FEELING BAFFLED?

There are plenty of options for club racers: wet sump, accumulator or dry sump. **Graham Templeman** explains the solution he and Rod Hill have opted for as their T5 750 Formula racecar takes shape

PITY THE poor rule-makers. Every time that there is a good enough reason to introduce a new rule, it brings with it unintended consequences.

In the 750 Formula, a recent increase in the weight limit to reduce costs has sent the owners of lightweight cars scurrying off to find ways of carrying weight that are more productive than mere ballast. This has included heavier and hopefully more robust gearboxes and the installation of dry sump systems.

For the T5 the weight limit was not a motivator; we were always going to use a dry sump setup because we were concerned about the engine's ability to function when inclined forwards at 40 degrees. It was another interesting technical challenge and, besides, it's not as if there isn't enough to do with simply building the thing in the first place.

WET SUMP

There were options. We could have stuck with a wet sump, which can be modified to cope quite adequately. In fact, the majority of the 750 Formula cars on the grid use this method on the grounds that there is no need to complicate things if there isn't a problem. But there is still a nagging worry about oil surge, especially when aero forces and radial tyres are gradually improving cornering speeds.

Chart 1 shows what we would hope to see with any effective system. The chart plots lateral acceleration along the x axis and oil pressure on the y. The points on the scatter plot are coloured to reflect engine speed. The cloud of points created by this sort of graph varies from car to car and circuit to circuit. Chart 1 is typical of a good system. The majority of the points lie within (in this case) a range of 40 to 80 psi (2.5 to 5.5 bar) and there is no significant drop off during cornering. The lowest pressures are almost all associated with low engine speeds.

Looking at a typical wet sump, as shown in the photograph, care should be taken to keep the oil where it ought to be and in this case, this was done by building in a significant horizontal baffle to discourage it from climbing the sides of the sump during cornering. The area under the baffle around the oil pump was packed with 'pan scrub'-type foam. This material is more usually used to prevent fuel sloshing around in tanks but has been widely adopted for use in wet sumps. There have been instances reported of production cars having to have the foam changed after three or four years, so a good tip is to use fuel tank foam designed for diesel fuel which has so far shown no signs of deteriorating with age.

Wet sumps are remarkably successful and all the evidence is that, if properly designed, they are completely fit for purpose. If fact, the data for Chart 1 came from a wet-sump engine. In the 750 Formula, the majority of cars use them and there are very few engine problems. One drawback is that the amount of oil that can be carried is limited by the need to keep the engine low in the chassis and restricted space for the sump pan. Increases in capacity can only come from increasing the sides of the sump outwards and this is not always convenient.

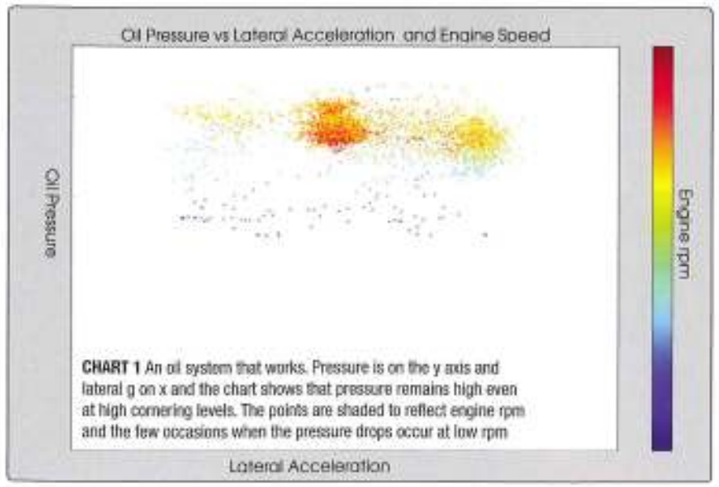

CHART 1 An oil system that works. Pressure is on the y axis and lateral g on x and the chart shows that pressure remains high even at high cornering levels. The points are shaded to reflect engine rpm and the few occasions when the pressure drops occur at low rpm

ABOVE This wet sump has a significant horizontal baffle and ample provision to ensure that the oil can return to the pump quickly enough. Tank foam is used to ensure that the oil pump pick-up has a reliable supply of oil

ABOVE With any losses compromising performance, the oil system is a vital part of the equation in any design. This is a complex dry sump pump arrangement on a V12 racing engine

> *"The emphasis with a wet sump or accumulator is on getting things right so that the engine survives. Using a dry sump opens up the possibility of positive benefits"*

Sometimes, though, looking at the data for a wet sump can give cause for concern. Charts 2 and 3 on the next page show a car where oil pressure drops to around 20 psi (1.4 bar) or lower in left-hand bends. This was not thought to be a problem because it was happening at low engine speeds. Adding the third dimension of rpm to the chart showed that this was not the case. Rockingham's high-speed left-hand turns really presents this oil system with some problems.

Another chart taken from the same car shows the same symptom of low oil pressure in left-hand bends but also improved pressure in the opposite direction. A plausible explanation for this is low oil levels. In straight line running there was not enough oil to provide full oil pressure and this was only achieved when the pick-up was fully immersed during right-hand bends. This illustrates the importance of getting the oil back into the sump as rapidly as possible.

Examining the data in this way is a worrying experience but there is comfort in the fact that the only major engine problems suffered with this setup was a crankshaft which might reasonably have expected a happy retirement after 12 years on the road. Instead it found itself subject to a further five seasons of racing at a rev limit way beyond anything Fiat had specified. Eventually it was fatigue that killed it. In normal running, bearings are only replaced at the end of every season as a precaution. Modern materials and lubricants mean that wear is so limited that it is often a judgement call whether to replace bearings or to trust the set that has done good service up to now. ▶

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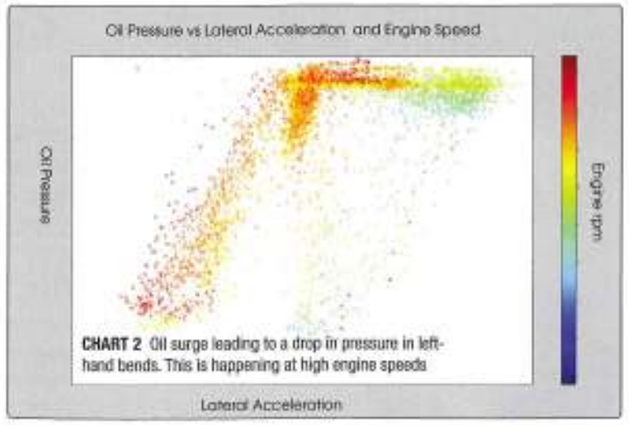

CHART 2 Oil surge leading to a drop in pressure in left-hand bends. This is happening at high engine speeds

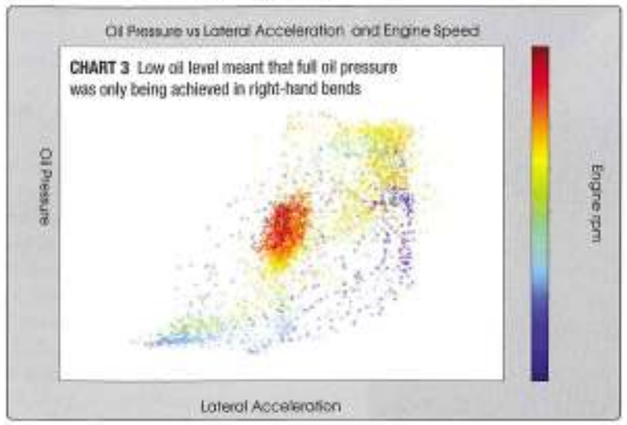

CHART 3 Low oil level meant that full oil pressure was only being achieved in right-hand bends

> *"Prices are sufficiently realistic to deter even the most ardent of do-it-yourselfers from making their own accumulators"*

THE HYDRAULIC ACCUMULATOR

If the wet sump does not appeal, an alternative is the hydraulic accumulator and this is the method chosen by Racekits for its cars. Two companies manufacture accumulators, Accusump and Moroso, and they provide a useful mid-point between the simplicity and cheapness of a wet sump and the cost and complexity of the dry sump alternative. Prices are sufficiently realistic to deter even the most ardent of do-it-yourselfers from making their own.

The idea is to plumb a small cylinder into the pressure side of the oil system. The cylinder has the plumbing at one end, a pressure gauge and air valve at the other and is split into two compartments internally by a moving piston. As the engine runs, it pumps high pressure oil into the cylinder and moves the piston towards the air-filled end. The travel is limited by the air pressure behind the piston which is pre-set to between 6 and 14 psi (0.4 to 1.0 bar) and which obviously builds as the piston moves along the cylinder.

During normal running we have a quantity of oil at engine pressure contained in the accumulator. In moments of crisis, if the pressure in the engine drops the accumulator has an excess of air pressure over oil pressure and equalises this by allowing the piston to move back down the cylinder to inject enough oil to comfort the distressed engine.

There are a couple of driver-related complications and a couple of warnings. To maintain pressure between runs, there is a shut-off valve between the engine and the accumulator and the driver has to remember to close this before stopping the engine. In this way, the accumulator is pre-pressured for the next start so long as the driver remembers his responsibilities. Experience shows that not all drivers faithfully go through proper pre- and post-race routines. It is possible to fit an electrically-operated solenoid valve but this tends to slow down the rate of refilling and so is not recommended for racing applications.

Martin and Andy Kemp specify a four-pint Accusump accumulator for their Racekits Falcon 750 Formula kit car and this is a rather larger size than the manufacturers would normally recommend for a small engine. They use a static pressure of 6 psi. The larger size unit is used partly to increase the amount of oil that can be carried but mainly in the expectation that the cylinder will contain a significant proportion of the total so that they can leave the sump as standard. They add no extra baffles at all, and rely entirely on the accumulator to keep them out of trouble. The evidence of Chart 4 is that it works.

DRY SUMP

The emphasis with a wet sump or an accumulator is on getting things right so that the engine survives. Using a dry sump opens up the possibility of positive benefits.

Properly designed, bullet-proof oil pressure is guaranteed. Which is where Oxford Brookes student Raghavendresh Nagaraju comes in. His job is to provide us with a system that will provide all the benefits without being over-specified at the cost of either power absorption or weight. ▶

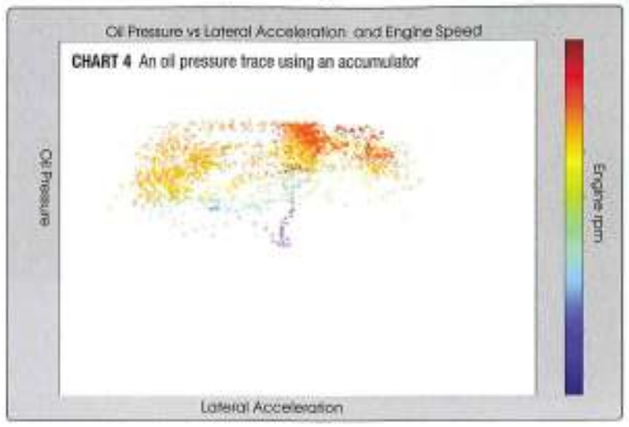

CHART 4 An oil pressure trace using an accumulator

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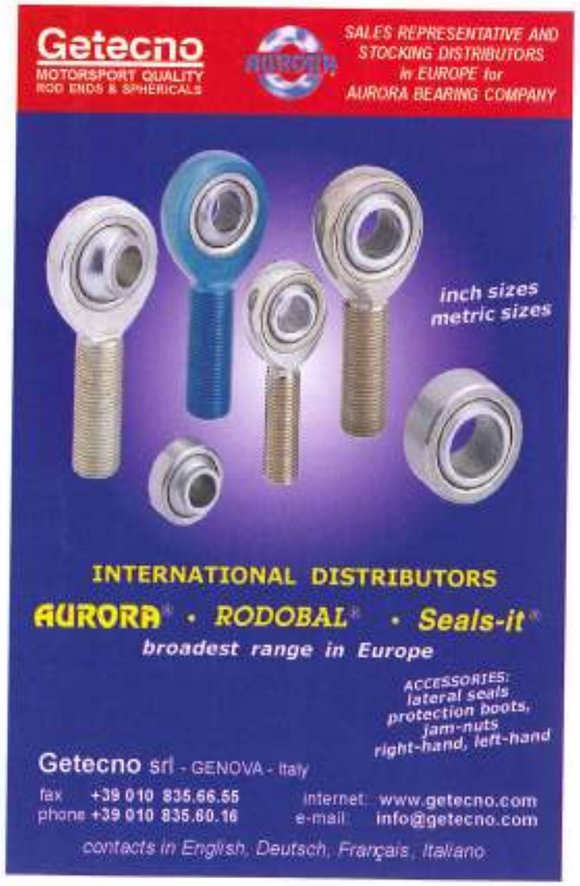

BELOW The Pace dry sump system fitted to a 750 Formula car

The other big advantage of a dry sump system is that it can reap the benefits of running with crankcase pressure below atmospheric. This can reduce the substantial amount of energy wasted in the crankcase. On our four-cylinder engines, the oil/air emulsion is being compressed by two pistons as they descend and it rushes into the void left by the other pair heading in the opposite direction. All this pumping and churning costs power and one way round this is to create a vacuum in the crankcase which reduces the amount of emulsion and therefore the pumping losses. But the benefits need not stop there. A lower crankcase pressure means a bigger pressure difference across the piston rings so that they are sealing more effectively. This opens up the possibility of reducing ring pressure and reducing friction still further.

CRANKCASE VACUUM

To get an idea of the magnitude of the losses (and savings) on offer, and based on data gleaned at a recent conference, the piston/ring package represents about 20 to 25% of the total engine friction losses and the crankcase pumping and windage waste a similar amount. These are very broad figures for a high-revving engine, but serve to get us in the right ballpark. It is obvious that any improvement in either would be most welcome. Hearsay suggests that the benefits come when the crankcase vacuum measures about 0.25 bar (8 in Hg or 4 psi) and they remain pretty constant unless very high rpm is used. In that case, the levels could increase to about 0.8 bar. The latter, very high levels will require special seals and even the more modest target will need careful attention to sealing off the crankcase.

Although a carefully-designed dry sump can have a scavenge system designed to provide the chosen level of vacuum, it is not the only way. The Americans have long been able to buy external ancillary pumps that lower the pressure in the sump and more than pay for their running costs of horsepower consumed. And before that it was possible to buy a system that used the exhaust gas flow. Small pipes connected the crankcase into the headers via check valves placed at a 45-degree angle to the flow. In this way, the exhaust gases do the job for free.

Part of Ragh's job will be to specify the right size and number of oil pumps that will get the job done without costing power. We will follow the current practice with modified engines of using the engine's production oil pump to take care of the high pressure delivery of oil to the engine and add an extra pump (or two) to return the oil to the tank.

ABOVE A rendering of the oil tank proposed for the T5

Ragh has applied all the normal rules of tank design and has come up with a tank with a long 'fishtail' device that takes the oil from the circular cross section of the pipes into a long thin rectangular section that feeds the incoming oil tangentially into the tall thin neck of the tank. This neck is designed to have the incoming oil swirling round the outer walls and has an inner tube to allow the air to escape. The oil then falls onto a series of baffles, the first designed to act like a weir to extract more air. The second one is a perforated plate that does the same job and the third conical baffle simply keeps the oil in the lower part of the tank. The engine is fed from the base of the tank.

The careful design of the tank means that the air can be properly separated from the scavenged oil and the pressure pump is supplying good quality oil back to the engine. Ragh would have liked something taller and slimmer, behind the driver, Formula One-style. He has had short and fat forced upon him by the need to keep it below the line of the bodywork.

The external tank means that the amount of oil carried is not limited by the size of the sump and the oil capacity can be decided upon according to need and not engine location. If we are in the happy position of needing to add ballast to the car, a couple of extra litres would give the engine oil an easier time. So the tank will be one of the last things to be manufactured and its size will depend on how close to the weight limit we are.

The choice of oil system depends on many factors, but the trade-off of ease of installation, performance and price of the hydraulic accumulator was certainly a surprise. No modification to the engine, rock solid performance as shown by the logged data and all at a moderate price certainly gives pause for thought. But a dry sump, well that's proper racing kit, isn't it?

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