THE EXPERT STEWART SANDERSON

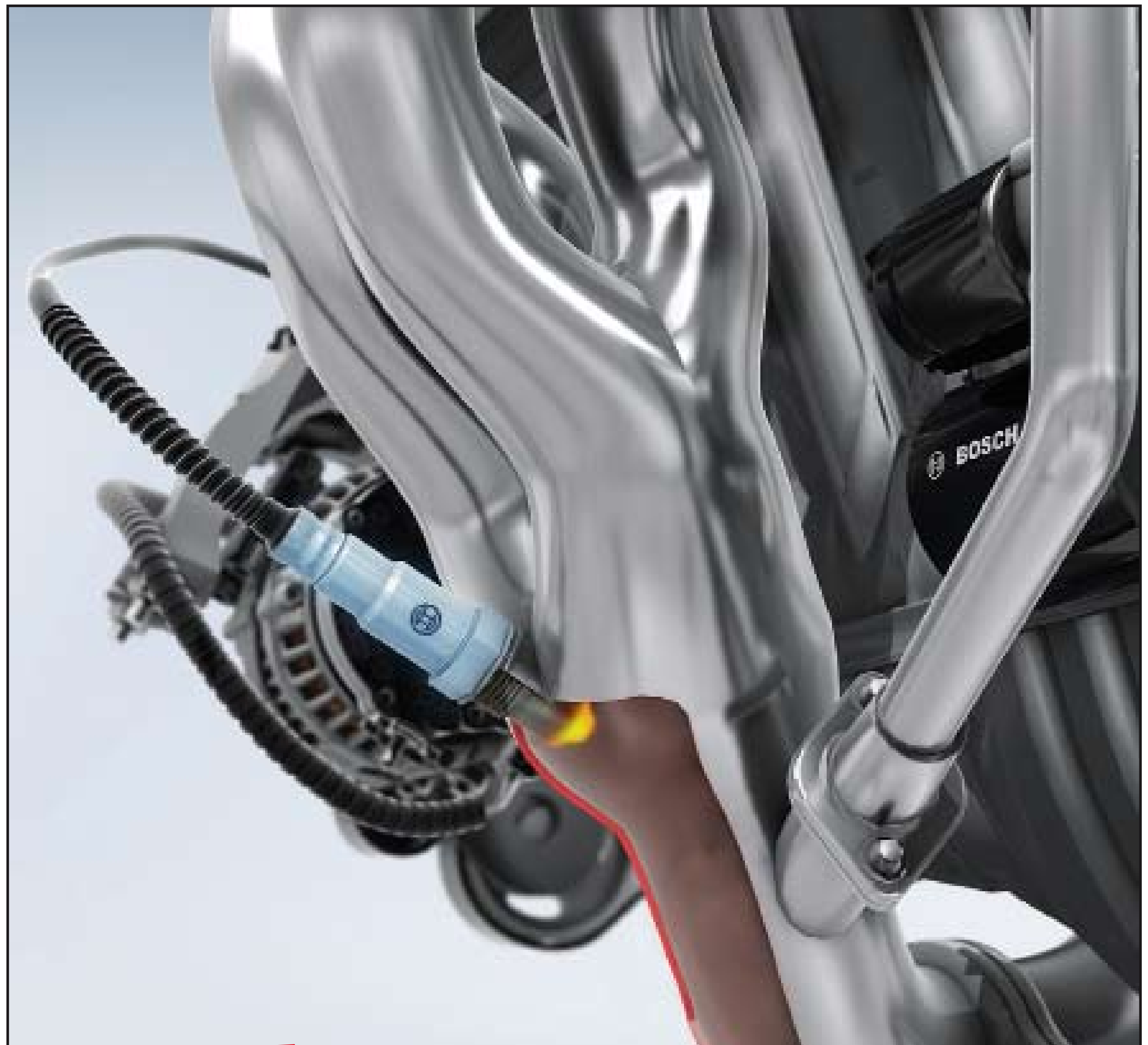
Having worked as a tuner for 17 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

A Level 5-trained fuel-injection technician, Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Eight years ago he joined forces with Kenny Walker and opened up Motorsport Developments near Blackpool (01253 508400, **www.remapping.co.uk**), specialising in engine management live remapping, as well as developing a range of Evolution chips which are now sold all over the world.

He is the creator and administrator of **www.passionford.com**, which he started in 2003. It has grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web.

Stu's enviable knowledge of the workings of modern-day Ford performance engines means that every month he's just the man to explain how and why things work, and importantly how they can be improved.



PART 1

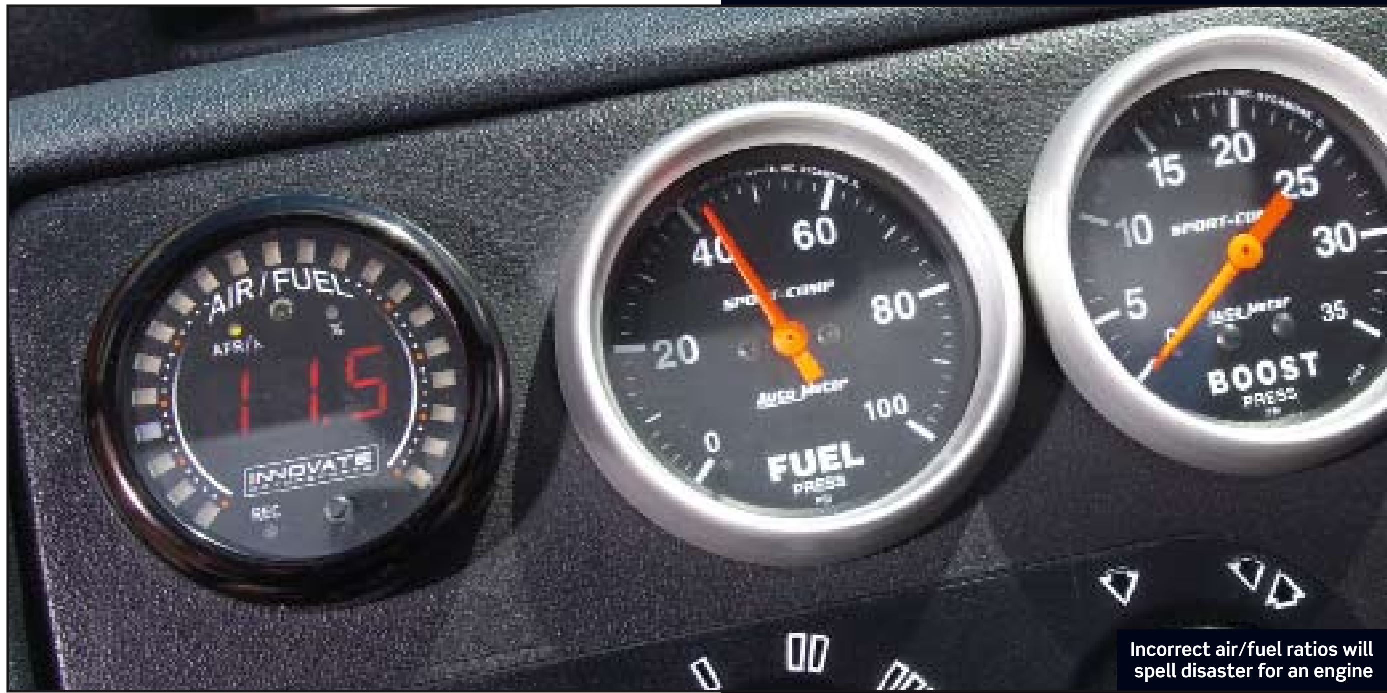
Words: Stewart Sanderson and Will Pedley

AIR FUEL RATIOS

THIS MONTH WE'RE LOOKING AT WHAT THE AIR/FUEL MIXTURE IS AND HOW IT AFFECTS THE RUNNING AND PERFORMANCE OF YOUR CAR.

We're sure that most of you will have heard people talking about their cars running 'a bit rich' or 'a bit lean'. In simple terms rich means too much and lean means too little, but too much or too little of what? The answer is fuel content in our air/fuel mixture.

AFR simply means Air Fuel Ratio and, as the name suggests, it is the ratio of air to fuel that enters the engine for combustion. If there isn't enough fuel present then the mixture is referred to as a weak or lean mixture. If there is too much fuel present then the mixture is referred to as rich.



Incorrect air/fuel ratios will spell disaster for an engine

HOW TO MEASURE AIR/FUEL RATIO

To measure the air/fuel ratio we need to use a Lambda sensor or gas sampling cell such as the type used at an MoT station that connects to your exhaust with a pipe. However, the sample cell only tells you the emissions at the tailpipe, so catalyst-equipped cars (cars produced in the last 17-plus years) won't read properly using this method. This is why Lambda sampling is preferred for ease of installation versus accuracy and portability.

Lambda sensors come in two main forms: narrow band and wide band. Narrow band sensors are normally found on production cars to ensure stoichometric fuelling is maintained at idle and under light cruise conditions to satisfy fuel economy requirements and emissions regulations. Due to their narrow range of operation, (normally a 1volt range) they're not really any use to us for tuning as they were only designed to monitor mixtures accurately around the Lambda 1 range to give the ECU feedback on fuelling levels and help it to keep the AFR around Lambda 1 (14.7:1 AFR) when it needs it to be there.

Wide band Lambda sensors are far more accurate and complex pieces of equipment and normally operate over a 5volt range. They provide a much wider picture allowing us to see the oxygen content of the exhaust gas through rich, stoichometric and lean conditions.

Some of the high quality units like the one we use at MSD can offer information on an AFR range as wide as 6:1 to 150:1 (0.4 to 10.0 Lambda) with accuracy as good as or better than 0.05% across the scale. Prepare to pay in excess of £6000 and upwards for a unit of this calibre though. That said, reasonably accurate equipment can be had for as little as £200.

WHERE TO MEASURE AFR

In an ideal world, fitting a Lambda sensor into each exhaust primary provides us with a far more detailed picture about how the engine is combusting the mixture in each cylinder. This will highlight any flow distribution problems within an inlet manifold or flow differences between injectors. Certain ECUs will even allow you to compensate for these differences by adjustment of the fuel injected to each cylinder, allowing you to create a virtually perfect running engine.

The reality is that due to the extreme cost and the mounting complications of such an installation only high budget racecars will normally go to these extremes. For most cars it is acceptable to take a reading of the air/fuel ratio from either the manifold collector in a naturally aspirated car or the downpipe from a turbocharged car.

ALTERNATIVE FUELS

There are a few reasons for wanting to look at alternative fuels including economy and performance. Here are some of the options.

LPG (Liquefied Petroleum Gas): Primarily used for economy due to its lower purchase price. While LPG has a lower energy content, 74% of that of petrol, it is also very resilient to detonation. This means that on an optimised set-up, it can produce more power through the use of more ignition advance and the resulting higher cylinder pressures.

Race fuel: Primarily used for performance or as part of a 'control fuel' within a race series. There's a huge number of race fuels around, some leaded, some unleaded and even some heavily oxygenated ones!

Race fuels are normally reviewed through their Motor Octane Number, and are designed to resist detonation on high compression, forced induction engines, so again allow considerably higher cylinder pressures to be achieved safely without detonation.

Methanol: This fuel is generally reserved for drag racing. Methanol is a very oxygenated fuel and as such has its own oxygen content. It also has around half the energy content of normal petrol-based fuels, and its stoichometric burn point is 6.42 parts air to 1 part methanol, so drastic changes are needed to run it!

Methanol is highly resistant to detonation, allowing even greater amounts of ignition advance and compression to be run safely. In addition, methanol combustion occurs at considerably lower temperatures that aid in engine cooling. The downside is that you'll need a fuel system capable of flowing some 200% more than for petrol-based fuels plus a mappable ECU! Methanol is toxic and incredibly corrosive to normal fuel systems.

E85: This alcohol-based fuel is being used in the UK more commonly now. It is ethanol-based and has similarities to methanol in that a larger quantity must be combusted to produce the energy equivalent to petrol, it is very detonation resistant and the fuel system must be chosen to suit E85 use. The considerable benefits of E85 are that it is environmentally friendly, cheaper than methanol is starting to be sold at petrol stations.


Lambda sensors are used to monitor AFRs

The air/fuel ratio can also be sampled at the tailpipe if a tuner only requires short monitoring periods during mapping. However, bear in mind that if there are leaks in the exhaust system, the readings can be compromised.

PETROL AND POWER

We all moan about paying so much for it but let's have a look at what fuel is to help understand how it impacts on air/fuel ratios.

We are concentrating on petrol-powered vehicles for the purpose of this feature so let's try and understand what petrol actually is.

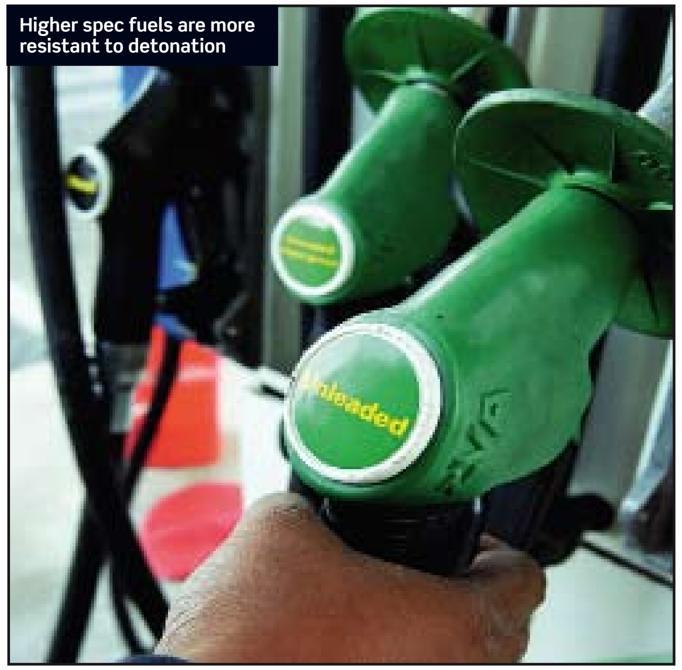
Petrol comes from crude oil. Crude oil is distilled into fractions at a refinery and then blended with additives to prepare it for use in the automotive industry. These additives are used to increase the octane rating, reduce emissions and clean the fuel system. TV ads show how much cleaner the inside of an engine that has run on more expensive fuel is, and there is a lot truth to that...

"THE MORE ADVANCE WE NEED OR ARE REQUIRED TO RUN, THE MORE CYLINDER PRESSURE WE CREATE."

Fuel contains energy, in the case of petrol around 32 mega joules per litre (MJ/L) on average. It is this energy that we are releasing to power the rotation of our engines. When we burn petrol in an engine the energy from the hydrogen and carbon contents of the fuel is released. We need to run richer than stoichiometric to release more power because hydrocarbons (the hydrogen and carbon mentioned) release most of their energy upon combustion to carbon monoxide (CO).

To safely release the most energy and power from the fuel, we need to ensure the combustion makes peak force at the right time in order to transmit the most power to rotation of the crankshaft, and not waste it heating our cylinder water jackets or fighting other cylinders power strokes. This is achieved via ignition timing. In general, the more advance we need or are required to run, the more cylinder pressure we will create and therefore the more resistant to detonation our fuel must be.

To understand more about advance and detonation see earlier tech articles, available to download from **www.fastfordmag.co.uk**.


Higher spec fuels are more resistant to detonation

LAMBDA AND HOW IT'S CALCULATED

The Brettschneider equation is the most popular method used to calculate the air/fuel balance (Lambda) for most diagnostic analysis systems used today. It is taken from a paper written by Dr Johannes Brettschneider, at Robert Bosch in 1979.

Dr Brettschneider established a way to calculate Lambda by comparing the ratio of oxygen molecules to carbon and hydrogen molecules in the exhaust gas. The equation is complex and beyond the scope of this article, but it's sufficient to say that using it allows a result to be relatively easily calculated from the measured values of CO, CO2, unburned HC, and unconsumed O2 in the exhaust.

The result of the Brettschneider equation is the term Lambda, a dimensionless term that relates nicely to the stoichometric value of air to fuel. At the stoichometric point Lambda = 1.000. A Lambda value of 1.050 is 5% lean, and a Lambda value of 0.950 is 5% rich. Once Lambda is calculated, air/fuel ratio can be determined by multiplying Lambda by the stoichometric air/fuel ratio for the fuel selected, ie 14.71 for unleaded petrol and 15.87 for LPG. So, if we have a Lambda reading of 0.85 with unleaded fuel and want to equate that to AFR we use this calculation: 14.71 x 0.85 = 12.50:1 AFR.

DILUTION EFFECTS

It is important to understand the effect that sampling air leaks will have on Lambda calculation. The percentage of extra air in the exhaust gases will result in the same percentage error in the Lambda calculation. For example, a 5% air leak present in the exhaust will result in the calculated Lambda being 5% leaner than it should. That means that a perfect Lambda of 1.000 will be reported as 1.050 if there is 5% air leak.

This is a significant error, and can occur relatively easily so beware of using these methods with leaking exhaust gaskets/joints.

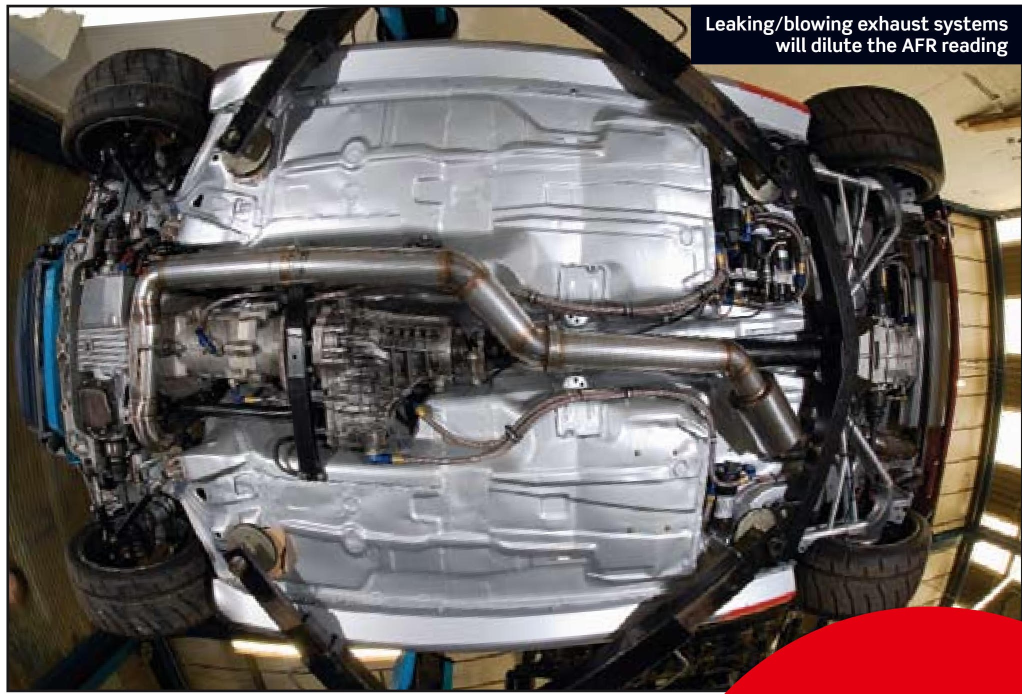
MISFIRE EFFECTS

One of the main advantages Lambda has over most other reading methods is that due to the calculation determining the balance between oxygen and combustible gases it is relatively insensitive to the degree to which the combustibles have been oxidized. So an engine misfire has absolutely no effect on the balance calculation.

It doesn't matter where the gases are measured, or how efficient the combustion process is operating provided that the sample is true and not diluted or contaminated in any way.

This table gives an approximate idea of how air/fuel ratios and Lambda numbers compare:

Lambda	AFR
1	14.7
0.99	14.553
0.98	14.406
0.97	14.259
0.96	14.112
0.95	13.965
0.94	13.818
0.93	13.671
0.92	13.524
0.91	13.377
0.9	13.23
0.89	13.083
0.88	12.936
0.87	12.789
0.86	12.642
0.85	12.495
0.84	12.348
0.83	12.201
0.82	12.054
0.81	11.907
0.8	11.76
0.79	11.613
0.78	11.466
0.77	11.319
0.76	11.172
0.75	11.025


Leaking/blowing exhaust systems will dilute the AFR reading

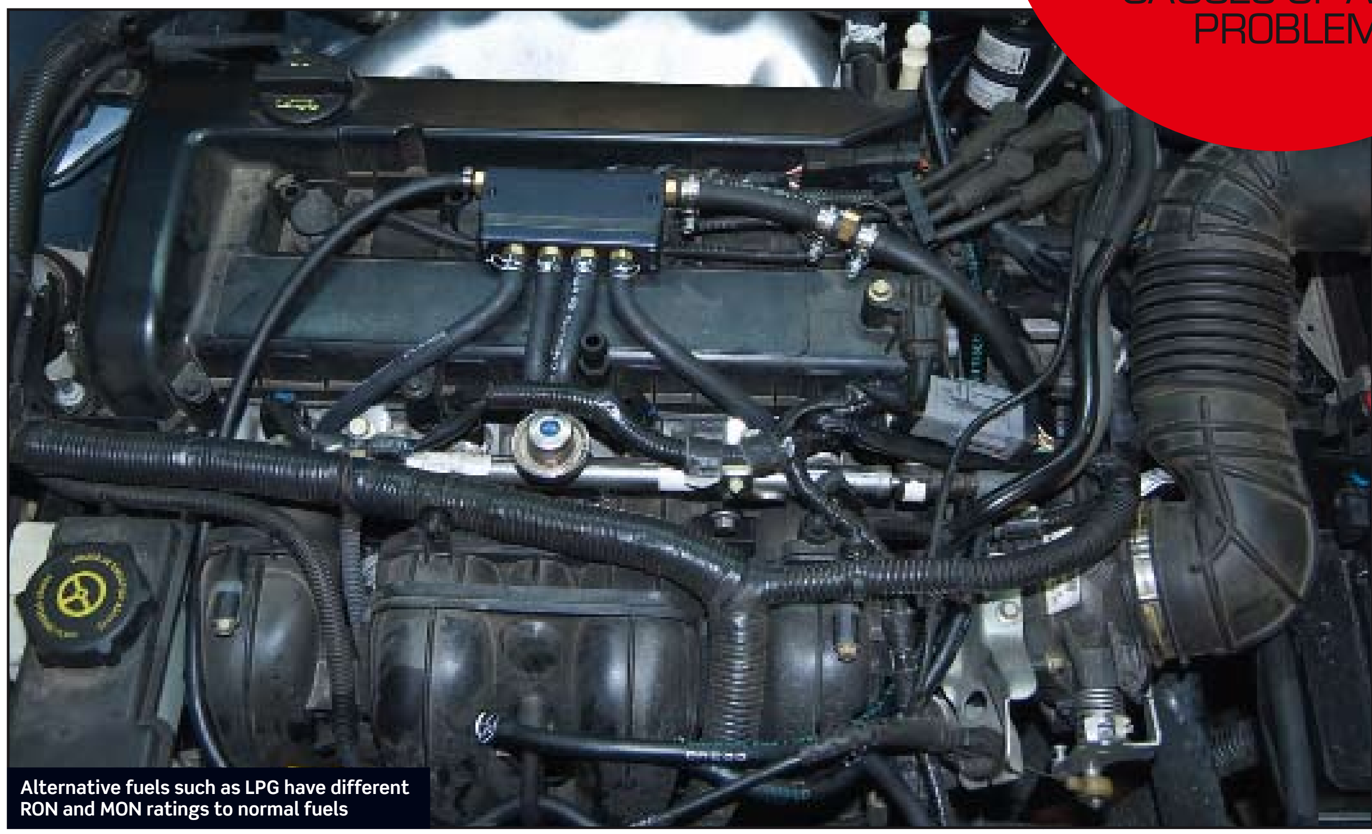
RON AND MON RATINGS

Manufacturers subject their fuel to a series of tests to produce a RON (Research Octane Number) and a MON (Motor Octane Number).

The RON number is achieved by running a test engine with a variable compression ratio at 600rpm and examining the iso-octane and n-heptane content. The MON number is achieved under slightly more strenuous conditions, using a 900rpm engine speed, preheated fuel and variable ignition timing. It is normal to find a MON number around 8 to 10 points lower than the RON value.

In the UK, fuel is advertised by its RON value on the forecourt. America uses the AKI (Anti Knock Index), which is the average of the Research Octane Number and the Motor Octane Number. In summary, the higher the number at the pump, the more resistant to detonation the fuel is.

NEXT MONTH
TUNING THE AIR FUEL RATIO TO ACHIEVE OUR GOALS AND COMMON CAUSES OF AFR PROBLEMS.


Alternative fuels such as LPG have different RON and MON ratings to normal fuels