TECHNOLOGY FOR MOTORSPORT

The International Journal

Racecar engineering™

FUEL CELLS THINK TANK
A look at what fuel containment technology can contribute

F1-POWERED HILLCLIMBER
New Martin Ogilvie-designed Predator breaks cover

November 2005 · Vol 15 No 11 www.racecar-engineering.com UK £4.50 · USA $8.95

Taking the heat

Could thermal imaging be the death of the temperature probe?

Aero hints and tips
Ways to avoid drag

Driver-friendly clutch
Tactile take-up technology

Ecotec engine
1000bhp off the shelf

9 770961 109050 11

Contents

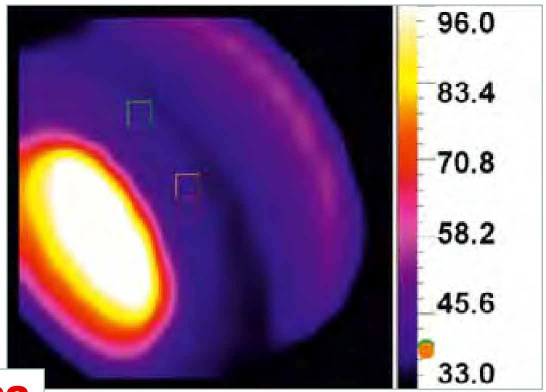
Features

Raceworld

Raceshop

Subscriptions

FOR SUBSCRIPTION DETAILS TURN TO
PAGE 67
Or visit www.racecar-engineering.com



Sam Collins

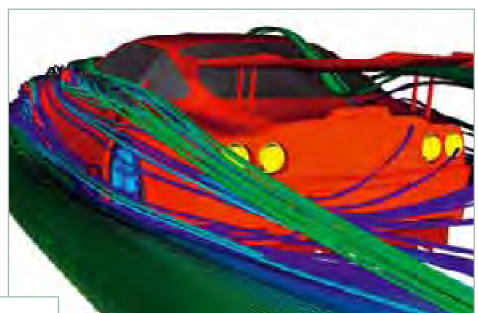
32


Simon McBeath

38


GM

48


Advantage CFD

54

Write Line

Everyone in the *Racecar Engineering* office was stunned to hear of the death of Michael Park, Markko Martin's co-driver, on the Rally GB. Thankfully we have not lost a World Rally competitor since the death of Henri Toivonen and Sergio Cresto in 1986. However, events over recent seasons have exhibited a number of alarmingly heavy accidents. Fortunately the crews have all survived, most without serious injury, but each incident has left an uneasy feeling that things could have been worse. Tragically that has now happened.

Why these accidents are happening is something I have pondered on before in this column [V13N2], but the subject is probably worth revisiting.

The last time there was a fatality, world rallying was in the grip of Group B, the rules that allowed enormous freedom for constructors. Low production requirements to achieve homologation opened the door for very powerful, fast cars. However, they also proved dangerous and were banned following the Toivonen crash. But the cars competing today are at least as quick over a stage mile, even if they are more predictable and forgiving.

"RALLY STAGES ARE NOT LIKE RACING CIRCUITS"

But speed is not the only issue. Rally stages are not like racing circuits. They lack run-off area, crash barriers or gravel traps. Instead they have ditches, banks, long drops and, worst of all, trees. Even at a relatively modest speed, the concentration of force a tree generates on a rally car 'shell is considerable. It is impossible to make the car strong enough to resist this force in all cases because if the car doesn't deform then the sudden deceleration will prove fatal. Nor is it practical to remove all the trees or wrap them in crash barriers. Apart from the logistics, the trees are an intrinsic part of what makes a forest a forest. Take them away and you change the nature of the event.

The alternatives are to take the cars out of the forests and put them in a more controlled environment. We already do that and call it Rallycross. Or, we change the emphasis of the sport of rallying. At the risk of sounding like an old git, years ago world rallies were very different events. Lasting for four or five days, going through the night on occasions, they had punishing schedules and covered hundreds of miles between stages. They had a strong endurance element and gaining results called for an ability to keep going and avoid trouble. They forced a degree of caution and margin for safety in both the teams and the crews. Today's events are more like sprints, always run in daylight and with very limited road mileage. Consequently, all resources can be channelled into producing the best possible stage times. Crews drive on the absolute limit with no margin and the crashes, when they happen, are huge.

Rallies are not races, they can never deliver a neatly packaged three hours of entertainment on a Sunday afternoon. Let them return to being endurance events and promote them in the same way as Le Mans or the rallies of the 1960s and '70s. That way the emphasis will shift away from pure speed, the events will survive the regulators and, most importantly, more lives will not be lost.

Editor
Charles Armstrong-Wilson

The International Journal
Racecar engineering

Pit Crew

Vol 15 **No.11**

Editor Charles Armstrong-Wilson
Deputy Editor Sam Collins
Art Editor Barbara Stanley Borras
Chief Sub Editor Mike Pye
Editorial Assistant Katie Power
Contributing Editors Paul Van Valkenburgh, Allan Staniforth
Technical Consultant Peter Wright
Group Art Editor Patrick Morrissey
Contributors George Bolt Jr, Mike Breslin, Dan Carney, Charles Clarke, Simon McBeath, Mark Ortiz, Martin Sharp, Ian Wagstaff
Photography LAT, Tony Tobias
Business Development Manager Tony Tobias +44 (0) 20 8726 8328 Mobile 07768 244880 Fax +44 (0) 20 8726 8399 tony_tobias@ipcmedia.com
Advertisement Sales Executive Andy King +44 (0) 20 8726 8329 andy_king@ipcmedia.com
Group Advertisement Manager Kevin Attridge
Publisher Gavin de Carle
General Manager Niall Clarkson
Managing Director Paul Williams
Editorial & Advertising Racecar Engineering, Focus Network, Leon House, 233 High Street, Croydon, Surrey CR9 1HZ, UK
Tel +44 (0)20 8726 8364
Fax +44 (0)20 8726 8399
E-mail racecar@ipcmedia.com
Back Numbers John Denton Services, Unit 1 A1 Parkway. South Gate Way, Orton South Gate, Peterborough PE2 6YN, UK
Tel +44 (0)1733 370800
Fax +44 (0)1733 239356
Worldwide News Trade Distribution Marketforce (UK) 5th Floor, Low Rise, Kings Reach Tower, Stamford Street, London SE1 9LS, UK
Tel +44 (0)20 7633 3300
Worldwide Subscriptions Racecar Engineering Subscriptions, PO Box 272, Hayward's Heath, West Sussex, RH16 3FS, UK
Typesetting & Repro Planart Ltd
Print Text Benham Goodhead Print
Cover BR Hubbard Printers
Printed in England ISSN No 0961-1096 USPS No 007-969
***Racecar Engineering* is a Focus Network publication, published by IPC Country & Leisure Media Ltd**
A part of IPC Media, a TimeWarner company

www.racecar-engineering.com

IMechE at ASI

January's Autosport International show will host the inaugural International Motorsport Engineering Conference, organised by the Institution of Mechanical Engineers on 11 and 12 January next year. The new event will cover the full range of motorsport engineering and will consist of 24 lectures split into one-hour sessions. Subjects confirmed so far are design, analysis, development, simulation and testing of engines, transmission, chassis, aerodynamics and control systems. IMechE also hopes to showcase a Formula Student car.

If you would like to receive more information please contact: Stephanie Love, IMechE, 1 Birdcage Walk, London SW1H 9JJ, UK. Tel: +44 (0) 20 7973 1312, Email: s_love@imeche.org.uk

Red Bull Minardi

Red Bull, the Austrian energy drink firm that took over Jaguar in 2004, announced after the qualifying for the Belgium Grand Prix that it will obtain 100 per cent of Minardi's shares, therefore becoming solely responsible for the team.

The takeover of the Italian team has come about from Red Bull's constant backing of young driving talent. Yet, with too many drivers and not enough cockpits, the winning solution was to buy a second team, as opposed to sending drivers to the opposition.

Although the 2006 season will now see two Red Bull teams on the track, the team has announced that both will compete completely independently of each other. The second team, which at present is still waiting to be named, will be seen as the 'rookie' team in order to bring in more drivers from feeder series.

Despite claims, Dietrich Mateschitz has given his assurances that the Minardi takeover is not part of an elaborate plan to gain political power. However, a definite shake up between the teams siding with Bernie Ecclestone and the FIA is predicted, as Red Bull will now receive two votes in any decision making process within Formula 1.

Speaking at the Spa-Francorchamps circuit, Minardi owner Paul Stoddart commented that although he will be very sad to leave the sport he is convinced that Red Bull has the sufficient funds and commitment to take over the team, ensuring a stable future for the majority of Minardi's current employees.

LAT

First Jaguar, now Minardi. Red Bull does indeed give young drivers wings…

Williams tyred out

Williams has modified some of its bodywork after a succession of right rear tyre failures at the Turkish Grand Prix. The team reduced the size of the cars' diffusers and wing end plates after the problem appeared in practice, but failed to prevent a spate of failures during the race. The cause of the problems is rumoured to be linked with the fitment of new brake parts.

It has also been revealed that in 2006 Williams will be supplied by Bridgestone tyres, along with current Michelin runners Toyota.

SEAT Leon WTCC unveiled

SEAT's new WTCC challenger was revealed to the world last month. Pictured here is the car in BTCC colours at the British launch.

LAT

Second test success for A1 Grand Prix

LAT

Paul Ricard hosted the second A1GP group test, now with an even bigger field

Russia, Ireland, Germany, Indonesia and the Czech Republic joined motorsport's inaugural world cup shortly before its second group test at Paul Ricard in France.

Germany's franchise is owned by driver/manager Willi Weber and will be run by Super Nova.

The first grand prix of nations at England's Brands Hatch circuit was being heavily advertised in the UK and, as RE closed for press, a large crowd was expected at the Motor Sport Vision-owned venue.

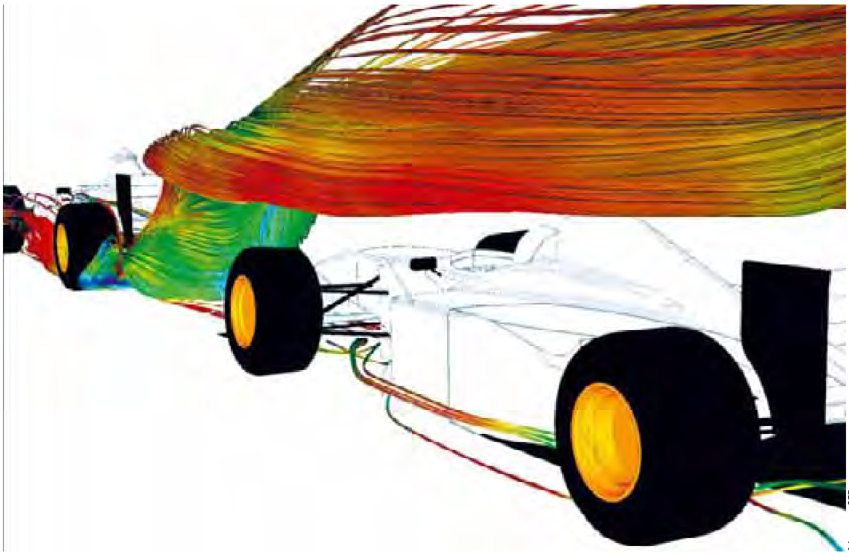
F1 to undertake CFD aero study

Following the results of the FIA's fan survey, AMD has been appointed as 'official technical partner' of the governing body.

One of the very first joint projects that this new partnership will undertake is a CFD study into vehicle aerodynamics, particularly focussed on developing aerodynamic regulations that promote overtaking.

This comes in the wake of research done last year by Advantage CFD and published by *Racecar*, looking into the effects of two-car airflow.

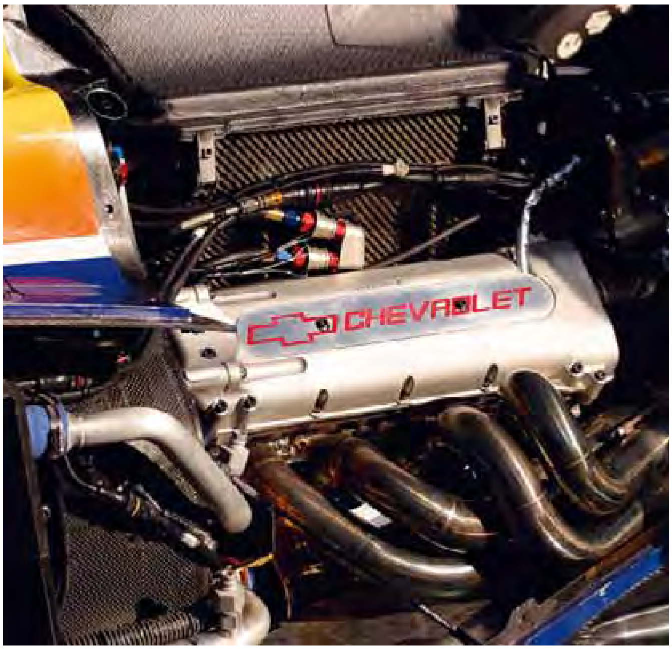
For more information see V14N10.



Advantage CFD

Racecar shows the way again – F1 at last committing to a full CFD programme, initially concentrating on airflow behaviour during overtaking

GM confirms IRL withdrawal



LAT

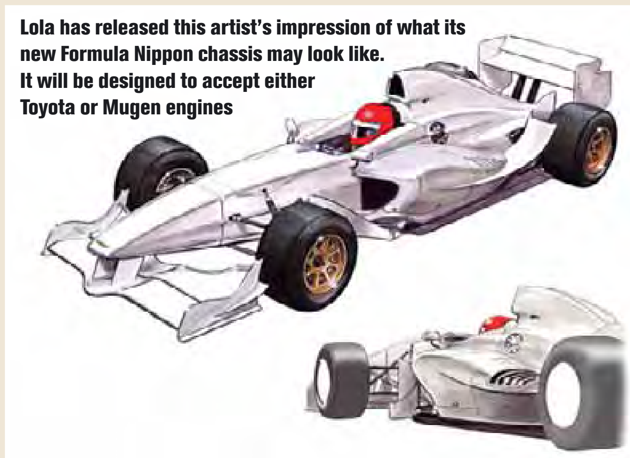
Badge engineering - rule changes could allow Cosworth to supply IRL engines under its own name in the future, now that GM has confirmed it is pulling out

GM has confirmed its withdrawal from the Indy Racing League. Currently Cosworth's IRL powerplant is badged Chevrolet and, if the Cosworth units were withdrawn from the series, it would leave teams with only one engine choice as Toyota has already announced its withdrawal at the end of 2006. Honda, who now stands to be the series' sole engine supplier, has committed to the series for the foreseeable future.

However, it looks possible that the rule may be altered to allow Cosworth to continue to supply engines to the series.

2006 Lola B06/51 Formula Nippon

Lola has released this artist's impression of what its new Formula Nippon chassis may look like. It will be designed to accept either Toyota or Mugen engines



British steam challenge shows its metal

The British attempt on the steam car world record is gathering momentum as the team unveiled its completed chassis in September. Since last mentioned in *Racecar* in 2000 (V10N6) many changes have been made, including turning the car's steam turbine through 90 degrees from transverse to longitudinal. The turbine has been specially designed and built for the job after a suitable off-the-shelf unit couldn't be found.

Chief engineer Glynne Bowsher and engineering logistics coordinator Frank Swanston are also confident that the challenge of designing suitable boilers is nearly finished. Testing of the gas-fired units has demonstrated their potential to produce super-heated steam at temperatures in excess of 700degC. This should provide the power to push the 127.66mph world record to 200mph+.

The team is aiming to take outright world records, Bonneville records and womens' world records next year.

CvO delay LMP2

Christian Van Oost's Le Mans Technoparc-based CvO team has delayed its LMP2 plans until 'after 2006', due to sales of its 'LMP3'-type baby prototype not being as good as expected. CvO had initially planned to try and get an entry for the 2006 Le Mans 24 Hours race.

Talk to us and win cash

Racecar Engineering would like you to give us feedback on the magazine and the chance to win £150/$270 in the process. All you have to do is to visit the magazine's website at www.racecar-engineering.com and complete the simple online questionnaire. It only takes a few minutes and your feedback will help us make sure that Racecar Engineering gives you the information you really want every month.

Chiron blow over

Chiron's LMP3-05 (V15N9) suffered a 'blow over' incident during a BritSports race at Oulton Park just days after the risk of such an event was highlighted by RE.

The no.6 car had just exited the fast uphill left hand sweep of Clay Hill when its front lifted off the ground. The resulting flip shocked Chiron staff member Bill Nickless: 'It was airborne for about 50 to 60 metres and landed right way up on the barrier.' It is the first blow over for an LMP3-type car and has the manufacturers worried. 'It's a warning. It can happen again, these cars are going quicker every race,' said Nickless. The problem could spread further to many of the flat-bottom prototypes in competition around the world.

ALMS extend LMP900 regulations

IMSA, the governing body of the ALMS, has extended the life of LMP900 and LMP675 cars until the end of 2006. This move allows the dominant Audi R8s to continue to compete for another year. So-called hybrid cars will be allowed to compete in the US-based series until the end of 2007. 'The prototype field is going through an important transition, and this opens the field up to a wide variety of cars,' explained IMSA's Tim Mayer.

In the possible event of an LMP900 car performing well enough to finish in a position that would normally warrant an automatic entry into the 24 Hours of Le Mans they would effectively be ignored in favour of the next highest placed full LMP1 chassis.

Old spec cars such as the R8 will be required to run 50kg of ballast and a smaller restrictor.

LAT

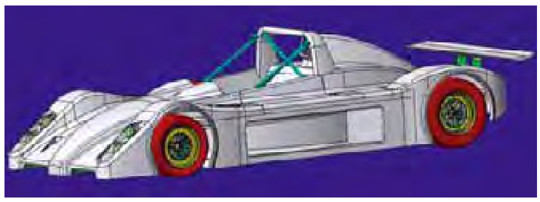
Audi's all-conquering R8 gets a years further lifespan under new regulations

IMSA light headed as the ALMS heads for Utah

In the wake of RE V15N9's LMP3 cover story it has been rumoured that a new sports racing series will be supporting the ALMS in 2006.

IMSA Light is said to be a tightly controlled lower budget formula with restrictions on chassis options and car spec.

IMSA has revealed that the ALMS will have a round at the brand new Miller Motorsports Park in 2006. The Tooele, Utah circuit is the longest in the USA at 4.5 miles.



New 'small' prototypes could soon have a series of their own

Lotus Circuit Car debut

Lotus's 'Circuit Car' made its debut at Shelsley Walsh in August. According to vehicle development manager Nick Adams, Lotus has initially targeted two markets for the car - track days and driver training. The Shelsley run indicated that the new car will also be suitable for outright competition although Lotus has no intention of running a series itself. Lotus believes it will be suitable for series such as the AMOC mid-engined championship and that there could eventually be others, both in Europe and in the USA.

The prototype performed 'faultlessly', despite only having been run briefly at Hethel the week before. A number of changes will now be made to the front geometry and the air intakes.

Significantly, the Elise-based 'Circuit Car' will be the first 'racecar' to come off the Lotus production line. The first customer cars will be available by the middle of next year.

Ian Wagstaff


Ian Wagstaff

The Circuit Car is a first for Lotus, being the only purpose-built racecar to be constructed on the company's production line

NEWS IN BRIEF

- Williams has confirmed that it will be using Cosworth V8 engines throughout the 2006 Formula 1 season.
- Houston will return to the Champ Car calendar in 2006, bringing the series to 15 rounds in total.
- SEAT's BTCC Toledo Cupra Rs have been given a 15kg weight reduction to move the super 2000 spec base weight to 1085kg. The move comes as part of the attempts to equalise the performance of British and World spec touring cars.
- Panoz Esperante GTLM customer cars will be competing in LMES next year, most likely with Team LNT. Courage Competition has been involved with the cars European sales.
- Historic Russian marque Russo-Baltique looks set to return to the track, with A-Level Engineering boss Vladimir Raikhlin planning to revive the company.
- Circuit de Catalunya is planning to increase its seating capacity by 8000 for the Spanish Grand Prix next year.
- Antonio Ferrari's Euro International team will take part in a number of Champ Car races next season. The team has already equipped for the campaign.
- GP2 cars will have fully reworked aero next year, along with slick tyres. Bridgestone is likely to continue as the single tyre supplier.

New FSAE announced

Formula SAE has a new event in 2006. FSAE West is to be held at the California Speedway in June next year. The event will sit alongside the traditional Formula SAE event which will run from 17–21 May 2006. FSAE West is scheduled to take place between 14-17 June.

'Formula SAE West is being opened to meet the growing demand of university teams to compete in North America. For the past three years all 140 slots at Formula SAE were sold out,' explained Steve Daum, the SAE's collegiate manager. 'Registration for FSAE 2005 filled up in just 73 minutes and we know of over 30 teams that couldn't get a slot. With a second competition there should be space available for every team that wants to compete,' he continued.


LAT

California Speedway is to host the new event in 2006

Recruiting of event captains, judges, technical inspectors (scrutineers) and other volunteers necessary to the successful running of the event will start soon. Anyone based in the Los Angeles area with knowledge of motorsport engineering and design who might be interested in becoming involved are asked to step forward and volunteer.

'We picked California Speedway because it's a great site where we can lay out challenging and exciting courses, and it is also a site that provides excellent pits and support facilities. Locating the second competition in California will make Formula SAE more accessible to, and lower the travel costs of, universities on the West coast and around the Pacific Rim.'

Aussie rules spreads its wings

Aussie V8s will rumble their way to the Middle East next year with a round at the Bahrain International Circuit during November. The 2006 calendar also sees China make a return after the first races took place there this year.

LAT

V8 Supercars return to China and head to the Middle East in 2006

2006 V8 Supercar Championship Series calendar

23-26 March	Clipsal 500	Adelaide
30 March-2 April	Australian Grand Prix	Melbourne*
21-23 April	Placemakers V8 International	New Zealand
12-14 May	V8 300	Perth
9-11 June	Shanghai Round	China**
30 June-2 July	Sky City Triple Crown	Darwin
21-23 July	Queensland 300	Ipswich
11-13 August	Oran Park	Sydney
8-10 September	Betta Electrical 500	Melbourne
5-8 October	Super Cheap Auto 1000	Bathurst
19-22 October	V8 Supercar Challenge	Gold Coast
10-12 November	Ferodo Triple Challenge	Launceston
22-24 November	Bahrain International Circuit	Bahrain
8-10 December	Grand Finale	Phillip Island***

*Denotes non-championship event
**Denotes date subject to final FIA and FASC approvals
***Denotes provisional

MoTeC and Rouelle go on tour

The European leg of the ever-popular Racecar Dynamics and Data Acquisition Seminars, presented by Claude Rouelle, begins this November, with courses in Italy, France, Germany and the UK. The final '06 seminar will be held in Orlando, USA after the December PRI show.

November dates are: 5-7 USA; 11-13 Italy; 15-17 France; 19-21 Germany; 23-25 and 26-28 UK (the second UK date being a Formula Student special).

Motor racing Bajan-style

Barbados's biggest and most spectacular circuit racing event – the Internationals Showdown – attracted an impressive 69 entries this year, mostly domestic and from Guyana, but the organisers are pushing for the event to expand further. See future issues of Racecar for more details.


Sam Collins

Softly, softly

In one of the most serious NASCAR rule infractions in recent years NASCAR suspended Busch Series crew chief Brian Pattie and tyre specialist Brandon Stafford for six races, while the Ganassi team was deducted 50 car-owner points and Pattie was fined $35,000 when they were caught applying a tyre softening compound to the tyres of a Ganassi Dodge at Bristol.

The Ganassi car was not allowed to qualify for the race and started at the rear of the field after the team was forced to buy new tyres and the original three sets were confiscated by NASCAR. Ganassi did not appeal the fine or issue a statement.

'06 rules

NASCAR officials met with all Nextel Cup crew chiefs on 23 August this year to explain possible rule changes for 2006, including reducing testing to six manufacturer-specific tests each year at Daytona, Indianapolis, Charlotte, Richmond, Texas and Homestead.

Currently teams can only test at NASCAR tracks five times for two days and four times for one day each year, but many teams test at non-Cup tracks like Kentucky Speedway, which the governing body hopes to halt by introducing a tyre leasing policy at the races where teams will have to return all tyres after each event. 2006 will also see 31 of the 36 races be impound races so only minimal changes can be made to the car post qualifying, with zero track time after timed laps.

NFL into NASCAR

Two former NFL superstars, Roger Staubach and Troy Aikman, have teamed up with Trans-Am driver Bill Saunders and Texas Instruments to sponsor their 2006 Nextel Cup venture, now with Joe Gibbs Racing, not Hendrick Motorsports.

Curbing the blow outs

In an effort to curb the tyre blow out problems at Pocono – the first Michigan event – and Indianapolis, NASCAR mandated a maximum front wheel camber angle of eight degrees, both positive and negative, starting at the second Michigan event.

Aggressive negative camber to help the cars stick in the turns, coupled with unusually high temperatures, low tyre pressures and poor track conditions have been blamed for the high number of cut tyres seen so far this season. At the second Michigan event rear tyres blew on four cars.

For several years now NASCAR has implemented a rear camber rule, so the emphasis was placed on air pressure and a new procedure at the track where an inspector logs the front tyre pressures of each team prior to the start of the national anthem. NASCAR said the pressure information gathered at each race would not be shared between teams and stated post race that all the rear tyre issues were brought about by cuts and not camber or air issues.

LAT

An increase in blow-outs is causing NASCAR officials to implement new tyre control procedures

Old Wood, new tricks

Despite losing some of the backing from Motorcraft, Wood Bros is expanding by joining forces with ST Motorsport

LAT

The 55-year veteran Wood Bros team is planning an expansion with the announcement at Michigan that is has formed a partnership with long time Busch Series operation ST Motorsports to become Wood Bros/ JTG Racing. ST will continue to field two Busch teams while the pairing works to put together a second Cup team and eventually a programme for two trucks, too. A second truck team is planned for 2007, or sooner if suitable backing is secured.

The joint venture will receive backing from Ford Racing, although Motorcraft (a Ford owned company) is apparently cutting back its support of the Woods next season.

Group N rules WR Cars out sharp in 2006

LAT

Banned - WR Cars no longer welcome

Sweeping changes are planned for the 2006 British Rally Championship. Six rounds are proposed next year – three gravel and three asphalt – a drop of two rallies from this year's eight, with Wales Rally GB as the final event.

The technical rules are aimed at adopting the proposed FIA class structures due for implementation in 2007.

World Rally Cars will no longer be eligible to contest the championship, and the main focus will be on Group N cars which comply with the proposed rulings for the R1, R2, R3 and R4 categories. Super 1600 and Kit Variant A6 cars will also be able to compete for British honours, and it is expected that Super 2000 cars will be allowed by invitation only.

On yer 'bike

The UK's governing motorsport body, the Motor Sports Association, has 'clarified' its ruling on the use of motorcycle-engined cars in rallies.

It deems that this comparatively reliable and economical method of providing the necessary power for competition machines is now unacceptable in rallying.

However, it has also been decided that competition car log books for vehicles already existing with this configuration will not be withdrawn, although any new applications to register motorbike-engined rally cars will be rejected.

Peugeot still troubled by damper demands

Further development by team Peugeot saw the cars returned to in-house dampers for Rally Deutschland

LAT

The true cause of the Peugeot 307 WRC's failure to inspire confidence in its works drivers continues to evade its engineers, although progress has been made through positive developments in the way its shock absorbers operate.

One car was equipped with hybrid Peugeot/Öhlins dampers for Rally Finland. The driver found the now more conventional shim pack-restricted Swedish damper inserts to be more predictable in their operation than the Peugeot units. It was also noted that the opportunity for these to be adjusted for rate through the simple expedient of 'a few clicks', rather than the more lengthy and intensive dismantling procedure required by the valve-equipped in-house shocks, offered greater flexibility.

For Rally Deutschland, continued development was deemed to have reduced friction in the Peugeot dampers and both works Peugeot drivers were returned to these.

Like Peugeot, the works Mitsubishi rally team has also invested heavily in an in-house damper development facility and has designed its own valve-type shock absorbers which have been run on the works Lancer WRCs since the beginning of the 2005 WRC season. It is said that the Japanese team has also investigated Öhlins dampers as an alternative. Öhlins units were used on Mitsubishi works rally cars before the team developed its own-brand dampers.

Skoda slides revised five

A revised five-speed gearbox was used in two of the three official works Skoda Fabia WRCs on Rally Deutschland. Designed and manufactured by Xtrac in the UK, these gearboxes will be available as an option to the originally homologated, Xtrac designed and built, six-speed unit until the end of this year.

The official Skoda team will know whether it can continue world championship rallying into 2006 after a board meeting being held in mid-September.

LAT

Choice of either the five- or six-speed gearbox will be down to driver discretion

Rules of attraction

In an attempt to attract more manufacturers into world rallying, Super 2000 is reducing costs by simplifying the cars themselves

BY MARTIN SHARP

Could the new, less technically complex Super 2000 series replace the current breed of International Rally Cars, be they Group N, Super 1600 or WRC?

Manufacturer teams are following the South African lead and readying rally cars built to the new Super 2000 regulations, which come into force for world rallying next year. The South African Motor Sport Federation has already sanctioned the use of Super 2000 cars in rallying this year and examples from the South African wings of Toyota and Volkswagen – the Run-X RSi and Polo Playa respectively – made their rallying debuts in May.

Renault's new Super 2000 rally car, based on the Logan 'world car', will be badged as a Dacia. Simon Jean-Joseph has already tested the prototype Dacia. Additionally, Peugeot Sport has said that it is working on a Super 2000 development of the new 207 road car, which is due out next year. While Peugeot Sport leaves the World Rally Championship in its official capacity next year, the rally car derivative of the 207 will be aimed at customers

Conceived as an alternative to Group N, the Super 2000–Rallies' rules aim to attract more manufacturers to the world rallying party through reduced costs.

Under these rules cars are based on Group N, as opposed to the Group A basis of World Rally Cars, with three exceptions. Group A variant options, or 'VOs', are not allowed in Super 2000, nor are any sporting and type evolutions or WRC rules eligible.

Titanium, magnesium, ceramics, composites and reinforced fibre materials are not allowed unless they are already in use on certain parts on the production car. Single-layer Kevlar is allowed, however, only so long as it coats the visible face of a component.

The wheelarch design, transmission tunnel, rear suspension and differential 'box' are identical to the specification laid down by the World Rally Car rules and all dimensions remain the same. Body material specifications for World Rally Cars also apply. As a means of creating an identifiable difference between a World Rally Car and a Super 2000 rally car, the rear spoiler and front bumper must comply with the Super 1600 regulations. Super 2000 cars must also have no more than $1200cm^2$ of cooling holes in their front ends.

Engines must be wet sump 2.0-litre units with no turbo or supercharger, rpm limited to 8500, a maximum compression ratio of 11:1, with standard valve sizes, a maximum 11mm valve lift and a 64mm-diameter single throttle butterfly. 'Fly-by-wire' throttles are banned, as are variable geometry intake and exhaust manifolds. An ignition and/or injection cut system for gear changes is allowed and the regulations specify a very similar unit to that of a WTC engine. World Rally Cars' 34mm restrictors keep their turbocharged maximum power figures at around 320/340bhp, but the important urge from a turbocharged WR Car engine comes from its wide spread of torque – between 500 and 600Nm. Super 2000 rally engines on the other hand only produce around 270bhp, with a maximum torque of some 250Nm. The power is produced higher up the rpm range, too, typically at around 7500rpm.

"ROAD CAR MANUFACTURERS SEE THE NEW SUPER 2000 RALLY RULES AS AN OPPORTUNITY"

Only MacPherson strut-type suspension is allowed. All uprights must be interchangeable front-to-rear and left-to-right and either cast in aluminium or fabricated from steel. Spherical 'uniball' joints may be used, as may reinforcement bars and reinforced pick-up points.

Only one type of – non-ceramic – wheel bearing is allowed and just 6.5in × 15in rims are allowed on dirt rallies (8in × 18in for asphalt) while mousse and run-flat option are expressly banned.

Anti-roll bars must be mechanical and must not be adjustable from the cockpit, although spring specifications (so long as they are of the same type as homologated) are free. There must only be one shock absorber per wheel, and adjustments to damper and spring settings from the cockpit is forbidden.

Any electronic driving aid system, such as launch control, stability control – and any sensors which contribute to such – is outlawed, as is any ground speed sensor anywhere on the car.

In addition to the Volkswagen South Africa Super 2000 project it is rumoured that VW Motor Sport in Germany is also preparing a Super 2000 car.

Most advanced of the main manufacturer projects so far however is Fiat's Super 2000, based on the next generation Punto, while Lada has already exhibited a Super 2000 car based on its 112 model.

It seems as though road car manufacturers see the new super 2000 rally rules as an opportunity. With WR cars banned from at least one country's premier championship, how long is it before Super 2000 becomes the world's premier rally class?


LAT

Mo Nunn


LAT

Willi Weber


LAT

Dietrich Mateschitz


LAT

Gordon Murray

● **Bill Pappas** separated from Chip Ganassi Racing shortly before the Chicagoland Speedway round of the IRL. **Mo Nunn** stepped in to help the team shortly after auctioning off his team's equipment, some of which was purchased by Ganassi.

● Former Sports Car Club of America president **Steve Johnson** has become the new president of Champ Car. Johnson had been the first person to serve as both president and CEO of the club and professional wings of the SCCA.

● Meanwhile, former Champ Car president **Dick Eidswick** will take on the new role of CEO and chairman of the organisation after having helped select Johnson for his old role.

● **David Williams**, the 'voice of British rallying', died suddenly last month aged 43. Over 300 people attended the funeral of David 'Deke' Williams in early September, and words about him were read out by three of his closest friends. Williams was a founder director of the essential website worldrallynews.com and was also rally correspondent for The Guardian newspaper in the UK, as well as magazines in Italy, Japan, Australia and many other countries.
David is survived by his brothers, Richard and Julian, and his mother Lindsay.

● **Willi Weber** has been announced as the head of A1 Team Germany. Weber also manages drivers, including the Schumacher brothers. Meanwhile, former Jaguar and Jordan F1 staffer **Mark Gallagher** will head up the Irish entry.

● In Austria, new Minardi owner **Dietrich Mateschitz** has teamed up with Niki Lauda to create Austria's A1 Grand Prix entry. In doing so Mateschitz's Red Bull brand looks to become one of the most widely spread in the motorsport arena.

● **Gordon Murray** is reported to be eyeing a return to motor racing with a new firm. GT cars are more likely than prototypes but neither is impossible.

● Long time Stack Ltd staff member **Steve Crabtree** has moved to Zica Consultancy. Crabtree, who had been at Stack for eight years, joins the technical consultancy firm as business development manager

● Grand Prix Masters has announced that former Champ Car chief medical officer **Steve Olvey** will assume the same position with the new series.

Send your company and personnel news direct to the *Racecar Engineering* team: tel: +44 (0)20 8726 8363; fax: +44 (0)20 8726 8399 or email racecar@ipcmedia.com

ON THE GAS...

GEOFF GODDARD
Geoff Goddard Engines Ltd

Geoff Goddard is an engine design and development consultant and also lectures at Oxford Brookes University

How did you first get involved in motorsport?
I knocked on Keith Duckworth's door at Cosworth and asked him for a job. He gave me an extended interview and I benefited, along with several other young engineers including Paul Morgan and John Hancock, from the best post graduate training experience in the world.

What's the most interesting project you've ever worked on?
They've all been interesting as every project adds to the knowledge and understanding of engines. Typical projects have covered everything from designing and delivering a running 800cc flat twin prototype production engine to VW in five weeks to dominating an F1 World Championship season.

What achievements are you most proud of?
During the early 1990s as chief designer of Cosworth I ensured our name was synonymous with winning, or competing with honour, in every major championship we participated in.

The successful Aston Martin DB7, and the Oldsmobile Aurora Indy Racing League engine programmes demonstrated that the name of TWR Engines could also become synonymous with the pursuit of excellence and winning. This confirmed that the original magic of Cosworth could be bottled and exported by the leading engineers to found or expand other successful companies such as Ilmor, TWR Engines, TRD etc. Note: In 2003 Renault F1 bought most of TWR Engines division to capture this essence that creates success...

Can you name your favourite racing cars of all time?
Perhaps the Lotus 49C. Watching it being hurled around Monaco in 1970 by Jochen Rindt demonstrating the ultimate limits of a racing car with inadequate downforce. Closely followed, for obvious reasons, by the 1994 Championship-winning Benetton.

Who do you most admire in racecar engineering and why?
Too many to list here, but historically going from BC to AD (Before Cosworth to After Duckworth) I would have to say the founders of Cosworth, together with Colin Chapman, Gordon Murray, Patrick Head, Ross Brawn and Rory Byrne, who have all moved the technical goal posts forwards further and faster than their contemporaries over extended periods.

What racing era/formula would you have liked to work in and why?
I thought the DTM series in the mid-'90s was the most entertaining series to work in, as all the teams and drivers were committed to hard racing, great communal parties for everybody involved were hosted by each team in turn, and the fans had the freedom of the paddock.

What tool/instrument could you not work without?
An HP 45 calculator – still the fastest and best ever with its reverse Polish notation etc.

What engineering innovation do you most admire?
The attention to detail epitomised by the second compound gear set Keith Duckworth created to overcome the stab torque and torsional problems affecting the valve gear train of the early DFV.

Is motorsport about engineering or entertainment?
Both in equal measures to ensure that the best team can win, but acknowledging that the audience want to see close racing.

Norton capabilities

A bespoke component manufacturer, also capable of offering a range of services to the motorsport industry

Words Katie Power

The 2006 Autosport Engineering show will be host to manufacturing engineer Norton Motorsport, now making its fourth appearance at the event.

The self-proclaimed 'new kid on the block' has successfully grown to establish itself as a quality, bespoke machined parts company within the industry. It provides customers with in-depth individual services on all sizes of projects, working closely with them to meet their exact needs.

Norton Motorsport's history stems back to a company called TG Can Technology, originally formed in 1998 by Ian Williams, with the aim of supplying precision engineering solutions to the packaging industry. Since then the company has expanded rapidly. In 2000 it relocated its business to Milton Keynes to enlarge its manufacturing base and to be more conveniently positioned to supply the UK motorsport industry.

The company then gained a vital asset with the recruitment of present director Peter Norton. This signified a key milestone in the company's history as his arrival brought a vast and detailed knowledge of the industry to the business. The company's expansion continued to develop and in 2003 Norton Motorsport emerged as a limited company, with Peter Norton officially appointed as director.

Last year Ian Williams successfully created a new branch to the company with the partnership of Fine-Line Developments. This joint venture with a mechanical engineering design company enabled Norton Motorsport to provide its customers with a larger spectrum of manufacturing, design and engineering solutions

High-precision engineering of bespoke components is the mainstay of Norton's work but far from all the company has to offer

Although the company is relatively small in size, currently consisting of just 18 employees, its list of clients has grown to include some of the biggest names in motorsport. It currently supplies to a broad range of racing series, including Formula 1 and the World Rally Championship. More recently racecar manufacturer Lola Cars International contacted Peter Norton for help with the manufacture of a bell housing for its Judd-engined GT LMP2 project.

Norton Motorsport primarily concerns itself with manufacturing bespoke parts for individual teams or companies but also offers services including CAD/CAM, CNC milling and turning and wire and spark erosion, as well as producing a line of its own products varying from engine, chassis, steering and suspension parts to gearbox and transmission products.

In order to maintain the tight relationship it has with its customers, Norton Motorsport carefully chooses the companies it works with, but it still views the Autosport Engineering Show as an excellent opportunity to strike up relationships with prospective customers and pursue its aim of increasing the industry's awareness of the company.

Contact

Address: Norton Motorsports
34 Burners Lane
Kiln Farm
Milton Keynes
MK11 3HB
Tel: +44 1908 561444
Fax: +44 1908 307519
Email: peter@nortonmotorsports.co.uk

News

Autosport International 2006 is set to be the host of the F1 in Schools National and International Finals.

Over 30 UK secondary schools, colleges and organised youth teams are due to take part in the two-day event where they will reveal stimulating new engineering projects and portfolios to the automotive industry.

The finals will also include an against-the-clock challenge where competitors will race cars they have manufactured at speeds of up to 80mph.

Nolan O'Connor, marketing manager at Haymarket Exhibitions Ltd, commented on the event saying: 'The CAD/CAM Design Challenge brings engineering, science and technology to life by creating a fun and exciting learning environment for students to make informed career choices.'

Radical will also be adding to the showcase of engineering developments, exhibiting two of its new projects at next year's show. Radical will have a total of three stands at the event, one being in the engineering sector. It will use its international stands to present the new, low-cost Le Mans Prototype SR9. The Radical SR8 will also be on display on Racecar Engineering's own show stand, enabling visitors to inspect the car at close quarters.

To make sure you secure a ticket of your own and to find out more information about the event visit www.autosport-international.com.

Talk to TT

If you are thinking of exhibiting at the show and would like to speak to someone about how to go about it, then contact Racecar's Tony Tobias. Email: expo@tonytobias.com or call him direct on: 07768 244 880.

By Paul Van Valkenburgh

Tyre testing – indoors

Tyre testing has been done for over half a century but still surprisingly few understand what the results mean

Whenever we engineers hear the words 'tyre test,' our first thought is probably of race tyres on a racecar on a racetrack. And that has to be the ultimate proof of the suitability and tuning of tyres in competition. However, for real engineering sophistication and precision, there's no way to beat a modern laboratory tyre test.

When I was in college in the early '60s, I came across an amazing collection of prescient papers from the British Institution of Mechanical Engineers, called 'Research in Automobile Stability and Control and in Tyre performance,' by Bill Milliken and others at Cornell. One paper described a sophisticated tyre test rig mounted to the back of a cargo truck, which was the first to measure all six forces and moments on a tyre running on pavement. It was sponsored by the US Air Force, but was soon applied to passenger car tyres.

When Chevrolet started on its racing research programme in the late '60s, we developed the first racetrack computer simulations, in collaboration with Bill Milliken at Cornell. But there was no race tyre data to use in them, except for some walking-speed data from a flat-bed tester at GM Research. So R&D built its own rig, a one-tyre skidpad. It consisted of a boom pivoting around a fixed anchor in the middle of a ring of concrete pavement about 80ft in diameter. At the outer end was a Corvair engine and transaxle, driving one wheel, which could be angled in toe and camber through the u-jointed halfshaft. Ballast could be added to vary the load, and there was a load cell to measure the →

> "THOSE MINISCULE DIFFERENCES ARE WHAT WINS RACES IN THESE DAYS OF OTHERWISE NEARLY IDENTICAL CARS"

cornering force. At the pivot point of the boom was an operator's seat, engine controls, and an analogue strip chart recorder. It was relatively crude and, I can confirm, a nauseating job for the test operator.

Subsequently, Cornell Aero Labs (now called Calspan) took its truck-mounted tyre measuring experience into the lab, creating a high-speed surface made up of a textured steel belt running on an air-bearing platen between two huge rollers. My exposure to the Calspan tyre test data came again in the late '70s, while working on vehicle overturn simulations for the US DoT, at a place called Systems Technology. We sent dozens of tyres off to Calspan for the extreme limit data we needed. After studying the results for a few days, however, it didn't seem to make sense. Ultimately, I discovered that our procedure was too abusive, and didn't control for the abuse, and during a single run the tyre would wear and overheat so badly, as the slip angle and load was increased, that by the end of the run it was essentially a different tyre. We rapidly learned the importance of the A-B-A controlled test, in which you frequently return to the baseline, to see if it has shifted. This is still true in track testing – and even more so, as the track is probably changing as much as the tyre is.

"THERE ARE FEW PLACES YOU'LL FIND RACING ENGINEERS WHO UNDERSTAND THIS SORT OF TYRE DATA"

You may wonder just how valid racing tyre data is, when taken on a steel belt in a laboratory. But consider how 'noisy' real track data is. It takes a lot of signal filtering to eliminate all the track irregularities from surface contamination and other surface coefficient variations, while the high-speed belt is self-cleaning. I have seen load cell hubs designed to isolate the lateral force component on racecar suspensions. But that still doesn't allow you to accurately control the camber or slip angle during a test.

And that brings us up to today, and why the topic came up. Except for F1, Formula SAE and Formula Student, there are few places you'll find racing engineers who understand this sort of tyre data. That's why Denny Trimble (University of Washington), Dr. Bob Woods (University of Texas at Arlington), and Edward Kasprzak (University of Buffalo) formed a consortium of teams, and contacted Calspan about running comparison tests on their tyres. Since the cost is astronomical, Calspan agreed to a student discount. Doug Milliken volunteered to handle the money, he and Mike Stackpole volunteered to analyse the data into Matlab and Pacejka formats, and Goodyear and Hoosier donated tyres. Ultimately, over 30 schools joined the consortium, at $500 each, to have access to all the data.

Most of the rest of the schools felt that their students weren't ready for that degree of sophistication – although anyone can buy the data later.

Dr. Woods developed the test plan, with feedback from Calspan's test operator, Dave Gentz. Based on a survey of member teams, they decided on seven tyres: a comparison of two diameters (on 10 and 13in wheels) of the same width, a comparison of two widths (6 and 7in) at the same diameter, all from both Goodyear and Hoosier, plus one tyre from Avon. The standard test procedure is to fix the pressure, load, camber angle and speed, then during a run, sweep through continuously varying slip angles, while recording six components of force and moment, plus three infra-red tyre temps, followed by a needle probe at the end. In this case, the upper limits were 450lb load, four degrees camber, and 15-degree slip angle, even though the tyres seem to reach their peak at about six degrees. A slip angle sweep starts slightly offset, passes through zero to peak cornering force one direction, passes through zero to a peak in the other direction, than back past zero again. Five increments of load and camber were taken to define a curve.

At press time, five of the tyres had been tested in two days, and none of the raw data had been reduced. Kasprzak was the attending test representative, and some of his comments were '...they act like real race tyres...very sticky...the test wasn't too abusive...' And their budget affords one more day to test the other two tyres, and to resolve any other questions in the data. I asked him if there were any surprises in the data that he could share, and he said he had been more concerned with making sure the data was complete and the runs were consistent. But he admitted he was surprised that these tyres seemed relatively insensitive to camber. That *would* be a revelation, considering how much time engineers spend using camber to balance a racecar.

This was a groundbreaking event for racecar engineering students. The combined efforts to get this data will make their modelling a lot more accurate. And yet the data selected was primarily for *design* or simulation engineers, and not much use for track or development engineers, who more likely need to know how tyre characteristics vary with temperature. When I use a skidpad to study tyres, I record speed or gs or Cf while watching infra-red temperatures (the control variable), to resolve which tyres have the best Cf at what temperatures. Then, you find the optimum pressure and camber by running them in steps through that temperature. This should be very easy to run at Calspan also – just find the peak force slip angle, then run there at a constant speed until the temperature rises through the optimum. Maybe they'll try that on the remaining day.

As Kasprzak said, differences appeared small. However, those miniscule differences are what wins races in these days of otherwise nearly identical cars. Next year we may see some of the teams running different tyres depending on manoeuvre and ambient temperature, or pre-heating tyres for short runs.

STRAIGHT TALK

By Mike Breslin

The tracks of my tears

Are the new generation of Hermann Tilke-inspired Formula 1 race circuits robbing the sport of its very essence?

Formula 1 was once so much more than a series of races. It was a great adventure too, an epic journey of technical discovery. From the 'green hell' of the Nürburgring to the concrete chutes of Longbeach, with every variation on the theme of twisting ribbon of asphalt in between, the world championship was a constantly changing challenge to both drivers and engineers.

Granted, we had a few duffers, particularly events like Vegas (the car park GP) and the American street races of the 1980s, but even they threw up their own peculiar engineering and driving challenges, and they also sometimes threw up damned dramatic races too, such as Phoenix 1990, or Detroit 1982.

And then, of course, there were always the 'classic' tracks – the aforementioned Nürburgring Nordschleife, the super-fast Osterreichring, or even Brands Hatch. Just to mention these names evokes images of Clark on take-off at the Flugplatz, Villeneuve snr shaving the rail at Rindtkurve, or Reutemann outfumbling Lauda at Clearways.

All gone now though. In their place we have more grands prix then ever before, 19 this year, and yet we also have less variety than ever before, too. I for one have difficulty in telling many of the new circuits apart. Indeed, if they didn't have sand and camels at Sakhir it could just as well be the new Hockenheim. Time was when I could look at a picture of an F1 car on any given corner and tell you the name of the circuit and the corner. Not now. And that's not just because I'm getting out more.

Hockenheim is a good case in point. Not so very long ago the high summer of an F1 season would see the circus arrive in Germany in August with a completely new set of challenges to address: flat out blasts through the forests, a few chicanes, and the twisty infield stadium section. This was a track that was all about highly stressed engines and aerodynamic compromises, where low drag set-ups for the outfield section would often mean high drama in the stadium as the cars scrabbled for grip, while long bouts of full throttle would put the engines under immense strain. Because of this it was also a track that sometimes threw up the odd result against the run of form. But best of all, it was a bit different.

Now it's been Tilked. If you're not familiar with the verb, to Tilke, (Tilkering about, Tilked-up, completely Tilked...) it means to either build or modify a circuit to the extent that it looks pretty much like every other track on the calendar. Tilke refers to Hermman of course, the architect behind Shanghai, Sepang, Sakhir, Istanbul, A1 Ring and the new Fuji. All of them, along with Hockenheim, clones of each other: bent paper clip circuits with highly artificial complexes of slow corners and Saharan expanses of paved run off – by the way, slow corners mean the track-side →

Photos: LAT

Bahrain International Circuit, Sakhir – one of the new breed of highly artificial F1 circuits designed with safety in mind but, according to some, a lack of soul

Inset: Hermann Tilke, the designer behind many of the lacklustre, modern tracks

> **"IF THEY DIDN'T HAVE SAND AND CAMELS AT SAKHIR IT COULD JUST AS WELL BE THE NEW HOCKENHEIM"**

Classic overtaking manoeuvres like this – Montoya outbraking and ducking inside Schumacher on the rumble strip coming into the Bus Stop at Spa Francorchamps in 2004 – are a rarity on today's smooth, ultra-safe F1 racetracks

advertising is on camera for longer, but that's surely just a coincidence... Isn't it?

To be fair to Herr Tilke, he's just following a brief, and perhaps the reason why these circuits tend to look the same is because, by and large, they do actually allow for more overtaking, and some of the dicing at Sakhir, Sepang and Hockenheim has in fact been pretty good stuff. And yet, there's something missing. It all seems so artificial.

Why? Well, think about the most memorable overtaking moves of recent times: Montoya on Schumacher at Interlagos. Hakkinen on Schumacher at Spa. Barrichello on Raikkonen at Silverstone. What have they in common? They all happened on *real* circuits. In fact, I reckon one pass at Spa is equal to about five at Sepang or the like. It's because the moves you remember best take place at tracks where to overtake is still a huge challenge, but most

"I RECKON ONE PASS AT SPA IS EQUAL TO ABOUT FIVE AT SEPANG OR THE LIKE"

importantly perhaps, at circuits where there is an element of jeopardy if the move should go amiss. And that's important. At this year's Bahrain Grand Prix Mark Webber made a mistake and went sailing off the track – I forget which corner, they all look the same. He didn't seem to fight the car, he just let it go, to save the tyres I guess and that's fair enough. But the point is, nothing happened. The car just switched from one ultra smooth surface to another – paved run-off – and in the course of his 'incident' Webber almost explored as much of the Arabian peninsula as Wilfred Thesiger. There was not even a gravel trap to ruin his day.

Now to me this seems wrong. Drivers at the highest level should be punished if they make a mistake, because it's the treading of the thin line between success and disaster that is the very essence of our sport. A car on opposite lock through The Swimming Pool Complex at Monaco is 10 times more exciting than the same at some anonymous Tilke turn with an empty lorry park for run-off.

Some people don't agree though. The other day I was reading a report that said Formula 1 should even re-brand itself as the 'safest extreme sport in the world.' Only a sport as out of touch with the real world as F1 could ever come up with something as ridiculous as that. Why would anyone want to watch an extreme sport that wasn't extreme? That's just *extremely* dull.

I'm not saying we should make all the circuits more dangerous here, and there's no way F1 would or could for very many reasons, not least involving the legal implications should the worst happen. But just maybe we have gone far enough, just maybe it's time to stop building new circuits and to start looking after what's left of F1's once proud heritage of challenging autodromes and differing engineering challenges from track to track. After all, in these days of increasing pre-race simulation – some of the teams have finished the race before they get to the track – the older, *real* tracks, particularly impermanent facilities like Monaco and Montreal, offer something a baby's-behind smooth Tilke-drome can't – bumpy surfaces that can change in character year on year. Which surely must add to the challenge from an engineering standpoint?

So then, with all that in mind, what's my 2006 calendar? Melbourne, Imola, Monaco, Nürburgring (funny isn't it, we used to think that place was bad), Silverstone, Montreal, Indy (it's different at least), Spa, Monza, Suzuka, Interlagos, Jerez, Estoril, Donington (please!) and just a couple of those Tilke go-kart tracks – Sepang and Hockenheim perhaps, but with gravel traps instead of hard aprons.

Just a dream, of course, for the cigarette money says we have to head east, and chances are that each new GP will be on a purpose-built track cut from the same cloth as all the others. Actually, some think this suits the little big man in charge of F1 perfectly. For there is nothing Bernie Ecclestone likes better than order and uniformity – so maybe this is all part of his master plan to make F1 fit the Bernie mould? If that's the case, here's a cheaper way: what about 20 races, all held at Shanghai? And maybe we could have the exact same race each time, too – that would save us the bother of having to tune in.

Formula stupid?

Just some thoughts on the Formula Student report in V15N9. Firstly, I built two FStudent cars in my final two years at University. I did the suspension on both and was in charge of overall vehicle concept on the second. I now work in motorsport and was an FS design judge this year and judged Lulea amongst others. As such, I feel my opinion is well informed.

I hate to use individual cases, but Lulea got a stack load of undeserved credit in that article. The MR dampers did not have any learning capacity and did not in any way, shape or form use vehicle acceleration inputs to adjust vehicle balance. None of the telemetry had actually been used and they could show us no data acquisition plots. Data acquisition is meant to be used to make the car go faster, right?

All the trick stuff is great, but when I asked them about the difference between strength, weight and stiffness and weight in relation to upright design, they just looked confused. I ask you – stiffness to weight or Bluetooth gear shifting, which is more important for a racecar engineer/designer to know about?

I thought the comment about 'dumbing down', in relation to chassis construction techniques was unfair. The idea that a spaceframe is inappropriately low tech is wrong.

Finally, yes Ewan Baldry from Juno works at UCLAN, but this doesn't mean its ridiculous approach of building a massively overweight and poor car because

Email the Editor: racecar@ipcmedia.com
or send your letters to: The Editor, Racecar Engineering, IPC Media, Leon House, 233 High Street, Croydon, CR9 1HZ, England Fax: +44 (0)20 8726 8399
Visit www.racecar-engineering.com and submit your project for a feature online

LAT

UCLAN's class one FS entry – tank or innovative challenger?

'we can take it sprinting' should be given more credit than many of the other better engineered cars. UCLAN again: 'We decided we didn't like the rules...' Well don't build a car then. FSAE is based on Solo II autocross in the States. The only thing you will hit head on is a cone, hence the rules are perfectly appropriate. If I turned up to Le Mans with a Chieftain tank because I thought the LMP1 roll hoop regs were inadequate should I be entitled to race? No, I'd be told I'd built an inappropriate car and then told politely to leave.

Ian Allen, by email

CAD amusement

I received my copy today of Vol 15N10 and got stuck in. I got to the Forum section and started to laugh at the 'CADs or bounders' letter. Where has this guy been hiding or living recently? He is obviously fixated by AutoCAD by the amount of times he mentions it, which probably indicates that this is the only system he can actually use!

I'm not being disrespectful but he needs a reality check. Even as long ago as 1996 I was using a system for low pressure, die cast mould designing and producing high speed CNC programs from the surface of solids models. All we were given were certain design constraints, dimensions and pre-supplied combustion chamber and port geometry values and the rest was up to us! I could visualise in my mind and reproduce it at will. Even nowadays, the software is amazing and there are plenty more 2D and 3D designers out there who will agree that if you can dream it or think it up you can make it. How does he think F1 bodywork or aircraft wing contours are made? Presumably by hand as a model and then somehow copied like we did all those years ago. He is right in saying that they are *tools* but the old saying still stands, 'a bad workman blames his tools!'

Chris Cudlip, by email

Dear Lee...

We understand that Radical has not won the SCCA Run-offs but the Radical is a two seater designed to fit many classes, while the Stohr is a single seater optimized for SCCA, DSR and CSR classes. This does not mean that the Stohr is not a wonderful car, just that it is optimised for classes not found elsewhere. If I were going to race one of these classes I would have a Stohr!

Peter Lott, Texas, USA

Hot shots

With thermal imaging cameras now affordable, could they herald a breakthrough in understanding how a racecar performs? **Racecar** puts one to the test to find out

Words	Sam Collins
Images	Collins; Woodvine/IRISYS

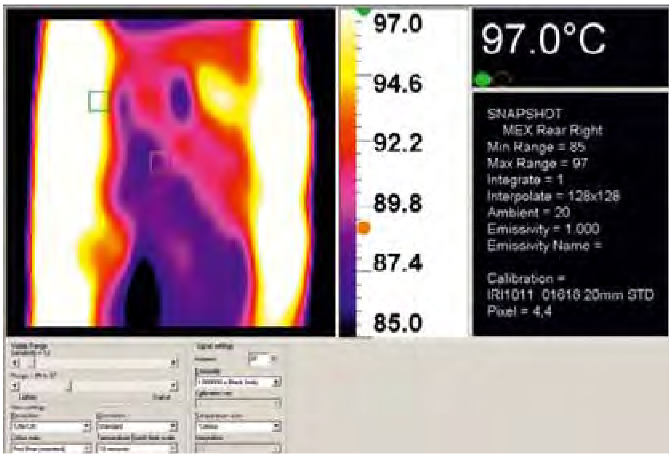
Andy Woodvine of IRISYS demonstrating the thermal imager at Silverstone. Above, taking readings from the A1 Team France car

How many tyre temperatures should you take per tyre? The man from RML said three across the tyre – 'outside edge, middle and inside edge.' Would any more tyre temperature information help, asked *Racecar*? 'It's not relevant because you simply can't get round four tyres and get any more than three good readings in time before the tyres have cooled.' That is the perceived wisdom and little has come along that can change that. Until now. Maybe.

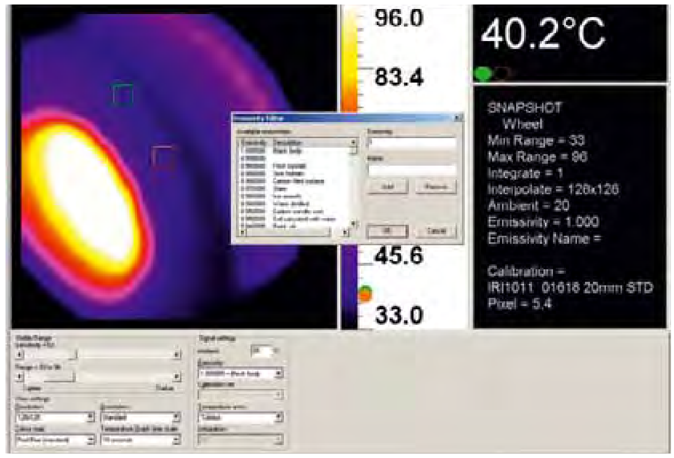
The IRISYS low-cost thermal imager could allow teams to record tyre temperatures in seconds, without the scramble round all four corners to record 12 spot temperatures. With the thermal images, each tyre instantly gets 10 spot temperatures that can be determined later on a laptop.

The usefulness of this technology was illustrated during a recent club race meeting at Silverstone, where a Speads single seater showed a strange cold spot on its right rear tyre – chances are a pyrometer could easily have missed it. Other trials were conducted on the day on a variety of racecars and objects hot and cold, including a shot of the engine bay of Rod Birley's Ford Escort WRC taken immediately after a race which revealed the turbocharger was over 100 degrees hotter (325degC) than anything else around it. Even inadequately heated cups of tea were captured, but more serious tests were required.

French outfit Driot Associates Motor Sport (DAMS) offered to trial the

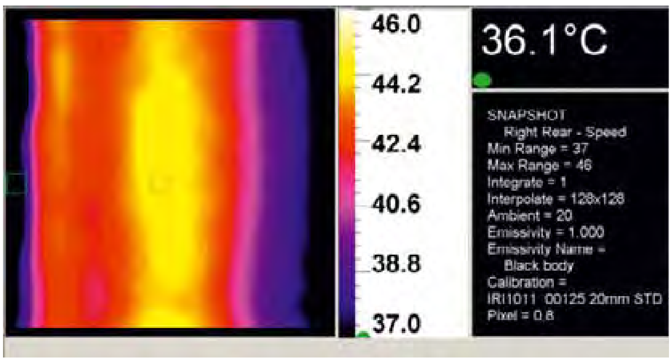


Right rear tyre of A1 Team Mexico's Lola just after removal of tyre blankets. Uneven heating is clearly evident, with nearly 10 degrees of fluctuation. Particularly of note are the hot and cold spots left on the tyre

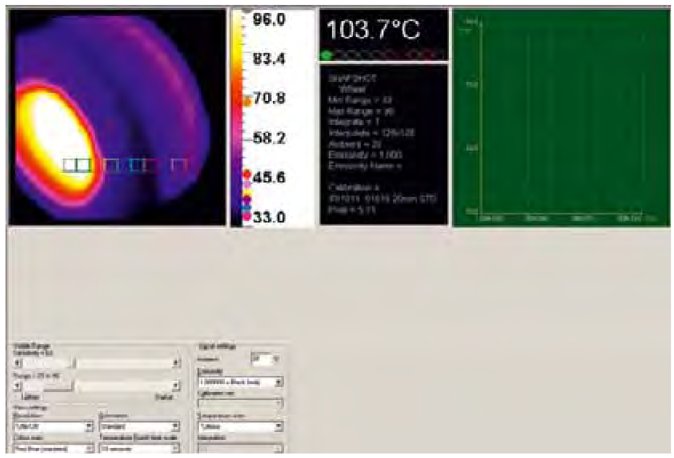


Getting the right emissivity value for a surface is key to obtaining an accurate reading. The IRISYS thermal imager comes with a number of preset values but currently none specifically for motorsport applications

Right rear tyre of a Speads RM05 taken in parc ferme after a 10-lap club race on Silverstone's National circuit. Note the cool stripe on the left running the entire circumference of the tyre. Although it was only a two-degree difference it could point to a number of problems, including a tyre defect. Interference from the engine and exhaust is unlikely as the problem did not manifest on two other identical cars racing at the same event



Taking 10 temperatures across a tyre is easy with the thermal imager. But spot tyre temperatures are perhaps redundant with an overall visual image

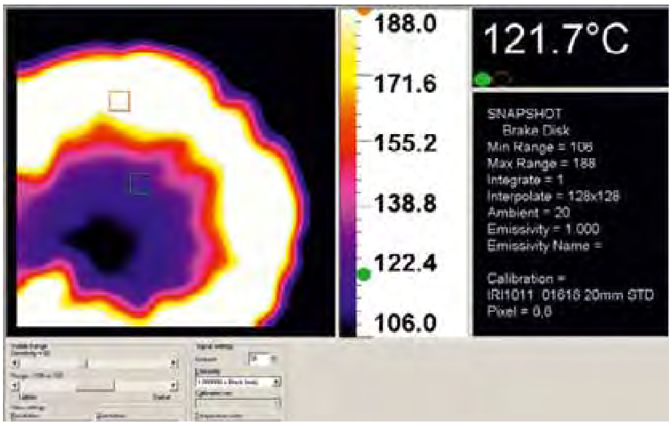


"EMISSIVITY IS THE RATIO OF RADIATION EMITTED BY A SURFACE"

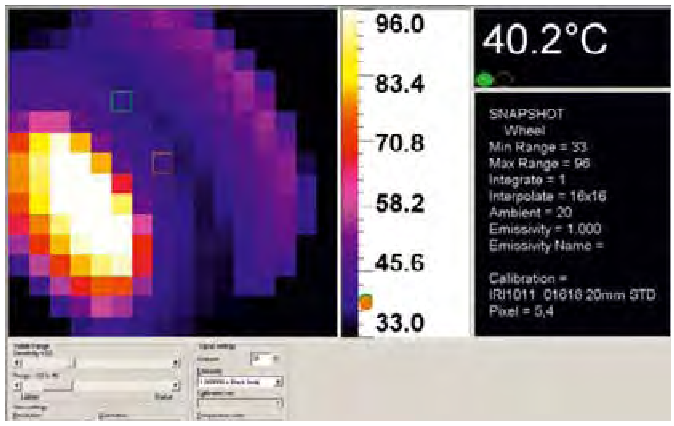
technology on the tyres and brakes of its GP2 and A1GP Cars, offering a direct comparison with the usual probe-type pyrometers. One of the team engineers commented: 'It is good because when you have images you can instantly view the situation. With a probe you must look at just the numbers.' The competitive spirit was soon present as it became clear that the imager could be used to establish what the competition is up to as well. 'It would be great in a series like GP2 because you can see what your competitors' tyres are doing without touching them or even being that near to the car.' Something *Racecar* put to the test earlier in the day, walking in the back of one team's garage and taking temperature readings from several metres away without being challenged. IRISYS representative (and Formula Vee racer) Andy Woodvine claims 'it's accurate from -10degC to 300degC, so it quickly gives you a snap shot of the whole temperature range of the desired area.'

Head-to-head testing started on the A1 Team France car run by DAMS. AP Racing's Nic Olsen used a traditional tyre probe to take readings from the car's brake discs, registering a spot temperature of 260degC, while the thermal imager only recorded a temperature of 160degC, around 100degC out. It seemed Woodvine's claims were somewhat optimistic, but Olsen had the answer: 'On carbon discs it would work fine because they are a black body, but once you get a shiny steel disc it can be a couple of hundred→

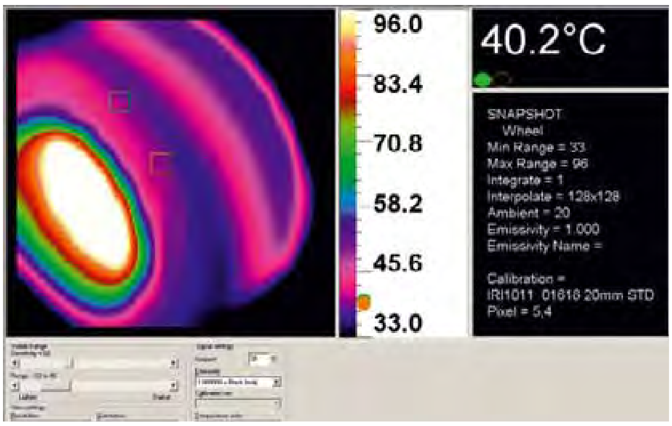
"IT COULD ALLOW TEAMS TO RECORD TYRE TEMPERATURES IN SECONDS"

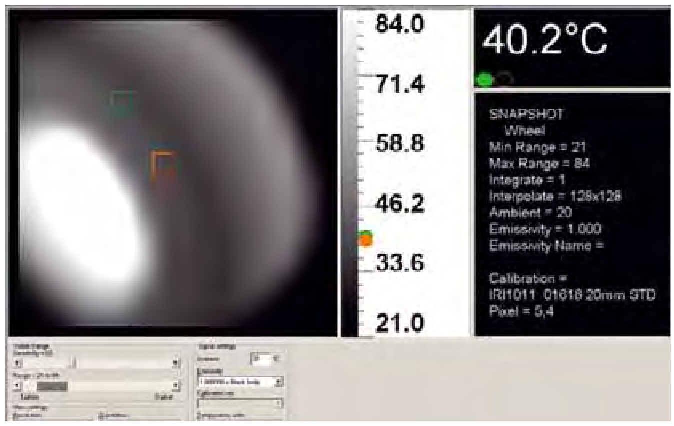


Due to the shiny, reflective nature of the steel surface the camera struggled with brake disc temperatures, but could be adjusted to suit the surface under scrutiny. However, black carbon discs present no such problem



How the camera 'sees' the image – as a series of temperature readings. It then uses built-in software to translate the readings into a more user-friendly image. It will take up to 256 data points per image with 10 spot temperatures





Colours can be adjusted to suit the user and the amount of colour change to temperature can also be adjusted. *Racecar* found the default setting to be the best

Left: in a head-to-head test with Nic Olsen's probe on the AP Racing calipers, the thermal imager performed well

Right: A1 Team Mexico car with tyre blankets fitted just before tyre temp test was run with thermal imager

degrees off, and this is why I go back to my old probe,' said the AP Racing man. 'The problem is the emissivity – it's fine with a black surface but on shiny surfaces, depending if there's any pad smear or similar, what you are getting reflected back can change by 200 degrees just by moving around on the disc. With a probe, although it's a bit basic, it is not upset by emissivity,

In case you are wondering, emissivity is the ratio of radiation emitted by a surface, and varies with how reflective that surface is. A very shiny surface may reflect 98 per cent of energy and only absorb two per cent whilst a dull black surface (like a tyre for instance) may absorb 98 per cent of the energy and reflect only two per cent of it.

"WHEN YOU HAVE IMAGES YOU CAN INSTANTLY VIEW THE SITUATION"

Olsen then went on to show that the camera wasn't as unreliable as it had first appeared. 'The caliper will be fine. You'll probably get good results from it because it's a fairly dull grey body. What we have to do with ours is change the emissivity according to the surface we are trying to measure. I don't know if you can do that on→

Covert temperature readings are easy to gain using the imager, as Woodvine demonstrates without getting too close to the cars. Here the team did not know who he was or what he was doing, nor did they question it

your camera?' queried Olsen, before continuing. 'On the caliper we use a value of 1.1, which is weird because there is not meant to be an emissivity of more than 1. I got hold of the Raytech guys and asked how it is possible to have an emissivity of greater than one. They replied that 1.1 was a great value. It's not an emissivity value, it's more a fiddle factor.'

In response to this Woodvine demonstrated that it was possible and in fact quite easy to adjust the emissivity on the camera, and then proved its reliability on the car's calipers.

Olsen's pyrometer gave a temperature reading on the caliper of 78degC while the camera showed a peak temperature of 81degC. Pretty much spot on considering the camera under test has a quoted accuracy of +/- two degC. More accurate versions are available, but at a cost.

Tyres, however, are distinctly non reflective, and that is where the imager could really come into its own. A quick head-to-head with Olsen's probe showed that the A1 Team France right rear tyre was around 34degC, while the camera image showed the temperature in that area as being around 33degC. Accuracy then is not an issue on a tyre, and also it will store every image you take – after all it is effectively just a digital camera.

In a head-to-head test on the A1 Team Mexico car (also run by DAMS) the thermal imager worked equally well, giving accurate temperatures faster than a pyrometer and in a far more informative way. As the car's tyre blankets were removed Woodvine took an image of the rear tyres. The result showed the edges of the tyres were evenly heated but there was inconsistency with the middle portions, suggesting perhaps that the blanket

Readings can be taken quickly and easily in a pit garage or trackside, working around other team members and, at the same time, keeping out of the way

was not in consistent contact with the tyre surface. After a three-lap run the car showed relatively even heat distribution across both rear tyres, the camera again out performing the probe.

Of course the issue of capturing rivals' tyre temperatures is a very relevant one in series like A1 Grand Prix, GP2 or even F1, and it's not surprising that a number of Formula 1 teams expressed an interest in the imager when *Racecar* approached them. However, equally unsurprisingly, they were not happy with the results being published. After all, imagine if a rival team could stand at the front of your team's garage and take your tyre temperatures without ever going near the car...

"IT MUST SURELY BE THE NEXT ESSENTIAL ADDITION TO A GOOD TEAM'S KIT"

'The imagers use a fixed focus lens, so the field of view increases as the distance increases. At five metres the 'hot spot' – that is one pixel – is 11cm of the surface you are measuring, but the area within the pixel gets smaller and more accurate as you get closer,' explains Woodvine. 'And it can see differences in temperature of as little as half a degree.'

The imager we tried out in tests at Silverstone did show a lot of potential, but the engineers and software developers at IRISYS could really benefit from working with a racing team to develop a set of emissivity readings for commonly found surfaces in motorsport. Having said that, even in its current form, a clued-up race engineer could still use the thermal imager to find real benefits.

One thing remains to be asked then – why doesn't everyone use them? Quite simply because accurate thermal imagers have always been out of what many would consider a realistic price range, but the IRISYS imager similar to the one we tested can be bought for around £1000 ($1800). More than a very good quality probe certainly but, as with most things, you get what you pay for – in the case of the thermal imager, what you get is increased functionality, faster, more in-depth readings, instant analysis and, of course, the potential to spy on your rivals. Other than the cost issue it must surely be the next essential addition to a good team's kit.

In the meantime *Racecar* is going to continue to test the device and possibly to work with racecar manufacturers to develop a specific motorsport spec version. RE

Labour of love

One man's quest to build the ultimate hillclimber resulted in a car the cynics said would never work. Yet, with patience, it looks like it might succeed

Words & images | Simon McBeath

Seeing him drive a racecar, no one would doubt the commitment of the 2001/02 British Hillclimb champion, Aberdeenshire's Graeme Wight junior. But this commitment was tested when the driver turned constructor decided to install a V10 Formula 1 engine into his new creation. Plenty of 'expert' advice warned against constructing a car, never mind using a virtually current F1 engine. But undeterred, Wight Jnr can now bask in the glow of satisfaction as he receives plaudits for a fine job done, even though the stunning GWR Predator is far from sorted yet.

Completed literally on the eve of its first event, and at the time of writing after just six closely-packed events of the 2005 British Hillclimb Championship (and zero testing), the car has demonstrated teething problems aplenty, and some paddock cynicism regarding the basic concept remains. But assuredly, potential is beginning to show…

Wight jnr's 2001/02 championships were attained in a Gould GR51 powered by a 2.5-litre, ex-DTM Richardson Cosworth V6 (see Racecar V10N10). But in 2003 the GR55 emerged from Gould Engineering, with 3.3-litre Nicholson McLaren NME V8 power (based on the Cosworth XB CART engine of 1992, see V14N10). Adam Fleetwood pedalled one such car to the next two titles. In 2003 only Wight Junior's GR51 could keep in touch on a regular basis, but it was now clearly underpowered. For 2004 the NME V8 was enlarged to 3.5-litres, increasing the power deficit to over 150bhp. By then Wight jnr had commenced his own project.

But why build an entirely new car? Why not fit a bigger engine to his Gould, the champion manufacturer since 1998? 'It was something we'd toyed with for a long time,' said Wight jnr, whose father Graeme (the boss) also drives, 'partly to be fully in control. But I also enjoy working on the cars I drive so we thought we'd design our own. And we also felt we could market something up here in Scotland.'

> "[MARTIN OGILVIE'S] PCD SAXON BASICALLY DID IT FOR ME"

Our old car had great handling but it was underpowered for its weight. So our first concept was to build a smaller, more nimble package using the same V6 engine. We'd talked with various hillclimb car manufacturers, including Gould, but none of them had what we envisioned. Even an F3 car has lots of intrinsic deficiencies compared to what you could build. Then we spoke with [former Team Lotus F1 chief designer] Martin Ogilvie at Prototype Car Designs. His PCD Saxon basically did it for me. It was a great advert, so we hired Martin to take control of the design.'

Readers will recall the Ogilvie-designed 1100cc PCD Saxon profiled in V11N7 that weighed just 208kg and which subsequently became a class record holder. For his part Ogilvie was 'excited and pleased to be asked, in preference to the established manufacturers, by the then current champion to design a car.'

Woodwork

Ogilvie proceeded to scheme out the car in 2D on Autocad. Prior to that, on Ogilvie's first visit to the GW Racing workshops, a wooden mock-up of a fairly reclined seating position was built to establish the shape and dimensions of the driver cell. This defined a very small, low chassis [Wight jnr is about 5ft 9in and under 70kg] that required a plain rear bulkhead to mate with various other engines later. A former RTN colleague of Ogilvie's, Rick Simpson of EVO Design, then modelled the chassis, which was to be moulded in carbon composite, in 3D using Pro/ENGINEER.

The CAD software produced transverse section templates every 25mm along the length of the chassis, which were used to CNC cut 25mm thick MDF panels. Upper and lower chassis patterns, which could be dowelled together, were then built up from these panels. The 'stepped' surface was then blocked down by hand, Wight jnr doing all this graft.

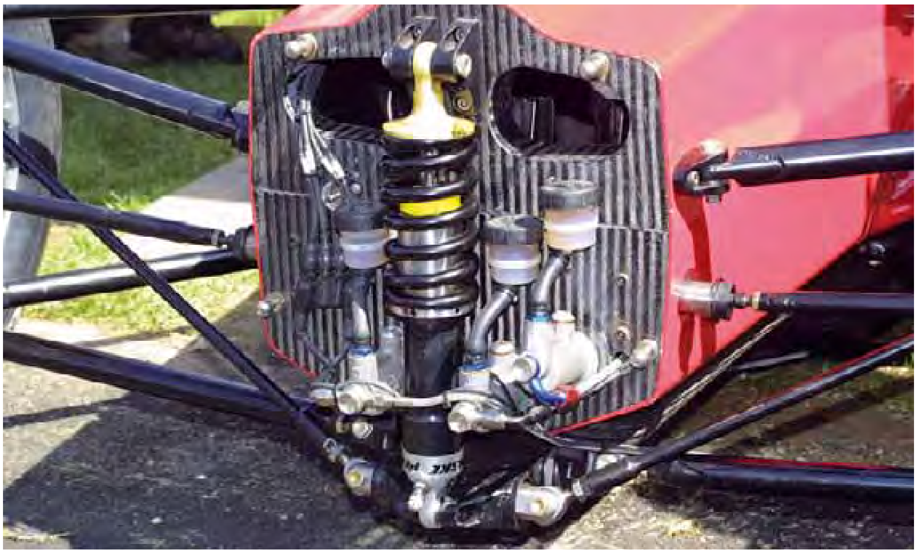
The raw shape was painted with high-build acrylic primer/surfacer so that paint rather than wood was being sanded to get the required finish. The same primer was used for the final finish too, applied with a roller, and then blocked down progressively and polished before release agent was applied.

Moulds were then made using an epoxy wet lay-up system before chassis manufacture was done in carbon pre-preg and honeycomb core using oven and vacuum consolidated cure by PPS of Inverurie, close to the GWR base. 'There are very few composites companies in our area but PPS has for years been doing racecar glass fibre parts, and a few carbon parts, but nothing really structural like a chassis. So to keep ourselves right we used a former Team Lotus colleague of Martin's, Barry Koerbernick, now a composite design consultant, to provide guidance on the lay up for the chassis. Again we wanted to hire the correct intelligence to prevent making expensive mistakes' said Wight jnr.

The general chassis construction is 17mm honeycomb core between 2.5mm carbon skins 'but there are different materials in different places' reported Wight jnr. 'Based on Barry's experience, everything's been done to improve rigidity and safety. For example, we've got a thick ring of Kevlar rope around the return lip of the cockpit surround, purely for a multiple impact protection so the cockpit won't split.'

Low line suspension

One particularly interesting feature is the pull rod-actuated monoshock front suspension. 'I mentioned to Martin that I would like to use the damper mounted vertically on the front of the car, operated by a pushrod rocker system,' commented Wight jnr, 'so we could reduce the height and lower the centre of gravity. Martin →



Top: front suspension uses unequal length wishbones; middle: pullrod front monoshock enabled a very low line chassis; below: rear suspension is also conventional design while rear brakes use motorbike calipers

came back and suggested a pull rod. That way we could mount the rocker underneath the car and the heaviest items of the monoshock system would be underneath instead of on top of the chassis. This meant that the chassis only needed to be the height of your feet, which let us lower the line of the car dramatically, and also meant we didn't need a separate top damper cover. There is still a little bulge shaped-deflector to be made to clean up the airflow around the bottom of the damper though.'

Martin Ogilvie remarked: 'I don't know whether the pull-rod monoshock is novel, nothing is new in motor racing so doubtless others have done something similar. It's not ideal though because it angles forward, so all the loads are angled and the effective torsional length of the car is increased. But with the relatively low spring rates on hillclimb cars I thought we could get away with it. Installation wasn't easy, the rockers and damper getting mixed up with the master cylinders and rack, but that's the sort of challenge I enjoy!'

Indeed, in order to put the damper on the front bulkhead the steering rack was located inside the chassis, just forward of the pedals. To allow for left foot braking the column comes up vertically and into a transfer box before running horizontally to the steering wheel. Most of these components are from a Formula Renault but the rack bars, the rack housing and the transfer box housing are bespoke.

Suspension geometry is what Ogilvie calls 'very pure, with good roll centre control, no anti-dive or anti-squat and traditional kpi, caster and Ackermann. So, if the car has a handling problem we won't have to step back and wonder if some pet theory that has been included has actually caused the problem.' This approach was vindicated during the early events when a handling problem was easily diagnosed and solved with rising rate rear rockers and re-valving of the dampers.

“THE V10 RUNS ON TO 15,000RPM SO THE EXTRA POWER IS AT THE TOP END”

From V6 to V10

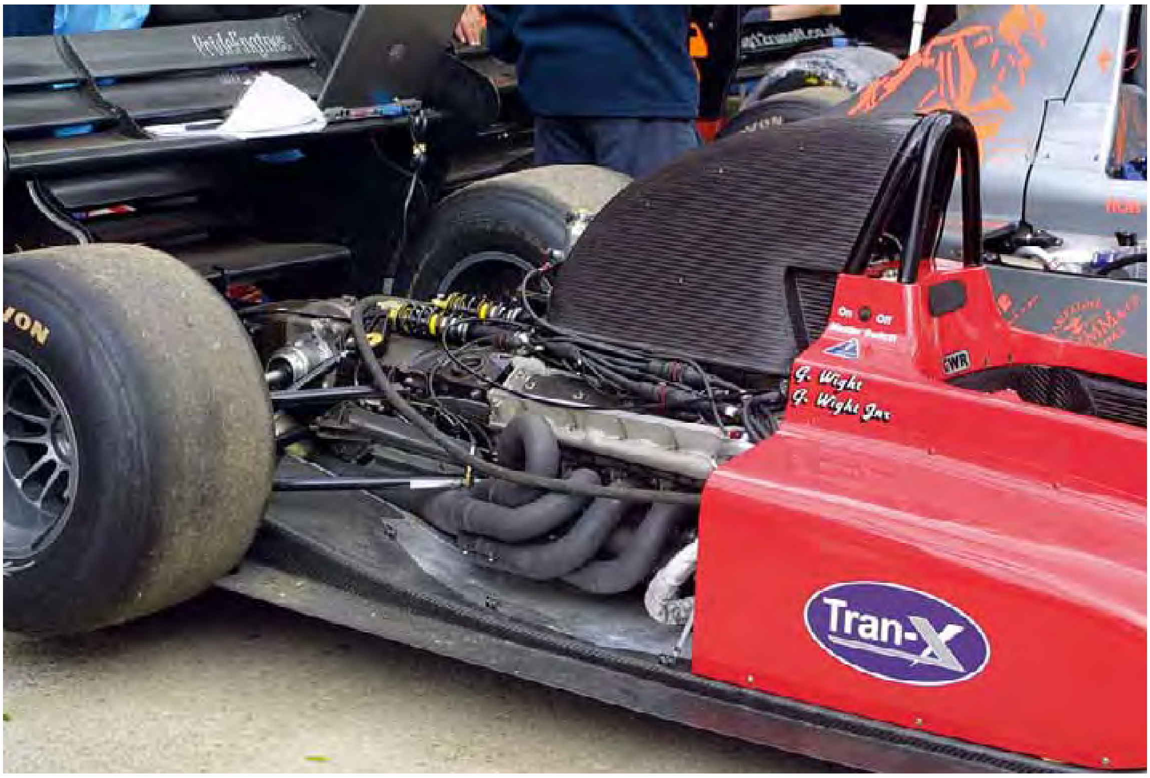
Although Wight jnr's previous V6 had potential for uprating, it could only be semi-stressed and would always be less powerful than the now commonplace 3.5-litre NME and 4.0-litre Judd V8s. Then the option of a 2000-spec, ex-Arrows Formula 1 3.0-litre Hart V10, complete with pneumatic valve gear arose. Even rpm restricted for longevity this would be lighter, lower and potentially more powerful than the V8s. Furthermore, the original John Barnard-designed carbon and titanium cased transmission was also available, all 'at an attractive price.' A shrewd move or was this asking for trouble?

There have certainly been issues. Unexpected problems with the oil system occurred because of piston blow by – a symptom of the designers' quest for reduced friction at high rpm – and required solutions involving crankcase breathing and increased tank capacity. And there have been low voltage problems, exacerbated by running generally at lower rpm than the charging system was originally designed for.

But that's all with the benefit of hindsight, and it would have been unrealistic not to expect teething problems. So consider the logic that swayed the team from an off-the-peg V8 to the V10, explained by Wight jnr: 'Basically it's a torque issue. Watching the big V8-powered cars last year, they were short shifting their first three gears. It was obviously hard to get them to handle in the lower gears because they had so much torque – they were traction limited. We thought that the V6 car handled its power really quite well; it just didn't have enough of it. So we thought with the V10 we'd have everything and more up to the 11,500rpm limit of the V6, but the V10 runs on to 15,000rpm (as currently limited) so the extra power is at the top end.'

And as Wight jnr reminds us, 'we've built a car as light as a 2.0-litre class car, and in any part of the rev range we've either got more than 2.0-litre power or completely mental power! We can also programme the shift lights to come on at different pre-selected rpm levels depending on the gear we're in. That was one of the beauties of the EFi engine management, and later we'll be able to programme the engine's characteristics according to what gear we're in.' Another unexpected problem has been the extreme heat the engine produces. 'When the engine starts up it's just like standing next to a space heater. That plus voltage issues have caused most of our initial bugs.'

Operating the V10 involves particular methods, as explained by engine builder Neil Peters of Pride Race Engineering: 'It has to be pre-heated to 70degC before you even start cranking it. And



The Predator's ex-Arrows Hart V10 powertrain – longer but with more forward weight distribution than the competition you have to evacuate the sump every time you start it so you don't seize the scavenge pumps and shear the drive to the pressure pump, which would lose oil pressure and break the engine.

'We aren't using a fly-by-wire throttle so making that work nicely with a good mechanical rising rate linkage was important. One of the biggest things is the lack of inertia in the engine. The engine will rev at 14,000rpm on 17-18 per cent throttle but there's no power there, so popping the clutch drops it to about 2000rpm, and if you've still got light throttle it'll just stop. We can't add a flywheel because of potential torsional vibration problems, but a basic form of launch control now helps in getting the car off the start line successfully.

'The engine responds very well to mapping – it needs large amounts of ignition advance, lots more in some parts of the rev range than you'd expect.' The exhaust primaries are about an inch (25mm) longer than the originals, and the tailpipes, incorporating silencers, are 'a lot longer but that had quite a beneficial effect.

'Original engine life was about 350km (220 miles) but reducing maximum rpm to 15,000 will hopefully raise this to around 1600km (1000 miles),' continued Peters. 'Different camshaft profiles have been manufactured for increased tractability and once rolling the car has been pulling from under 4000rpm and it accelerates well from that, too. It starts really thinking about it at about 8000rpm but to make it sing it needs to be above 10,000rpm. There's about 180lb.ft at 8000rpm but it really takes off when you hit 10,000. In that 2000rpm it produces another 100lb.ft of torque, and then torque hangs on nicely to generate the horsepower.

'We're keeping an eye on what F1 are doing with cams at the moment because they're getting ever-wider power bands. But they also have fly-by-wire throttle which helps modulate the throttle for improved control. It's very difficult for the driver to do that.'

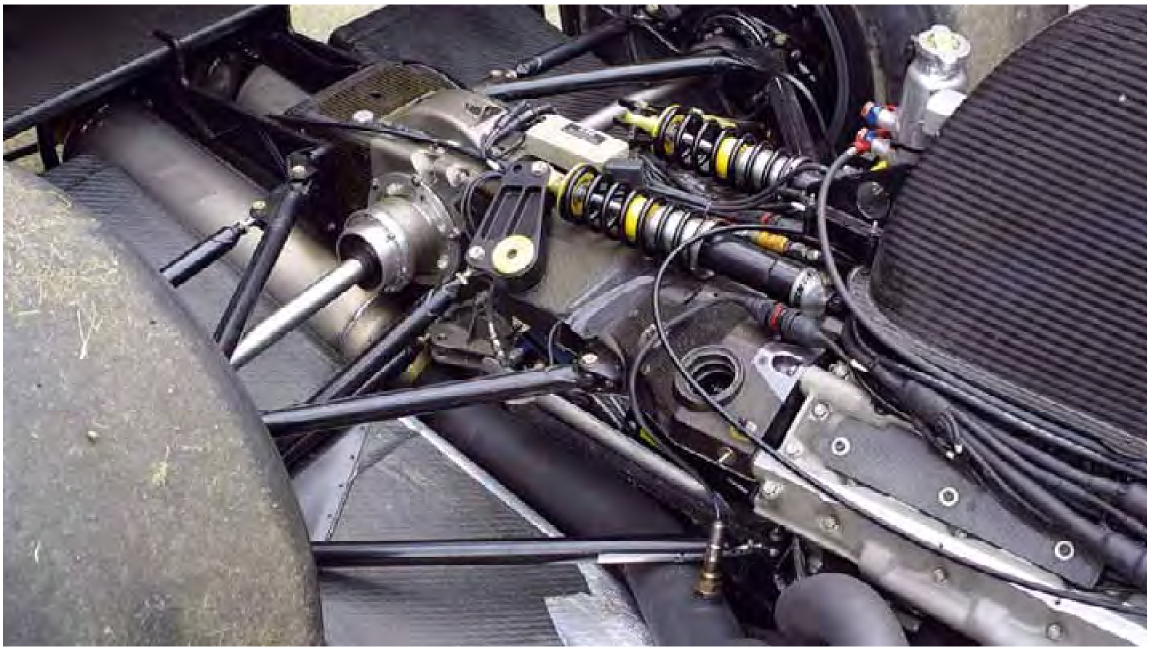
Tech specs: Predator

Chassis:	carbon/honeycomb composite
Bodywork:	'glass/honeycomb composite
Aerodynamics:	profiled underbody, dual-element front wing, two triple-element rear wing tiers
Suspension:	front and rear unequal length wishbones, front pull-rod monoshock with anti-roll shuttle, rear pushrod double spring/dampers, Penske dampers
Brakes:	AP four-piston calipers front, two-piston rear, drilled & skimmed discs, Questmeed pads
Wheels:	10.5×13in front, 14×13in rear
Tyres:	Avon, 225/600-13 front, 315/660-13 rear
Transmission:	Arrows/Xtrac six-speed, longitudinal, Jack Knight cam and pawl differential, AP multi-plate 4.5in carbon clutch, MIL electro-pneumatic paddle-operated assisted gearshift
Engine:	Arrows Hart V10, 2998cc, four valve per cylinder, bore 91mm, stroke 46mm, pneumatic valves, four camshafts to bespoke profile, 13:1 compression ratio, EFi EMS, TAG coils and single injectors
Power:	650bhp at 14,500rpm, torque: 280lb.ft at 10,000rpm, weight 115kg including ancillaries and oil tank
Data acquisition:	EFi with 2D dash display
Dimensions	Wheelbase: 104.3in(2649.2mm)
	Front track: 57.5in(1460.5mm)
	Rear track: 54.0in (1371.6mm)
	O/A length: 177in (4495.8mm)
	O/A width: 68.5in (1739.9mm)
	Weight: 924lb (420kg) including fluids

Weighty issues

The Wight's V6-engined Gould used an ex-Arrows A14 transverse gearbox, and original thoughts for the new car centred on the same unit, but the longitudinal transmission that came with the V10 ultimately selected itself. 'This gave a longer wheelbase, but also a slightly further forward weight-bias, which is what I was looking to achieve,' commented Wight jnr, while declining to be specific on the actual weight bias. 'This is different thinking really, and there are sceptics. There is going to be that initial problem off the startline because the weight is not hanging over the rear wheels but, as we found with the V6 →

> "SUSPENSION GEOMETRY IS VERY PURE"



The John Barnard-designed carbon/titanium cased transmission extended the wheelbase but reduced the polar moment of inertia

Upright pick ups were dictated by the chosen geometry and the original gearbox pick up locations

Gould, a more forward weight distribution enabled higher cornering speeds, especially on corner entry. The car also had a lower polar moment so now we've taken that a step further.

'Getting off the line was not a priority. We can use the car's electronics to aid that (and other aspects) later. The main thing was to get good mechanical balance. Just about every hillclimb car understeers, but that's not a bad thing, depending on what stage it's at, but quite often with my previous cars I've sacrificed traction to make them loose to help the front end. With this car we tried to not create an understeerer – and we haven't! Even from the limited running so far we know we're going in the right direction. In fact we're actually working the other way, shifting grip from the front to the back.'

Gear selection

It seemed to onlookers during early running that the car's paddle shift-operated, electro-pneumatic assisted gear change mechanism was misbehaving causing some missed runs. Wight jnr corrects this misconception: 'Although I've been frustrated at not being able to drive as much as I should, the issues have not been with the gear system itself – that works without problems. The car's installation of the gear system has been the problem. There have been difficulties getting the engine control unit to allow the gearbox control unit to do its job, but the electrics have been working fine. Ian Haley of MIL who supplied the shift system and controls has been frustrated too when people have erroneously blamed his system. Also the incredible heat build up from the engine was causing the gear selection mechanism to drag and not change properly. That hopefully

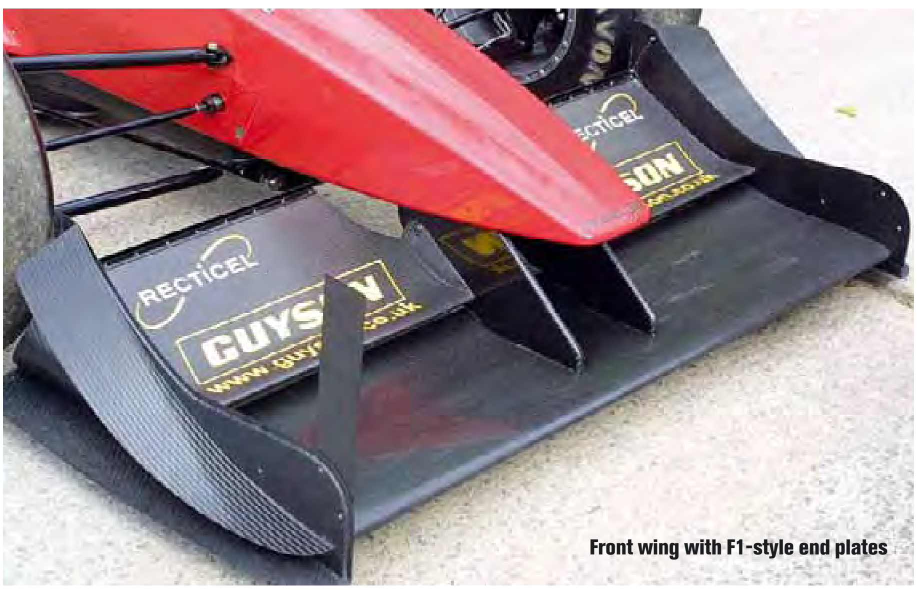
> **"THE MAIN THING WAS TO GET GOOD MECHANICAL BALANCE"**

has been resolved now [with larger radiators and more ducting out of the engine cover].'

The bulk of the Xtrac-manufactured gearbox internals have been retained, complete with the final drive. The drop from the original 18,000rpm maximum to the chosen limit of 15,000rpm has effectively lowered the gearing to suit the hillclimbing environment without needing a different final drive or different gear ratios. But the differential has been swapped to a cam and pawl unit supplied by Jack Knight Developments. 'We bought the Moog valve control systems for the engine and the original active differential as well but couldn't afford the software side of things just now. We intend to install the systems at some point though,' commented Wight jnr.

Aerodynamics

Targeting the smallest, tightest, smoothest package achievable, the Predator nevertheless has an aggressive look to it, mainly because of its wing package. But appropriately Martin Ogilvie describes the aerodynamics as 'very much a finger in the air design.' The underbody reflects the freedom in the technical regulations – no flat floors mandated in hillclimbing – and though the Predator's underbody owes much to long outlawed, ground effect single seater concepts ➔



Front wing with F1-style end plates

it also incorporates current thinking: 'our system is meant to work better than a flat floor because it can never be choked completely. The shape we've gone for should allow more pitch change without sensitivity coming in.'

The wing package was obviously chosen to try and generate as much downforce as possible. The emphasis was clearly placed on the rear, given that the car could still be traction limited at relatively high speed. However, with its large chord mainplane and flaps at the front, early running suggests the aerodynamic balance may well be biased to the front. At the time of writing an experiment with a new bump stop arrangement to prevent excess front compression as speed builds was due to be tried, spring rate changes already seeing the front stiffer than originally envisaged. Revisions to the front flap cut-outs are also on the development list.

Just reward

So, a challenging project all round? Martin Ogilvie nicely sums up from his viewpoint: 'The client had the funds to make a car, not to analyse it, CFD it, FEA it, or wind tunnel test it, so the biggest challenge has been to design and assist with the manufacture of a state-of-the-art car with limited resources at a location far away from 'motor racing valley.' This has required some imaginative design and construction techniques, cost efficiency and simplicity, while attempting to achieve an aesthetically elegant, effective engineering design.' On the face of it, the partnership has achieved its aims.

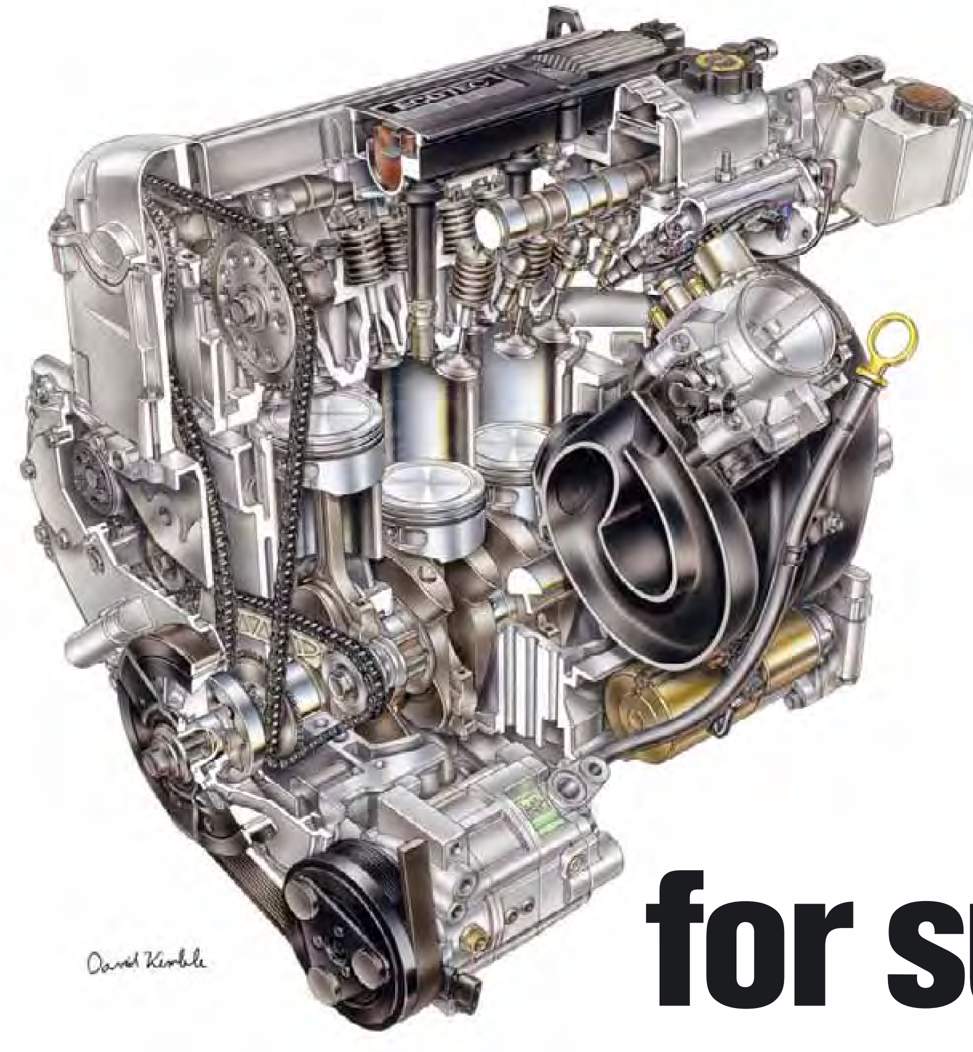
> "FROM THE OUTSET THE PLAN WAS TO MANUFACTURE 'REPLICAS' OF THE PREDATOR"

From the project outset the plan was to manufacture 'replicas' of the Predator, with options to fit just about any 2.0-litre plus 'automotive' motor, and also smaller capacity motorbike-engined versions. Graeme Wight jnr always said that he would not take any deposits until the basic concept had been thoroughly proven, but he is hoping shortly to embark on the first customer car. With refreshing honesty he admits, 'although I knew what I wanted to do, at the beginning of this project I had no idea what I was getting myself into. I haven't looked at the hours I've put in – all I know is that there have been lots. But it's been a labour of love – it's the most rewarding thing I've ever done. We're aiming to win with the car of course, but in a sense wins will just be a bonus.' RE

Sidepod and underbody inlets – designed so that airflow under the car can never be choked off

Complex twin tier rear wing assembly. The lower tier does not extend into the wake of the rear wheels

The diffuser tunnels at the back of the car integrate aerodynamically with the rear wing assembly



General Motors chose two very different motorsport arenas in which to showcase its new four-cylinder world engine, programmes designed with racers firmly in mind

Words	Mike Pye
Photos	GM; Pye

Recipe for success

General Motors Corporation, as well as being the world's largest vehicle manufacturer is also one of the most successful competitors in the worldwide motorsports arena. So when it set its collective minds to producing a new production car engine that would be equally well suited to motorsport applications, it knew it had to come up with something special, and an equally special strategy for getting the engine worldwide exposure.

GM cites five 'pillars' to its motorsport strategy: a dynamic training ground for its engineers; technology transfer; employee enthusiasm; a marketing platform and high performance parts sales. And in a world dominated by marketeers, motorsport is big business, affording a valuable in-road to a market of millions that attend motorsport events across the world and billions that view it on TV.

It also wanted a real return to the philosophy of its founders – to win on the track and win in the marketplace – and the huge sums of money GM is currently pouring into its racing programmes is doing just that, with the results already filtering down into its production models with beneficial results for the buying public.

Ever since GM debuted its quintessential small block V8 engine in 1955, it has been aware of this fact and has provided for it through its performance parts divisions. But times have changed, and growing levels of environmental awareness led GM engineers to develop a new engine – an engine that was suitable, not only for the future, but for more widespread use outside the United States of America as well – a truly 'global' engine. With the company in partnership with Fiat, Isuzu, Suzuki, Subaru, Daewoo, as well as in technological collaboration with Toyota, BMW and Renault, and with facilities in Europe, Asia, Latin America, the Middle East and Africa, the global market was where it focussed its view.

> "THE GLOBAL MARKET WAS WHERE IT FOCUSSED ITS VIEW"

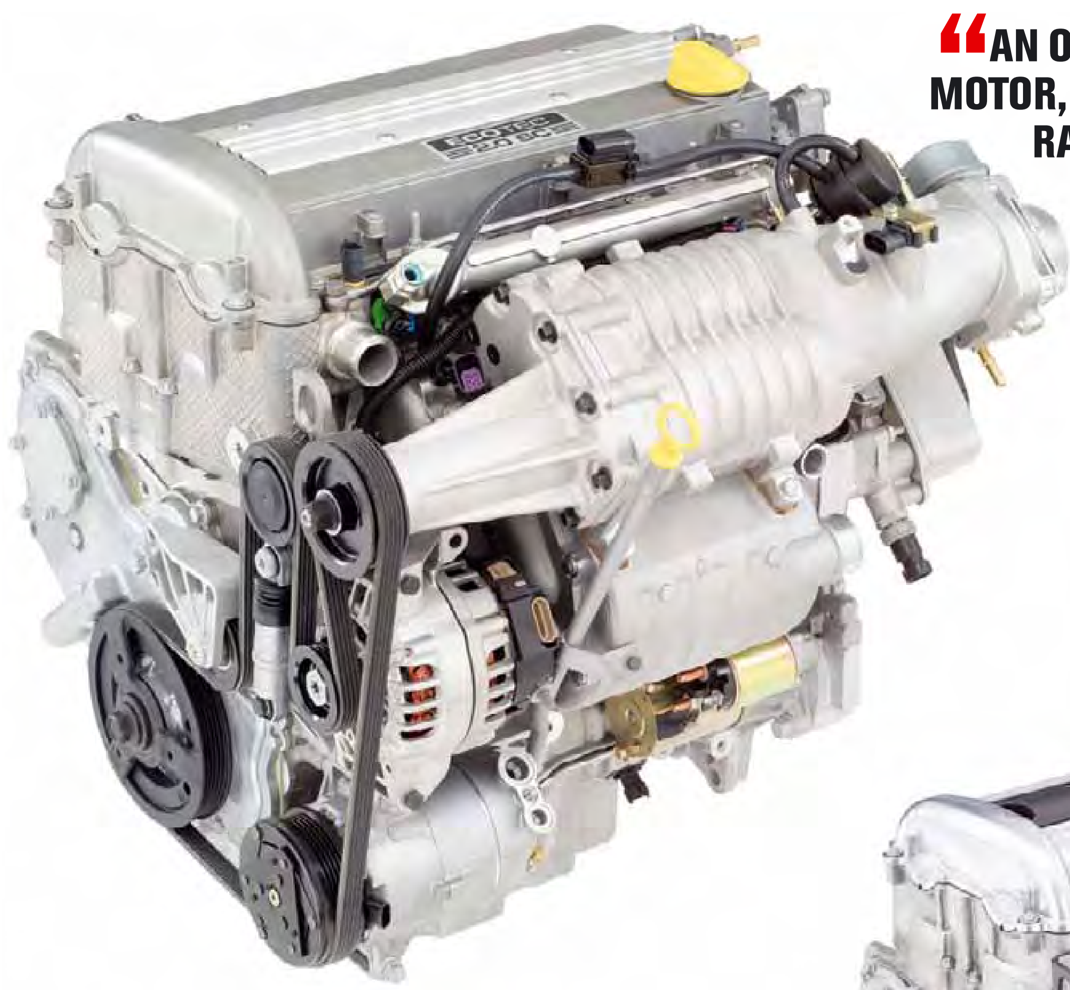
'In today's business world, the expenditure of any amount of money requires a solid business case,' said Doug Duchardt, former director of GM Racing. 'It is important for both marketing and engineering reasons to have strong links between the products that we race and the products that we sell to the customers. Racing is a sport, but ultimately it's about business.'

GM therefore had to design and build a new engine that would fulfil all these criteria. An engine that would be suitable in a wide range of vehicles across its brands, one which was a sound investment and would last long into the future, and yet one that would also enable it to race successfully, both to promote the product and to continue its long history in motorsport.

The next big thing?

Already being likened to the small block V8 for its simplicity, versatility, reliability and unlimited potential, GM's four-cylinder Ecotec engine features lightweight, all-aluminium construction, a four-valve-per-cylinder head and dual overhead camshafts. Nothing new in that perhaps but, using 'recipes' from the GM Sport Compact Performance Build Book (GM part no. 88958646), power output can be raised from the 140bhp it produces in stock form up to a prodigious 1100bhp+ in drag racing spec. Better still, all this can be achieved with products available directly off GM's parts shelf. 'The Ecotec was designed with many technologies in mind from the beginning – turbocharging, supercharging, variable valve timing and direct injection were all thought of when it was originally designed instead of an afterthought,' said Tom Read of GM Powertrain Communications.

Its design, too, was to be a truly global affair, involving over 200 engineers from Opel's



"AN OFF-THE-SHELF RACING MOTOR, SUITABLE FOR A WIDE RANGE OF MOTORSPORT APPLICATIONS"

Above: the 205bhp 2.0-litre SC unit produces 205bhp at 5600rpm and 200ft.lb of torque at 4400rpm

Right: 140bhp 2.2-litre L61 engine is the most commonly used in vehicles across the GM range

Top right: 2.4-litre VVT version is the latest addition to the Ecotec line-up

International Technical Development Centre in Rüsselsheim, Germany, GM Powertrain in Michigan, USA and Saab in Trollhäten, Sweden, with all components being modelled in 3D using UniGraphics and GM-specific CAD software. The resulting engine is currently being built in Tonawanda, New York State, Spring Hill, Kentucky and Kaiserslautern in Germany and is already in use in 16 GM vehicles worldwide, including Saturn (Ion, Redline, Vue and upcoming Sky), Pontiac (Grand Am, Sunfire, G6 and upcoming Solstice), Chevrolet (Malibu, Cobalt, Cavalier and HHR), Saab (9-3 and 9-3 Aero), Opel and Vauxhall (Astra, Zafira, Vectra and Signum) models.

Initially offered in either 2.0 or 2.2-litre naturally aspirated and supercharged formats with power outputs ranging between 140 and 210bhp the range has now been expanded to include a 2.4-litre version with variable valve timing (available in 2005 Chevrolet Cobalt and HHR models, as well as Pontiac's G6 and Solstice).

The basis of the engine is a one-piece block, lost-foam cast from A356-T6 aluminium with flanged, cast iron liners press-fit into a semi-floating support structure. This is supported by a die-cast aluminium girdle with five main bearing caps and a structural cast aluminium oil pan. Each main cap structure has six fasteners and is deliberately thick to resist the differential thermal expansion of the nodular iron crank and the aluminium block (turbo and supercharged versions use a steel crank). All blocks come ready cast with passages for piston cooling jets and for an oil cooler used in higher output variants.

The 16-valve, twin-cam cylinder head is again lost-foam cast from A356-T6 aluminium and uses matched pairs of steel valves (35.18mm (1.385in) intake and 30.1mm (1.185in) exhaust). Pent-roof combustion chambers have centrally-mounted spark plugs for fast, efficient combustion. Dual overhead camshafts are chain driven directly off the crank and actuate the valves through hydraulic roller finger followers, with provision made for upgrading to variable valve timing.

The 205bhp SC Eaton M62 supercharged version benefits further from a block-mounted oil cooler, heavy duty pistons, forged steel connecting rods, a forged steel crankshaft, a larger sump and sodium filled steel exhaust valves.

Engine management is a sequential electronic port fuel injection design with an integral compression-sensing ignition module.

While competition versions of the engine, either in 2.0-litre or 2.2-litre specification, utilise a vast array of modified and aftermarket GM parts, the production block, main bearing girdle, cylinder head and chain drive are all retained. In the words of Russ O'Blenes, Ecotec race engine developer, 'it's simply amazing what can be done with the basic engine package.' Combined with the engine handbooks, written by GM engineers based on experience already gained in competition with the Ecotec, there's everything you need to know to build a 1000+bhp four cylinder engine just a 'phone call away at your local GM dealer. →

Taking it to the track

To prove the performance potential of its new engine, GM went racing with it, taking it both to the drag strips in the then fledgling Sport Compact drag racing series and to the Bonneville salt flats in Utah to try for existing land speed records – two dichotomous motorsport environments chosen to test the engine to its absolute limits, and of course to prove it could win at both.

Conceived in 2001 to showcase the growing Sport Compact industry in the USA, and with national TV coverage of every round it's no wonder GM saw the NHRA Summit Sport Compact drag race series as a worthwhile market to promote the Ecotec engine in.

With a Pontiac Sunfire in FWD Hot Rod, driven by GM Racing's Marty Ladwig, and a Chevrolet Cavalier in Pro FWD, driven by Nelson Hoyos – both cars running in 2002 under the Bothwell Motorsports banner – its assault team was in place. Both used turbocharged, methanol-burning, 2.0-litre Ecotec engines producing over 1000bhp without nitrous oxide injection, specifically because GM wanted to prove that the Ecotec engine can reliably make over 1000bhp without recourse to gas. And it worked.

By the close of the 2003 series, Ecotec-powered cars were the ones to beat. Ladwig's Sunfire went on to win outright four out of the 10 events entered and to win the '03 series overall, in the process becoming the first US-built car in Hot Rod to run an eight-second quarter mile. In Pro FWD Hoyos made the finals in all 10 events, winning seven and finishing runner-up in the remaining three, along the way becoming the first front-wheel drive competitor to reach 190mph. Ladwig later went on to become the first to run a seven-second quarter in a monocoque front-wheel drive car and the first to break the elusive 200mph barrier. As Ladwig put it, 'When you look at the amount of horsepower we are producing on the dyno, there's no question that the Ecotec is the choice for power.'

Returning in 2004 under the expansive wing of GM Racing both teams won five events and finished runner-up in at least three. 'We're extremely pleased with the progress we made with the programme in a year's time,' said Hoyos. 'It all boils down to the GM engineers, the team and their dedication to this sport. They want us to succeed and to show the world the power of the Ecotec.' At the time of writing, Ecotec-powered cars continue to dominate the Hot Rod category in Sport Compact drag racing.

Having proved its point and, more importantly, proved the Ecotec engine, GM then went on to unveil at the Specialty Equipment Market Association show (SEMA) in Las Vegas in November 2004 a new generation of purpose-built racecar aimed squarely at this now all-important market. Based on the new Chevrolet Cobalt coupe, the Cobalt Phase 5 dragster features a 2.2-litre, turbocharged, 535bhp, race-prepared Ecotec engine, as well as chassis and safety components by GM. The package uses 65 per cent production engine parts and was, according to Doug Duchardt, designed as an 'example of what Sport Compact performance enthusiasts can do to create their own Cobalt race cars.'

And this is the essence of the entire Ecotec programme, not just to produce a world beating global engine, but to make it available as an off-the-shelf racing motor, suitable for a wide range of motorsport applications. 'GM is opening the door for [tuners] to race with Chevy by offering easily installed components specifically engineered for racing,' said Fred Simmonds, GM's drag racing group manager.

Land speed racing

On the other side of the racing spectrum is GM's Bonneville programme, aimed at showcasing the 205bhp supercharged and 210bhp turbocharged variants of the 2.0-litre Ecotec to a whole new audience in an entirely different environment.

Mark Reuss, executive director of GM Performance Division, might like to say GM's assault on the 2004 World Finals at Bonneville was a 'classic grass roots effort', but really it was far from it. Tony Thacker, vice president marketing at the So Cal Speed Shop in California – the company chosen to prepare the vehicles and provide logistical support for the Bonneville programme – put it succinctly: 'It's a collaboration. GM was happy to use So Cal's history as probably the best known Bonneville racing company. They provide the powertrain and support.'

In October 2003, under the watchful eye of GM Racing Division, a front-wheel drive, turbocharged, 700bhp, 2.0-litre, Ecotec-engined Saturn ION Red Line Coupe, driven by GM engineer Jim Minneker, set a new record of 212.684mph in the G/Blown Fuel Altered class (1.5-2.0-litre engine category).

Internal wrangling at GM meant the Saturn project was prematurely shelved, replaced with a new programme for 2004, now under the wing of GM Performance Division and involving Chevrolet instead. The focus was Chevrolet's new Cobalt SS Coupe. According to Thacker, 'It's a development exercise for them, a different extreme form of motorsport. Drag racing is a short blast, this is a long blast at full throttle – it's a different kind of development for the engine.' →

The 2004 GM/So Cal Bonneville entry was chosen to illustrate the variety of applications for the Ecotec engine package

In Sport Compact drag racing spec the 2.0-litre Ecotec is boosted to 1100+ bhp and dominated the NHRA Hot Rod championship in 2003 and 2004

"DEMONSTRATING THE ULTIMATE PERFORMANCE CAPABILITIES OF THE ECOTEC"

The Ecotec Lakester - a stroke of marketing genius and a class record holder at Bonneville, having reached a best of 189mph with stock 2.0-litre SC Ecotec power

While these projects were certainly successful, the combination of GM and the So Cal Speed Shop pulled a worldwide media coup with the unveiling of a stunning 21st century rendition of the post-war Bonneville belly tank lakesters. Dubbed the Ecotec Lakester, the project was so successful that GM decided to build a second generation Lakester for 2004, but this time one more designed for racing than for show. It would again feature a 2.0-litre version of the Ecotec motor, this time mounted longitudinally and supercharged, rather than turbocharged.

And recognising the potential for winning the hearts of American motorsport enthusiasts across the board, GM also provided powertrain and support to two other projects at Bonneville that year – the Haas family's '34 Ford roadster and Ron Main's re-named Ecofire Streamliner, now running with an 800+bhp, 2.0-litre Ecotec engine in place of its supercharged Ford flathead, and aiming for the 300mph barrier.

Shaver Racing Engines in Torrance, California, were commissioned to build the blown, intercooled race motors and, backed by GM 4T65 Hydra-Matic transmissions, the engines acquitted themselves admirably, revving to 9500rpm without problems and, in the Cobalt, recording a speed of 243.127mph, some 30mph higher than that attained by the Saturn in 2003. According to Bobby Waldren, former Cobalt crew chief for So Cal Speed Shop, 'The Cobalt SS Bonneville speedster is really very close to a production car. It's just a straightforward approach to Bonneville racing that a guy could build in his garage.'

While these were pure competition versions of GM's Ecotec, the 2004 Lakester, debuting with a production 205bhp, supercharged and intercooled 'crate' motor beneath its composite body set a new record of 179.381mph in the G/Blown Gas Lakester class. At the 2005 Speed Week the team pushed this higher still to 189.205mph.

The cars chosen by GM to represent it and its latest generation engine pay tribute to the versatility of the Ecotec powerplant, featuring all

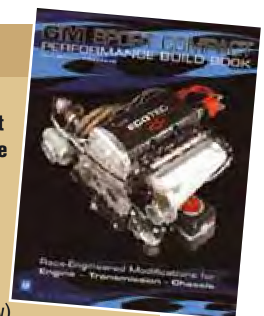
"A RETURN TO THE ROOTS OF AMERICAN HIGH PERFORMANCE"

configurations from front-mounted, transverse-engined, front-wheel drive, to front-mounted, real-wheel drive, longitudinally-mounted, rear-wheel drive and rear-mounted, rear-wheel drive. As a mark of its durability, in all the runs made during GM's four visits to Bonneville between 2003 and 2005, there were only two failures – and one of those was put down to human error.

What these programmes have proved beyond any doubt is that GM's Ecotec engine is a force to be reckoned with in today's performance orientated, yet ecologically concerned market. Choosing the Sport Compact drag race series and the Bonneville land speed record events as proving grounds were shrewd moves – one is the fastest growing youth sector of the market, the other is steeped in American history and appeals to the old guard and young performance enthusiasts alike. In the words of Mark Reuss, 'We're showcasing the Ecotec in a distinctly American way that our Japanese competitors simply can't match. The Bonneville programme is a return to the roots of American high performance – but we're doing it with a technically advanced, four-cylinder engine.'

Is it the engine of the future? Only time will tell but, in some motorsport circles, it certainly seems to be being considered the engine of the now.

'A cookbook for racing'



The Sport Compact Performance Build Book contains comprehensive information on preparing Ecotec engines for competition. Like a recipe book for racing enthusiasts, it is a step-by-step guide to modifying Ecotec engines, based on GM Racing's experience

Stage 1 stock (140bhp) – 250bhp
Adjustable cam gears
75bhp nitrous oxide injection kit
GM/Eaton supercharger kit
Control module recalibration

Stage 2 – 250-400bhp
H-beam forged steel connecting rods
Forged aluminium pistons
Replacement head gasket and head bolts
Uprated valve springs
150bhp nitrous oxide injection kit
Hahn Racecraft turbocharger/intercooler kit, with recalibrated fuel management unit

Stage 3 – 400-600bhp
OE block with high strength liners (stock bore size)
Eagle forged steel crankshaft (over 550bhp only)
Eagle connecting rods
Wiseco forged aluminium pistons
CNC ported Sportsman cylinder head (OE casting)
GM high performance cams
Fabricated sheet metal intake manifold

Stage 4 – 600-1000bhp
GM Racing prepared OE engine block
H11 1/2in 13 head studs
H11 7/16in 14 main studs
Fabricated sheet steel oil pan (if necessary)
GM Racing prepared billet steel crank
H-beam billet connecting rods
GM Racing prepared JE aluminium forged pistons
GM Racing prepared OE cylinder head
Copper head gasket with stainless sealing rings
Investment cast rocker arms
Fabricated intake manifold with 5.3-litre V8 throttle body (75mm)

Stage 5 – 1000-1400bhp
GM Racing prepared OE engine block with 3.5in bore
Heavy duty flywheel bolts
GM Racing sand cast LSJ cylinder head and matching cover
Dual valve springs and titanium retainers
Jesel roller rockers
Competition Cams race camshafts
Fabricated intake manifold with 90mm Acufab throttle body
Meziere high flow electric water pump

Smooth operators

There's a lot more to aerodynamics than just wings and underbodies and overlooking even minute details can cause dramatic losses of aerodynamic efficiency

Words	Simon McBeath
Images	Advantage CFD; McBeath

Recent correspondence in our 'Forum' pages spotlighted the human-powered speed record attempt vehicle, and in particular how dust that sticks to an oily fingerprint could cause transition from lamina to turbulent airflow over the vehicle's surface. On such a vehicle great effort is paid to maintaining lamina flow in order to minimise skin friction drag (also known as viscous drag), but details like this are not generally the dominant sources of drag on a racecar. In rough, though not strict order of influence, the major drag sources on a racecar are: its basic shape; wheels (and wheel housings); wings and spoilers; internal flows (cooling, ventilation) and details like handles, mirrors, window seals, panel fit, surface finish etc.

Individually, small details would appear to be low priority when it comes to racecar performance but cumulatively their effect can be significant. And details don't only affect drag – they can also lead to a loss of downforce, and occasionally to a loss of engine power…

The transition from laminar to turbulent flow occurs over distance as viscous effects near the vehicle's surface remove energy from the flow, and the swirling and mixing of turbulent flow takes the place of laminar flow. With racecars the flow usually goes turbulent pretty soon over the vehicle, partly because speeds are considerably higher than those attained by human-powered vehicles. We generally tend to be less concerned about this transition because viscous drag is a small contributor to the overall drag that a racecar creates. But we should be concerned about details that cause flow separations, adding to the form drag (also known as pressure drag), a major contributor to overall drag. The other particularly significant type of drag acting on a racecar is induced drag, also known as vortex drag, which results from the generation of lift (or downforce), but this is more about set-up choice than attention to the kind of details we're looking at here. Let's look at some examples where overlooked details can cause aerodynamic deficiencies, and where common sense often provides a solution.

A paper published in 1963 and cited in Milliken and Milliken looked at several aspects of surface

> "OVERLOOKED DETAILS CAN CAUSE AERODYNAMIC DEFICIENCIES… AND COMMON SENSE OFTEN PROVIDES A SOLUTION"

Figure 11: the Lola B1/00 ChampCar had a nicely radiused radiator inlet duct insert – shown here being taped in place – for blanking off some of the intake area

details in relation to their drag contributions. One topic examined was called 'permissible roughness', in which the maximum size of surface particles that would affect the so-called boundary layer sufficiently to cause additional skin friction drag was plotted against vehicle speed (reproduced in figure 1). Note the boundary layer is the layer of static or slow moving air close to a body's surface that is held back by viscous interaction with the surface. The first and most obvious conclusion from this plot is that at racecar speeds a rougher surface appears to be more tolerable than at land speed record velocities. Secondly, at the upper end of the racecar speed regime a decent finish would still seem to be necessary.

As already stated though, we are not usually overly concerned with skin friction drag, so why is surface finish important here? Well, it's a matter of degree. Figure 1 implies that protruding surface 'imperfections' as small as 0.001in or 0.0254mm might affect the boundary layer at around 100mph (160km/h). So how thick is the tape you use to cover over details? And how thick is the vinyl from which your decals are made?

But can details this small actually make a noticeable difference? Practically speaking, it probably depends on where they're located. Take an aerodynamically sensitive area of a racecar – the underside of its wings, and more especially towards their trailing edges for example. As regular Aerobytes readers will know, in this region the airflow is 'climbing' an adverse pressure gradient, where the static pressure is gradually increasing from its lowest value, generated further forwards under the wing, back up towards ambient pressure again as it nears the trailing edge. If the wing is being run anywhere near its maximum angle, or if speed is too slow, it is all too easy for the airflow to separate (and ultimately stall) in this region as the gradient becomes too steep for the air to 'climb'. What a layer of vinyl (or paint, or dirt) can do, especially in these more marginal circumstances, is to 'trip up' that airflow and cause it to separate prematurely. The likely result being more drag, less downforce and therefore worse performance. So if it's necessary to put decals on the rearward-facing surface of your wing or flaps, maybe consider spraying the whole area with clear varnish that can be polished as smooth and flat as a good paint job. Surface treatments can also be applied to areas where separation is likely to occur which actually delay its onset. So-called 'turbulators' are sometimes applied to a wing suction surface to trigger transition to turbulent flow in an effort to reduce the likelihood of, or delay, separation.

Staying with wings for a while, another avoidable surface 'imperfection' that can occasionally be seen is the attachment of the Gurney flap, or wicker bill, to the wrong surface (see figure 2). These simple, effective aero-tuning aids usually comprise thin (approx. 1mm or 0.04in) carbon or aluminium right angle strips stuck, bolted or riveted to the trailing edge. They should be attached to the upper surface. If they are attached to the lower surface there will be an edge protruding into the airflow that will cause early separation once again. This will negate some of the benefit the Gurney would have achieved, which in part is to delay separation and permit more downforce to be generated.

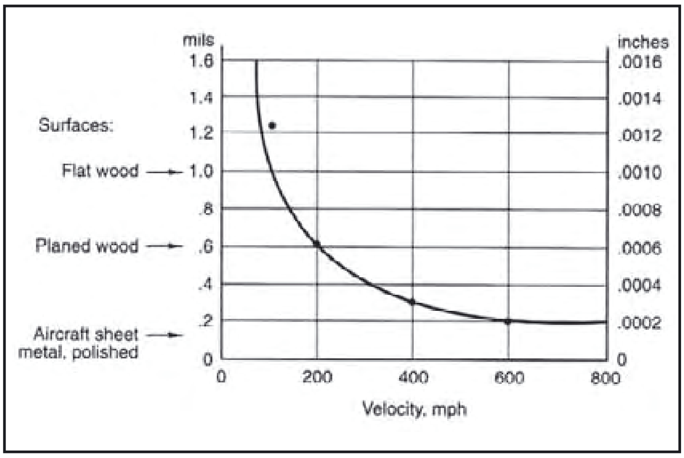
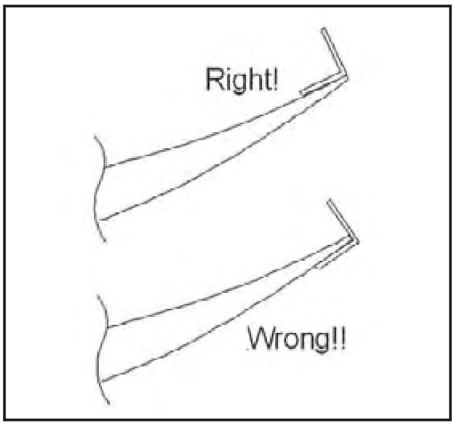


Figure 1: 'permissible roughness' varies with speed regime

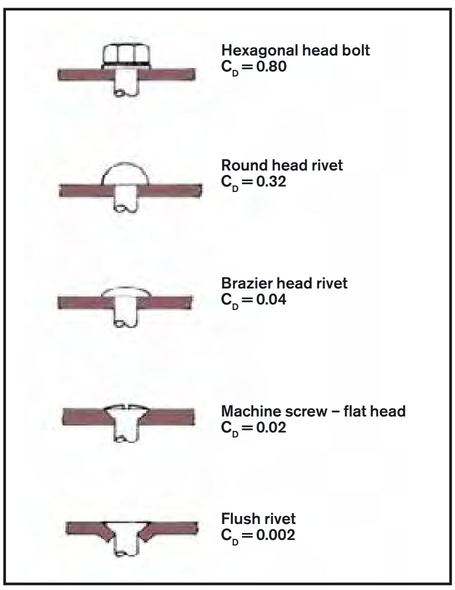


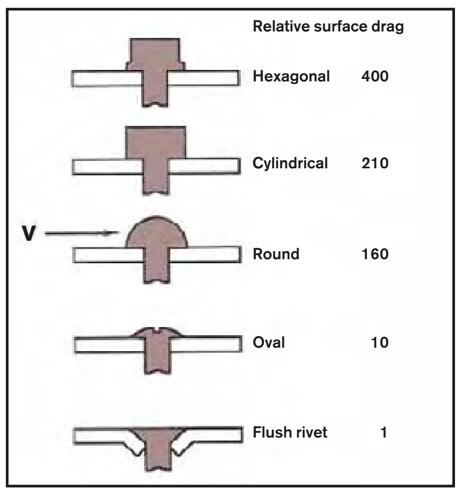
Below left – figure 2: Gurneys should be attached to the upper surface, not the lower

Small-scale errors

This leads us onto two related areas – fasteners, and protruding edges generally. Carroll Smith told us about these in *Tune to Win* in 1978, but looking around paddocks nowadays it appears that not everyone paid attention. Hopefully Carroll wouldn't mind us repeating his words of wisdom. Figure 3 comes from that esteemed title and shows the drag coefficients for various types of fasteners, data that came originally from that same 1963 reference cited above. Figure 4 shows similar information as portrayed in Milliken and Milliken, with relative drag values indicated. Both figures make it abundantly clear that we should make fasteners as unobtrusive as possible, and although the drag forces involved per fastener will obviously be small because of the small size of the items involved, every little helps. →

"IT'S NOT JUST THE DRAG OF THE FASTENER THEMSELVES THAT MATTERS"





Left – figure 3: drag coefficients of a variety of surface mounted fasteners; Above – figure 4: relative drag of the same types of components

But, as Carroll Smith also pointed out, it's not just the drag of the fastener themselves that matters, but the wakes extending rearwards from them. Just think about the shape of a wake you can see easily, such as that from a boat moving through water. Depending on the exact circumstances, the wake spreads out downstream and potentially affects the flow to other parts of the racecar, as well as causing drag and local flow separation. So to really offend an aerodynamicist, just attach your Gurney to the underside of your wing and use hex headed bolts to hold the thing in place! If you do use nuts and bolts to hold a Gurney on, at least use the dome-headed type (wing trailing edges are generally too thin for countersunk or flush fasteners) with the heads on the underside, and the more obtrusive nut and bolt shank on the upper surface where they sit ahead of the vertical portion of the Gurney and have minimal influence.

Moving on to protruding edges, borrowing once more from Carroll Smith and *Tune to Win*. Figure 5 shows the drag coefficients of various sheet metal joints, and again the conclusions are pretty obvious. Yet the occurrence of forward facing edge overlaps is all too frequent, especially so on the flat aluminium sheets used to panel in the underside of racecars. Panelling in the underside is aerodynamically a good thing to do (providing cooling has also been carefully considered), but leaving forward facing protruding edges clearly negates some of the effort. The designs in figure 5 point at the most aerodynamically efficient ways of joining such panels, and the small amount of extra effort will surely be worthwhile.

There's a tale told of a well-known racecar manufacturer's managing director who had the habit of running his thumbnail across the joins in bodywork after initial assembly to ensure they were as tight fitting and smooth as possible – not very scientific perhaps, but a valid inspection technique nevertheless. And you can see his reasoning – with all the effort put into CFD and wind tunnel development programmes, it was vital that there were no major tolerance problems on the finished product. But a good fit between body panels is vital whether or not you've developed your car on a computer or in a wind tunnel. Figure 6 once again appears in Milliken and Milliken, and originates in that 1963 paper. Although this time the drag numbers are relative to the third example from the top, we can see from the second example from the bottom of figure 5 that if a simple, shallow gap creates significant drag, then it is probably fair to assume that wider and deeper gaps will be worse. And figure 6 tells us that certain gap shapes create appalling drag.

An easy and frequently used way of improving body fit at the track is to tape over the joins, preferably with very thin tape. This at least will be better than leaving large gaps. Similarly, where body cut outs have been made, to clear suspension legs for example, these can be taped over to bridge the gap (see photo figure 7). Body fasteners may beneficially be taped over, too.

Scratches and ridges have also been examined to see their effect on skin friction drag, and figure 8 illustrates, this also coming from that 1963 paper via Milliken and Milliken. Although actual dimensions are missing in this figure, we can at ➔

"CERTAIN GAP SHAPES CREATE APPALLING DRAG"

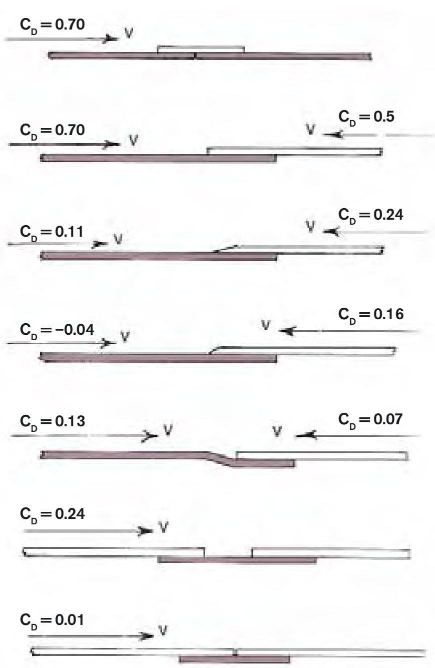


Figure 5: drag coefficients of all the major joint types between sheet metal bodywork sections

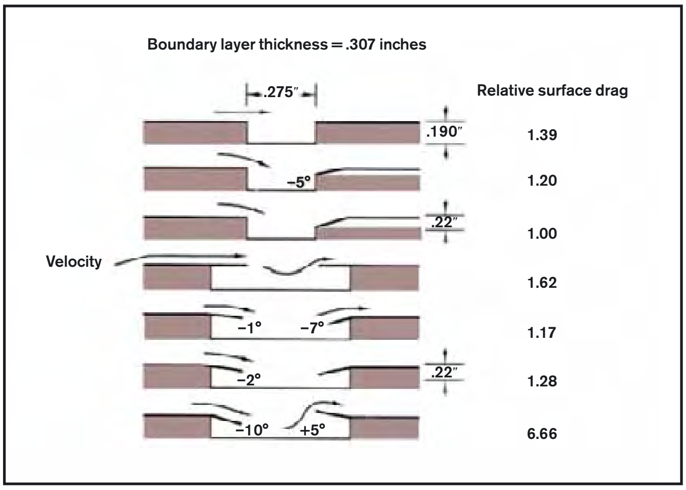
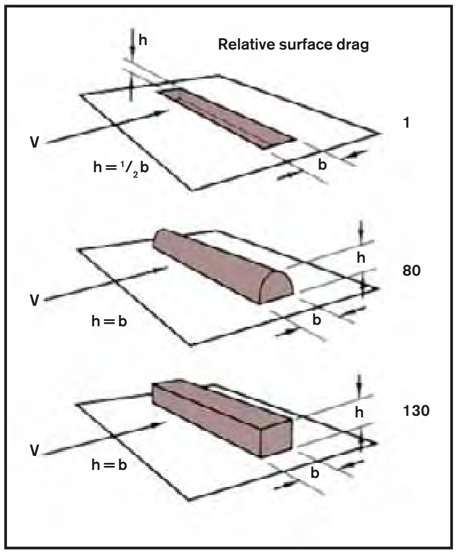


Figure 6: relative drag caused by different shaped gaps in panels

Figure 7: thin tape over gaps in bodywork can help reduce drag

Below – figure 8: relative drag caused by scratches and ridges on bodywork



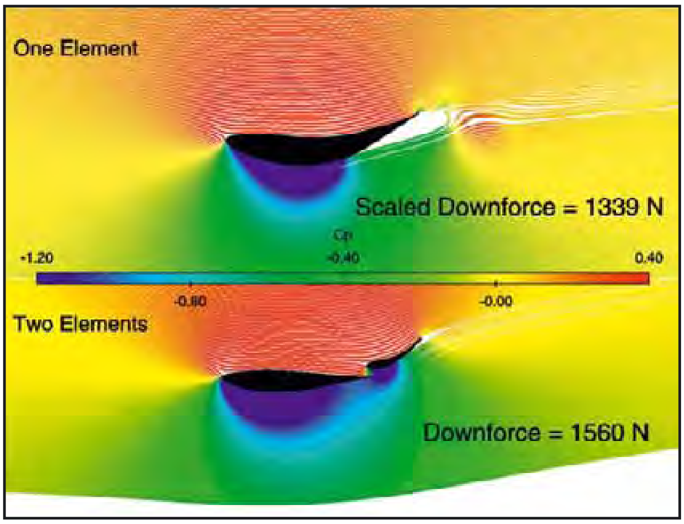


Figure 9: pressure coloured streamlines show the flow going around the leading edge of a single and dual element wing (Advantage CFD)

Figure 10: this Dallara F305 demonstrates nicely rounded duct inlets, and a taped-over radiator duct...

Figure 12: a less sophisticated attempt at adding a radius to an underbody inlet...

least conclude that ridges, especially square ones, are a lot worse than grooves when aligned perpendicularly to the airflow. A significant example where a small ridge can have undesirable effects relates to the rear wing on a 2005 Formula 3 car spotted in a paddock recently. Running fingers around the leading edge it was apparent that the joint between the wing's upper and lower halves had not been finished off, and a small ridge of perhaps 0.5mm (0.02in) could be felt on the main element's leading edge. Figure 9 (from Advantage CFD) shows pressure coloured streamlines around a single element and a dual element wing, and both demonstrate that the stagnation point – where the flow divides to go above or below the wing – is above the leading edge. Air can be seen flowing around the leading edge, so this is not a good place to encounter a ridge jutting into the airstream, albeit a small one. Fortunately, the fix is quick and simple: a bit of work with a medium grit sanding block would remove the offending ridge and polish would go some way to restoring a nice surface.

> **“LEADING EDGES SHOULD BE GENEROUSLY RADIUSED”**

Large-scale errors

Other oft-ignored details are slightly larger scale. A guiding generalisation in racecar aerodynamics is that the leading edges to all parts of the 'wetted' bodywork should be generously radiused, within the regulations of course. This rule of thumb applies particularly to inlets, such as to radiators, engine airboxes, underbodies and any other ducts. A frequently missed detail is the required radius on the forward-facing rear lip of the opening to a NACA duct – if this edge is left sharp then separation will occur and the duct will function inefficiently. Interestingly, the other corners of a NACA duct need to be left sharp. It appears that many moulded 'NACA ducts' available from catalogues have ignored at least the well-established radiused lip rule.

The entrance to radiator ducts, engine airboxes and underbodies need a generous radius so that at whatever angle the air approaches (a moveable target with dynamic changes in yaw particularly) separation is not triggered. Figure 10 shows that this F3 Dallara has nicely radiused radiator inlet duct edges, and the airbox on the Mugen engine has certainly been thought about. But the tape over the radiator inlet is a typical trackside tweak that must make the designers cringe with frustration. Having said that, moulded inserts could be offered, such as Lola provided for its ChampCar customers, shown being taped in place on the car in figure 11. Only the corners between the insert and the original duct surround are left 'sharp', the rest of the reduced area duct is provided with the correct form of radius this way.

Some trackside modifications leave even more to be desired, and in fairness the one in figure 12 was done tongue-in-cheek after it was suggested that the inlet to the venturi-profile underbody on this hillclimbing Ralt would be better if radiused. It's doubtful that even the product branding could help in this case, though it can be reported that at least the weight had been drained from the cans...

Occasionally the location of one item relative to another can be the cause of problems. For example, there have been instances where engine inlets have been positioned in the wake of rear view mirrors. Figure 13, a CFD streamline plot on the Prodrive-built, Advantage CFD-optimised Ferrari F550 GTS racecar, illustrates how far downstream the effects of the disturbance to the airflow caused by a mirror actually extends. Figure 14 is a front view of the Dallara F305, →

Above – figure 14: it might look like the wake from the mirror on this Dallara F305 could reach the airbox inlet, however, it was tested and does not

Right – figure 13: the disturbance caused by a mirror can travel well downstream though, as CFD streamlines of a Ferrari 550 show (Advantage CFD)

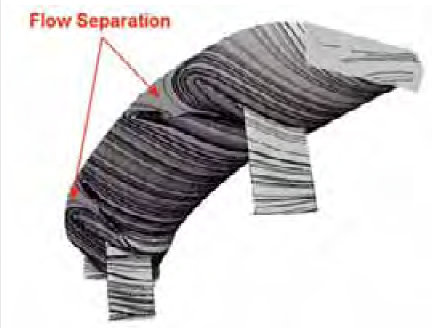


Figure 15: ineffective wing mounting plate design can disturb the airflow over a significant area of the wing's suction surface (Advantage CFD)

Figure 16: a modified mounting design created less disturbance to the airflow (Advantage CFD)

and at first glance it might appear that the mirror's wake could affect the engine inlet. However, F3 support engineer Jos Claes reports with typical thoroughness that wind tunnel tests revealed the mirror's wake to extend 500mm. The distance to the airbox inlet is 700–800mm, depending on engine, and the airflow at the inlet is actually said to be 'back to what it would be without a mirror.'

A detail that has frustrated F3 designers and race engineers alike in 2005 is that it is no longer permitted to shroud the wheel tethers, so that the aerofoil-section wishbones now have the cables, clearly seen in figure 7, taped in place on their leading edges. The safety angle – shrouds may have had the potential for severing the tethers in an accident – is evident though. It is perhaps worth noting here that the wider section tube used on the wishbones of the Dallara F305 was apparently adopted for increased rigidity rather than any benefit to the airflow.

And finally, another topic discussed by Carroll Smith in *Tune to Win* was wing mounts, and their potential for flow disturbance on the wing's crucial suction surface. Benefiting from the clarity that CFD visualisation now offers, we can see what he was getting at. Figure 15 shows the effect of the supports on the original wing assembly used on the Prodrive Ferrari F550. Even these relatively sleek-looking plates were causing marked regions of separation, and their effect became worse when yaw angle was introduced. Figure 16 shows the modified mounting system on the re-profiled wing developed by Advantage CFD. The reduction in the separation caused by the slimmer mounts is clear, and these mounts also created less disturbance when the car was in yaw. The separation zone at the rear of the new wing was eliminated with a 6mm Gurney. Modifications to the profile and the mounts produced a 2.5 per cent reduction in drag for a similar level of downforce – significant on this type of racecar. For real life confirmation that the effect of apparently 'aerodynamically clean' wing mounts can be significant, look at figure 17, where oil was used to visualise flow on the rear wing. The effects of the mounting plates are clear to see.

"THE LOCATION OF ONE ITEM RELATIVE TO ANOTHER CAN BE THE CAUSE OF PROBLEMS"

And so it can be seen that small things, cumulatively and even individually, can and do make a genuine difference.

Figure 17: oil streak marks on this real wing show the effects of the mounting plates

References

C Smith – *Tune to Win* – Aero Publishers Inc, 1978

WF Milliken and DL Milliken – *Racecar Vehicle Dynamics* – SAE, 1995

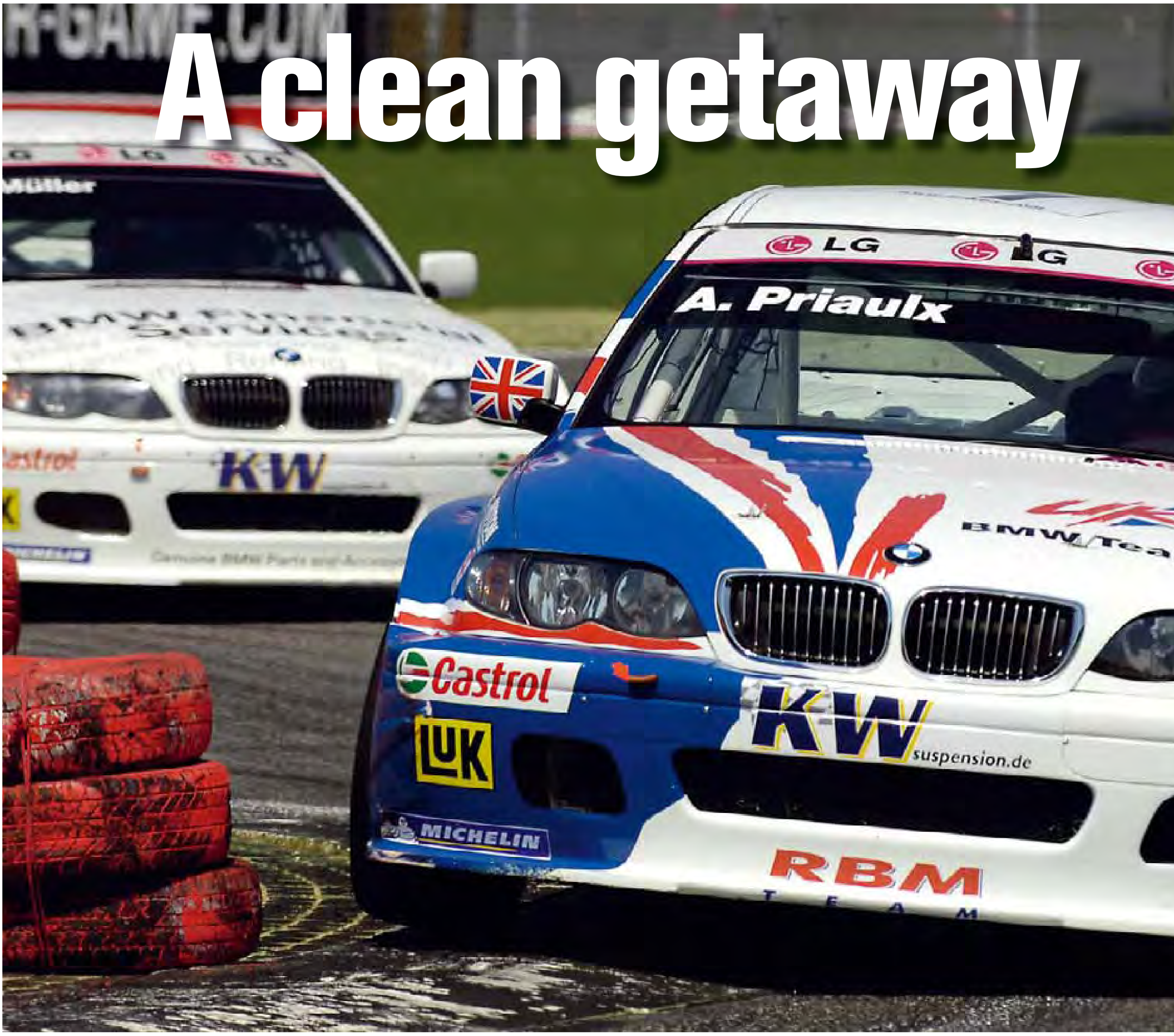
K Kelly and H Holcombe – *Aerodynamics for Body Engineers* – SAE paper no. 640050, 1963

J Katz – *Race Car Aerodynamics* – Robert Bentley, 1995

S McBeath – *Competition Car Downforce* – Haynes, 1998

S McBeath – *Competition Car Aerodynamics* – Haynes, publication due 2006

A clean getaway



In an effort to ease the immense strain on clutches during standing starts, AP Racing has developed a new, patented cushion system to lighten the load

Words	Peter Cox
Photos	AP Racing; LAT

Successfully transferring large amounts of kinetic energy from the engine to the driven wheels via a manual transmission has always been one of the purest measures of a racing drivers' skill. At no point is this more true than during a standing start from the grid or pit lane – an event that places enormous stress on both car and driver and which can often decide the outcome of an entire race.

At the heart of the mechanical maelstrom that gets a static car up to full race velocity is the clutch. While the well-established interplay of primary clutch components has not changed significantly over recent decades, many leading suppliers have made huge strides in reducing weight and the critical dimensions. The resulting changes have been dramatic. For example, AP Racing – which supplies the upper echelons of most major international formulae, including nine of the current 10 Formula 1 outfits – has seen the weight of its grand prix car clutches fall from over 4kg in the mid-1960s to around 1kg in 2005.

As well as reducing the weight and size of its clutches (where regulations allow), Coventry-based AP Racing has also been actively devising new ways of providing the driver with a greater level of modulation and 'feel' during those crucial standing starts. This effort first resulted in the company's Cushion Flywheel System (CFS), an innovation protected by international patents.

With an AP Racing CFS-equipped clutch, Belleville washers are set into machined recesses in the face of the flywheel and take up a small but predictable proportion of the load as it begins to be transferred from the bottom clutch plate. The washers compress, creating a secondary lower spring rate that permits a less linear, more progressive transfer of force that makes the clutch more controllable in engagement.

With CFS clutches Belleville washers are added to the flywheel; with CPPS clutches the washers are in the pressure plate

> **"BELLEVILLE WASHERS TAKE UP A SMALL BUT PREDICTABLE PROPORTION OF THE LOAD"**

The success of the CFS lies in its simplicity, something that underpins its impressive reliability. To accommodate CFS on a typical 140mm clutch, eight M6 mounting holes must first be machined into the face of the flywheel. Retaining screws are used to keep two Belleville washers in place in each of these holes. The outer edges of the washers are left exposed and, when the clutch is engaged, they come into contact with replaceable high temperature stainless steel split rings located in the bottom clutch plate.

'Consistent positive feedback from the drivers during the early CFS tests meant we soon became very ambitious about the potential applications,' comments Norman Barker, sales and marketing director at AP Racing. 'Since its launch it's been rolled out across a wide range of applications in F1, F3, GT and endurance racing, as well as multiple touring car formulae worldwide.'

The WTCC challenge

One popular outlet for CFS was the European Touring Car Championship (ETCC). However, in the shift to the new World Touring Car Championship (WTCC) format and regulations, alterations to the flywheel became outlawed. This meant AP Racing could not market any of its ETCC clutches to the WTCC teams, without first removing the CFS feature.

Determined to bring an alternative iteration of its 'cushion' effect to the WTCC clutch market, AP Racing's design team went back to the drawing board as the new WTCC rules were taking shape. As well as precluding changes to the flywheel, the technical regulations mandate clutch diameter to a minimum of 180mm – larger than many of the key products in AP Racing's clutch range where a 140mm diameter has become typical. →

After World Touring Car Championship regulations outlawed flywheel alterations, the CFS feature was relocated to the rearward face of the pressure plate

Designers also decided to take advantage of the fact that the WTCC allowed competing teams to adopt carbon/carbon clutch plates.

The outcome of the AP Racing design effort is the Cushion Pressure Plate System (CPPS), introduced for the first time in the new CP7832 WTCC clutch. The original concept of the CFS – where Belleville springs accommodate some of the initial force during the first phase of clutch engagement – is largely carried over for CPPS. The use of high temperature stainless-steel split rings, set into the face of the neighbouring clutch plate and acting as bearings for the Belleville springs, is likewise replicated from the CFS design.

However, as the name implies, the 'cushion' effect is moved to the opposite end of the clutch body, with the Belleville assembly embedded in the rear face of the pressure plate. When the new CPPS clutch is engaged, the diaphragm spring creates a force acting on the pressure plate, which in turn causes the outer edge of the riveted Belleville washers to come into contact with the split rings recessed in the clutch plate. Where required, these cushioned pressure plates can be returned to AP Racing for servicing and/or replacement of the Belleville springs.

From behind the wheel, CPPS affords a similar improvement in clutch controllability to CFS. In a standing-start situation, it is easier for the driver to modulate clutch engagement with a rapid increase in power, while simultaneously taking in information about available levels of tyre grip.

'CPPS is particularly relevant for a carbon/carbon clutch application as the frictional performance of the plates improves very suddenly as the clutch is engaged,' adds Barker. 'With sintered plates, the level of friction is lower but is more apparent to the driver at an earlier stage. Carbon is more effective and behaves more consistently over a wider temperatures range, but it can be harder for the driver to read the point at which the plates start to bite. CPPS adds a welcome extra degree of controllability.'

The new CPPS-equipped CP7832 clutch was extensively trialled by a variety of WTCC teams at an early stage in its development. It made such an impact that four of the leading works outfits – BMW, Alfa Romeo, SEAT and Chevrolet – chose to adopt it with immediate effect for the inaugural 2005 season and beyond.

Reduced servicing costs

Although devising CPPS was a key focus for the designers of AP Racing's new WTCC clutch, significant consideration was also given to those characteristics that could help reduce running costs. One core feature that may appear to run against that philosophy was the adoption of carbon/carbon plates, but Barker is quick to challenge the notion that carbon is necessarily more costly. 'While the move to carbon/carbon plates means the initial purchase price of the WTCC clutch is higher than that of the sintered ETCC model, the durability of carbon will actually reduce the outlay for teams used to making more frequent sintered plate changes,' adds Barker. The intention is that the new clutch should therefore require a smaller financial commitment during its useful life.

Perhaps the simplest measure aimed at reducing cost for customers was the selection of clutch cover. Rather than adopt the more sophisticated 12-bolt design seen on the company's existing carbon clutch range, AP Racing elected to replicate the race-proven six-bolt format already used on its sintered clutches. Teams are then given the option to request a more complex, machined cover to better suit specific weight reduction or cooling objectives for an individual car.

> **"CPPS IS PARTICULARLY RELEVANT FOR A CARBON/CARBON APPLICATION"**

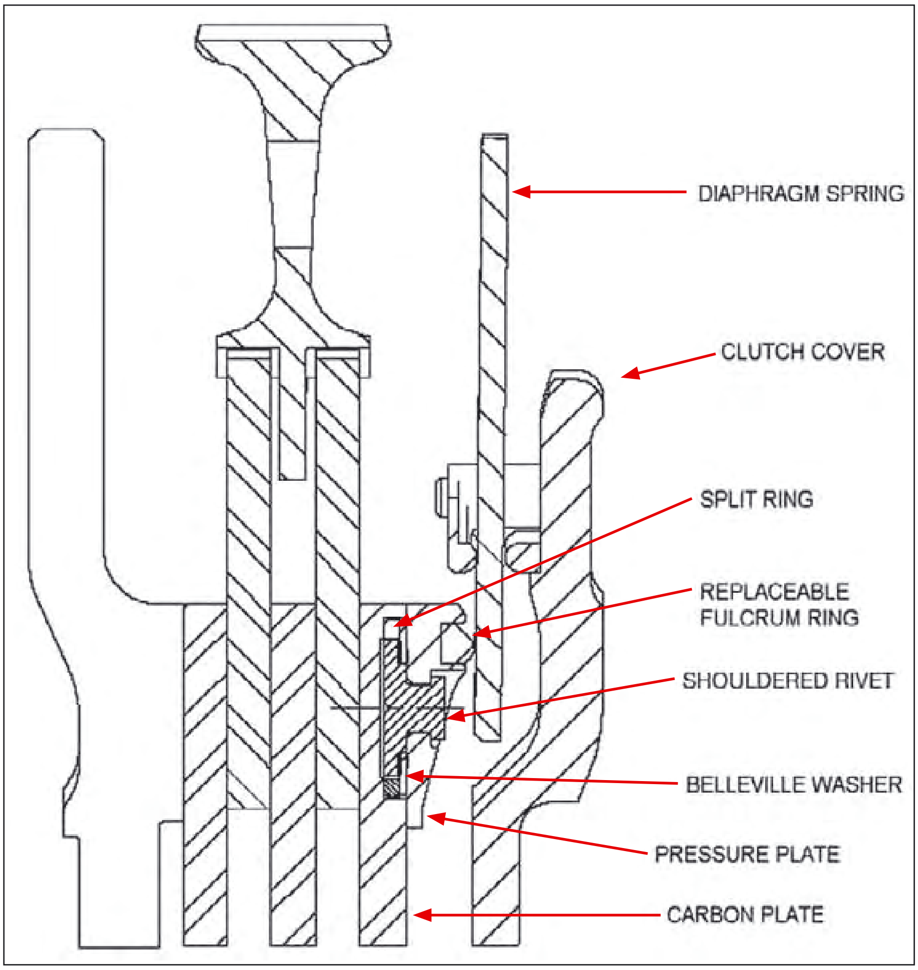
The most obvious change related to cost efficiency is the redesign of the pressure plate. With a conventional carbon clutch, pressure plates have to be changed regularly to counteract the effects of wear to the driven and intermediate plates. The greater the wear to the stack, the deeper the pressure plate must be in order to provide the same response during engagement.

Conventional clutches are normally purchased together with spare pressure plates of varying thicknesses to allow for the progressive reduction in depth of the plates. The new WTCC clutch abandons this well-established approach in favour of a replaceable fulcrum ring that sits in contact with the diaphragm spring.

The replaceable fulcrum rings are available in 0.25mm increments to compensate for gradual overall wear of the carbon stack. 'Rather than replacing the whole pressure plate, when wear increases the mechanics only have to replace a much smaller, lower-cost item,' explains Barker.

The new clutch began life as a single plate unit, as this provides sufficient torque capacity for the WTCC. However, AP Racing has since produced a twin-plate model, offering an even higher degree of controllability and longer life at greater operating temperatures.

Changing to a pressure plate-based cushion from the previous flywheel-based solution has so far proved successful. All of the works teams that adopted the CP7832 clutch with CPPS for the first year of WTCC have already indicated their intention to continue with it into 2006.



Raceshop

Raceshop is a section of *Racecar Engineering* written for people who are in the process of designing, building or running racecars. Raceshop is designed to be interactive. We want you, our readers, to let us know about your company, your new products and your engineering problems. Raceshop can provide you with a showcase for your products or the answers to your engineering questions.

Send your details to those listed below for each of Raceshop's sections. You can either send material direct to the Leon House address on Page 5, or to the email addresses below…

Racegear: racecar@ipcmedia.com

Database: Tony Tobias
tony_tobias@ipcmedia.com

The Consultant: Mark Ortiz
markortiz@vnet.net

Aerobytes: Simon McBeath
via: racecar@ipcmedia.com


LAT

Fuel for thought

Much more than just somewhere to store unused fuel, fuel safety cells are an imperative part of any racecar. We look at the top manufacturers in the field

Words | Ian Wagstaff

The fuel safety cell has its origins in aviation during the latter part of the Second World War, as a means of gunfire or crash protection. If the tank was punctured, an inner layer of rubber between two layers of fabric would swell and plug the hole. Advanced Fuel Systems' Jonathan Tubbs believes that the first time such a product appeared in a race was during the 1950s in the Jaguar D-types at Le Mans. In their case the reason for use was not crash protection but to provide a structure that would not suffer fatigue during the 24-hour race.

"THE FUEL SAFETY CELL HAS ITS ORIGINS IN AVIATION"

There was a time when the term fuel tank was widespread but current construction techniques mean that fuel safety cell is now far more appropriate. A typical modern fuel cell will be made from a high-performance material such as ballistic nylon and coated in tough urethane. In the case of an accident, such a cell will deform on impact. As Tubbs points out, the benefits are two-fold. Fuel is allowed to move away from the point of contact yet remains contained within the cell. →

Today's racing fuel cells are of complex manufacture, designed to absorb energy and not to rupture in an accident

Fuel cells, or bladders, are designed to freely deform and absorb energy under impact, rather like a passenger car's air bag. The more energy the cell absorbs, the lesser the chances of a rupture. One of the most important features of the fuel cell is the foam. This is used to reduce fuel slosh and the chance of an explosion by reducing the air volume of the cell. If the cell should ignite internally, the foam absorbs the expansion and the energy of the explosion. At that point, the oxygen is used up and flames go out. The cell must be filled with at least 80 per cent foam to perform effectively. Of course, none of this is of any point if, as the Paul Belmondo Racing team found out during practice for the Silverstone 1000kms, any one part of the structure has been altered. In this instance, the fuel cell plates had been removed from the front of the tanks while a technician was working on a wiring loom with a heat shrink gun. The heat element ignited the fuel vapour leaving ATL co-director Kevin Molloy and his team to come to the rescue by treating and re-coating the elastomer and pressure testing the cell.

Levels of safety

There are several distinct levels of fuel safety cell crash resistance, mainly based on the standards established by the FIA. The FIA also limits the life of a cell in Formula 1, NASCAR and elsewhere to a maximum of five years (though it is possible to have them re-certified for a further two years). Fuel cells age with time and also with the use of fuel; the more exotic the fuel, the faster the cell will age. Fuel cell foam should be replaced between three and five years depending on the type of fuel used. Bladder-type cells also start to lose their strength after about five years.

"THE MORE EXOTIC THE FUEL, THE FASTER THE CELL WILL AGE"

Two FIA main standards are used for most of motor racing, FT5 and FT3. The former is appropriate for Formula 1 and prototypes. FT3.5 and FT3 cover most of the rest of motorsport with NASCAR, for example, likely to use the higher specification FT3.5. The United States Auto Club has its own fuel cell standards specifically for alcohol (methanol) fuels. USAC 1000, as it is known, is suitable for the sprint cars, midgets and modifieds found on America's short ovals.

The FIA lists 13 companies homologated to produce motorsport fuel cells. Some, such as Advanced Fuel Systems, PRONAL and Queensland-based Australian Fuel Cell, tend to serve domestic markets. Aero Tech Labs (ATL), Fuel Safe and Premier Fuel can be seen as international.

Of these, ATL has a monopoly on the Formula 1 grid. It also claims around half of all the current motorsport fuel cell market. The company was formed in 1971 when US club racer Peter Regna rolled his frog-eye Sprite Mk1. The driver escaped but sparks caused by the roll bar hitting the track combined with fuel leaking from the tank to cause a fire. It was, thought Regna, an inexcusable result of the crash. Aided by his first employee, Steve White, he started to construct fuel cells – fairly simple items filled with foam, the secret of which was their patented flexible material. This is manufactured from Du Pont Kevlar fibre, tightly woven, surface treated and made fuel proof. Today, all ATL fuel cell systems comprise an impact resistant, rubberised bladder filled with explosion suppressant foam bafflings and outfitted with a leak-tight cap and fittings. Additional safety equipment often includes roll-over check valves and a metal container to deflect impacts and serve as a flame shield.

Despite its US base ATL soon found itself supplying grand prix teams. It is claimed that ATL was the only company able to meet FT5 with a single layer of material, other suppliers requiring three layers, which proved too heavy. ATL believes it is this weight advantage that maintains its monopoly. A typical ATL fuel cell weighs just 5.6kg and not one has

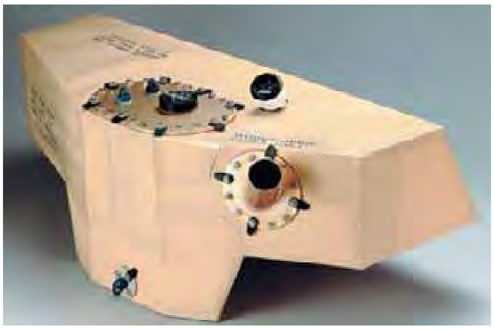
→

It's not just fuel tanks either, all aspects of racecar fuelling must adhere to rigorous safety standards

Racing fuel cells are manufactured to closely fit the space available like these ATL products for a motorcycle...

...a Ferrari F40...

...a Porsche 911...



...a Subaru Impreza...

... and a Porsche 996

Advanced Fuel systems tanks for the Alfa TZ2...

...BRM P126...

...Ferrari F40...

...Ford GT40...

...March 702...

...and Porsche 917K

been penetrated in the 16 years it has been supplying to Formula 1 teams (at least not in racing). Mechanics, on the other hand, have been known to accidentally drill through them...

Given the location of most of the grand prix racecar manufacturers, the next move was obvious and, in 1988, a $500m^2$ factory was established in Milton Keynes. Two moves on, ATL is now in a $2500m^2$ premises in the same city. The raw material comes from the USA and is converted into fuel cells in Britain, only the carbon fibre components not being manufactured in-house. Steve White meantime crossed the Atlantic and has remained in the UK since, as managing director alongside co-director Kevin Molloy. Although F1 is its most important market, ATL does produce fuel cells for across the range, annually manufacturing, for example, 400 Formula Ford fuel cells. In the USA it is the major supplier to NASCAR's Nextel Cup.

Oregon-based Fuel Safe also serves an international market, but tends to be mostly active in the USA where is supplies fuels cells to a wide variety of formulae from Nextel Cup, IRL and ChampCar to World of Outlaws. The company has over 30 years of experience and has achieved and maintains the ISO 9001: 2000 quality certification.

Newport, Essex-based Advanced Fuel Systems was established in 1998. It grew out of the UK agent for Fuel Safe, going on to develop its individual processes and gaining FIA approval for its own products. Last year it was presented with the Motorsport Industry Association's Business Excellence Award for Technology and Innovation.

The company claims to have a 'unique' approach to the manufacture of fuel cells in that it simultaneously manufactures both the composite material and the finished fuel cell. Because the fabric is dry and not initially coated with elastomer it can be pulled over the complex geometry of the tool. The coating is the last process to be carried out.

"THE FIA LISTS 13 COMPANIES HOMOLOGATED TO PRODUCE FUEL CELLS FOR MOTORSPORT"

Advanced Fuel Systems' first customer was a somewhat significant one – the Thrust SCC with which Andy Green took the Land Speed Record up to 763.035mph. The company now has customers across the board, including many in historic racing. This field can be particularly demanding having to create a shape for a cell where previously there was not one. ATL has also now opened its Historic Racing Fuel Cell Division and claims to have thousands of historic templates in stock.

Another complex task for Advanced Fuel Systems was manufacturing the fuel cells for the Spyker Le Mans effort in 2003. The car was short but still featured a conventional longitudinal engine. As such the fuel cells were incorporated into the door sills.

Also UK based is Premier Fuel Systems which, like ATL, is responsible for all parts of a racecar's fuel system, not just the safety cells. The majority of the latter are fitted with low pressure lift pumps and collector pots for the collection of the fuel inside the cell. As with the other companies mentioned here Premier can manufacture to the designs of its customers and its products can be found across the world in most forms of single seater, endurance and touring car racing, as well as rallying. It also manufactures a series of standard FT3 specification fuel cells that can be brought straight from the shelf.

The French manufacturer PRONAL indicates that it is not just from the aviation world that fuel safety cells have developed. It first started business in 1961 manufacturing flexible tanks from elastomer-coated fabrics for the French Army. It currently supplies to a cross section of industries including motorsport. For this it offers pre-shaped FT3, FT3.5 and FT5 fuel cells, manufactured from Kevlar that has been rubber-coated on both sides. PRONAL has also been certified to ISO 9001:2000. RE

The new 'intelligent' SpacePilot from 3Dconnexion is a major step forward for CAD users, putting all the necessary functions quite literally at your fingertips

Control in motion

3Dconnexion have launched a pre-programmed intelligent controller designed to save time when using 3D CAD packages

Words | Charles Clarke

One of the badges of office of the 'power' CAD user in the late 1990s was the SpaceBall, or 3D motion controller. Now 3D motion control has moved up a gear with the introduction of the SpacePilot from 3Dconnexion with its so-called 'intelligent, two-handed CAD interface'.

The SpacePilot is an intelligent controller that responds to your every need and 'adaptive sensing technology' delivers the functions you want when you want them. This means that the controller senses where you are in your application and presents the appropriate commands available in that context to the LCD on the SpacePilot, which you can then access directly with the 21 speed keys on the device.

> "IT'S A REAL PRODUCTIVITY BOOST FOR MINIMUM OUTLAY"

These commands update dynamically when you switch applications or tackle different work modes within an application. Whether you're doing part modelling, assembly, analysis or animation, the SpacePilot reacts with the appropriate functions available in that context. These function keys are extendable and programmable so that you can customise and/or extend the standard offerings if you wish. It's a way of extending the application's GUI to the desktop and allowing you to interact much more effectively with the crowded and often cumbersome and inadequate Windows user interface common in today's sophisticated technical applications.

All the motion control facilities of the SpaceBall are available on the new, more sensitive, hockey puck controller. Plus there are keys to adjust motion sensitivity or restrict the motion to just one axis at a time with the 'Dom' key.

The 'Fit' key allows you to size your model or scene to the centre of the screen quickly. You can zoom in to work on a part, then quickly zoom out for a look at the whole design. The 'Modifier Keys' give you access to the same Esc, Shift, Ctrl and Alt functions as a normal keyboard and they are readily accessible on the SpacePilot without removing your hand from the control cap.

The 'View' keys provide rapid access to the standard views of your model with the T (Top), R (Right), F (Front) and L (Left) keys. You can also disengage the 3D View Lock mode for working in 2D for quick pan and zoom functions.

There are real productivity benefits to having these functions so directly available. SpacePilot comes with pre-programmed commands for over 120 popular technical applications so you just plug the device into a USB port and off you go.

Now that mid-range 3D CAD is more popular than ever, 3D motion control should be available to every CAD user rather than remain the preserve of the dedicated CAD operator. Yes it's an additional expense but at about £320 it's a real productivity boost for minimum outlay, especially when so many context sensitive functions come pre-programmed. RE

3Dconnexion Corporate Headquarters
180 Knowles Drive
Los Gatos, CA 95032
USA
Telephone: +(1) 408.376.2500
Website: www.3dconnexion.com

In United Kingdom:
Tel. +44 (0) 1952 243629

Pro latch

UK-based latch designer and manufacturer Protex has created a new economically priced latch to add to its extensive line of quick-action fasteners. The 47-2650 latch is compatible with a range of re-sealable fasteners found in commercial, agricultural and logistical applications.

The zinc-plated mild steel fastener, measuring 207mm long by 40mm wide, offers a 20mm grip range adjustment. A threaded draw bar is built into the device, designed to withstand forces up to 1000kgf.

The latch has been designed for use alongside the Protex type 04-2650 catchplates. Lockable padlocks or purpose-designed sealing pins can also be used as protective devices.

● **For more information call +44 (0) 1527 63231 or visit www.protex-fasteners.com**

Belter of a pump

US fuel system specialist, Barry Grant Inc, has redesigned its belt-drive fuel pump for engines with high volume fuel demands, particularly those running on alcohol.

The BG belt-drive fuel pump has been re-engineered to streamline production and now features a one-piece gear housing and fewer seals for ease of maintenence.

The company claims fuel starvation problems in high-output racing engines are eliminated when the pump is used alongside a diaphragm bypass with a -8 return lines. Using the fuel pump with a fuel log with integrated diaphragm or pill-style bypass also enables simpler plumbing.

● **For more information call +1 (706) 864 8544 or visit www.barrygrant.com**

Simple acquisition

Racepak Data Systems in California, USA, has released its new G2X data acquisition system as an easy and economical way to monitor on-track vehicle dynamics.

Motorsport users will be able to make use of the multi-channel logger's track mapping, lap distance, G-force and miles per hour facilities through the G2X's GPS and G-meters.

A main feature on the G2X is its dash display, which can be mounted onto either the dash or steering wheel. Lap number, lap gain/ loss, battery voltage, rpm and gear indicators are just a few of the facilities available on the display.

The G2X system is easily installed, requiring only a 12V power source, and has the capacity to store over 30 hours of GPS data in its 128MB memory.

● **For more information call +1 (949) 709 5555 or visit www.racepak.com**

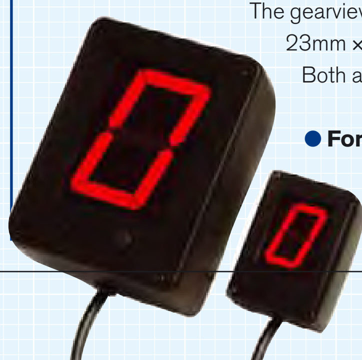
Counting gears

DC Electronics in Essex, UK, is introducing a new, stand-alone, gear position indicator into the racecar market.

Designed for sequential gearboxes with a conventional rotary potentiometer, the gearview has been developed to display up to eight forward gears, as well as neutral and reverse. An additional input device is also included for gearboxes with separate shafts for reverse.

A gear count function has also been incorporated into the indicator to record the number of gear changes, allowing teams to correctly maintain and accurately predict the life expectancy of its gearboxes.

The gearview is available in two sizes, small – 23mm x 30mm and large – 45mm x 64mm. Both are priced at £199+VAT.



● **For more information call +44 (0) 1621 856451 or visit www.wiringlooms.com**

Finding all the angles

Kistler Instrumente AG, based in Switzerland, has used its knowledge in pressure, force and acceleration measurement sensors to create a new crank angle measurement system. The Type 2613B crank angle encoder has been improved and is now obtainable as a modular system to provide more accurate measurements of crank angles.

A trigger mark on the flange and case allows any trigger position to be accurately set with an adjustable lever arm, whilst the improved design also allows the flange to be set at any angle required.

The crank angle encoder can be ordered either as a complete set or as individual components, depending on requirements.

● **For more information call +41 52 224 11 11 or visit www.kistler.com**

No confusion

UK-based tuning specialists Burton Power has introduced a new range of auxiliary fuse boxes to keep wiring systems neat and simple when adding new components.

Ensuring all additional systems are adequately fused protects electrical machinery and can help prevent fires.

The fuse boxes can handle up to 30 amps per circuit and, as they use modern blade-type fuses, can also be used to update old fuse boxes. The fuse boxes come with easy to fit side connections, a screw down clear lid for visibility and come in 4, 6, 8, 10 or 12 fuse configurations.

● **For more information call +44 (0) 208 554 2281 or visit www.burton power.com**

A long stretch

Automotive Racing Products (ARP) from California has recently released a new style rod bolt stretch gauge to accurately measure connecting rod bolt lengths.

Measuring rod bolt stretch is the most accurate method of establishing preload and the rod bolt stretch gauge makes this task simple. It also enables the user to ascertain whether a fastener is compromised and about to fail.

Aimed at the professional engine builders and skilled enthusiasts, the gauge reads in .0005in increments and comes with a built-in handle and protective carrying case.

● **For more information call 800 826 3045 (within USA) or +1 (805) 339 2200. Alternatively visit www.arp-bolts.com**

RACEGEAR

New products and services for racecar engineers

Bleedin 'em dry

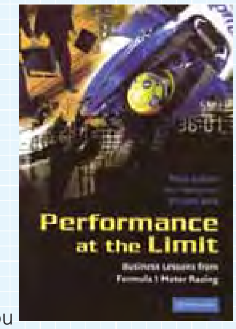
UK-based quality tool manufacturer, Sykes-Pickavant, has released a new vacuum-operated brake bleeding system to empty the brake system of all brake fluid. Using vacuum operation to draw the unwanted fluid from the master cylinder reservoir is far more efficient than the traditional method of pushing the fluid through with pressure.

It also simplifies the process of brake and clutch fluid changes as, once the old fluid has been removed from the system, the reservoir is simply topped up with fresh fluid and sucked through the system by vacuum pressure.

By using a vacuum instead of a pressure bleeding system, fluid changes are quicker, the risk of spillage is reduced and pressure-tight seals on master cylinder reservoirs are no longer needed.

● **For more information call +44 (0) 1922 702200 or visit www.sptools.co.uk**

Performance at the limit



By Mark Jenkins, Ken Pasternak, Richard West

Formula 1 is a business, but it has characteristics that place it distinctly apart from businesses outside motorsport. It operates on as level a playing field as you are likely to find in the world of commerce and its competitors are exposed to a stark comparison every fortnight throughout the season. Consequently, inefficiencies or performance-sapping internal conflicts become apparent in a way non-motorsport businesses never encounter.

It is within the culture this environment breeds that this book has searched for examples of practices that can be applied to benefit mainstream business. Much emphasis is given to leadership and management using scenarios like the F1 pitstop as an example. It also looks at techniques like leveraging relationships for maximum benefit.

Perhaps the greatest value of this book is that Formula 1 attracts some of the brightest, most capable people in business and their advice and insight is quoted throughout. Admittedly, translating this into the non-motorsport world may not be so straightforward, but applying them in other areas of motorsport would be a very realistic goal.

● **Published by Cambridge University Press, hardback, 238 pages, £25.00**

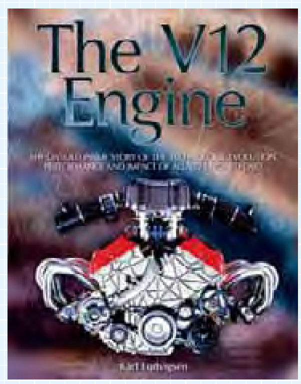
Dirt excluders

High performance US suspension component supplier Hyperco has come up with a new line of products to protect its existing range of hydraulic spring perches.

The new 'Dirt Jackets' are manufactured from a waterproof, high-density material and, with Velcro closures, are designed to shield perches from the ingression of dirt or grime. This, it is claimed, will prolong the life of the unit and increase performance between rebuilds. Dirt Jackets are one size fits all.

● **For more information call +1 574 753 6622 or 800 365 2645 within the US. Alternatively visit www.hypercoils.com**

The V12 Engine



By Karl Ludvigsen

From an engineering perspective, nothing links these engines other than the number of cylinders. Yet, as a group, it needs no further justification because anyone with an enthusiasm for engineering will know exactly what they are in for. In this tome, the author has tried to cover every V12 engine that ever travelled under its own steam in a car.

The list includes a number of racing cars, including the first GP V12 from Delage, the endurance engines from Lagonda and the methanol-burning twelves from Mercedes and Auto Union in the 1930s. Post war, Ferrari comes under the spotlight followed by Maserati, BRM and Matra before F1 adopted the format as the standard for a while. At the end it devotes a few pages to explaining how the more than 20 million possible firing orders for a V12 were whittled down to the nine used.

Such is the scope that, even running to 424 pages, there is a limit to the depth of its technical content. But, as an entertaining browse through some of the most charismatic engine projects in history, it offers a very absorbing journey.

● **Published by Haynes, hardback, 424 pages, £40.00**

Exhaust blowing

The engine exhaust dumps unused energy, but it needn't all go to waste. At least, not in aerodynamic terms

Blowing exhaust gases across aerodynamic surfaces can bring small but worthwhile benefits to downforce and drag levels

LAT

The practice of using the momentum in the jet of gas from an engine's exhaust pipe to aerodynamic benefit has been around for a while. In the 1990s F1 cars routed their exhausts into the rear diffusers, but even when this practice ceased exhausts were commonly routed so as to blow over the top of the diffusers. But what benefits are available using this principle, and how do they accrue?

It is generally known that the aim of using the energy in the exhaust gas stream is to increase downforce. In the days when it was permitted to blow into the diffuser, the jet was arranged so that it emerged tangential to the diffuser roof, and the additional momentum thus imparted to the airflow in that region re-energised the thickening boundary layer and helped to delay flow separation. This in turn allowed a steeper diffuser angle to be used, which helped create more underbody downforce. But how can blowing the exhaust jet over the top of the diffuser help? The following study may throw some light on the situation.

A few years ago Advantage CFD, originally a part of Reynard Motorsport, performed a study on that constructor's 01I model ChampCar in 'road track' specification to study the effects of exhaust gas flow, and some of the results have now been exclusively revealed to *Racecar Engineering*. The location and geometry of the region of the car in question is shown in figure 1, but the flow over the entire car was modelled to assess the global effects of the selected modifications. Three cases were run: no exhaust flow, cold exhaust flow and hot exhaust flow. The only really realistic model of course is the hot exhaust flow one, so that's what the data presented here will focus on, in comparison with the baseline model with no exhaust flow. The gas flow and temperature data was based on a 2000 specification Ford XF V8, and →

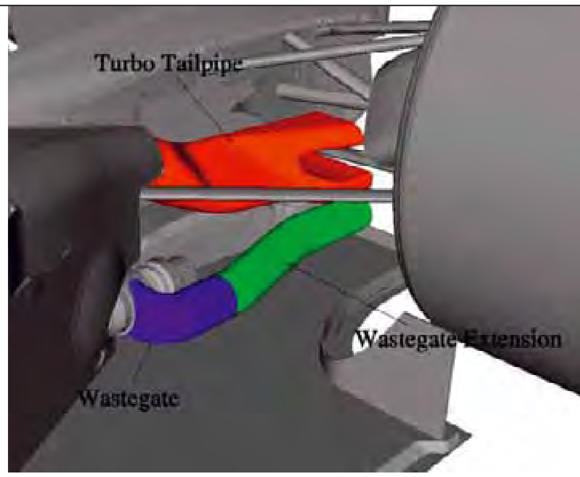


Figure 1: illustration of the wastegate and tailpipe layout tested on the Reynard 01I ChampCar in 'road track' specification

Illustrations courtesy: Advantage CFD

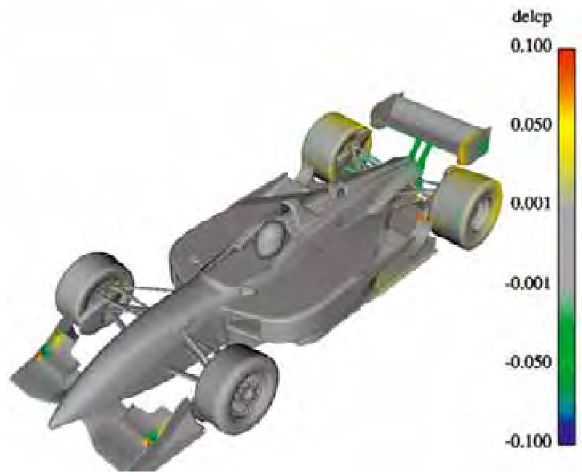


Figure 2: delta Cp plot shows the changes to upper body static pressures using the short wastegate. Yellow on upper surfaces indicates increased static pressure caused by the exhaust gas stream

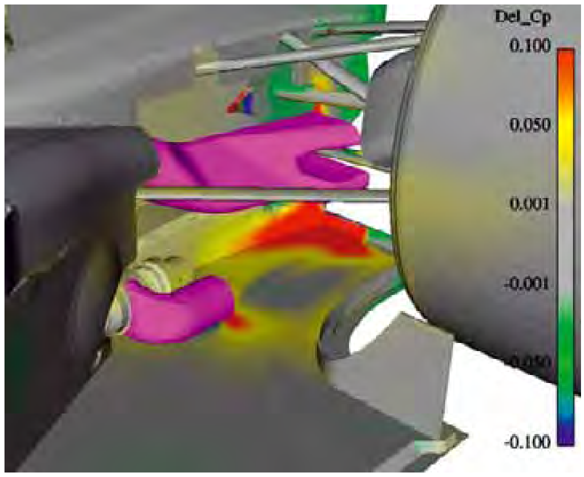


Figure 3: delta Cp plot in close up shows the increase in static pressure (red and yellow) caused by the exhaust gas from the wastegate impacting the skirt and Gurney

by dividing the mass flow (at 730degC) by the turbo tailpipe area a figure of 76.8m/s was arrived at for the exit velocity. For the wastegate (at 770degC) the velocity was 176.5m/s.

Variations of wastegate geometry were tested, designated 'short' and 'long', and the effects of running the simulations with hot exhaust flow on total drag and total downforce are tabulated below.

	Change to total drag	Change to total downforce
Short wastegate	-0.90%	+0.96%
Long wastegate	-0.98%	-0.02%

So in round numbers, drag was reduced by about 1 per cent in both cases. Downforce increased by 1 per cent with the short wastegate, offering a small but extremely efficient dual benefit, but it barely changed when using the long variant. About 80 per cent of the downforce gain with the short version was felt at the rear of the car implying, not surprisingly perhaps, that this was where changes to the flow occurred. In fact a breakdown of the forces on individual car components indicated that the extra downforce came from two main areas – the majority from the underbody, but a significant contribution came from decreases in lift felt by the rear wheels. The drag reductions meanwhile came predominantly from the rear wheels.

To visualise where the force changes arose we can look to the delta-Cp plots. These show how the static pressures around the car changed as the result of running exhaust gas compared with the 'no exhaust flow' case, using the short wastegate variant. In figure 2 it is clear that changes have occurred around the rear of the car, with areas of small increases in static pressure (yellow and red) on top of the 'skirts' (the horizontal shelves at the base of the underbody ahead of the rear tyres), which add to downforce. The close up in figure 3 shows that the short wastegate is actually blowing onto the skirt and the Gurney at the rear. Pressure increases are also visible on top of the rear tyres, associated with the reductions in wheel lift.

In figure 4 it is apparent that there has been a small reduction in the static pressure (mainly green) over a large area of the rear underbody and on the rear wing underside (green), both of which add to downforce. An increase in static pressure on the back of the rear tyres is also evident, which ties in with the reduction in wheel drag.

It appears that the wastegate flow directed onto the skirt and Gurney is producing higher pressure here. As for the decrease in static pressure in the underbody region, can this have come from this wastegate variant? Well,

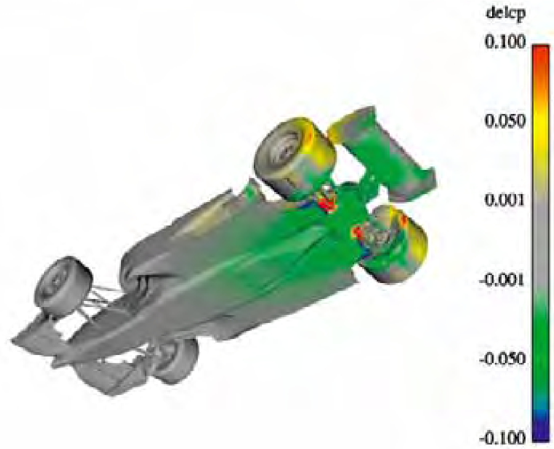


Figure 4: underside shows extensive area of static pressure reduction in underbody and wing underside (green), and the intensified reduction on the back of the 'skirt' Gurney (blue) with the short wastegate

flowing exhaust gas through the long wastegate provided the drag reductions but not the underbody downforce gains that the short wastegate achieved. The long wastegate did not blow onto or over the skirt or the Gurney, and the pressure reductions did not occur in the underbody. The small area of blue visible behind the Gurney shows the static pressure behind the Gurney is reduced when gas blows onto it, and this would have the effect of reducing the rear underbody pressure. So blowing onto the Gurney with the short wastegate does seem to have been responsible for the underside gains by making the Gurney work harder.

The rear wing has been aided too, with an extra reduction in pressure on its lower surface. However, the wing actually gained similar amounts of downforce with the exhaust flowing in both wastegate variations, so we can conclude that the wing performance has been supplemented by the combined flow of exhaust from wastegate and turbo tailpipe.

So again we've seen that a very small, localised change to the flow can have a surprisingly extensive effect on the flow around a racecar, although the magnitude of the force changes seen here was relatively small. Nevertheless, one per cent more downforce with a one per cent reduction in drag is not to be sniffed at.

Of course, what has not been stated so far is that this effect will only be present when maximum gas flow is emerging from the exhaust, and as such this benefit will fluctuate with throttle opening and engine rpm.

Mark Ortiz is

THE CONSULTANT

Too much left percentage?

While in principal more left percentage is better, on banked circuits where friction coefficients diminish, the optimum static left percentage should be similarly decreased

LAT

Q My question is regarding left side weight percentage on oval track cars, specifically dirt Late Models. I have heard it stated that more left side is better in all situations, and I see a lot of paved track classes have limits on left side percentage. I understand the concept of load transfer and equal tyre loading in steady-state cornering but my question is about the point of diminishing returns. As grip decreases or banking increases, is it correct to assume that left side weight should be reduced to keep the left side tyres from being more heavily loaded than the right sides?

A In theory, yes it is possible to have too much left percentage and to have the left tyres more heavily loaded than the right tyres, even at the limit of adhesion in steady-state cornering. In almost all cases though, practical constraints or rules stop us short of that point.

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. In these pages Mark answers your queries on chassis set-up and handling. If you have a question to put to him, email to **markortiz@vnet.net**, call **704-933-8876** or write to **Mark Ortiz, 155 Wankel Dr., Kannapolis, NC 28083-8200 USA**

We can also have too much left percentage for the tyre package short of that point, if the left side tyres are smaller than the rights, or if the lefts are inflated to a much lower pressure than the rights.

Or, we might conceivably want more than 50 per cent left dynamically, if

"LARGE LEFT PERCENTAGE MAKES A CAR TURN RIGHT UNDER BRAKING"

the left tyres are about as big as the rights, and we have a rule requiring a hard tread compound on one or both of the rights but not on the lefts.

Let's consider a simple, if not very typical, case study. Suppose we have a car with a one-foot c of g height, a six-foot track width, and →

Large left percentage also tightens a car during entry and loosens it in exit (LAT)

> **"IT IS STILL FUNDAMENTALLY TRUE THAT MORE LEFT PERCENTAGE IS ALMOST ALWAYS BETTER"**

identical right and left tyres. Suppose that the overall coefficient of friction is 1.00. That would be about what we'd get from sticky, street-legal radials. For this car to have 50 per cent left dynamically at the 1.00g lateral acceleration that those tyres will theoretically sustain, it would need 66.7 per cent left statically. That's a wider, lower car than most, on tyres with less grip than racing slicks. If the same car is fitted with racing slicks that have a coefficient of friction of 1.30, the static left percentage needed to have 50 per cent left dynamically increases to 71.7 per cent.

If the car has a wing that acts equally on the right and left tyres, lateral acceleration increases and the desired static left percentage goes up more.

But what happens if we put the car on a banking? The result is a bit surprising. If the coefficient of friction stayed the same, the ratio of car-horizontal (y-axis, per SAE conventions) force to car-vertical (z-axis) force would be unchanged, although all forces would increase. This assumes the car is at the limit of adhesion both with and without the banking, not at an identical y-axis acceleration or an identical earth-horizontal acceleration.

However, due to the same tyre load sensitivity that makes us want equal loading, on the banking the coefficient of friction will diminish, so the questioner's intuition is correct after all, and the optimum static left percentage will decrease.

In an earlier column dealing with this question, I noted that if we do get to the point where left percentage is excessive for conditions, wedge or diagonal percentage adjustments will work backwards, and so will roll resistance adjustments. After that, a reader wrote in and said he had encountered this, with a go-kart on a very steeply banked dirt track.

Upon further discussion, it came to light that the kart had a much smaller tyre on the left rear than on the right rear. This not only affected the optimum load distribution for the rear wheel pair, it also meant the kart had a lot of tyre stagger. More load on the left rear increased the stagger-induced yaw moment on the kart, also causing more diagonal percentage to loosen the vehicle (add oversteer), contrary to what one might expect. This effect can easily occur in any car with a locked or partially locking rear end. This in turn affects our ability to infer whether left percentage is excessive, purely by noting how the car responds to adjustments.

I have also noted in earlier discussions on this subject that large left percentage makes a car tend to turn right under braking and turn left under power. This tightens the car (adds understeer) during entry and loosens it (adds oversteer) during exit. There are of course ways to counter this tendency with suspension design and tuning, but sometimes these are not wholly legal, or the team doesn't fully understand them. In such cases, the car may well turn faster laps with less than optimal left percentage, even though it is slower in steady-state cornering.

These complexities can, in practice, muddy the waters when tuning an actual car but it is still fundamentally true that more left percentage is almost always better, provided we are able to understand and work with the full package of consequences.

Q When NASCAR teams use a chain for one of their sway bar links, are they using it as a lost motion device, allowing wheel travel before the bar rate becomes active?

A More common than a chain nowadays is an adjustable pad on the end of the sway bar, bearing on a pad on the lower control arm. Chains are still seen sometimes in the lower divisions, where original equipment-style bars are required. But the basic idea is the same either way – have a connection that transmits force in only one direction. The bar only resists rightward roll, unless it's pre-loaded, in which case it does resist leftward roll up to the point where it unloads.

> **"A CONNECTION THAT TRANSMITS FORCE IN ONLY ONE DIRECTION"**

The intent here is to help keep the car from going quite so loose when the driver gets the left front wheel on the apron of the track, which is sometimes abruptly flatter than the banked turn.

Usually, the bar is run snug or slightly pre-loaded at static condition. That means that the bar acts just like it normally would in a left turn. When the car is cornering, the bar has substantial load on it. The one-way connection (be it a pad or a chain) will only go slack if the left front wheel hits the apron hard enough to put the front suspension into a left roll condition – left front deflection greater than right front. This leads me to question the use of these devices, especially since they make the car loose when turning or spinning to the right, which can happen during a crash or when avoiding one. Nevertheless, they are very popular. RE