FORD MONDEO – PRODRIVE'S BATTLE TO CREATE A WINNER

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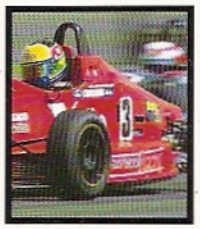

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March 2001 • Vol 11 No.3

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MONDEO

How Prodrive finally turned Ford's family car into a title winner

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Spend, spend, spend

SuperTouring rules taken to their ultimate conclusion forced team's to spend enormous budgets and Ford's Prodrive run Mondeo was no exception

THERE IS A perverse logic to motorsport's technical regulations which ensures the tighter they are, the more expensive it becomes to find a way round them. Normally, money is the factor which ultimately keeps a cap on the process, but even that becomes irrelevant when big manufacturers compete with each other on the international stage. The phenomenon must surely have reached its apogee during the last years of the SuperTourers, and the irony is once again that freedoms designed to stop manufacturers building production runs of homologation specials merely created more opportunities for those persistent enough (and sufficiently well funded) to exploit them. The ultimate instance has to be the Prodrive-developed Ford Mondeo which dominated last season's British Touring Car Championship.

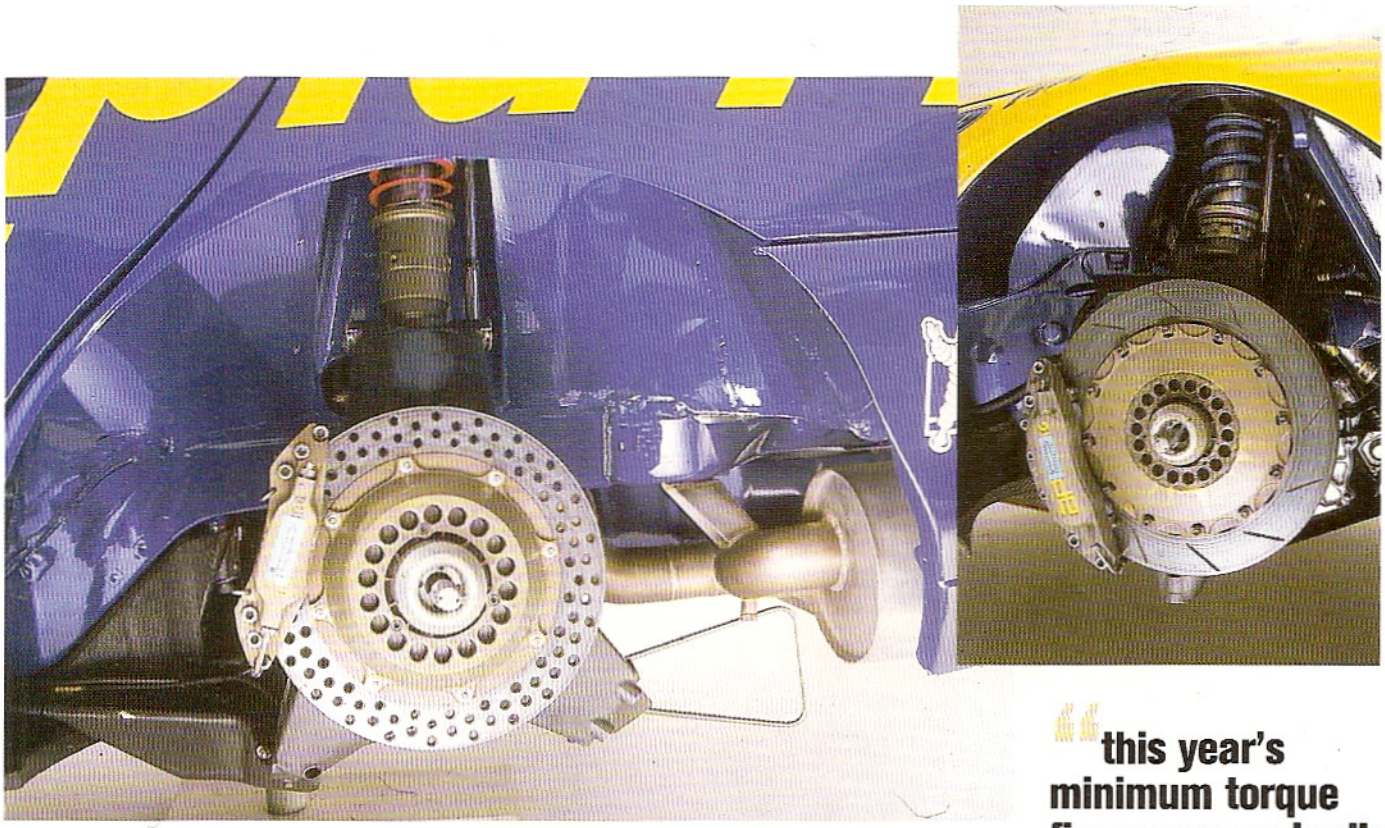
Ford had some initial success with the V6-powered racer in the early 1990s (Paul Radisich won a number of British races and the European title at Monza with a Rouse prepared car) but since then, various concerns have tried in vain to return the car to the winner's circle against the likes of Honda, Renault, Alfa and Nissan. By the time Prodrive inherited the project from West Surrey Engineering at the end of the 1998

Words | Mark Hales
Photos | Jakob Ebrey, LAT, John Colley

season, the Mondeo was no more than a midfield runner in a grid where slots were routinely decided by thousandths of a second. The architect of the Mondeo's eventual rise to dominance was former Lotus engineer George Howard-Chappell who, together with Prodrive Technical Director David Lapworth, elevated the science of front-driven saloon car racing to a level which even he describes as 'ridiculous'.

But how did Prodrive succeed where the rest had failed? 'I suppose it was because we wouldn't believe anything until we had proved it for ourselves,' says Howard-Chappell, 'we measured absolutely everything and we did almost as much on the car as we did in the workshop because it is very important to test in the condition in which it's going to be used. That was part of a philosophy which said we wouldn't specify what we thought would make the car fast and then build it to find out, but instead we'd spend part of Ford's pot finding out what makes it fast beforehand. It's an important difference because you have to make a decision where to spend the money, and it is not always obvious.'

Howard-Chappell does say though, that the engine was one of the first areas to receive attention. 'We inherited it from Cosworth,' →



Brakes are the ubiquitous six-pot AP calipers with big vented Alcon discs. They never gave too much trouble except at Donington or when Swedish driver Rickard Rydell indulged in rally-style left-foot braking

"this year's minimum torque figure was actually greater than last year's maximum"

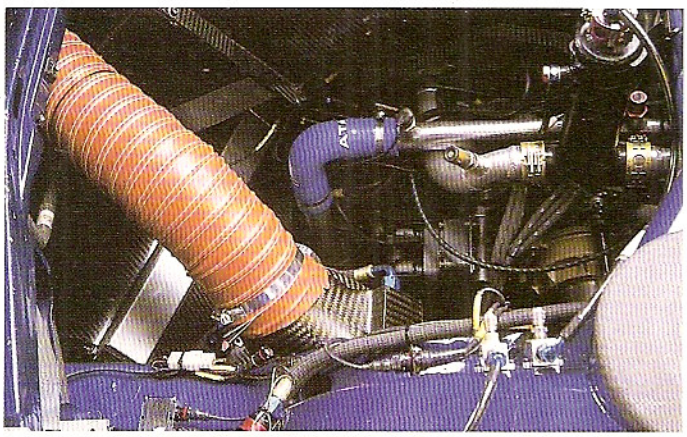
he says, 'and by halfway through the 1999 season we knew it wasn't strong enough. We had been running the Honda and the Alfa engines so we already knew what it takes, and having tried to help improve the engine throughout 1999, we decided to do it ourselves for the following season.' Paddock rumour even suggests that Prodrive boss David Richards was sufficiently sceptical of the dyno figures that he put an engine on his own test bed and subsequently marched hot foot to Cosworth for an explanation... Howard-Chappell will also admit that a V6 (the Ford's was unique in SuperTouring) was not an ideal choice, but Ford's fours were even less suitable because of their cylinder head design. 'That,' he reckons, 'is why it was 11th for so long. People who might have been able to make it work decided they didn't want to start from there.'

Prodrive says that it altered everything but the basic block, and a sneaky look inside one of 1999's rocker covers showed a huge amount of welding of holes and redrilling – a trend which has been continued although GH-C refused to reveal any specifics – other than 'it's not something you have to do with every engine.' Prodrive altered the firing order from the Cosworth spec (which was already different from the road car's) partly because it felt there were power advantages to be had – in particular from the exhaust – and partly because it cured a mysterious harmonic vibration which was migrating all the way to the gearbox and causing failures. It also converted the valve actuation from traditional bucket between cam and valve, to the more fashionable finger follower found on most modern four-cylinder engines.

On road cars this is partly for economy of production and partly because it is easier to add hydraulic lash adjusters to quieten the valve train. The incidental benefit for racing is greater freedom of cam profile – the finger occupies less area than a bucket so it can be made to move more accurately – or to speed up and slow down during the actuation. The downside of 'getting more from the geometry' according to GH-C is the mathematics of cam design because the follower works in a ratio which alters as it moves along the cam profile. Much work was then carried out on mapping of the electronic fuel injection and engine ignition management using a Pectel system and although GH-C remains inscrutable about exact power outputs, he allowed an educated guess at about 305bhp – a more honest figure he suggested, than some, and one which the car's success makes all the more believable.

He would also add that this year's minimum torque figure was actually greater than last year's maximum but rather more important was the torque area 'under the curve' and enhancement of this formed a large part of the in-car test programme. It was far more relevant he says, to see and measure how fast the car actually accelerates rather than try and work out what is needed from the dyno, especially as the cold air for intake and the exhaust layout will be slightly different. More important still is the cut of the gears, how and what you do to unload the dogs during the change and how you cut the ignition for the flat shift mechanism which allows a driver to keep his foot in it while pulling the lever. The Ford engine was extremely sensitive to this and much work was done on gradual fuel and ignition cuts, and in particular on the way both are ramped back up once the shift is complete. The whole process takes only a fraction of a second but round a lap it makes a 'big difference' not least because the drivers are obliged to shift so often to keep the engine working at an optimum.

The engine work ate a substantial amount of the budget – a fact made worse because of six cylinders, a simple piece of accounting which adds 50% to almost every bill before you spend anything extra on making the engine fast. Following that there was the packaging problem of a vee engine between the front wheels coupled with the essential of keeping a major mass as low as possible. Howard-Chappell uses the word 'packaging' a lot and once you look at the car you see why. The engine, for instance, →



Mondeo's cockpit is very simple (top left) with floor mounted pedals and left hand drive to balance the weight of the engine. The rollcage (above) picks up on suspension mounts in the floor. Packaging the engine (left) was a problem, but Prodrive managed to reduce engine changing times from eight hours to one hour

is almost hidden by the huge moulded carbon fibre inlet plenum which feeds air from low down just above the front bumper, up and over the engine to the intake tracts. When the car arrived at Prodrive, the design of items like this was a contributory factor in the eight hours required for an engine change, a figure which has been cut to under an hour.

The engine is solid mounted via large lugs on the top of the crankcase, and from the rear cylinder head by three tubular links which hang from the strut towers while a large sump shield attaches to more lugs on the engine and gearbox and spreads the loads under the floor. The power unit is leant forward and moved down and back such that the lower bank of cylinders is almost horizontal, which puts the crank almost against the bottom of the firewall. The gearbox is on the nearside end of the engine with the case stretching back in front of the driver's feet (the cars are left hand drive to balance the weight of an engine to the right) but the differential is mounted on top and further forward, such that a jackshaft runs along the bottom of the vee to take the drive to a cv joint and then out to the offside front wheel.

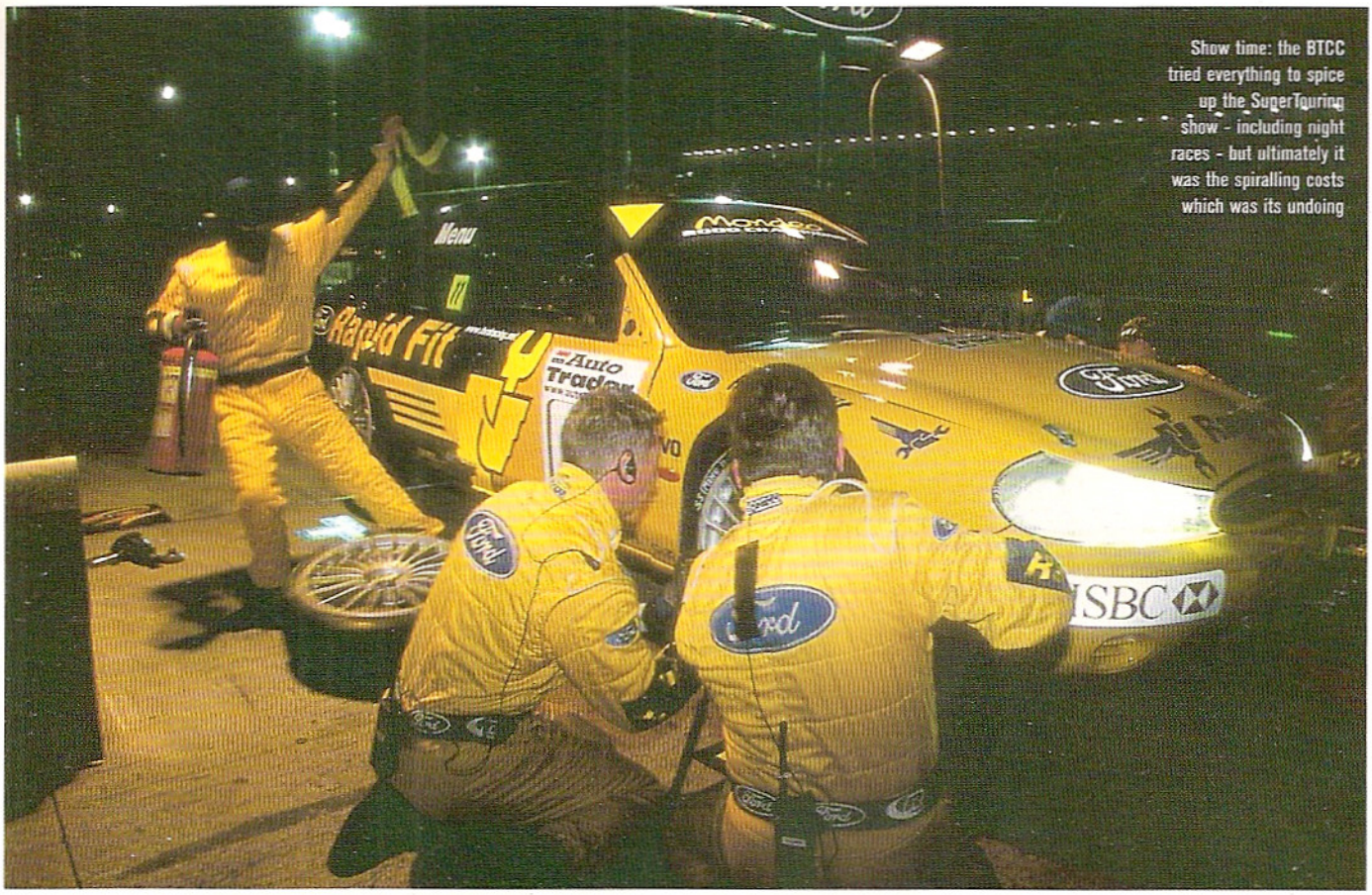
This much dates back several years and was not Prodrive's idea, but for the 2000 car they did incorporate the front wishbone mounting into the rocker box casting – involving a controversial interpretation of the rules which used two rose joints and allowed them to widen the total distance between front and rear wishbone pickups beyond the '25mm in any direction' stated in the book . It was, says GH-C, more to do with packaging and to make room for the gearbox than any geometric advantage. The starter motor is right at the back and bottom of the gearbox (weight down and back) and the oil tank comprises an ingenious carbon fibre snake which starts with a small reservoir to the nearside of the rear cylinder head and then threads its way down the firewall, past the gearbox and on along the floor.

"David Richards was sufficiently sceptical of the dyno figures that he put an engine on his own test bed and subsequently marched hot foot to Cosworth"

Exhaust is another area critical in extracting power from an engine restricted to 8500rpm – even more so when there are more cylinders – and again Prodrive took a liberal interpretation of the wording. A measurement intended for parallel lines offers more area when applied to a curve – which allowed tunnels in the passenger side footwell of sufficient size to accommodate six pipes and two collector boxes. This was critical for packaging (that word again) because had they not been able to steal extra space for exhausts, it would not have been possible to move the engine as far down and back. The water system is also runs a higher pressure – partly to reduce capacity and therefore weight – but also so that it can stand being left for long periods at high temperatures without venting, something that occasionally happens when races are red flagged or cars are held in the pits.

Traditional front-drive folklore says that the transmission and in particular the differential occupies huge amounts of time and budget and when we questioned Ray Mallock about the victorious Nissan it was his turn to become inscrutable, but Howard Chappell seems content to gloss over the topic almost as if it is a plug-in item. 'We made a new casing because it allowed us to do what we wanted with suspension pickups but the internals are from X-trac and although we had a hand in the development and we do build it here, it's nothing special, and neither is the diff. We have six dog-engaged gears like everyone else and we use a fairly standard touring car differential which is a combination of plate and visco. The visco part is nice at low speeds but if it's tight enough to hold the power it becomes too hard for the drivers – especially as we don't have power steering – so you use the plate half for that. It is all a question of how you set it up, and although it can affect the rate of tyre wear, once we've found an optimum we leave it alone. The drivers tend to think the diff is more important than it is because they feel it through the wheel but I don't think we changed Alain's (championship winner Menu) diff spec all year.'

The shell starts life as standard a Mondeo steel on which 500-hours are then expended to turn it into a racer with major concentration on stiffness and in placing weight as low as possible and here GH-C says, 'although the regulations are now extremely tight there are still freedoms to be exploited. Weight, and where it is in the →



Show time: the BTCC tried everything to spice up the SuperTouring show - including night races - but ultimately it was the spiralling costs which was its undoing

car, is still very important but nobody says how heavy things like the rack or the pedal box have to be...' Interestingly the time to prepare the shell is half that quoted by Mallock for the same job on the Nissan but it is nevertheless beautifully done – in-house and with great attention to detail. All seams are welded and the inner wings are cut and lifted to accommodate the wheels. A roll cage with a vast number of mounting points is installed in the cabin, noticeably more complex in the rear where the diagonals feed down to the centre of the floor to the inboard rear suspension pickups. Steel outer wings are cut and rolled to match the low ride height and big wheels are one of the very few items to be entrusted to an outside contractor. Bumpers are standard Ford mouldings – just as well in that they seem to be an item of conspicuous consumption in SuperTouring races. The doors are standard steel.

Inside the cockpit there is extensive use of black, shiny carbon fibre – for minor items like dash pods for the need-to-know display and the moulded channelling which provides a conduit for wiring and fluid lines – and major ones like the cell which holds the 70-litre bag fuel tank. This is mounted centrally in the floor behind the driver's seat and also accommodates the electric fuel pumps and the blow-off valves. Carbon fibre is also used for the pedal box and Howard-Chappell is particularly proud of this – the implication being that he was personally responsible for its design. It is very stiff, very neat and very large.

It comprises a complete unit which is bolted to the floor and which mounts both master cylinders and pedals. These are hinged at the floor end while the cylinders pivot at the base so that they can swing as the pedals and actuating rods move through their arcs of operation. Its size and position ahead of the driver's feet is only possible because he sits so far back in the car. Throttle is designed to be very smooth in operation – which it certainly feels – and brake bias is adjustable via a Bowden cable and knob on the central switch and circuit breaker binnacle. Anti-roll bars are no longer driver adjustable – of which more in a moment, while the lever for the sequential gearshift is to the right of the driver's seat and is, as always, a dominant cockpit feature. Otherwise the interior looks a great deal simpler than some – 'minimalist' as GH-C puts it.

"The shell starts life as standard Mondeo steel on which 500 hours are then expended to turn it into a racer"

The suspension design is the next area where Prodrive is reluctant to release full details. 'It was again a case of having to make the best of what we had,' explains Howard-Chappell, 'and because a lot of our opposition was fitted with neat double wishbone and link setups at the front where we had a good old MacPherson strut, we had to adopt some creative solutions. We don't really want to give all that away until we know exactly what we're doing this year.' The solutions were apparently controversial, but discreetly put, the Prodrive adaptation is designed to provide better control of the roll centre and camber change than is usual with a strut, but in addition allows the designers to dispense with much of the castor and king pin inclination commonly found in strut-based racecar front suspension. This was essential to reduce steering effort because there was to be no power assistance and according to Howard-Chappell it was, 'about halfway towards the characteristics of double wishbones, but would have been better if they hadn't had to do it that way in the first place.'

The front upright is another exercise in packaging, moving the bottom joint as close to the inner rim and as low as possible – this to keep the roll centre management at an optimum within the very large diameter wheels now fashionable – and to move the whole assembly as close to the wheel centre as feasible. This is to reduce wheel offset and is again →

particularly important because of the absence of power assist. Rose joints and spherical bearings are tiny – Formula 1 sized – items and the whole thing obviously cost a fortune to make. Brakes are rather less expensive – the now ubiquitous six-pot AP calipers with big vented Alcon discs are off the shelf but there is additional water cooling from a pump in the nearside underbonnet. Brakes are generally not a problem except at Donington or where the team's third driver Rickard Rydell uses the rally driver's left foot brake technique to excess.

springs – one at each end – operated by a piston which bears on the inner end of the spring, and a rod which runs up the centre. The rolling input is fed by a link from the suspension to a bellcrank which pulls on the piston and compresses the springs which in turn feed roll loads across the bar through the opposing bellcrank to the other side's front suspension. It was of course purely for packaging, say the Prodrive men, because it enabled them to mount the bar on the bulkhead. Shock absorbers are supplied by Koni, which is an interesting choice

injury criteria and lighting – will allow in the quest for low fuel consumption. It is intended to create as little lift as possible in the interests of high speed stability. The term downforce is not really relevant. The original SuperTouring regulations were derived from Group A which stated that any bodywork additions like splitters and spoilers had to be produced in the minimum number for homologation – or 5000 units. Alfa Romeo spiked this very neatly when it produced the 155 Silverstone with its monster front splitter which came as a kit to be retrofitted by the

Money well spent: Prodrive and Ford finished the BTCC SuperTouring era as champions

At the rear there are struts again with two long transverse links for lateral location with their inner pickups meeting the collection of tubes feeding loads into the rollcage, and two forward facing links. The four links no longer consist of traditional tube as in the 1999 car but instead are fabricated from sheet into a large rectangular box structure whose lower surface fills in the space where the floorpan sweeps up over the rear axle assembly. GH-C says this was 'primarily for strength' but it seems more likely that this was designed to keep the underbody airflow as smooth as possible.

The anti-roll bars are another packaging exercise in an underbonnet already crowded with two extra cylinders and they operate laterally rather than in the more conventional twisting mode. The bar comprises a pair of

because, although the Dutch company has a long tradition in the business, it has not embraced the multi-speed technology which is another part of current front-drive folklore, born of the need for SuperTourers to be able to drive over kerbs without launching. 'No, they don't have

"you have to make a decision where to spend the money, and it is not always obvious"

two way adjustment,' admits GH-C, 'but they do adjust the damper unlike some others. We're happy with them.'

Which brings us to the infinitely tricky area of aerodynamics. A modern saloon car is designed to be as slippery as the stylists – and the legislation on items like pedestrian

owner once the car was safely out of the showroom. The rulemakers had no choice but to make aero kits free, albeit within certain dimensions.

It is still a minefield and the gains are directly proportional to the amount of time spent and the facilities available. Prodrive did a lot of initial research with a full scale model at Ford's fixed-ground wind tunnel in Cologne, 'looking for the normal things', then with a 3/8 scale model at Jordan's facility at Silverstone. Howard-Chappell was predictably tight-lipped on the specifics, but he did allow that one of the first things they learnt was that standard test methods do not necessarily carry over to the track. 'One of the main problems of working only in the wind tunnel,' he offers, 'is that you only get the figures for straight ahead running when what →

you really want is some that work in corners. If you're lucky though, the results correlate and it might give you a direction.' After that, the team instrumented the car and did a massive amount of running at the Idiada test facility in Spain, concluding once again that the tests didn't prove what they were expecting.

This is a similar problem to that which confronted Formula 1 designers when they tried to use aerodynamics to regain the grip lost with the introduction of grooved tyres, and was one of the factors that made the cars extremely difficult to drive. Jordan's Gary Anderson once said that a Formula 1 car lost about 50% of its downforce with 10% yaw, and while the figures might not be quite so high with a Touring Car because it starts with less in the way of aerodynamic appendages, it does tend to spend more time out of shape. It also explains why the braking distances shortened so dramatically once aero packages were allowed and why SuperTourers are still so very pitch sensitive.

Looking at the front end of the Mondeo it is clear that whereas at one time the rationale was to keep as much air as possible from getting under the car in the hope that higher pressure from the flow over the body would reduce lift, this is no longer the case. The Ford has a raised section in the middle of the front splitter designed, says Howard-Chappell, to make the splitter act like a wing by passing air over both sides and there are also extra diffusers to the side to keep the airflow attached when the car yaws. More air is then directed to a pair of radiators which are mounted as low as possible and exhaust each side just in front of the wheel.

The whole wing is attached via telescopic mounts which give just enough to avoid damage during kerb bashing or when the car attacks a gravel trap, and interestingly once removed, reveals two 17-kilo ballast weights just ahead of the front wheels. Having expended so much time and effort on getting weight as far back as possible, this seems surprising but having built an underweight car, there are only so many places you can legally replace what you have spent thousands to lose. Total is 1065 kilos, including the driver.

The underside behind the front wing area is then as smooth as possible all the way back with a discernible upward sweep which begins just in front of the rear wheels where the air passes over the box rear wishbones. Back on top, the boot supports the very narrow chord rear spoiler with its very steep curve and interestingly, a distinct lip on the back surface. At one time, conventional wisdom suggested that the rear wing did little because there was hardly any airflow – one of the reasons for the Handley Page flap on the roof of the BMW 635 racers of the 1970s – but GH-C says that the modern variety does 'loads' and is a very important part of the package. 'The right aero balance is critical,' he says, 'not only because of the performance gains round the lap but because it helps look after the front tyres. If you went round the paddock, though, you would find very different ideas on how it should be done.'

The V6 engine was not regarded as ideal and is buried deep under the scuttle with drive running through the vee

But no longer it seems, because SuperTouring is now effectively dead in the UK with the rules for next year aimed towards lower costs, more participants and closer racing. Ridiculous it may all have been but Prodrive's enterprise represents one of the most comprehensive efforts to exploit an optimum within a set of regulations ever seen and it was, according to Howard-Chappell, as much a question of philosophy as engineering. 'You need engineering technique of course,' he says, 'but a lot of the time it was a question of recognising that things you didn't expect to make a difference were actually extremely important. And we didn't spend as much time as some at the race track. We did a huge amount of non-circuit testing. It's a great shame that Renault and Nissan pulled out because if you look at the lap times, I think we would still have won.'