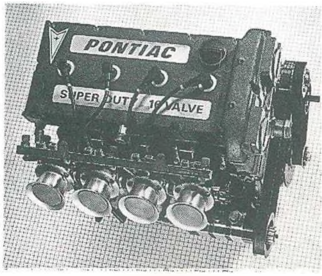
The turbocharged V-6 Ford F1 engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1986	GBA	1497	750 (later 1000)	A 120-degree V-6 twin turbocharger engine developed for Ford, for use in F1 racing in 1986 and 1987. 1,000 bhp available, with 'rocket fuel', for Benetton, in 1987.

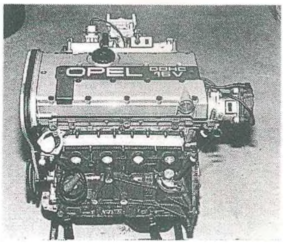
GM-Pontiac engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1987	DBA	3000	370	Typical Cosworth twin-cam 16-valve conversion for GM (Pontiac division) Super Duty four-cylinder engine, for

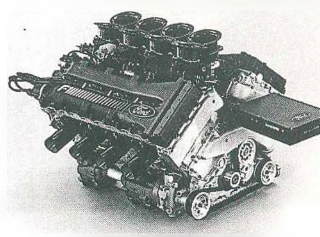
Cosworth produced a high-performance 16-valve engine for GM, labelled 'Pontiac Super Duty 16 Valve', but known, internally, as 'DBA'.



The Cosworth KB engine was produced on the basis of GM-Europe's Family 2 2-litre cylinder block, and is now fitted to a whole variety of Opel and Vauxhall passenger cars.



New for 1989 was the normally-aspirated 3.5-litre V-8 engine, the HB unit, which had a 75-degree cylinder bank angle. It was more compact than the DFV/DFR/DFZ series, and lighter. A peak power rating was not revealed in 1989, but it was thought to be nearly 650 bhp.



				use in the USA. Fuel injected, and normally aspirated, with chain drive to the camshafts. To be sold in kit form.

Vauxhall-Opel 2-litre 16-valve engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1987	KBA	1998	156	16-valve twin-cam conversion of Vauxhall-Opel 'Family 2' 2-litre engine, fitted to Astra, Kadett, Vectra, Cavalier models. Cylinder head casting and complete head assembly by Cosworth at Worcester/ Wellingborough at first.

Normally-aspirated Ford F1 engine

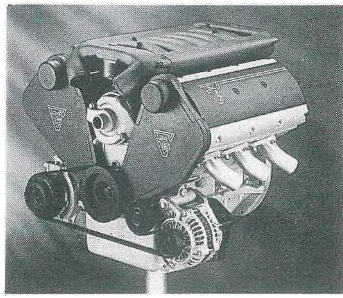
Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1989	HB	3500	600+	An all-new 75-degree V-8 Formula 1 engine, designed for Ford for use in the Benetton cars in 1989 and beyond. Though equipped with twin cams per bank, and four valves per cylinder, no carry-over parts from the famous DFV series. Very few details made public at first. First win in Japanese GP, October 1989, two more victories by 13,000rpm Series IV types in 1990. Peak power then approached 680bhp. Used in the successful Jaguar racing sports cars of 1991 (and known as the HBC), its development continued. At least 700 bhp was available for Benetton in 1992, while Benetton and McLaren both used 700 bhp-plus 'air-valve' Series VII and Series VIII types in 1993, when there were six GP victories. By this time the engines revved to 13,500 rpm. When the Zetec-R vee-8 arrived, the HB then became available as a 'customer' engine for other F1 teams: four F1 teams used HBs throughout 1994, and the 1995 F1 3-litre 'customer' engine was effectively a further redesign.

Cosworth MBA V-6 engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1991	MBA	2497	226	Cosworth's MBA design was a concept engine, to demonstrate and evaluate

many novel features. Although it appeared to be a conventional four-valves/cylinder, twin-camshafts-per-bank road-car unit, there were many advanced details. Cosworth also revealed that this could be the basis of a modular range, which may explain the 90-degree vee angle and the very compact dimensions. A possible vee-12 was mentioned, and even three-cylinder derivatives would have been possible. It was meant to be completely 'green' – and it was purely a private venture.

When previewed in 1991 development was at a very early stage, and although engines were tested (and demonstrated) in a four-wheel-drive Audi 80 quattro (where it fitted the engine bay very easily), the project did not find a customer, though many features may be used in later Cosworth designs. Innovative design details included the use of a contra-rotating balance shaft which doubled as an oil separator, and two throttles per cylinder, the second being inside the head casting itself.



The 24-valve vee-6 MBA was a pure research engine, designed to demonstrate Cosworth's engineering talents in a new package. Some detail features, demonstrated only to important clients, have not yet been revealed to the general public. The MBA was also advertised as a modular unit, meaning that vee-8, vee-12 and other derivatives of the same basic layout could also be produced at will.

Ford Scorpio 24-valve engine

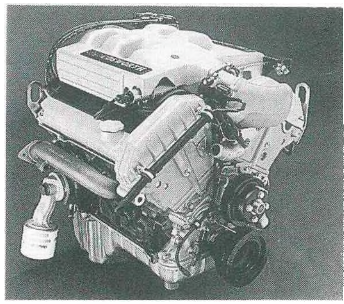
Year	*Type*	*Size (cc)*	*Bhp*
1991	FBA	2935	195
1992	FBE	2935	300
1994	FBC	2935	210

Comment

Having absorbed Brian Hart Ltd in 1987, Cosworth acquired the rights to a conversion on the Ford Cologne 60-degree vee-6 engine, to a twin-cam 24-valve unit with new cylinder heads. This then became a full Cosworth/Ford mainstream engineering programme, eventually being installed in the Scorpio 24V model.

Manufactured in a new factory at Wellingborough, the original FBA was a refined and flexible road-car unit, with 'only' 195 bhp. Fitted with chain-drive to the camshafts, with Ford EECIV engine management, and designed to pass every standard Ford test, and to run in conjunction with exhaust catalysts, this engine was intended for use in Ford's flagship, and was always mated to automatic transmission.

Thus equipped, the Scorpio was



The FB was the productionised version of a 24-valve four-cam vee-6 unit originally conceived by Brian Hart Ltd. Based on the long-established Ford-Cologne vee-6 block and bottom end, in production form it was a totally refined, and environmentally 'green' road-car unit, which went on sale in 1992.

much more refined than before, but was transformed from a 123 mph to a 136 mph car, with acceleration to match. Cosworth laid down capacity to build 7,000 engines a year, at the same time offering a race-tuned version (the FBE) producing a reliable 300 bhp. For the revised 1995-model Scorpio, Cosworth and Ford then produced the 210 bhp FBC, and development continued.

During the initial development phase, Cosworth also built single-overhead-camshaft-per-bank versions of the vee-6 engine, but these were never revealed.

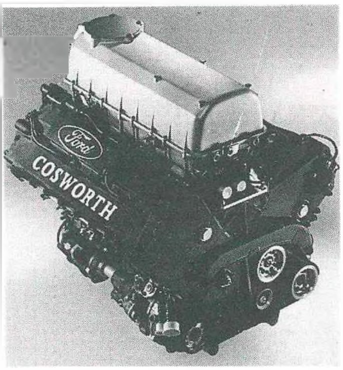
[In 1994 Cosworth also took over complete manufacture of the overhead-valve Ford-Cologne vee-6 engine.]

Ford-Cosworth turbocharged Indycar engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1991	XB	2650	750–800	Although it had a 75-degree vee-8 layout, like the HB F1 engine of the period, the XB was a totally new turbocharged vee-8 engine with different cylinder block, head and other major castings and forgings. It was specifically designed for Indycar racing, where there was a strict limit on boost pressure, and where the engines were fuelled by an alcohol-based blend.

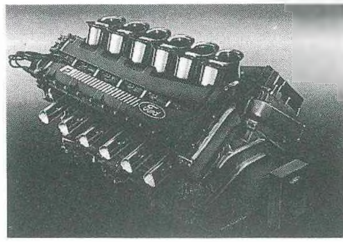
Like the HB, it had four-valves per cylinder and twin-camshaft cylinder heads. Also like the HB, virtually no other information was ever issued, for rebuilds were always carried out by Cosworth itself, either at Northampton (for Newman-Haas) or at Cosworth's USA base at Torrance, California.

First used in 1992, the XB won six of that year's 16 races (Michael Andretti's Newman-Haas Lola was second in the Championship), while in 1993 it powered Nigel Mansell's Newman-Haas Lolas to his sensational 'rookie' victory in the Indycar Championship, there being six race victories in all. More victories were gained in 1994, but the competition was even tougher. Although Indycar engine sizes were due to be reduced to 2.2 litres for 1996



Designed to replace the long-running DFX/DFS CART/Indycar engine, the 2.65-litre XB was launched in 1991. Although there were a few similarities to the HB, the XB was totally different in detail. Instantly competitive, it provided race-winning power in the next few seasons, most noticeably for Nigel Mansell, who became Indycar Champion in 1993.

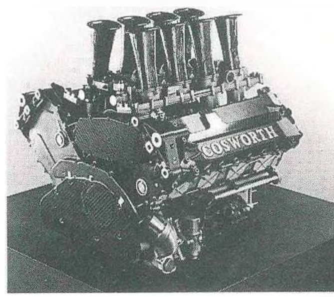
(when a new engine had to be designed), development continued for 1995.



The 3.5-litre VB vee-12 race engine was designed in 1991 and 1992 as an F1 engine for Benetton to use as a successor to the compact HB vee-8. Although development was protracted, and competitive power was achieved, the VB was never fitted to a car, and the project was later cancelled. This project drawing was the only illustration ever issued by Ford, in mid-1991.

Ford vee-12 F1 race engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1991 /1992	VB	3500	Not quoted	Intending to replace the successful HB F1 engine in the Benetton F1 car, Ford asked Cosworth to design a 3.5-litre 70-degree vee-12 unit. Extensively bench tested, but never installed in a car, the vee-12 eventually produced more power than the HB, which was an ever-improving vee-8 during this time. Cosworth persevered with a modified vee-12 design, the final version being slightly longer and less cramped in its detailing than the original, but because the architecture of the Benetton changed so much to meet changing regulations, the VB was abandoned. In the meantime, the Series VI/Series VII/Series VIII HB vee-8s had become more effective. No VB vee-12 was ever seen in public, or installed in an F1 car, before cancellation. In its place, Cosworth therefore developed the very successful Zetec-R vee-8 F1 unit, which took over at Benetton in 1994.



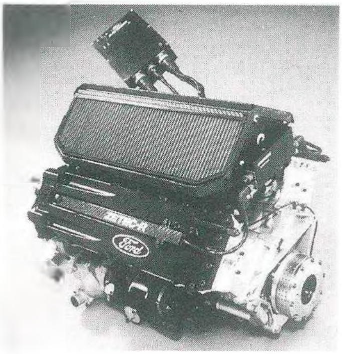
The AC was a 90-degree 3-litre race engine, especially designed for use in European F3000 racing, where the venerable DFV had been successful for so long. Introduced in 1993, it immediately became the most successful power unit in the category.

Cosworth F3000 vee-8 race engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1993	AC	3000	Not officially quoted (approx 450 bhp)	To follow the famous DFV engine, the legendary ex-F1 unit which was still successful in much-modified form in F3000 in the early 1990s, the AC was designed as an all-new purpose-built 3-litre vee-8 for this Formula. Except that this was a 90-degree vee-8 engine with twin-cam cylinder heads and four valves per cylinder, limited by regulation to 9,000 rpm, very little was ever revealed about its character – not even the horsepower developed! Cosworth's customers were expected to accept that it would be competitive

– and it was!

Immediately successful in the latest dominant Reynard chassis, the AC dominated the F3000 scene of 1993, being used by Olivier Panis to win the International series. Using AC power, no fewer than 14 drivers scored points in that International series, and the engine was equally successful in 1994.



No sooner had the VB vee-12 engine been abandoned, than work began on a brand-new F1 vee-8. This design, originally coded EC, but later known as Zetec-R, was phenomenally successful in its first – and only – season as a 3.5-litre engine, when Michael Schumacher's Benettons won the World Driver's Championship.

Ford Zetec-R F1 race engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1994	Zetec-R (originally called EC)	3500	750+ (est'd by author)	Once the F1 VB vee-12 engine programme was abandoned, Cosworth designed yet another compact, 75-degree, four-valve engine for Ford. The new Zetec-R engine (so named for publicity purposes, to align with Ford's latest road-car engines, though its original Cosworth project code was EC) took over from the HB at Benetton in 1994. Though with a similar vee-8 layout to the HBs, the Zetec-R was different in every detail. Compared with the HB, it was longer, with larger cylinder bores and shorter strokes, and more sophisticated detailing.
1995		3000	670 (est'd by author)	

Particularly when driven by Michael Schumacher, Zetec-R powered Benetton B194s were incredibly successful in 1994, winning the majority of F1 races. On-screen TV telemetry relayed from Benetton confirmed that the engines revved to 14,500 rpm, and rumours of 750 bhp and more (at least 214 bhp/litre) were not denied, before FIA rule changes reduced top-end outputs during the season.

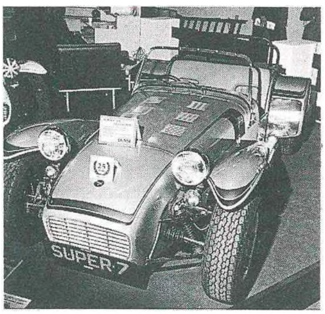
With a new 3-litre F1 engine formula due to be imposed for 1995, the original Zetec-R was therefore a one-season wonder, and a total internal redesign was carried out to make it a 3-litre unit for that year, when Sauber became the Ford-backed 'works' team.

Ford ED F1 race engine

Year	*Type*	*Size (cc)*	*Bhp*	*Comment*
1995	ED	3000	650 (est'd by author)	When the FIA imposed new regulations for F1 in 1995, the engine size was reduced from 3.5 to 3.0 litres. This immediately rendered the successful HB obsolete. Teams which had previously used the HB, or other 3.5-litre F1 engines, needed a new 3-litre F1 engine to allow them to stay in racing. Cosworth designed a new 3-litre engine for 1995, which was a 75-degree vee-8 using many of the successful and proven features of the HB.

Cosworth-engined road cars

No engine, not even a Cosworth engine, can prove itself, unless it powers the right sort of car. Over the years, Cosworth-designed, developed, or manufactured, engines have been used in a fascinating variety of road cars. Here, in summary, is the road car story. So that I cannot be accused of favouritism, they are listed in alphabetical order:



Caterham took over manufacturing rights of the Lotus 7 in the mid-1970s, changed the car's name, and sold the car very successfully in the years which followed. Some of these cars were fitted with Cosworth BDR engines.

Caterham Super Seven (introduced: 1974)

This two-seater sports car, the direct descendant of the famous Lotus Seven model, has been built with a whole variety of Ford-based four-cylinder engines. Like the Lotus Sevens themselves, Caterhams have used several different units – Lotus-Ford twin cams, Vegantune VTA twin-cams, and modified Ford 'Kent' units. The most powerful option of all, however, was the Cosworth BDR unit, offered either as a 155 bhp/1,598 cc or a 170bhp/1,698 cc size.

Basic layout: Two-seater open sports car, front engine/rear drive.

Performance: (170 bhp version) Top speed 120 mph, 0-60 mph 5.0 sec, typical fuel consumption 27 mpg.

The Chevrolet Cosworth Vega.

Chevrolet Cosworth Vega (produced: 1975 and 1976)

As detailed in the text, the Chevrolet Cosworth Vega used a productionized version of the EAA 16-valve engine, which had originally been designed for F2 and sports car racing.

Development of the road car was protracted, and although it was mentioned in 1973 and 1974, it did not go on sale until the spring of 1975. It was built in the USA, and sold almost entirely in that continent. It was a limited-edition, top-of-the-line derivative of the mass-production Chevrolet Vega car. At this stage, normal

Vegas had 2.3-litre single overhead-camshaft engines producing 78 or 87 bhp. The productionized EA unit was a 2.0-litre twin-cam producing 122 bhp. In 16 months, 3,507 Cosworth Vega production cars were built.

Basic layout: Three-door four-seater hatchback, front engine/rear drive.

Performance: Top speed approximately 112 mph, 0-60 mph 9.0 sec.

Ford Escort RS1600 (produced: 1970–74)

Ford's first 'hot' Escort was the Twin-Cam of 1968-1971, which used the Lotus-Ford twin-cam for which Cosworth had provided development and racer-tuning expertise.

To replace the Twin-Cam, Ford produced the RS1600, which was effectively a Twin-Cam model, re-engined with the first of the 16-valve BDA engines. Cosworth manufactured some of the pieces, but never assembled the engines, which were originally sourced from Harper Engineering of Letchworth. All road-car engines were 1.6-litre units, with twin horizontal twin-choke Weber carburettors, rated at 120 bhp (DIN), with cast iron blocks at first, but light-alloy blocks from the autumn of 1972.

The RS1600 road car was assembled at the AVO plant at Aveley, but many RS1600 competition cars were 'created' from parts, or by the re-engining of tired Twin-Cams. The RS1600, in 1.6 litre, 1.8-litre and eventually in light-alloy 2.0-litre form, was an incredibly successful competition car. Ford has never revealed accurate production figures for this car.

Basic layout: Two-door four-seater saloon, front engine/rear drive.

Performance: Top speed 113 mph, 0-60 mph 8.9 sec, typical fuel consumption 22 mpg.

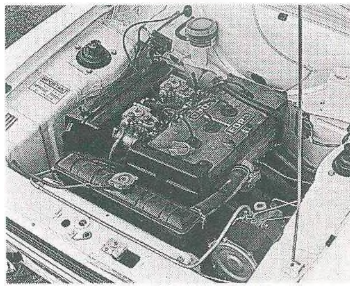
Ford Escort RS1800 (produced: 1975–77)

Ford's mainstream Escort was restyled for 1975, which meant that the RS1600 was rendered obsolete. After a short interval, a new BD-engined car, the RS1800, took over.

Like its predecessor, the RS1800 was very closely related to other Escort RS models of the day, having the new and rather more angular body style. The engine was no longer 'pure' Cosworth, for it was an enlarged BD type (with a 1,835 cc/86.75 mm bore × 77.62 mm stroke layout), and a single downdraught dual-choke Weber carb, producing 115 bhp (DIN).

Ford's BDA-engined Escort RS1600 was an extraordinarily successful rally car. This was Hannu Mikkola's 1.8-litre BD-engined 'works' car, testing before the start of the 1972 Safari rally, which he went on to win.

The Escort RS1600's BDA installation left little space for other components.



In standard road-car form, the Escort RS1800 looked simple, and stark. In that tune the BD-based engine developed a mere 115 bhp, but Group 4-tune rally engines sometimes produced 270 bhp or more.

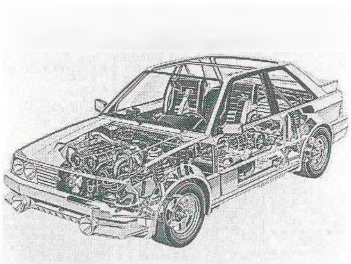
Ford revealed the original BDT-engined Escort RS1700T in 1981, well before it was ready to go into production.

Very few of these cars were produced as road cars, the engines being assembled by a variety of specialists, including Brian Hart Ltd. The first few cars were built at the British Halewood factory, but most RS1800s were sent over from West Germany as RS Mexicos, where they were re-engined and re-badged at the Aveley plant. Accurate production figures are not known. As with the RS1600s, many RS1800s were 'created' for motorsport purposes, some by the re-shelling of old RS1600s.

Basic layout: Two-door four-seater saloon, front engine/rear drive.

Performance: Top speed 111 mph, 0-60 mph, 9.0 sec; typical fuel consumption 27 mpg.

Ford Escort RS1700T (announced: 1981, cancelled 1983)

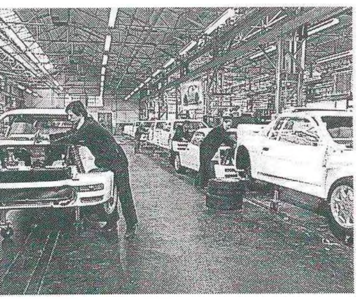


This was the anatomy of the Escort RS1700T, complete with 'North-South' installation of the BDT engine, and the rear-mounted transmission.

For the 1980s, and for the new 'Group B' category, Ford proposed to build a new 'homologation special' called the Escort RS1700T. Although it looked superficially like the newly-announced transverse engine, front-wheel-drive Escort Mk 3, it had a different floorpan/running gear layout – with an in-line engine driving the rear wheels through a rear transaxle. To take advantage of new regulations, the engine was a 1.78-litre turbocharged and fuel-injected version of the famous BD family (which, with the 'equivalency factor' built in, made it equal to a 2.5-litre normally aspirated unit); this was basically a Ford-developed unit, dubbed BDT (T = Turbocharged).

200 cars were slated to be built in 1983, with road cars producing 200 bhp, and full-house rally cars up to 350 bhp or more.

Engine kits were manufactured by Cosworth, but JQF Engineering carried out assembly. The engines were fine, but the rise of four-wheel-drive rendered the car itself obsolete before sales could begin. In March 1983, just as production-build preparations were well-advanced, the new motorsport supremo, Stuart Turner, cancelled the project. The engines went back into store – to be used in the RS200 project which followed.



Ford produced 200 mid-engined/four-wheel-drive RS200s in 1985/86, using BDT engines rebuilt from those originally designed for use in the Escort RS1700T.

Basic layout: Three-door, two-seater hatchback, front engine/rear drive.

Performance: No authentic figures recorded.

Ford RS200 (produced: 1985–86)

To replace the cancelled Escort RS1700T project, Ford Motorsport developed the Group B RS200 coupé, which bore no relation to any other existing Ford. This was a mid-engined two-seater coupé, with permanent four-wheel-drive, a steel/Kevlar/carbon fibre chassis 'tub', and glass-fibre bodywork.

The chosen engine was a slightly enlarged and improved version of that developed for the still-born RS1700T, with a larger cylinder bore, different manifolding/turbo layout, and Ford fuel injection and EECIV engine electronics. The 1,803 cc unit was 'equivalent' to a normally-aspirated 2,524 cc engine – for Ford intended to enlarge it to the full 3-litre class limit in due course. For road use 250 bhp was offered, and the 1986 rally cars had 420 bhp, rising to 450 bhp before the end of the season.

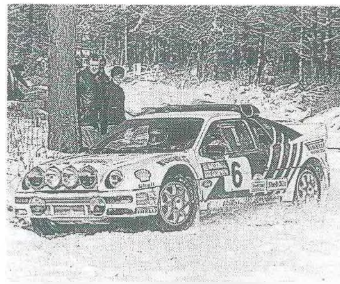
A total of 200 cars were assembled (at an ex-Reliant factory) in 1985/86, but following the cancellation of Group B by the sporting authorities, many cars were then dissembled. The balance were further developed as road cars, and all were sold off by the end of 1989. 25 Evolution cars were produced, almost all for use in motorsport.

Not only were 300 bhp and 350 bhp conversion kits of the 1.8-litre version offered by Ford, but Brian Hart Ltd developed the 2.1-litre BDT-E (E = Evolution) engine for motorsport purposes. In 'standard' form this produced more than 500 bhp, in 'sprint' configuration for rallycross approximately 650 bhp was available.

Basic layout: Two-seater sports coupé, mid-engine/four-wheel drive.

Performance: (250 bhp version) Top speed 140 mph, 0-60 mph 6.0 sec, typical fuel consumption 18 mpg.

In standard road-car form the RS200's 1.8-litre engine developed 250 bhp, but 'works' rally cars produced 420 bhp at first, and 450 bhp by the end of 1986.



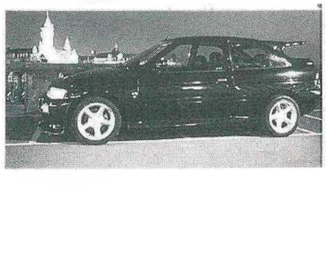
Ford Escort RS Cosworth (introduced: 1992)

As the ultimate in YB-engined 'homologation specials', Ford developed a new car using a shortened/modified Sierra Cosworth 4x4 platform and running gear, clothed in a much-modified three-door Escort superstructure, with ambitious and extrovert aerodynamic aids, including a vast rear spoiler.

Compared with the Sierra Cosworth 4x4, the Escort used an uprated YB-type engine, with larger turbocharger, and was rated at 227 bhp at first. More than 2,500 cars were built before the end of 1992, this ensuring sporting homologation into Groups A and N. From mid-1994 a new version took over, with a smaller (Type T25) turbocharger and Ford ECU electronics.

Using much-modified Group A machines, with seven-speed transmissions, the 'works' rally team won numerous

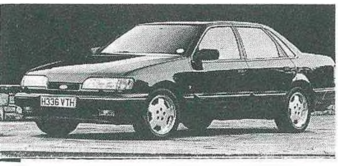
Conceived by John Wheeler at Ford's Motorsport department, the Escort RS Cosworth was always seen as the ultimate 'homologation special' for Ford to use in World Championship rallies. A modified Escort body shell hid a shortened Sierra Cosworth 4x4 platform, with YB power to provide the performance. Production cars went on sale in 1992, and 'works' cars began winning World Championship events the following year.



World Championship rallies in the first two seasons, including the prestigious Monte Carlo Rally of 1994.

Basic layout: Three-door four-seater hatchback, front engine/four-wheel drive.

Performance: Top speed 137 mph, 0-60 mph 6.2 sec, typical fuel consumption 21/22 mpg.



The Ford Scorpio 24V (available as saloon, hatchback or estate car) used the FB vee-6 engine, and was Ford's early-1990s flagship. Surprisingly, it was only ever available with automatic transmission. The engine was built at Wellingborough alongside the famous YB Sierra/Escort Cosworth four-cylinder unit.

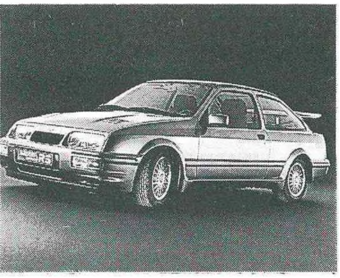
Ford Scorpio 24V (introduced: 1991, facelifted 1995)

Having developed Brian Hart's original four-cam vee-6 engine concept to the production stage, Cosworth then supplied it to Ford for use in a Scorpio 'flagship' model. Intended purely to be a top-of-the-range car, rather than a sports saloon, Ford asked for the new 195 bhp FB-Type Cosworth engine to be 'green' and totally flexible, offering it only with automatic transmission in a large (187 in/4,744 mm long) car which weighed about 3,280 lb/1,488 kg.

This was definitely the least sporting of all cars powered by Cosworth engines which had been released up to that time. When the Granada/Scorpio range was extensively revised for 1995, the 24-valve engine was itself up-graded, to 210 bhp.

Basic layout: Four-door saloon, five-door hatchback, five-door estate car, full five-seater, front engine/rear-wheel drive.

Performance: Top speed 136 mph, 0-60 mph 8.5 sec, typical fuel consumption 22 mpg.



Ford designed the Sierra RS Cosworth as a competition car, but built 5,000 YBB-engined examples in 1986 to gain Group A Homologation. In standard form the car produced 204 bhp . . .

Ford Sierra RS Cosworth (produced: 1986)

With Group A motor racing in mind, Ford developed a very special version of the Sierra, which became a 'cult' car as soon as it went on sale, and also became a very effective rally car in the late 1980s. Using a three-door version of the Sierra structure, but graced by the massive 'whale tail' type of rear spoiler, it was powered by Cosworth's turbo-charged YB-type 16-valve two-litre engine, and backed by a Borg Warner 5-speed gearbox. In standard form (YBB) this engine produced 204 bhp, but for rally use around 300 bhp was available, and up to 340 bhp was eventually produced for Group A racing.

. . . but as a fully-tuned Group A Rally car it produced about 300 bhp. This was Jimmy McRae on his way to winning the Scottish International rally in 1988.

More than 5,500 examples were produced at Genk, in Belgium, in the second half of 1986. Later developments included the 500-off RS500 Cosworth, the four-door saloon Sapphire RS Cosworth, and the Cosworth 4x4.

Basic layout: Three-door four-seater hatchback, front engine/rear drive.

Performance: Top speed 145 mph, 0-60 mph 6.0 sec, typical fuel consumption 21 mpg.

Ford Sierra RS500 Cosworth (produced: 1987)

To take advantage of the 'Evolution' clauses in Group A Regulations, Ford arranged to build exactly 500 derivatives of the Sierra RS Cosworth, calling them RS500 Cosworths. Partly-built at Genk as Sierra RS Cosworths, these cars were completed by Aston Martin Tickford at Bedworth, near Coventry, the 'conversion' work including the installation of an 8-injector 224 bhp version of the Cosworth YB engine, the YBD, which had a larger turbo-charger, and further improvements to the car's aerodynamics.

Road cars were little faster than the 'standard' RS Cosworth, but race-tuned engines were capable of more than 500 bhp. Such cars won the World Touring Car Championship in 1987, the European Touring Car Championship in 1988, and countless other touring car races all round the world.

Basic layout: Three-door four-seater hatchback, front engine/rear drive.

Performance: Top speed 154 mph, 0-60 mph 6.0 sec, typical fuel consumption 20 mpg.

Ford Sierra Sapphire RS Cosworth (introduced: 1988)

From the beginning of 1988, Ford took the Sierra + Cosworth theme a stage further, marrying the original (204 bhp) Sierra engine and drive-line package to the four-door 'Sapphire' saloon version of the Sierra structure, and making this a mainstream production car. The three-door machine had been a 'homologation special', built only for a short time, but the Sapphire was a refined, regular-production, 'businessman's express'. It was never intended for use in front-line motorsport, though it proved to be very competitive in Group N 'showroom' form. A four-wheel drive version was launched in 1990.

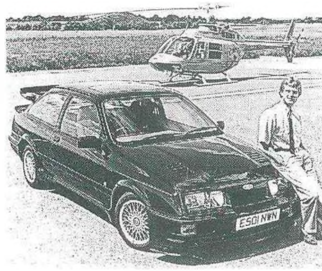
Basic layout: Four-door four-seater saloon, front engine/rear drive.

Performance: Top speed 142 mph, 0-60 mph 6.0 sec, typical fuel consumption 20 mpg.

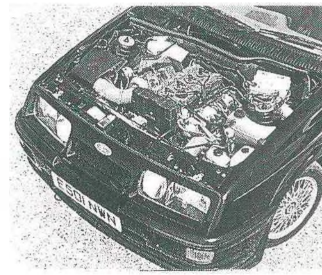
Ford Sierra Cosworth 4x4 (produced: 1990–92)

The final development of the Sierra Cosworth theme came in 1990, when Ford replaced the rear-drive Sapphire RS

The Ford Sierra RS500 Cosworth was the 500-off 'Evolution' version of the Sierra RS Cosworth, with the more powerful (224 bhp) YBD-type engine, and refined aerodynamic aids. Here is F1 driver Jonathan Palmer posing on the car, with his own helicopter in the background.



The YBD engine powered the Sierra RS500 Cosworth, and is identified by the larger turbocharger, and the eight-injector inlet manifold installation.



Proof that Ford built as many Sierra RS Cosworths as claimed in 1986!

Cosworth with the Sierra Cosworth 4x4, by adding an updated version of the Sierra XR4x4 four-wheel-drive installation to the existing chassis and structure. This car used the new MT75 five-speed transmission, and according to Ford the uprated YB-type engine developed 220 bhp. More than 5,000 cars were produced quickly in 1990 so that Ford could use it as a World Championship rally car; assembly continued, but at a lower rate, thereafter.

The Sierra Cosworth was a successful rally car, particularly in Group N categories, but there was no suitable racing category for it.

Basic layout: Four-door four-seater saloon, front engine/four-wheel drive.

Performance: Top speed 144 mph, 0-60 mph 6.6 sec, typical fuel consumption 22 mpg.

Ford's second-generation Sierra RS Cosworth was the four-door saloon Sapphire model, more of a 'businessman's express' than an homologation special. Once launched, the engine for this car took up *all* of Wellingborough's production potential.

The Sierra Cosworth 4x4 combined the four-door body style, the developed YB turbocharged engine, and Ford's latest four-wheel-drive system to produce a very effective package. Not only was this a successful road car (more than 10,000 sold), but it was also an excellent rally car . . .

This 'works' machine is seen in Portugal in 1991.

General Motors (Opel/Vauxhall) Kadett/Astra 2.0i 16V (introduced: 1987)

GM introduced its front-wheel-drive Kadett/Astra series in 1979, and introduced a completely restyled version in 1984. By the late 1980s there were saloons, hatchbacks, and estate car types. All had transversely-mounted four-cylinder engines, driving the front wheels. Most cars were Opels, but British-built/British-market types were badged as Vauxhalls.

GM contracted Cosworth to develop a 16-valve twin-cam version of the 2-litre Family 2 engine for their use, this KBA engine becoming available in 1987. Road-car engines produced 156 bhp, but full Group A competition versions produced about 220/240 bhp.

By the early 1990s the KB-type engine had become a GM 'mainstream' unit, and was used when the new-shape Astra was launched in 1991.

Basic layout: Three-door four-seater hatchback, front-engine/front drive.

Performance: Top speed 132 mph, 0-60 mph 7.5 sec, typical fuel consumption 28 mpg.

General Motors (Opel) Vectra 2.0i 16V (introduced: 1988)

GM produced its second-generation medium-sized front-wheel-drive range in 1988, to replace the successful Opel Ascona/Vauxhall Cavalier range of 1981–1988. The Cavalier name was retained, but the new Opel became 'Vectra'. Its smooth style was available as a four-door saloon or a five-door hatchback, both cars having a wide choice of transversely-mounted engine driving the front wheels. For the first time, too, a four-wheel drive alternative was also on offer.

GM installed the Cosworth-developed (KBA) 16-valve Family 2 engine in the top-of-the-range Vectra four-door saloon, also giving that car a choice of front-wheel or newly-developed four-wheel drive. GM manufactured the engines itself, in West Germany.

The sleek Calibra Coupe, introduced in 1991, used the same platform, and the same KB-type engine.

Basic layout: Four-seater, four-door saloon, front engine/front drive or front engine/four-wheel drive.

Performance: Top speed 135 mph, 0-60 mph 9.0 sec.

When it was originally launched, the Cosworth connection with GM's 16-valve engine was not publicised, but this is now generally known. The first British car to use this engine was the Vauxhall Astra GTE 2.0i 16V of 1988.

General Motors (Opel/Vauxhall) Omega 2.0i 16V (introduced: 1993)

GM introduced a new-generation Omega range in 1993, to replace the older Omega/Senator models. One of the engines used was yet another version of the Cosworth-developed but now Opel-built KB four-cylinder unit, this being rated at 136 bhp.

Basic layout: Four-door/five-door five-seater saloon/hatchback, front engine, rear drive.

Performance: Top speed 130 mph, 0-60 mph 9.3 sec, typical fuel consumption 26 mpg.

Lotus Seven (produced: 1957–73)

The Lotus Seven was a cheap-and-cheerful two-seater kit car, with a multi-tube frame, old-fashioned styling, but very light and with excellent handling. Lotus always used proprietary engines, including the Ford 'Kent' 105E four-cylinder units. By the early 1960s Cosworth had developed more powerful versions of these engines, with fitment of Cosworth Mk V and Mk VIII units into Lotus Sevens beginning in 1962.

There were four families of Lotus Seven, the third being reborn as the Caterham Super Seven (already described) in the early 1970s.

Basic layout: Two-seater open sports car, front engine/rear drive.

Performance: (95 bhp 1.5-litre ohv version) Top speed 103 mph, 0-60 mph 7.5 sec, typical fuel consumption 25 mpg.

GM's new-generation Omega (badged as an Opel or a Vauxhall), appeared in 1993, with a whole variety of engines, one of which was a development of the Cosworth KB 2-litre. By that time GM had taken over manufacture of this rugged unit.

The ultimate technical accolade, for Cosworth, was to be asked to produce an engine for Mercedes-Benz. The result was the 190E 2.3-16, a plushy but very fast four-door saloon car, which was produced from 1983 to 1988.

Mercedes-Benz 190E 2.3–16 (produced: 1983–88)

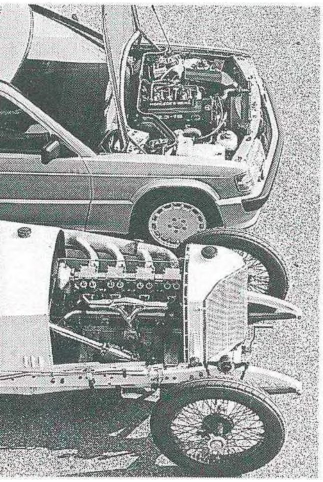
Mercedes-Benz originally approached Cosworth to produce a racing/rallying version of its new M102 four-cylinder engine. In the early 1980s, however, the motor-sport project was cancelled, but the 16-valve 2.3-litre WAA engine was refined, and fitted to the 190E 2.3-16 road car from 1983 on.

Although less flamboyant than Ford's Sierra RS Cosworth, this Mercedes-Benz model was definitely an ultra-fast road car, with front and rear spoilers and side skirts all to make the marketing, and aerodynamic, point more emphatically. The standard engine used Bosch injection, and produced 185 bhp.

As an 'autobahn-charger' the 190E 2.3-16 was a great success, with more than 20,000 examples produced. It was replaced by the larger-engined 2.5-16 in 1988.

Basic layout: Four-door five-seater saloon, front engine/rear drive.

Performance: Top speed 143 mph, 0-60 mph 8.0 sec, typical fuel consumption 24 mpg.



This Mercedes-Benz picture posed the 190E 2.3-16 alongside a pre-World War 1 race car, to emphasize that there is nothing modern about 4-valve engine technology!

Mercedes-Benz 190E 2.5-16 (introduced: 1988)

The developed version of the 190E 2.3-16 appeared in 1988, with 197 bhp/2,498 cc instead of 185 bhp/2,299 cc, and with a new type of limited-slip differential. Mercedes-Benz had lengthened the stroke, leaving the bore alone, and made other minor changes to the layout of the cylinder head, but in essence the car was unchanged.

Basic layout: Four-door five-seater saloon, front engine/rear drive.

Performance: Top speed 142 mph, 0-60 mph 7.0 sec, typical fuel consumption 22 mpg.

The 16-valve Mercedes-Benz engine was enlarged for 1988, the result being the 190E 2.5-16.

Mercedes-Benz 190E 2.5-16 'Evolution' (produced: 1989–90)

To extract the ultimate from its four-door saloon with German Touring Car racing in mind, Mercedes-Benz built two 'evolution' batches of the 2.5-16 model in 1989 and 1980. 502 cars were built in each year, with improved aerodynamic aids, and a shorter-stroke/larger-bore version of the engine – 2,463 cc instead of 2,498 cc. Both types, therefore, were 'homologation specials', the 1989 model being rated at 201 bhp, the 1990 'Evolution II' model at 235 bhp, though up to 350 bhp was available in Group A racing tune.

Basic layout: Four-door five-seater saloon, front engine/rear drive.

Performance: No authentic figures available.

Opel Ascona 400 (produced: 1979–80)

To provide GM with a potential rally winner, Opel produced the Ascona 400 model, the '400' referring to the number of cars which had to be manufactured to ensure homologation into the top, Group 4, category.

The basic Ascona was a conventional front-engine/rear-drive range of family cars. The Ascona 400, however, used a two-door saloon version of the range, with a Cosworth-developed 16-valve twin-cam (KAA) 2.4-litre engine. In road-going trim, this engine had 140 bhp and fuel injection, but for rally use it had 240 bhp (a figure later raised to 275 bhp).

Basic layout: Two-door four-seater saloon, front engine/ rear drive.

Performance: Top speed 124 mph, 0-6 mph 8.0 sec.

Opel Manta 400 (produced: 1981–83)

As a development of the Ascona 400, Opel later produced 400 examples of the Ascona 400, this being the two-door coupé version of the same basic 'chassis' and running gear. It was a lighter car than the Ascona, with somewhat more sophisticated rear suspension, but was otherwise mechanically the same.

Basic layout: Two-door four-seater coupé, front engine/ rear drive.

Performance: Top speed approx. 125 mph, 0-60 mph 8.0 sec.

In addition, because Cosworth manufactured and assembled all the cylinder heads, the company was closely concerned with these two Vauxhall models:

Panther Solo (1989–1990)

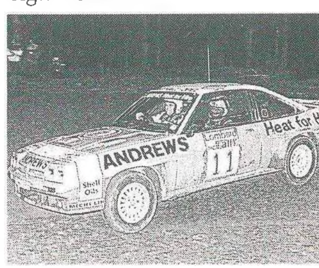
The original Panther Solo of 1984 was a mid-engined, rear-driven car, but that design was soon discarded in favour of a new mid-engined machine, which used the YBE version of the Sierra RS Cosworth engine. The revised car featured four-wheel-drive, and the YBE engine was mounted 'back to front', driving forward to the main gearbox which was ahead of it in the chassis.

The Sierra-engined Panther was revealed in September 1987, but deliveries from the Harlow New Town factory

After the original 190E 2.3-16, Mercedes-Benz produced three further versions. Only 502 examples of the 2.5-16 'Evolution II' model were produced in 1990, complete with outrageous spoiler style.

Opel's Ascona 400 was an 'homologation special', its engine the Cosworth KA-series. This was Walter Rohrl's 'works' car on its way to second place in the Acropolis rally of 1982 – Rohrl was rallying's World Champion in that year.

The Opel Manta 400 took over from the Ascona 400 as Opel's front line rally car in 1983. Like the Ascona, it used a Cosworth KA-series four-cylinder engine. This was Russell Brookes's Andrews-sponsored car on the Lombard-RAC rally of 1985, when he finished eighth overall.



The Vauxhall Chevette HS, which went on sale in 1977/1978, used twin-cam cylinder head assemblies produced by Cosworth.

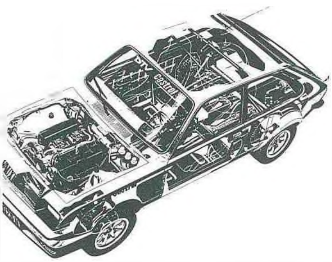
did not begin until the end of 1989. In spite of a very high price, the project was not profitable, and only 12 production cars were built.

Basic layout: Two-door two-seater coupé, mid-engine/four-wheel-drive.

Performance: Top speed 144mph, 0–60mph 6.8 sec, typical fuel consumption 26mpg.

Vauxhall Chevette HS (produced: 1977–79)

This was Vauxhall's very successful late-1970s 'homologation special', targetted at Group 4 competition in rallies, where 400 cars had to be built to gain approval.



The fully-tuned Group 4 Vauxhall Chevette HS, in 2.3-litre form, produced more than 240 bhp.

The Chevette HS was built around the basis of the standard 3-door hatchback shell, but in production form it was fitted with a Vauxhall-designed 16-valve/twin-cam 2.3-litre engine, developing 135 bhp, aided by two Stromberg carburettors, and mated to a five-speed Getrag gearbox. In rally trim, with twin dual-choke Dellorto carbs, 240 bhp was produced.

The original 'works' rally cars ran with Lotus 907-type 16-valve cylinder heads (in which Cosworth played no part), and used ZF gearboxes. Homologation was achieved in November 1976, well before the 400 cars had been produced, in fact well before the cylinder heads had been manufactured, but this was even before Cosworth became involved.

From the spring of 1978 the car's homologation was changed, by order of FISA, and after that the Vauxhall-designed/Cosworth made head was used in motorsport as well as in the rally cars. Peak power was 245 bhp.

Basic layout: Three-door four-seater hatchback, front engine/rear drive.

Performance: Top speed 115 mph, 0-60 mph 8.5 sec, typical fuel consumption 21 mpg.

During 1980 Vauxhall produced the Chevette HSR, an 'Evolution' of the 2300HS, complete with wheel arch extensions, plastic sills, and revised rear axle location. This was Tony Pond's DTV 'works' car on the Lombard-RAC rally of 1981.

Vauxhall Chevette HSR (produced: 1980)

In 1980, to keep the Chevette rally car competitive, Vauxhall produced the 50-off Chevette HSR. Visually these cars had flared front and rear wings, plastic sills under the doors, and a deeper front spoiler. These cars were completed (converted) from near-finished Chevette HS types, and had tuned-up engines of 150 bhp (by Blydenstein). Twin dual-choke Dellorto carburettors (offering even more power) were optional.

Basic layout: Three-door four-seater hatchback, front engine/rear drive.
Performance: No authentic figures recorded.

Victories by Cosworth-Ford-engined cars in World Championship F1 races

1967		
Dutch GP (Zandvoort)	Jim Clark	Lotus 49
British GP (Silverstone)	Jim Clark	Lotus 49
US Grand Prix (Watkins Glen)	Jim Clark	Lotus 49
Mexican GP (Mexico City)	Jim Clark	Lotus 49
1968		
South African GP (Kyalami)	Jim Clark	Lotus 49
Spanish GP (Jarama)	Graham Hill	Lotus 49
Monaco GP (Monte Carlo Rally)	Graham Hill	Lotus 49B
Belgian GP (Spa)	Bruce McLaren	McLaren M7A
Dutch Grand Prix (Zandvoort)	Jackie Stewart	Matra MS10
British GP (Brands Hatch)	Jo Siffert	Lotus 49B
German GP (Nurburgring)	Jackie Stewart	Matra MS10
Italian GP (Monza)	Denny Hulme	McLaren M7A
Canadian GP (St Jovite)	Denny Hulme	McLaren M7A
US GP (Watkins Glen)	Jackie Stewart	Matra MS10
Mexican GP (Mexico City)	Graham Hill	Lotus 49B
1969		
South African GP (Kyalami)	Jackie Stewart	Matra MS10
Spanish GP (Montjuich)	Jackie Stewart	Matra MS80
Monaco GP (Monte Carlo)	Graham Hill	Lotus 49B
Dutch GP (Zandvoort)	Jackie Stewart	Matra MS80
French GP (Clermont-Ferrand)	Jackie Stewart	Matra MS80
British GP (Silverstone)	Jackie Stewart	Matra MS80
German GP (Nurburgring)	Jacky Ickx	Brabham BT26A
Italian GP (Monza)	Jackie Stewart	Matra MS80
Canadian GP (Mosport)	Jacky Ickx	Brabham BT26A
US GP (Watkins Glen)	Jochen Rindt	Lotus 49B
Mexican GP (Mexico City)	Denny Hulme	McLaren M7A
1970		
South African GP (Kyalami)	Jack Brabham	Brabham BT33
Spanish GP (Jarama)	Jackie Stewart	March 701
Monaco GP (Monte Carlo)	Jochen Rindt	Lotus 49C
Dutch GP (Zandvoort)	Jochen Rindt	Lotus 72

French GP (Clermont Ferrand)	Jochen Rindt	Lotus 72
British GP (Brands Hatch)	Jochen Rindt	Lotus 72
German GP (Hockenheim)	Jochen Rindt	Lotus 72
US GP (Watkins Glen)	Emerson Fittipaldi	Lotus 72
1971		
Spanish GP (Montjuich)	Jackie Stewart	Tyrrell 003
Monaco GP (Monte Carlo)	Jackie Stewart	Tyrrell 003
French GP (Paul Ricard)	Jackie Stewart	Tyrrell 003
British GP (Silverstone)	Jackie Stewart	Tyrrell 003
German GP (Nurburgring)	Jackie Stewart	Tyrrell 003
Canadian GP (Mosport)	Jackie Stewart	Tyrrell 003
US GP (Watkins Glen)	Francois Cevert	Tyrrell 002
1972		
Argentine GP (Buenos Aires)	Jackie Stewart	Tyrrell 003
South African GP (Kyalami)	Denny Hulme	McLaren M19A
Spanish GP (Jarama)	Emerson Fittipaldi	Lotus 72
Belgian GP (Nivelles)	Emerson Fittipaldi	Lotus 72
French GP (Clermont Ferrand)	Jackie Stewart	Tyrrell 003
British GP (Brands Hatch)	Emerson Fittipaldi	Lotus 72
Austrian GP (Zeltweg)	Emerson Fittipaldi	Lotus 72
Italian GP (Monza)	Emerson Fittipaldi	Lotus 72
Canadian GP (Mosport)	Jackie Stewart	Tyrrell 005
US GP (Watkins Glen)	Jackie Stewart	Tyrrell 005
1973		
Argentine GP (Buenos Aires)	Emerson Fittipaldi	Lotus 72
Brazilian GP (Interlagos)	Emerson Fittipaldi	Lotus 72
South African GP (Kyalami)	Jackie Stewart	Tyrrell 006
Spanish GP (Montjuich)	Emerson Fittipaldi	Lotus 72
Belgian GP (Zolder)	Jackie Stewart	Tyrrell 006/2
Monaco GP (Monte Carlo)	Jackie Stewart	Tyrrell 006/2
Swedish GP (Anderstorp)	Denny Hulme	McLaren M23
French GP (Paul Ricard)	Ronnie Peterson	Lotus 72
British GP (Silverstone)	Peter Revson	McLaren M23
Dutch GP (Zandvoort)	Jackie Stewart	Tyrrell 006/2
German GP (Nurburgring)	Jackie Stewart	Tyrrell 006/2
Austrian GP (Zeltweg)	Ronnie Peterson	Lotus 72
Italian GP (Monza)	Ronnie Peterson	Lotus 72
Canadian GP (Mosport)	Peter Revson	McLaren M23
US GP (Watkins Glen)	Ronnie Peterson	Lotus 72
1974		
Argentine GP (Buenos Aires)	Denny Hulme	McLaren M23
Brazilian GP (Interlagos)	Emerson Fittipaldi	McLaren M23
South African GP (Kyalami)	Carlos Reutemann	Brabham BT44
Belgian GP (Nivelles)	Emerson Fittipaldi	McLaren M23
Monaco GP (Monte Carlo)	Ronnie Peterson	Lotus 72
Swedish GP (Anderstorp)	Jody Scheckter	Tyrrell 007
French GP (Dijon)	Ronnie Peterson	Lotus 72
British GP (Brands Hatch)	Jody Scheckter	Tyrrell 007
Austrian GP (Zeltweg)	Carlos Reutemann	Brabham BT44
Italian GP (Monza)	Ronnie Peterson	Lotus 72
Canadian GP (Mosport)	Emerson Fittipaldi	McLaren M23
US GP (Watkins Glen)	Carlos Reutemann	Brabham BT44

1975

Argentine GP (Buenos Aires)	Emerson Fittipaldi	McLaren M23
Brazilian GP (Interlagos)	Carlos Pace	Brabham BT44B
South African GP (Kyalami)	Jody Scheckter	Tyrrell 007
Spanish GP (Montjuich)	Jochen Mass	McLaren M23
Dutch GP (Zandvoort)	James Hunt	Hesketh 308
British GP (Silverstone)	Emerson Fittipaldi	McLaren M23
German GP (Nurburgring)	Carlos Reutemann	Brabham BT44B
Austrian GP (Zeltweg)	Vittorio Brambilla	March 751

1976

Spanish GP (Jarama)	James Hunt	McLaren M23
Swedish GP (Anderstorp)	Jody Scheckter	Tyrrell P34
French GP (Paul Ricard)	James Hunt	McLaren M23
German GP (Nurburgring)	James Hunt	McLaren M23
Austrian GP (Zeltweg)	John Watson	Penske PC4
Dutch GP (Zandvoort)	James Hunt	McLaren M23
Italian GP (Monza)	Ronnie Peterson	March 761
Canadian GP (Mosport)	James Hunt	McLaren M23
US GP (Watkins Glen)	James Hunt	McLaren M23
Japanese GP (Fuji)	Mario Andretti	Lotus 77

1977

Argentine GP (Buenos Aires)	Jody Scheckter	Wolf WR1
US GP West (Long Beach)	Mario Andretti	Lotus 78
Spanish GP (Jarama)	Mario Andretti	Lotus 78
Monaco GP (Monte Carlo)	Jody Scheckter	Wolf WR1
Belgian GP (Zolder)	Gunnar Nilsson	Lotus 78
French GP (Dijon)	Mario Andretti	Lotus 78
British GP (Silverstone)	James Hunt	McLaren M26
Austrian GP (Zeltweg)	Alan Jones	Shadow DN8
Italian GP (Monza)	Mario Andretti	Lotus 78
US GP (Watkins Glen)	James Hunt	McLaren M26
Canadian GP (Mosport)	Jody Scheckter	Wolf WR1
Japanese GP (Fuji)	James Hunt	McLaren M26

1978

Argentine GP (Buenos Aires)	Mario Andretti	Lotus 78
South African GP (Kyalami)	Ronnie Peterson	Lotus 78
Monaco GP (Monte Carlo)	Patrick Depailler	Tyrrell 008
Belgian GP (Zolder)	Mario Andretti	Lotus 79
Spanish GP (Jarama)	Mario Andretti	Lotus 79
French GP (Paul Ricard)	Mario Andretti	Lotus 79
German GP (Hockenheim)	Mario Andretti	Lotus 79
Austrian GP (Zeltweg)	Ronnie Peterson	Lotus 79
Dutch GP (Zandvoort)	Mario Andretti	Lotus 79

1979

Argentine GP (Buenos Aires)	Jacques Laffite	Ligier JS11
Brazilian GP (Interlagos)	Jacques Laffite	Ligier JS11
Spanish GP (Jarama)	Jacques Laffite	Ligier JS11
British GP (Silverstone)	Carlos Reutemann	Williams FW07
German GP (Hockenheim)	Alan Jones	Williams FW07
Austrian GP (Zeltweg)	Alan Jones	Williams FW07
Dutch GP (Zandvoort)	Alan Jones	Williams FW07
Canadian GP (Montreal)	Alan Jones	Williams FW07

1980

Argentine GP (Buenos Aires)	Alan Jones	Williams FW07
US GP West (Long Beach)	Nelson Piquet	Brabham BT49
Belgian GP (Zolder)	Didier Pironi	Ligier JS11
Monaco GP (Monte Carlo)	Carlos Reutemann	Williams FW07B
French GP (Paul Ricard)	Alan Jones	Williams FW07B
British GP (Brands Hatch)	Alan Jones	Williams FW07B
German GP (Hockenheim)	Jacques Laffite	Ligier JS11
Dutch GP (Zandvoort)	Nelson Piquet	Brabham BT49
Italian GP (Monza)	Nelson Piquet	Brabham BT49
Canadian GP (Montreal)	Alan Jones	Williams FW07B
US GP (Watkins Glen)	Alan Jones	Williams FW07B

1981

US GP West (Long Beach)	Alan Jones	Williams FW07C
Brazilian GP (Jacarepagua)	Carlos Reutemann	Williams FW07C
Argentine GP (Buenos Aires)	Nelson Piquet	Brabham BT49C
San Marino GP (Imola)	Nelson Piquet	Brabham BT49C
Belgian GP (Zolder)	Carlos Reutemann	Williams FW07C
British GP (Silverstone)	John Watson	McLaren MP4/1
German GP (Hockenheim)	Nelson Piquet	Brabham BT49C
Las Vegas GP (Las Vegas, USA)	Alan Jones	Williams FW07C

1982

US GP West (Long Beach)	Niki Lauda	McLaren MP4/1
Belgian GP (Zolder)	John Watson	McLaren MP4/1
Monaco GP (Monte Carlo)	Riccardo Patrese	Brabham BT49D
Detroit GP (Detroit, USA)	John Watson	McLaren MP4/1
British GP (Brands Hatch)	Niki Lauda	McLaren MP4/1
Austrian GP (Zeltweg)	Elio de Angelis	Lotus 91
Swiss GP (Dijon, France)	Keke Rosberg	Williams FW08
Las Vegas GP (Las Vegas, USA)	Michele Alboreto	Tyrrell 011

1983

US GP West (Long Beach)	John Watson	McLaren MP4/1
Monaco GP (Monte Carlo)	Keke Rosberg	Williams FW08C
Detroit GP (Detroit, USA)	Michele Alboreto	Tyrrell 011-DFY

154 victories by cars fitted with DFVs, one victory for a car fitted with the DFY engine.

Victories achieved by HB-engined cars:

1989

Japanese GP (Suzuka)	Alessandro Nannini	Benetton B189

1990

Japanese GP (Suzuka)	Nelson Piquet	Benetton B190
Australian GP (Adelaide)	Nelson Piquet	Benetton B190

1991

Canadian GP (Montreal)	Nelson Piquet	Benetton B191

1992

Belgian GP (Spa)	Michael Schumacher	Benetton B192

1993

Brazilian GP (Interlagos)	Ayrton Senna	McLaren MP4/8
European GP (Donington Park)	Ayrton Senna	McLaren MP4/8
Monaco GP (Monte Carlo)	Ayrton Senna	Mclaren MP4/8
Portuguese GP (Estoril)	Michael Schumacher	Benetton B193
Japanese GP (Suzuka)	Ayrton Senna	McLaren MP4/8
Australian GP (Adelaide)	Ayrton Senna	McLaren MP4/8

Victories achieved by Zetec-R-engined cars:

1994

Brazilian GP (Interlagos)	Michael Schumacher	Benetton B194
Pacific GP (T.I., Aida, Japan)	Michael Schumacher	Benetton B194
San Marino GP (Imola)	Michael Schumacher	Benetton B194
Monaco GP (Monte Carlo)	Michael Schumacher	Benetton B194
Canadian GP (Montreal)	Michael Schumacher	Benetton B194
French GP (Magny Cours)	Michael Schumacher	Benetton B194
Hungarian GP (Budapest)	Michael Schumacher	Benetton B194
Belgian GP (Spa)**	Michael Schumacher	Benetton B194
European GP	Michael Schumacher	Benetton B194

** Later disqualified due to a chassis infringement, after post-race scrutineering.

At the end of 1994 Cosworth-Ford-engined cars had officially won 174 World Championship F1 races. Michael Schumacher won the 1994 F1 World Drivers' Championship.

The list of F1 makes which have used Cosworth-Ford engines – 1967 to 1994 inclusive

In 1967 the DFV was only available to Lotus, and in 1968 the engine was only used by Lotus, Matra and McLaren. After that, the number of users increased rapidly. This, I *think*, is a complete list of all the makes of F1 car which started World Championship events between 1967 and 1994, while powered by Cosworth-Ford engines:
(All engines are DFV or DFV derived, unless indicated)

AGS
Amon
Arrows (see also Footwork)
ATS
Beatrice-Lola (GBA turbo V-6 1.5-litre)
Bellasi
Benetton (DFR, plus GBA turbo V6 1.5-litre, plus HB V-8, plus Zetec-R V-8)
Boro (see Ensign)
Brabham
Coloni
Connew
Copersucar (see Fittipaldi)
Dallara
De Tomaso
Ensign
Eurobrun
Fittipaldi
Fondmetal (HB)
Footwork (once the Arrows team, DFR, HB)
Hesketh
Hill
Jordan (HB)
Kojima
Larrousse (HB)
LEC
Ligier
Lola (DFV, DFR)
Lotus (DFV, HB)
Lyncar
March
Martini
Matra
McLaren (DFV, HB)
Merzario
Minardi (DFV, HB)
Onyx (later renamed Monteverdi)
Osella
Parnelli
Penske
Pilbeam (see LEC)
Rebaque
Rial
Safir (see Token)
Shadow
Simtek (HB)
Surtees
Theodore
Token
Trojan
Tyrrell
Williams
Wolf

Of these teams, by far the most successful have been Lotus, McLaren, Tyrell, Williams, Brabham and Benetton.

The thoughts of Chairman Duckworth . . .

For thirty years, any conversation with Keith Duckworth has been spattered with well-rounded aphorisms. As with Winston Churchill, such sayings took time to evolve, and were by no means as spontaneous as they might appear.

At the risk of boring some experienced Duckworth-watchers, here is a selection of the 'Thoughts of Chairman Duckworth' . . .

- It is better to be un-informed than ill-informed.
- Development is only necessary to rectify the ignorance of designers.
- Very few straight answers are ever possible. The decisive man is a simple-minded man.
- If you are telling the truth, it's simple. If you're lying, you have to remember what yesterday's lie was. It's safer to be honest.
- Academics are seldom any use at engineering. One must have a mistrust of theorists.
- First ideas usually turn out to be complicated.
- There seem to be two categories of racing drivers – those who can drive by natural ability, and those who actually gain competence by experience.
- If someone says something to me which has no meaning, it jars my mind. I worry about it, and I lose the next ten sentences.
- It must be possible to make an interesting living, messing about with racing cars and engines.
- We (Cosworth) are the only people who expect a prototype to go together straight away, without fitting . . .
- In engineering there is an answer to everything, it's just that we're usually too ignorant, or too dim, to see it.
- I always seemed to have enough nous to realize that unless your regular income exceeded your outgoings, then bankruptcy was certain.
- I think we (Cosworth) always managed to under-employ people. We achieved higher standards than the others – it comes from not promoting people to the level at which they're making a lot of mistakes. It's the reverse of the Peter Principle!
- It costs you very little to scrub out drawings on paper, and to start again. As soon as you have things in the metal, where you are fighting to make a silk purse out of a sow's ear, that is hopeless.
- A genius can make, for a penny, what a good engineer can only make for 10p.

- Inherently, by nature, I'm one of those people who would rather do a few things very well, than what I see as the other extreme, which is to make a nonsense of lots of things.

- Harry Mundy was stubborn, but I would't like to say that I was other than that.

- I think that borrowing money is the biggest immorality that there is.

- The only substitute for money is genius – if you can make your steps by thinking about them, rather than by trial and error, the end result is the same, and in general it costs less.

- My problem is that when I look at all the kind of people who have made quite a lot of money, I don't think that it is a great criterion of life . . .

- I have a vast natural curiosity, so I'm always inventing things.

- We must be the only outfit, ever, to make money from making racing engines – as a commercial venture.

- It is the years of socialism, and the high taxation that went with it, that was the death of all the morals and ethics of the City of London.

- The problems that have developed by suggesting that we are born equal! It just isn't so. It is absolutely paramount to appreciate that our chances in life are accidentally governed by our birth – 80 per cent of our possibilities in life are due to whether we have a lot between our ears, or very little between the ears.

- As far as I can see, in a large company the last thing you can afford to do is not to start replying immediately a question is asked.

- As I inscribed on the side of Mike's '25 Year Clock': 'From the Idealist to the Realist. Together, at Cosworth, we beat the world.'

- One of the things I have often done wrong was to stop projects at stages of development, because we couldn't afford to produce triumphs of development over design.

- To my thinking, turbochargers in Formula 1 engines were always expressly against the rules.

- I still don't want to be seriously rich. Neither am I interested in external honours. Having had a go at beating the world at building racing engines – I do like that. That's a reasonable accolade.

- I am gifted with a small amount of foresight, my problem being that I see problems arising, and that is inhuman. The human being doesn't realize he is in the mire until it's above his head – I can actually recognize that there is a pile of mire over there, and that if I'm not careful, I'm going to arrive in it, so I take avoiding action for some considerable time . . .

- The important thing, with racing cars, is to make maximum utilization of rubber.

- It's better to keep your mouth shut and be thought a fool, than to open your mouth and prove it.

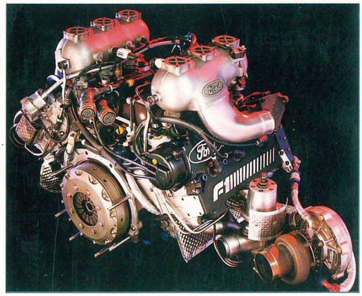
- I used to think that thinking ability is *the* important factor in life, rather than having a good memory. It wasn't until later that I realized that I had also been gifted with what appears to be a very good memory too – and I hadn't realized the advantages of that. How can people ever learn from their experiences if they've already forgotten what they were!

- One of my principles is that young fools go on to become old fools.

Index

Note: Keith Duckworth, Mike Costin and Ford have been so important to the story of Cosworth that their names crop up on almost every page. For that reason alone, I have made no attempt to include references in this Index.

Today Cosworth is a familiar name to motoring and motorsport enthusiasts throughout the world. In three decades the British company has established a reputation for the design and precision engineering of high-performance racing and road car engines that is second to none. The third edition of this award-winning book tells the full story of the products – engine supply for Michael Schumacher's 1994 World Championship-winning Benetton-Ford, Nigel Mansell's Indycar, the Monte Carlo Rally-winning Escort RS Cosworth, and Team Mondeo's World Touring Car vehicles for example – but it also goes behind the scenes to meet the people whose search for power created such world-beating technology.



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