March 717 Can-Am: 8 Cylinders, 8.8 Litres and 848 BHP!

AUSTRALIA'S MOST TECHNICAL MOTORSPORT MAGAZINE

RACE

RACE PERFORMANCE + CAR CONSTRUCTOR MAGAZINE

ISSUE 07 Aug - Oct RRP $8.80

Ford Escort

Cosworth Powered Giant Killer!

TECH:

- Racecar Data Logging
- Advanced Tuning: High/Low Injectors
- Nickle Bronze Welding
- Godiva Supercar

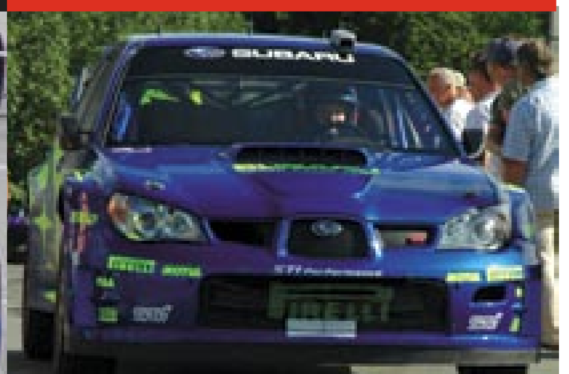
PLUS:

- MG Racers
- IPRA - XY Ford
- Goodwood Festival Of Speed
- Wheels on Wide Bay

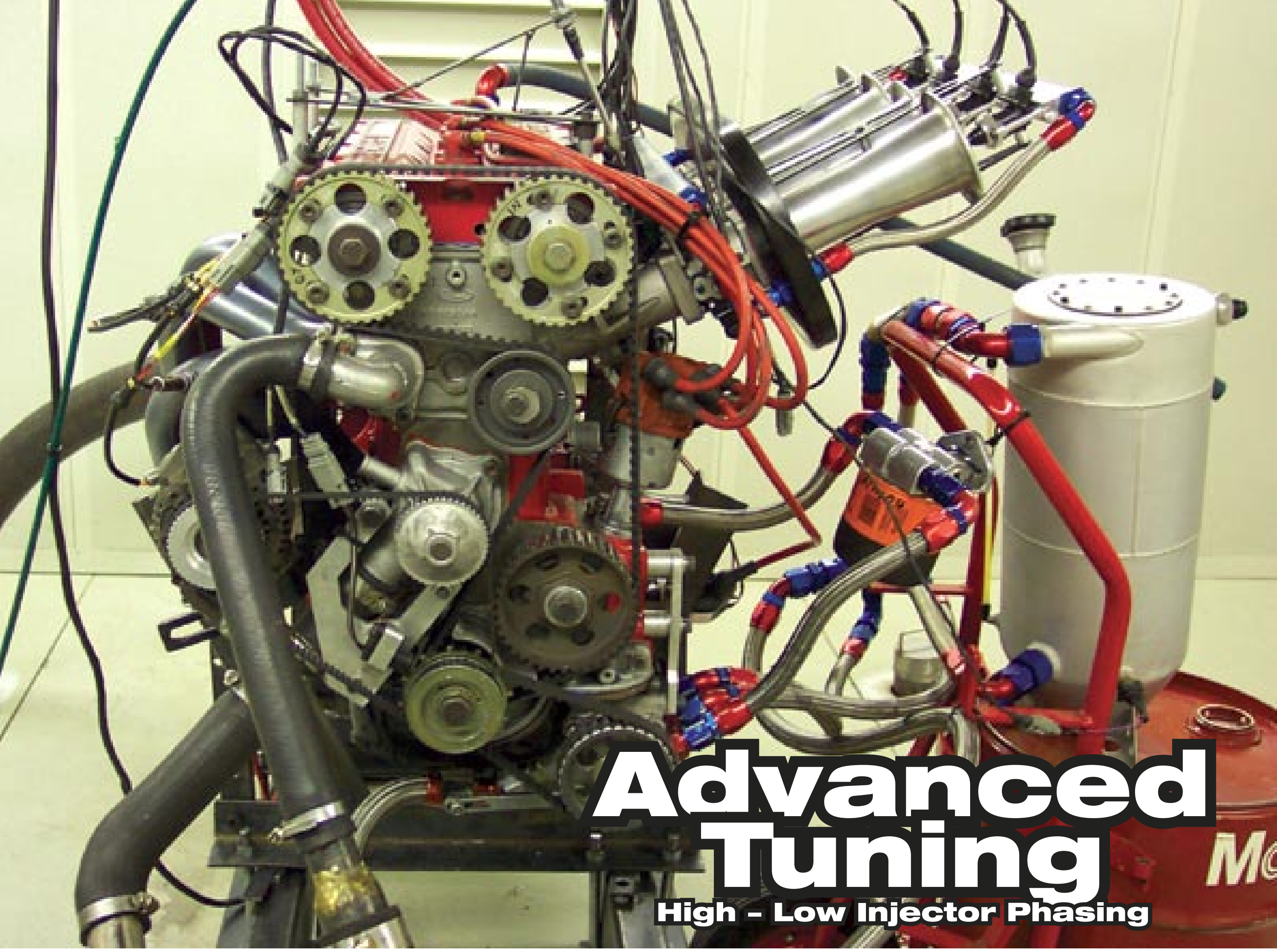
V8 Powered Autocrosser

Aussie FSAE 'World Champions'

WRC: WRX Turbo Secrets



SN 1832-2646
771832 264076



Advanced Tuning

High - Low Injector Phasing

Above: YB Cosworth on MoTeC's engine dynno, mapping high and low injector phasing.

Jamie Augustine is modest about the development he has put into the YB Cosworth in his Escort, however I would say that he has developed the tuning of his dual bank of injectors further than anyone else I have read about in any other magazine. As with all of the development of Jamie's car, this has not been the work of a moment and it has also been assisted by his experiences tuning V8 Supercars, which also use high position injectors.

Theory

There is no 'perfect' place to site the injectors in a race engine; there are always compromises and trade-offs as there is with so many aspects of an engines design.

The basic theory is that injecting the fuel further away from the intake valve allows the fuel and air that make up the intake charge more time to become homogenous. This means that the just-injected fuel will be more likely to evaporate into a gaseous form and/or form smaller droplets of fuel in suspension. Because of these changes the fuel is likely to be better distributed in the intake charge moving down the intake port and past the intake valve into the cylinder. The evaporated and smaller droplets of fuel (which have a greater surface area than larger fuel droplets of the same volume) will cool the intake charge more than fuel injected closer to the intake valve and thus will (most likely) be better distributed in the cylinder and combustion chamber. This better distribution means that the combustion will likely be of better quality.

Both the cooler intake charge and the better homogenisation will allow the engine to make more power (all other things being equal), which is what we are usually after in a race engine!

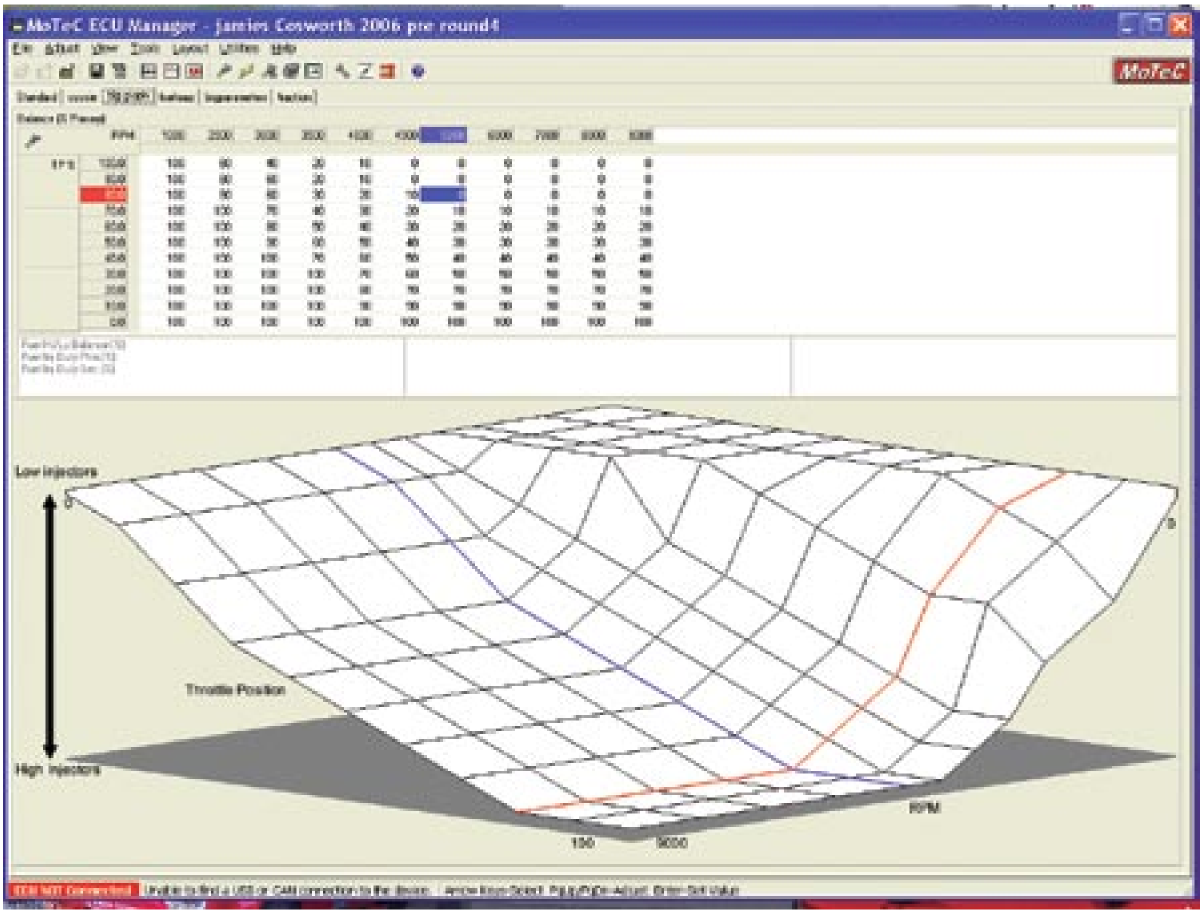
The Augustine YB Cosworth

Does it work? You can see in the engine dyno graphs, the difference in performance between the low injector position and the high injector for Jamie's YB, and from 5000rpm to 8000rpm there is a clear advantage to the high injector placement.

You can see that in the images that Jamie has positioned one set of injectors in the usual position and one set solidly mounted in the airbox, firing into the intake trumpets, seemingly straight at the back of the throttle butterflies. This may initially seem counter-intuitive however, Jamie noted: "...there is a possible advantage in having a butterfly throttle in front of the outer injector, as the turbulence that the butterfly creates at the throttle plate may assist atomisation of the fuel."

This is not always the case however, as Jamie agreed that if the throttle plate is 'wetting up' as the fuel hits it, then this may create its own problems as the fuel will form much larger droplets and atomisation and running may suffer as a result.

The turbulence created from a throttle plate can last for



Above: Jamie's actual injector map, showing that both high and low injectors are firing simultaneously 90% of the time, increasing power and drivability.

up to ten times the diameter of the throttle plate itself and thus there would seem to be some advantage in having the throttle plates and high injectors some distance from the intake valves to maximise the homogenisation of the fuel. But as with many things this has other implications, as Jamie noted: "…the further your throttle plate is up your runner then the slower the response will be i.e. the more lag you will get." But it is not only the throttle position that has this effect: "…that's the other thing from the high injectors, was the lag issues of having high injectors. By the time you come off a turn and close the throttles, you've already got this column of air and fuel in suspension that's on its way down (to the intake valve). So you do get more overrun fuelling and things like that. It's not much, but it is noticeable."

With such a long column of air and fuel there would seem to be the potential for intake harmonic effects and Jamie confirmed this, "There is certainly a reversion effect at certain rpm on the engine dyno. You can see this cloud (of fuel vapour) around the trumpets due to stand-off reversion and harmonics. The fix is to adjust the injector timing, either closer or further away from the valve opening to avoid the harmonic effect."

Jamie's experience in mapping the high injector placement Supercar engine did not lead him down the same path. Recognising the limitations for his application, Jamie chose a different path, "The problem with the high injectors is airbox fires. You get off the throttle and there is still fuel in the inlet runner. You close the throttle and there is a reversion effect into the airbox. This is especially a problem with a pit lane limiter that uses an ignition cut. You get a bit of a backfire up into the runner and this can set the airbox on fire. If you feel it happen then you have to get back onto the throttle and stand on it. It sucks the fire back into the engine and effectively makes it go out."

With this and other factors in mind, a decision was made to use two banks of injectors to fuel the engine. This use of two banks of injectors had been reported on some years ago in the much loved and now defunct British magazine: Cars and Car Conversions. In this magazine (and in a much newer British magazine) the banks of injectors were switched from the inner to outer over a defined rpm range in the order of 500-1000rpm, with some additional fuel added to try to overcome the hesitation that resulted from the switching.

Jamie's efforts originally follow this method as well; however despite many attempts to get rid of the hesitations he was never really happy with it. The hesitation issues were particularly apparent at some circuits, "…as I was in the sweeper at Winton the phasing would come in and out and create hesitations" unsettling the car and displeasing the driver.

Jamie's solution was to expand the phasing period (the period when both high and low injectors are firing) to cover almost 85% of the total injection duties (based on available throttle positions). You can see Jamie's actual injection map in the image above, this shows that the inner injectors alone are responsible for idle and the high injectors are used for wide open throttle (WOT). Between these points the map instructs both sets of injectors to fire simultaneously.

Jamie said that he uses one injection table for the high injectors and one for the low injectors, "…as soon as I get off the throttle, it switches to 100% low injectors, so there is no chance of misting in the airbox and starting a fire. It won't start on the high injectors as they are too big and do not atomise well at the very short duty cycle required for idling. With such a big injector and such a short duty cycle the injector may only be open for ten milliseconds and it will take you one millisecond to tell it to open and one millisecond to tell it to close. Because of this you need to have an injector to start the engine. You might at times be able to get the escort to start on the big injectors and then warm it up on the throttle, but it won't want to idle" Jamie has tried this and when he looked into the airbox he saw that the 363 injectors were not atomising the fuel at all, but were just dribbling fuel into the airbox…a situation best avoided!

Jamie went on to say, "In the wet the outer injectors are not used, as the car cannot use the added power. Using the inner injectors also gives a much better throttle response, which is important as you are constantly pedalling the car to keep it in a straight line." This change is made by eliminating the high injector may and resetting the secondary injector ratio to zero. This secondary injector ratio is the engine-tuner set ratio, which sets what proportion of total fuel load the secondary (high) injectors contribute. So if the engine needs say one point two cc of fuel from the lower injectors it also needs point eight cc from the top injectors. Jamie has set the ratio at 1.67 for his Escort.

Jamie's use of such an advanced mapping solution has resulted in him being unable to tell which injectors are working when he drive the car, as the engine gains momentum in one smooth rush of power and revs. This does not mean that Jamie has had an endless amount of money to throw at the engine to perfect the system, "… what we've done with the escort is to refine runner lengths, exhaust sizes, where you have the collectors etc. We've gone with it but we don't know if we are right or wrong and we don't have the money to try four different TB setups." As noted in the previous article, the throttle bodies are tapered items, the dimensions chosen to fit into the planned taper of the whole inlet tract. This raised the issue of what is the correct size throttle for any give engine. Jamie's experience in tuning race engines affords him a good insight into this issue, "…you can tell if throttle sizing is good by the amount of fuel you have to add in the last twenty percent of throttle opening. If you find that you need to keep adding lots of fuel for throttle opening up near the top of the throttle range, then it is suggesting to you that you do not have enough throttle size, as two to three degrees of throttle change is still making large throttle changes and affecting the airflow. Whereas if you find that at 80% throttle you've got your highest fuelling numbers or equal to you highest numbers, then this means you are getting no more airflow through, so at 80% open, that's how big you needed your throttle bodies to be as far as flow capability."

A carburettor having too large a choke means that the running will be adversely affected when airspeed reduces past a certain point. However as a throttle body does not have to influence the actual uptake of fuel, as it is injected at considerable pressure; as a result you might think that you cannot have too large a throttle body. However the disadvantage of having too large a throttle area is that it decreases the amount of throttle travel to control the engine's output. Jamie adding "…this means that you end up losing your responsiveness at the bottom end of the throttle. You give this tiny crack of throttle and you get this huge airflow change. The solution used on some of the V8 Supercars was to use cammed throttle body openers which give a much larger throttle pedal movement for the initial throttle opening. To ensure that the TB's are big enough you should be seeing little if any change in fuelling between ninety and one hundred percent of throttle opening."

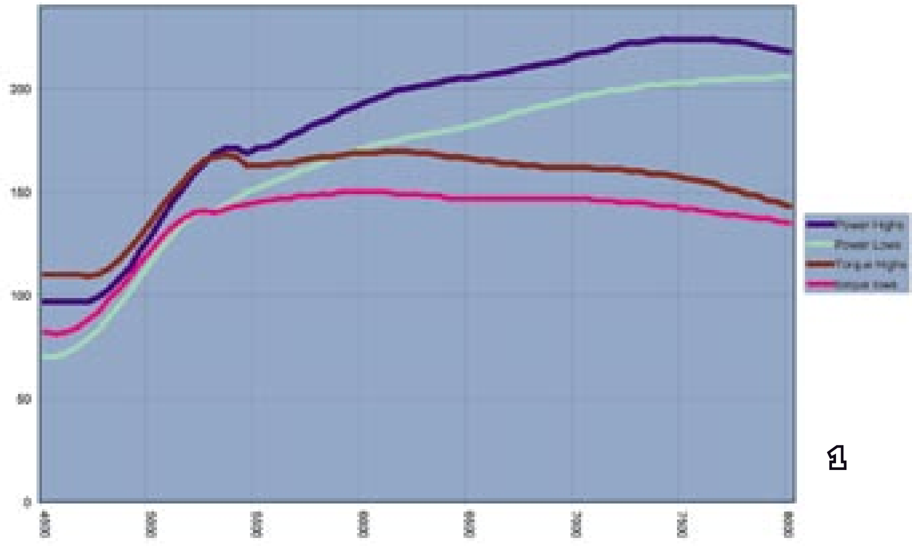
The throttle bodies are the air limiting devices; the fuel is obviously delivered by the injectors. The lower set of injectors are quiet small in that they flow enough fuel to be rated at 56 BHP each and the outer injectors are Bosch 363s which are the same as the Supercars use are rated at 90BHP each. The high pressure fuel first feeds into the high injectors and then into the lower bank of injectors, before hitting the fuel regulator and return line.

You can calculate the injector timing via a calculation using the predicted airspeed in the port with specific rpm and using the distance of the injector from the intake valves, but Jamie did not go down this path. Instead he placed his injectors at a similar distance from the back of the valves as per his experience with Supercars, with the logical reasoning that this was expertly engineered and it was what he had some information on the injection timing for the phasing of the outer bank of injectors. The low injectors were set using a different strategy "With the low injectors, I just took a proportion of it based on the cam timing. What you can set in the MoTeC M800 is the end of injection timing. This means that you don't tell the injector when to fire, but you tell it when to stop firing the fuel in. If you are telling it to start you also have to tell t how long the pulse width is to ensure that you will inject all of the fuel before the valve closes. By setting end of injector timing you say 'stop firing at 180BTDC at number one cylinder if you know that your valve closes at 120 BTDC, so you know all the fuel will get past the valve."

I asked how critical the use of end of injection timing is for this application: "I don't believe there are huge amounts in it as far as an increase in power, however it does depend on your duty injector cycle. If you are running are running a really high duty cycle of 80-90% then it will have little effect as the injectors are on 80-90% of the time anyway. So there is no real timing issue."

One of the reasons end timing is used on the escort is that the outer injectors are really high flow Bosch 363s. They have about twice the flow of the inner injectors and they therefore have a short duty cycle of about 45% when operating by themselves at full throttle. If the lower ones are used then they are at 85% duty cycle at full throttle. Timing on the large injectors is thus much more critical as an error in turning the large ones on and off will result in a greater fueling error than that would occur with the same error with the lower injectors. "…with the lower duty cycle injectors, I can time them to inject more accurately and thus I can inject at the highest airspeed. I haven't had enough time to perfect it yet. You can really only do this kind of work on an engine dyno as the differences are not great and you need to control the variances that will occur on a chassis dyno".

But this is not to say that the engine dyno is Jamie's preferred system for final tuning; "I work a little on the idle (after all it is a race engine) to make sure it is alright. Then go straight to full throttle at 4000rpm and hold it 4000rpm on full load and get it exactly where I want it with respect to the air and fuel ratio. Then I go to the next point and repeat



1

1. Power and torque curves of high vs low injectors.
2. High injector fires directly at throttle plate.
3. Injector pintle almost level with end of trumpet.

all the way along until I have done the full range. I then do the ramp runs, where you accelerate through the rev range and tune a little further and a little bit better. It is a good thing to do a ramp runs appropriate to your anticipated BHP/rev range/gearbox ratios, so your ramp speed (the speed the engine increases in rpm) is the same as you will experience on the track. The final thing to do is then take it to the track and do it all again."

Jamie is adamant that the most effective tuning is done at the circuit, as the engine is running with the correct exhaust, airbox, filters and atmospheric conditions etc that it will be expected to race with. For those of you who have looked closely at the pictures, you will notice that the current intake trumpets are much shorter than in the engine dyno shots. The reason for this is that the long trumpets extended into the airflow entering the airbox. This altered the individual cylinder fuelling (when measured with a lambda meter in each primary exhaust pipe) which required 10% more fuel to be added to number four cylinder and then progressively less - in the order of 7% and 3% respectively - for number three and two cylinders. This maldistribution was corrected by fitting shorter trumpets which did not extend into the air entering the airbox. Jamie did not retune the engine on the dyno, "…as I made the trumpet change I didn't really care what the bhp was. I would have liked to make more power, but it wasn't going to make a huge difference. So I didn't pull it out and put it back on the dyno to get a base map. Instead I tuned it on the track, so it really is the best tuning I could get out of it."

The circuit provides a much more definitive tune. The same occurs for the V8 Supercars, Jamie works on their tune every time the car comes in as the car is adjusted for the prevailing atmospheric and track conditions, "…air-fuel ratios change with ambient conditions and for optimum performance. For a road car you would get all of that sorted out by setting all of the compensation tables up, such that the EMS can adjust if conditions change. But with racecars you just don't have time to sit there and do this all of the time at different altitudes and temperatures etc to make up this beautiful compensation table."

As a result Jamie has made another logical change, "…the Escort uses a MAP and a BAP sensor and you can have both operating at the same time with individual compensation for both. I haven't gone down this track as I have the lambda readout on the dash and as I'm going down the straight I'm always looking to see where it is. If it is lean then I've got a dial switch on there and I'll dial some more fuel to be injected. A nine position switch and each increment is an extra 2% of fuel. So fuel can be added or taken out."

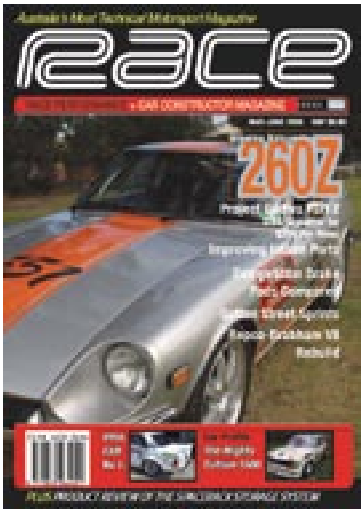
This setup came about because of the limited practice available in some series. Jamie felt that by the time he had come in from doing some circuits, downloaded the data, analysed it and made some changes, then practice was effectively over. This was the main reason why the dial switch was developed. There is a fuel table that is set up to read the voltage supplied by the nine position switch. A change of one position changes the voltage from its resting voltage of 1.6v to 2.1 volts, "…I've tried using a wide band lambda control but it's just not very effective on a racecar. You are traversing so quickly through the rev range that by the time the lambda has a reading and added some fuel then you are already somewhere else. You can't tell what it is going to be, so at 6000rpm it might be a bit lean and so the computer puts in a bit of fuel, but by the time that it does the engine might already be at 7000rpm and the added fuel may then make the engine rich and then some fuel might be taken out. This means that the engine is constantly chasing itself. On a race engine there is no shortcut, you need to tune it properly."

I am indebted to Jamie for being so willing to share his expertise and experiences.

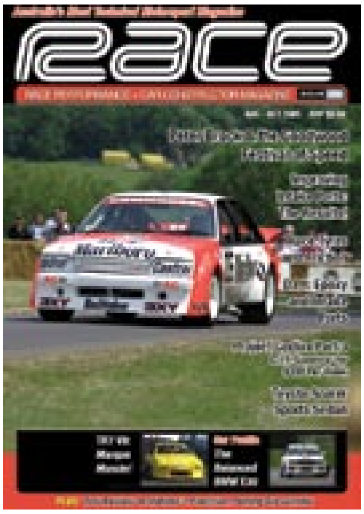
Back Issues

Order your back issues to make sure that you get ALL the information you need! All issues are available.

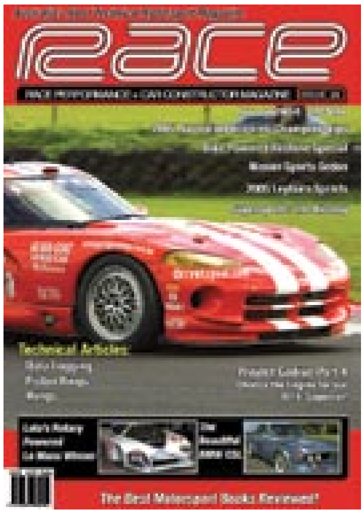
Issue two



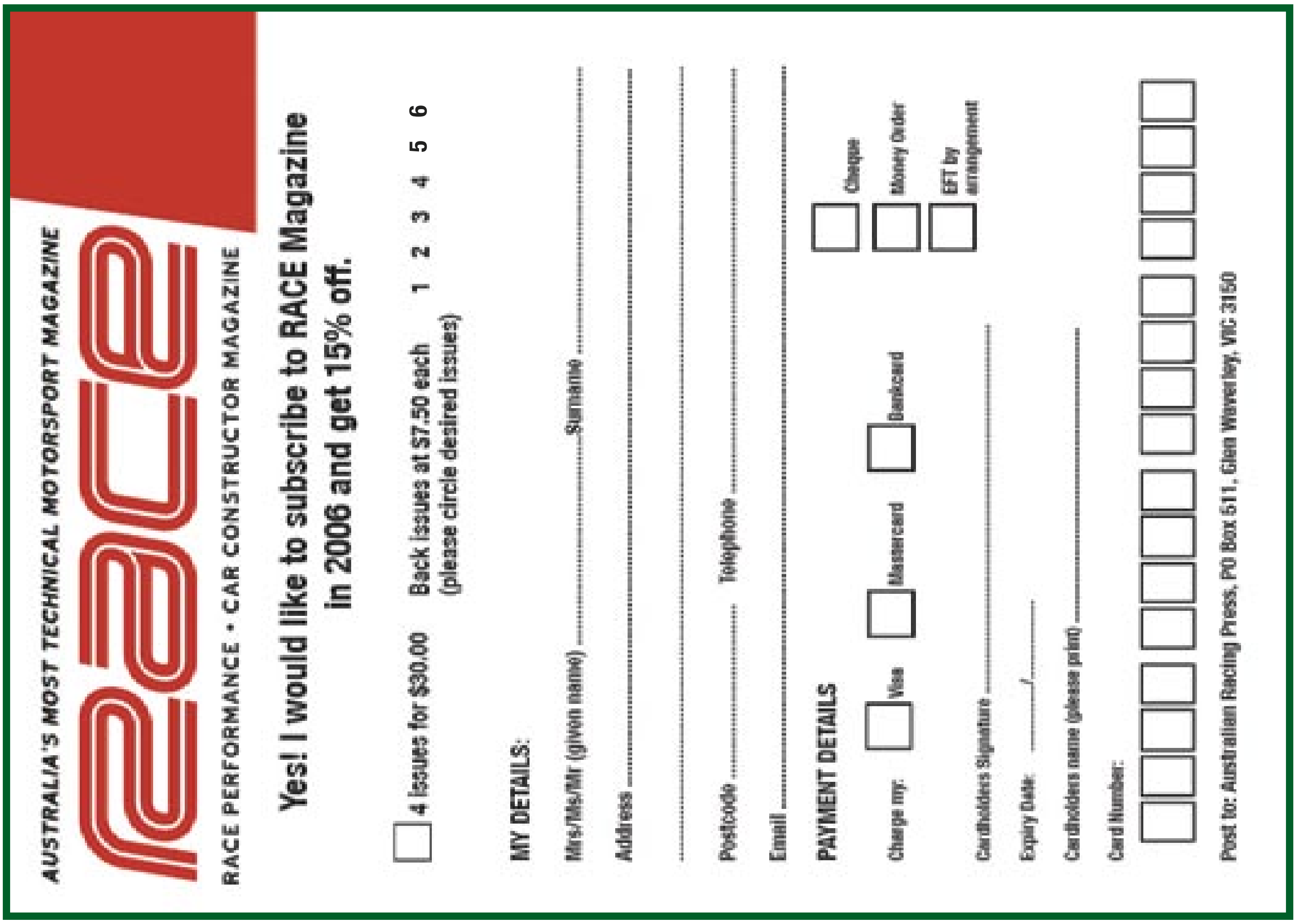
Issue three



Issue four



Issue five



AUSTRALIA'S MOST TECHNICAL MOTORSPORT MAGAZINE

RACE

RACE PERFORMANCE • CAR CONSTRUCTOR MAGAZINE

Yes! I would like to subscribe to RACE Magazine in 2006 and get 15% off.

☐ 4 issues for $30.00

Back issues at $7.50 each 1 2 3 4 5 6 (please circle desired issues)

MY DETAILS:

Mrs/Ms/Mr (given name) .... Surname ....

Address ....

....

Postcode .... Telephone ....

Email ....

PAYMENT DETAILS

Charge my: ☐ Visa ☐ Mastercard ☐ Bankcard ☐ Cheque ☐ Money Order ☐ EFT by arrangement

Cardholders Signature ....

Expiry Date .... / ....

Cardholders name (please print) ....

Card Number: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Post to: Australian Racing Press, PO Box 511, Glen Waverley, VIC 3150