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F50 - The ultimate Ferrari
An Autocar Book

free with the 7 June 1995 issue

OPEN HEART SURGERY

The 513bhp high-tech V12 starts life at Ferrari's F1 foundry. Keith Howard examines the F50's core

As you enter the foyer of Ferrari's Maranello factory one of the first objects to meet your gaze is a Formula 1 car. Not just any F1 Ferrari but the very car in which Alain Prost notched up the marque's 100th grand prix victory at the Paul Ricard circuit on 8 July 1990. Prost might well have made champion that year too but four months after the French triumph his challenge ended ignominiously in a Suzuka gravel trap when Senna punted him off at the first corner.

Ferrari hasn't come close to a world championship since, and no subsequent race win could quite match the magic of passing the three-figure mark. Small wonder, then, that when Ferrari took the momentous decision to produce an F1 car for the road, it was Prost's century-scoring 641/2 that became the official sire.

Why 'official'? Because it is the philosophy, the single-minded engineering ethos, which links the F50 to its famous F1 forebear rather than common componentry. The engine — the most identifiably F1 part of the F50 — actually bears closer relation to the racing unit of three years ago, immediately before the introduction of pneumatic valve springing, than to Prost's 1990 powerplant. Who's quibbling, though, when this is the only supercar on sale that can justifiably claim such close affinity to the track?

Paolo Martinelli, head of Ferrari's engine development and now working in the racing department, was the man charged with taming the brutal, noisy F1 engine into something acceptable for use on the road. That he has succeeded you can judge just by standing beside the F50 while it's idling. Not only does this still-fearsome powerplant, capable of 513bhp at 8000rpm, idle smoothly at below 1000rpm — not the 2000rpm-plus needed to keep the racing version spinning — but it's remarkably quiet while about it. Much quieter than an F355, for example. At full chat, though, its goose-pimple wail is all you could wish for.

Like his colleague Carlo Della Casa, responsible for the F50's suspension and brakes, Martinelli counts Ferrari as his only ever employer. He joined straight from university after obtaining his engineering degree, as did Della Casa, and has seen no reason to move on.

With such a high-powered brief for the car, the engine had to be a V12. Ferrari is hard at work developing a V10 for its F1 car but, for the present, a dozen cylinders remain *de rigueur*, a Ferrari trademark.

It also had to be naturally aspirated, like the F1 engine, not turbocharged like the F40's. This is one of the most significant differences between the F50 and F40, says Martinelli; a key reason why the F50 is at least four seconds quicker around the Fiorano test track. In the F40, if you're wise, you wait until the steering wheel is straight before you nail the throttle; in the F50 you can modulate the throttle opening in a corner without risking a sudden turbo surge-induced rearward exit into the outfield.

Providing this responsiveness while still bettering the F40's grunt — 513bhp versus 478 — meant increasing the F1 powerplant's capacity substantially, from 3.5 to 4.7 litres. To be precise, 4698cc, courtesy of a bore diameter of 85mm and piston stroke of 69mm. Such substantially oversquare dimensions (bore:stroke ratio of 1.23:1) are less extreme than those of the race version because maximum revs are pegged at 8500rpm, with peak power available 500rpm lower. But they still go well beyond those of other road-going sports cars (McLaren F1 0.99:1, Honda NSX 1.15:1) to ensure that the F50's powerplant can run reliably at a continuous 9000rpm — not that the standard fuel cut-off will ever allow it. Peak torque of 347lb ft is developed at 6500rpm but the torque curve is virtually a plateau from 5500 to 8500rpm.

Even with a capacity of 4.7 litres the engine needed to deliver remarkable specific power output. The final figure of 109.2bhp per litre betters even the outstanding 107.4bhp per litre of the F355, making it comfortably the highest of any normally aspirated supercar, including the McLaren F1 (103bhp per litre) and Honda's

VTEC unit in the NSX (90.5bhp per litre), both of which benefit from variable valve timing. The F50 unit doesn’t, although it employs some other tricks to make it more tractable.

To post such high specific output the F50 engine has to be unusually good at getting air/fuel mixture into the cylinder and exhaust gases out. This exceptional volumetric efficiency is achieved primarily by the use of five valves per cylinder — three inlet and two exhaust — but the alignment of the valve ports plays its part too. Two of the three inlet ports and both exhaust ports enter the cylinder radially to improve gas flow, an arrangement which incurs problems in camshaft manufacture. Because the radially aligned valves and their bucket tappets are not at 90deg to the camshaft’s axis, the cam lobes have to be ground at a matching angle. This demanded the purchase of some special cam-grinding equipment.

Materials usage in the engine is as extravagant as its F1 ancestry suggests although the block is, surprisingly, formed of cast iron rather than aluminium.

Aluminium is used for the cast heads, the forged Mahle pistons and the cast sump; the conrods are forged titanium; the crankshaft is forged steel; magnesium sand castings form the cam covers and oil and water pump housings. To maximise strength and minimise wear in the valvetrain, the four forged steel camshafts, two per bank, are first extensively heat treated and then nitrided to provide high surface hardness. As you would expect in such a high-revving engine — let alone one bolted directly to the rear cabin bulkhead — meticulous care is taken over balancing. All six conrods in each bank, for example, weigh within a gram of one another.

Camshaft drive is by low-noise Morse chain; the water and oil pumps are driven directly off the camshafts. Separate external drive belts on the front face of the engine power the air conditioning compressor and alternator. Although cheek-by-jowl with the cabin bulkhead, they can be changed in situ via a removable panel in the car’s flat underpanel. To keep engine height to a minimum and allow the engine/transmission assembly to be mounted as low as possible in the car, a dry-sump lubrication system is used. Echoing F1 practice, three scavenge pumps are employed, their inlets strategically positioned along the length of the sump to ensure uninterrupted oil pick-up in all extremes of acceleration, braking and cornering. Again F1-style, the oil tank for the dry sump system is not a separate entity but incorporated within the final drive housing. Oil from the sump is pumped first into a centrifugal separator which also forms the oil filler neck, where entrained air is removed. The de-aerated oil then falls under gravity into voids in the final drive casting beneath the differential.

Because of the engine compartment's enclosed underside, heat soak is a problem when the car is stationary, with no cooling air flowing through the side ducts. So two thermostatically controlled electric fans are fitted to the topside of the undertray which draw cool air in from beneath the car and blow it over the exhaust manifolds and catalytic converters. The heated air then exits through the slats in the transparent engine cover. When the engine is switched off, these fans can be heard running until the engine bay temperature is reduced to an acceptable level.

Although Della Casa expresses doubts whether there will ever be another car like the F50 because of increasingly stringent emissions legislation, it uses the very latest exhaust gas after-treatment technology. Large catalytic converters, one per cylinder bank, substantially reduce tailpipe pollutants, while secondary air injection is used to limit emissions during the warm-up period before the cats light off.

Along with all the engine's fuelling and ignition requirements, this is controlled by the Bosch Motronic 2.7 engine management computer. As you would suppose in an engine of this sophistication, fuel injection is sequential and the ignition system distributorless. The Bosch ECU also controls two other engine functions: the variable intake and variable exhaust systems, both of whose role is to help render this race-derived powerplant tractable enough for street use.

The inlet ducts in front of each rear wheel convey cool air to heat exchangers — an engine oil cooler on the left of the car and the air conditioning condenser on the right. But before the in-rushing air meets these, some of it is bled off through circular tubes in the top wall of each duct. These feed the two engine inlets, one per bank of six cylinders. After filtering, the inlet air first passes over the hot wire air mass sensor of the engine management system before reaching the carbon-fibre plenum chamber perched atop each cylinder bank's six upward-facing throttle bodies. This plenum is divided into halves by an electronically actuated butterfly valve, each half having separate access to the inlet air. Essentially this is the same system seen before on many six-cylinder engines, which offers a mix of high-rev and low-rev performance impossible to achieve conventionally.

At low engine revs the buttery valve is closed and each bank of six cylinders effectively operates as two in-line threes. This sets up beneficial air resonances within each half-plenum which help improve low-rev torque. At high engine revs the butterfly valve is opened to form a single plenum for all six cylinders, which optimises engine output in the upper half of the rev range.

A not dissimilar mechanism is also used in the F50's exhaust system, this time to optimise the scavenging of exhaust gases from the cylinders. There are two silencers, one per bank, each of which has two short tailpipes. In the upper tailpipe of each pair is another butterfly valve, also controlled by the engine management ECU but actuated using inlet manifold vacuum rather than an electric motor. As in the inlet system, this butterfly is closed at low revs but opened at higher engine speeds, the effect being to harness resonances in the exhaust system such that gas flow is again more nearly optimised throughout the rev range. Incidentally, both the inlet and exhaust systems were designed using computer-aided engineering software called Benson, developed at Imperial College, London.

Martinelli was also in charge of developing the F50's six-speed transmission, slung out behind the engine and incorporating inboard pick-up points for the rear suspension. Progressing backwards from the steel flywheel there is, of course, first the hydraulically actuated, twin-plate dry clutch. Next comes the massive final drive assembly, a complex aluminium sand casting which as well as housing the limited-slip differential and part of the gear set also forms the oil tank and carries mounting points for the rear wishbones, spring/damper units and anti-roll bar. On to the back of the final drive case mounts a much smaller magnesium sand casting which encloses the remainder of the gear set. To help support the mass of the drivetrain and resist loads reacted through the rear suspension, two massive cigar-shaped steel tubes link the final drive casing to the tub's rear bulkhead. Smaller drop links either side support the two stainless steel exhaust manifolds. In turn, steel brackets attached to the final drive and gearbox casings support the rear body panels and two large exhaust silencers.

There are two shafts in the gearbox: a primary shaft from the clutch, which passes beneath the final drive, and above it a secondary shaft culminating in the differential pinion gear. Gear wheel design has been optimised to reduce noise — there are always three gear teeth in mesh at any time — and close attention has been paid to reducing shift efforts when the 'box is cold. Double cone synchronisers on first and second gear are a key feature here, but so too is the use of an oil-water intercooler between the gearbox lubricant and engine coolant. As well as cooling the gearbox oil when hot this intercooler heats it when cold, helping ensure that the 'box rapidly attains its optimum working temperature.

With its forward driving position and rear-mounted transmission, the F50 has a long, long gear linkage. Maintaining the F1 connection it's a rod mechanism, naturally, comprising four sections, four universal joints and two sliding bearings — one in the extended sump casting, which also forms the lower engine mounting bracket, and the other in the forward end of the final drive casting. Happily this complex linkage is protected from road dirt, like the rest of the engine and transmission, by the all-enveloping undertray.

A downforce to be reckoned with

Most road cars produce modest amounts of aerodynamic lift at speed. These forces reduce the grip available for braking and cornering and can have a detrimental effect on the car's handling. Ideally there should be greater lift at the front than at the rear to promote understeer; more usually, though, the lift force is greater at the back.

The F50 is one of the very few road cars that produces significant levels of downforce, to the tune of about 440kg (970lb) — fully 35 per cent of the car's unladen weight — at its top speed of 202mph. What's more, that downforce is distributed as it should be: 40/60 per cent front/rear to match the car's 42/58 per cent weight distribution.

A price is paid for this substantial downforce in the form of a high 0.372 drag coefficient, which goes a long way to explaining why the F50's top speed only just exceeds the magical 200mph — over 30mph short of the McLaren F1. Ferrari's engineers have obviously made the decision that enhanced grip is of greater practical value than maximised top speed.

Two features contribute most to the F50's high downforce. First is the flat undertray that runs from the nose to just ahead of the rear axle line, at which point two upward-sloping diffuser tunnels are interposed between the engine and the rear wheels. The other is the F1-derived wing that dominates the rear of the car. One of the aerodynamicists' goals was to ensure that the wing works effectively in both open and hard-top configurations.

Up front, downforce is also produced by the radiator ducting. Air enters at high dynamic pressure and exits through two ducts in the front of the bonnet, where the accelerated airflow means dynamic pressures are low. So air is sucked through the radiator as well as blown, resulting in a fast upward flow of heated air which contributes to the downforce.

Wheel bone's connected to the ARM BONE

Rose-jointed suspension and a host of other race car features promise the most intimate, involving driving experience yet in a road car. Keith Howard reports

Road cars and formula racing cars are normally chalk and cheese. Even the F50, road-going homage to Formula 1, has to make some concessions to off-track realities such as variable road surfaces and no less variable driver skills. But in creating the F50's suspension, Ferrari has remained truer to racing practice than any supercar manufacturer has ever dared before.

If there is a single defining factor that separates road car suspensions from their track equivalents, it is the extensive use of rubber. To prevent road noise from being transmitted unattenuated through the suspension arms, springs and dampers to the car body and occupants, compliant bushes and seats are liberally applied. A big part of the skill in modern road car suspension design lies in minimising their inevitable effect on wheel control and therefore handling, or else exploiting them to provide passive steering during cornering and/or desirable toe changes under acceleration or braking.

In racing cars, suspension compliance — other than that provided by the suspension springs and tyres — is anathema. Parasitic compliance equals compromised wheel control, which must be avoided at all costs. So in place of rubber bushes and spring seats, racing cars use rigid ball joints (commonly known as 'rose joints' or 'uniballs') and metal-to-metal contact.

Conventional wisdom has it that applying similar techniques to a road car will result in an unacceptably harsh and noisy ride, with every pimple on the road surface conveyed unexpurgated to the occupants. But Ferrari has torn up the rule book for the F50, banishing parasitic suspension compliance without, it claims, throwing ride quality out the window.

Carlo Della Casa, the engineer charged with creating the least compromised suspension yet of any road-going Ferrari, admits he is slightly puzzled at how good the ride has turned out. Further research is under way at Maranello to understand more fully why the F50 rides substantially better than its F40 predecessor.

The F50's adaptive damping system — similar to those already used (and critically acclaimed) in the 456 GT and F355 — only partly explains the superior absorbency. Each of the four Bilstein gas-pressurised monotube dampers is adjustable via a slender shaft that runs within the piston rod to the valves in the damper piston itself. Splined to the end of this adjustment shaft is an electric actuator controlled by the suspension's electronic control unit.

Based on steering wheel angle and velocity, the body's vertical and longitudinal acceleration, brake line pressure and vehicle speed, this ECU reads off the appropriate damping force from a pre-programmed 'map' and adjusts the dampers as necessary. Maximum reaction time — from minimum to maximum damping force or vice versa — is 140 milliseconds (0.14sec) but typical adjustments can be executed in only 25 to 30 milliseconds. At 100mph that's the time the car takes to travel around 4ft — less than one rotation of the F50's large tyres.

What distinguishes the F50's system from those fitted to the 456 and F355 is that each damper is controlled separately, allowing each corner of the car to be adjusted independently during turn-in. At present bump and rebound forces still have to be altered together but this is likely to change in future variants of the system, adding further scope for refinement.

Stiffening the damper on the outside front wheel and relaxing that on the opposite corner was found to sharpen the car's transient response, much to the approval of test driver Dario Benuzzi. This was over and above the improvement in both transient behaviour and driver 'feel' elicited by removing all rubber from the suspension, which not only takes time to compress but can also give rise to handling variations as a result of temperature and ageing. Della Casa suggests that Ferrari is so impressed with the handling improvements elicited by the uniball suspension mounts that all models may use them in future. 'I think it is the way ahead,' he says.

In other respects the suspension is, for a car of this nature, mostly conventional, although it does employ pushrods to operate horizontally disposed spring/damper units. Again this echoes F1 practice, the only difference being that there is sufficient room in the F50 for the front springs and dampers to be accommodated across the width of the car rather than along its axis, as necessitated by the narrow tub of an F1 car.

Since there is no aerodynamic benefit to this arrangement as there is in an open-wheeler, it smacks somewhat of excess. But it does at least make it possible to raise the front of the car to help it to negotiate car park or ferry ramps. An electric motor is inserted between the inboard mounts of the front dampers which, when activated, forces the damper mounts apart and raises the nose by 40mm. If you forget to drop the front down again afterwards, no matter — the F50 does it automatically once it exceeds a preset speed.

One of the biggest problems facing the suspension designer of a light car carrying such generous footwear — the F50 tips the scales at only 1280kg unladen but deploys 245/35 ZR18 tyres at the front and 335/30 ZR18s at the rear — is that of low sprung to unsprung mass ratio. Ideally this ratio should be as high as possible to benefit ride quality and tyre adhesion on bumpy roads, but a lightweight body, fat tyres and the substantial brakes necessary for

200mph-plus performance militate against it.

Saving on unsprung mass was therefore a top design priority, dictating the use of lightweight materials for the suspension and brakes. The Speedline wheels are cast magnesium, the wheel hubs titanium and the brake disc bells, suspension uprights and brake calipers all aluminium. But the upper and lower wishbones at each corner of the car — the F50 could hardly boast F1 heritage without double wishbones all round — are made of steel, black powder-coated to resist corrosion. Della Casa's justification for this surprising choice in a car otherwise littered with low-density materials is simple: the weight saving to be gained by using aluminium suspension arms instead would have been minimal.

Goodyear, too, was asked to save weight wherever possible in the GS-Fiorano tyres developed specifically for the F50. Like the bespoke Goodyears on the McLaren F1 they are a product of Akron's racing department, which may help to explain why the first prototypes, while brilliant on the test track, proved quite unacceptable on the road. Painstaking development work by Goodyear's tyre specialists and Ferrari's suspension team was needed before the directional and asymmetric Fioranos shone on the street as brightly as on the track.

Even with all this determined weight saving, the unsprung masses are high for a road car at about 45kg (99lb) per corner at the front and 55kg (121lb) per corner at the rear — equivalent to sprung/unsprung mass ratios of only 5.7:1 and 6.5:1. This can only make the F50's adaptive damping even more valuable.

As you'll see from cornering shots, the F50 rolls very little even under the 1g-plus cornering forces it is able to generate. The roll angle is limited to about 1.5deg at maximum lateral acceleration, thanks to the rigidly mounted anti-roll bars front and rear, stiff springs and low centre of gravity. This makes one aspect of suspension design far easier: striking the right compromise between camber compensation in roll (which is desirable to keep the tyre upright during cornering) and camber change in bump (which is undesirable because it compromises straight-line stability and braking). Because the F50's roll angles are so small there is no need for a high degree of camber compensation or high static camber settings. Static camber angles for the F50 are a modest −1.0deg at the rear and −0.7deg at the front.

Because the modest roll angles use up less of the available suspension movement, the F50 also has unusually limited wheel travel for a road car. Front and rear the range of movement is about 55mm in bump, 60mm in rebound — roughly half that of most modern saloons. These values were arrived at empirically, by equipping prototypes with appropriate sensors and driving them on a variety of public roads.

Considerable design effort also went into optimising the front castor angle and bump steer characteristics, both of which proved to have a major effect on stability. Castor of 5.5 to 5.7deg was chosen as the best compromise between straight-line stability and sharp turn-in, while the height of the rack and pinion steering gear was eventually set to provide a modicum of stabilising toe-out on bump. It came as a surprise to Della Casa just how accurately the steering rack height has to be maintained, a tight tolerance of 1mm being required to ensure the desired handling characteristics.

In the interests of minimum weight and maintaining the Formula 1 connection, the F50 is not fitted with servo assistance on either steering or brakes. The result is what sounds like rather slow steering for such a car — 3.3 turns lock to lock for a 12.6 metre (41ft) turning circle — but it won’t feel that way thanks to the cornering stiffness of the tyres and fast turn-in assured by the adaptive damping and absence of rubber bushes.

With one of the main criticisms levelled at the McLaren F1 being the brake pedal forces required to stop it, the lack of a brake servo is a potentially more serious omission. But Ferrari engineers insist that, despite short brake pedal travel, the braking effort is entirely acceptable. This is partly down to the massive front and rear discs (355mm and 335mm diameter respectively), which provide a large brake moment arm, and partly down to careful selection of the friction material, supplied by Pagid.

Stiff Brembo calipers help, too, by providing good ‘bite’. The four-pot Brembos are not monobloc designs, machined from a single billet as in the McLaren, but are manufactured conventionally in two bolted-together halves. Della Casa says they are quite stiff enough and have the advantage of being a known quantity.

The cast iron discs are ventilated to maximise heat dissipation and cross-drilled to enhance pedal feel.

All of which adds up to suspension, steering and brakes in keeping with the F50's promise of bringing Formula 1 sensations to the road.

Any material so long as it's CARBON

Not even Kevlar gets a look in on the F50. Keith Howard examines how it's made

For a road-going Formula 1 car, nothing less than the most advanced composite construction would suffice. So the F50 body is built entirely of carbon fibre — not even Kevlar gets a look in (though inexplicably it does in Ferrari's lavish F50 brochure).

Forming the backbone of the structure is a one-piece tub comprising front bulkhead, floorpan, centre tunnel, high door sills and the hollow rear bulkhead, within which is housed a foam-filled, aircraft-type Sekur bag tank capable of holding 28.1 gallons of fuel. Sandwich construction is used throughout, with skins of carbon fibre and epoxy resin and a core of Nomex honeycomb.

Torsional stiffness of this tub, which weighs just 102kg, is extremely high at almost 25,500lb ft per degree — about three times that of a typical modern saloon. Although a torsional stiffness figure for the whole car, between axles, is not available, it is probably not much less than this, bearing in mind that the stiffness lost in the engine assembly must be regained in whole or part by the bonded windscreen.

Wherever the tub is subject to concentrated load inputs — at the front suspension and steering rack mountings, and at the solid engine mounts on the rear bulkhead — the necessary strength is provided by machined aluminium blocks, co-polymerised with the composite. The only steel components in the structure are a frame attached to the forward end of the tub which carries the front-mounted radiator and electric cooling fans, the two small roll-over bars which are part of the car's open-top configuration, and the side impact door beams. Exterior body panels — all unstressed — are in solid carbon fibre laminate. Total unladen weight is quoted as 1230kg.

Sound absorbent material is notable by its absence, the most extensive use of it being a 30mm-thick layer of what looks to be bonded acetate fibre covering the rear bulkhead and floor area beneath the seats, held in place by a thin carbon fibre panel. There is also a very small amount of open cell foam within the door spaces. Otherwise the only sound deadening of significance is an extra 1.5mm layer of resin applied to the back of the rear bulkhead and underside of the floorpan, and within the front wheel arches.

For a car with a solidly mounted engine, the F50 makes minimal concession to cabin noise levels.