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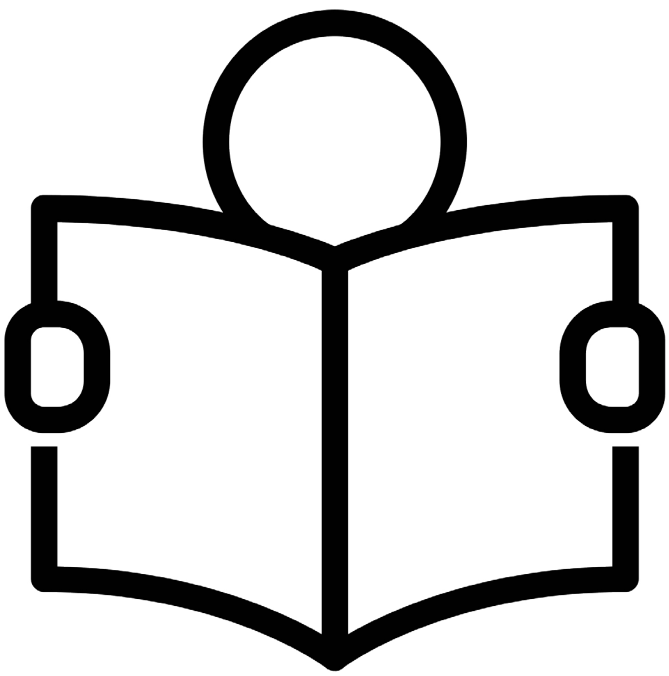
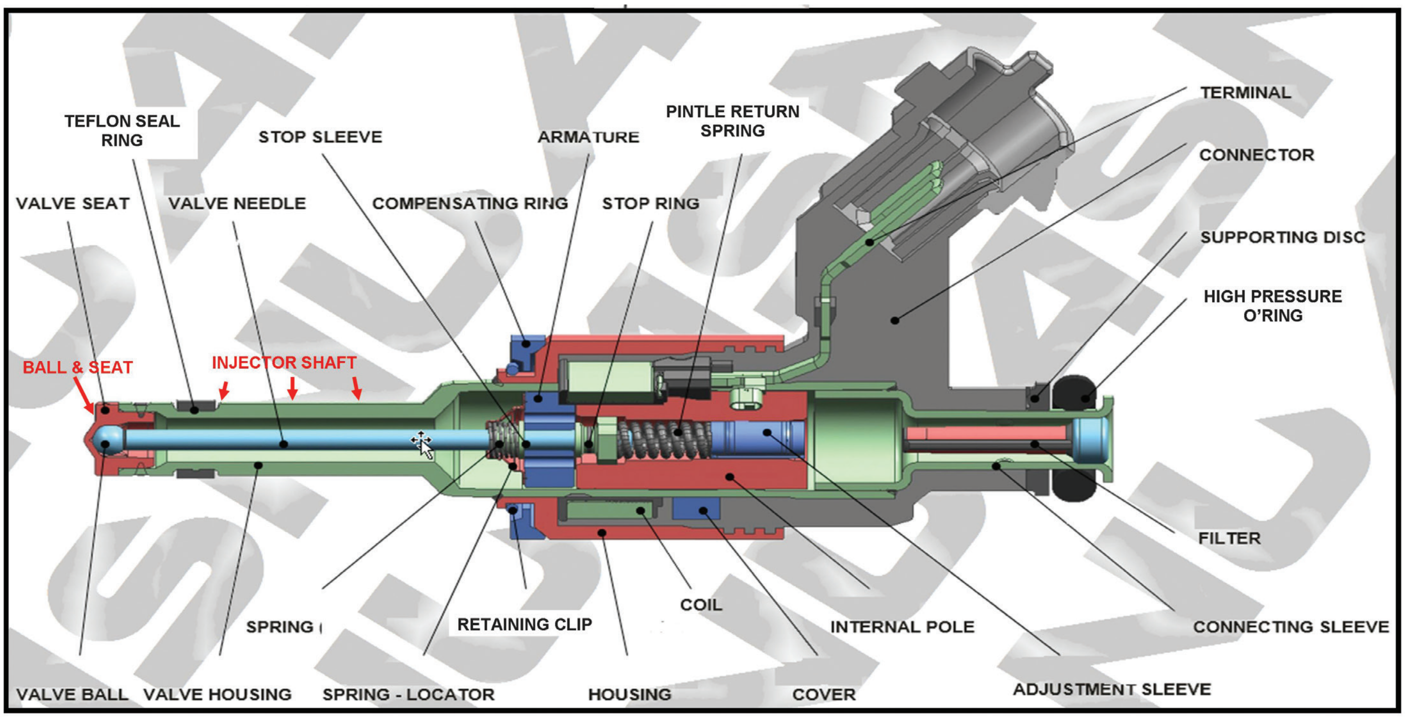


2018 Edition



TIME TO CLEAN UP

PART 1

DRIVEN BY FALSE EMISSIONS CLAIMS AND THE ASSOCIATED IMPACT ON POLLUTION, THE BELL IS TOLLING FOR DIESEL ENGINES. ASNU TAKES A LOOK AT WHAT THIS MEANS FOR GARAGES. AS EVER, WITH CHANGE COMES OPPORTUNITY FOR THE BRAVE TO CORNER A GROWTH MARKET IN GDI DIAGNOSTICS AND REPAIR. WILL YOU BE PRIMED AND READY FOR THIS TYPE OF REPAIR WORK?

The demise of the diesel engine is perceived to be imminent. Major towns and cities will soon see restrictions for entry by diesel-engine vehicles and this will have a major effect on the future car parc and the vehicle service and repair market.

Should workshops continue to invest in the expensive equipment required to test and service diesel vehicles, knowing that their market will dwindle as the cost of the repair becomes more expensive? At what point will owners begin to question whether the cost of the repair is more than the vehicle is worth?

Garage service and repair workshops are at a crossroads. Where to deploy capital expenditure? The growing market for petrol and alternative fuels would seem a logical answer. ASNU delivers three articles focusing on the options for garages around Gasoline Direct Injection (GDI) engine service and repair.

The first article here looks at how GDI came about and asks what the decline of diesel engines might mean for diesel specialist repairers. The second article in the July issue will investigate injector fault diagnosis and replacement options. Finally, in the September issue, we'll tackle the technology around GDI and injector diagnostics, understanding flow rates and spray patterns. Then we'll turn theory into practice, featuring a case study on an independent garage who has already taken the GDI plunge. Has the investment been worth it so far?

IS THIS HOW DIESEL DIES?

The diesel service market can be divided into different sectors. The professionals' core business is testing, servicing and repairing diesel injectors and fuel pumps. Conversely, the perceived amateurs' core business is general vehicle repairs and servicing, with diesel injectors akin to a side-line of the main business.

The professionals are the recognised groups of Bosch and Delphi Diesel Workshops. The equipment used for testing, servicing and repairing diesel injectors and fuel pumps within these groups is equivalent to many hundreds of thousands of pounds of capital expenditure. Major investment in equipment, staff and training, stock of service and repair items, a clean room and premises to house their diesel service programme, can cost anything up to £35,000.

For the amateur, buying a test bench could cost anywhere between £13,000 and £26,000 and the equipment is possibly only geared to test one injector at a time. This is on a small scale by comparison, delivering a time-consuming service, taking longer and, in many cases, with the injectors not being repaired in the same manner as the well-structured and equipment-rich professional groups.

PRICE WARS AND PARTS SHORTAGES

As the diesel arena declines, the professionals are destined by commercial nature not to let their market dominance be diluted by small scale operations. Many will find additional services to offer, some may reduce their staff, but they will try to maintain their business against all odds.

First notice will be struck with a price war. What the professional knows is that the amateur checking one injector at a time will take far longer to service a set of diesel injectors than themselves. By reducing the price of a service or an exchange set of injectors, they know this will push the amateur to the limit of what is cost effective, working all day to do a set of injectors at a cost, with a profit that will only just cover the cost of the lease/loan repayments on the equipment the amateur is using. The second notice will come from the shortage in supply of specific parts required to service the diesel injectors.

Whilst the market is buoyant there are several parts suppliers, but as the market shrinks, the manufacturers will not be so keen to produce parts in bulk, in fear that they will be left on the shelf. Production will reduce and costs will increase.

VERDICT

The time is now to prepare for a sea of change in servicing and repair, as developments in Gasoline Direct Injection (GDI) engines make petrol once more the chosen fuel. GDI is here to stay and, with vehicle manufacturers prioritising its development, the outlook is set to fair for at least the next two decades. GDI injectors will fail and these vehicles will require professionally trained engineers with the right equipment to carry out diagnosis and repair.

ASNU: Experts in injector diagnostics

There's not much we haven't seen in our 27 years as market leaders in gasoline injector diagnostic testing and servicing. The ASNU network services over 600,000 gasoline injectors per year worldwide, with distribution in over 60 countries. Our injector diagnostics programme covers all gasoline injectors used on cars, bikes and marine engines. As you can imagine, we have an extensive knowledge base that we gladly share with service workshops using our kit via education and support materials and advice, which you too could benefit from.

With both the workshop and the VM warranty department equipped with the ASNU system and support, the ability for the workshop and the warranty department to both quickly and simply identify, confirm or eliminate injector related problems has improved immensely.

GDI: A FAMILIAR FRIEND

Since the creation of the gasoline combustion engine, the fundamentals haven't changed. With a GDI engine, combustion still requires three essential elements: Air, Fuel and Ignition. The quantity, timing and delivery of these three elements has been refined and now, through research and development, are delivered in a more efficient manner and at unimaginable speeds to original conception.

There are many different manufacturer-led names for GDI; Spark Ignited Direct Injection (SIDI), Smart Charge Injection (SCI), High Precision Injection (HPI), variants of 'petrol direct injection' and Fuel Stratified Injection (FSI), to name a few. They all have the same feature; direct injection for a gasoline engine. The advantages offered for the motorist and the VMs mean there will never be a return to the original manifold/port injection systems.

GDI as we know it now, has been in mass production since 1997, when Mitsubishi introduced Carisma, using Hitachi-produced GDI injectors. The initial launch was one of expectation; all the other VMs waited to gauge acceptance for this type of engine. Even though most of them had already been working on such systems, the motorists' reaction to the GDI vehicle was the question that hung in the air.

It was answered swiftly; GDI proved to be a winner. As a family saloon, Carisma appealed perfectly to a mass market desiring both performance and economy. The die was cast. Exposure was good to start with and any initial problems with the system were credited to teething problems caused by the fuel quality in the UK leaving deposits in the combustion chamber. This wasn't necessarily the case, but it wasn't known at the time.

GDI TODAY

Fast forward to modern day. The GDI System has two running modes:

STRATIFIED CHARGE

This mode is the economical combustion cycle. In some systems, the Air to Fuel ratio can be as high as 65 to 1. In this mode, the injector delivers a minimum amount of fuel in to the combustion chamber, just before the piston reaches TDC and before ignition. This mode is used at idle and light throttle settings when the vehicle is driven slowly.

HOMOGENEOUS

This mode is what would be called a normal combustion cycle, with an Air to Fuel ratio of 25 to 1. In this mode, the injector delivers a normal amount of fuel into the combustion chamber. This gives the engine the required performance as the vehicle accelerates.

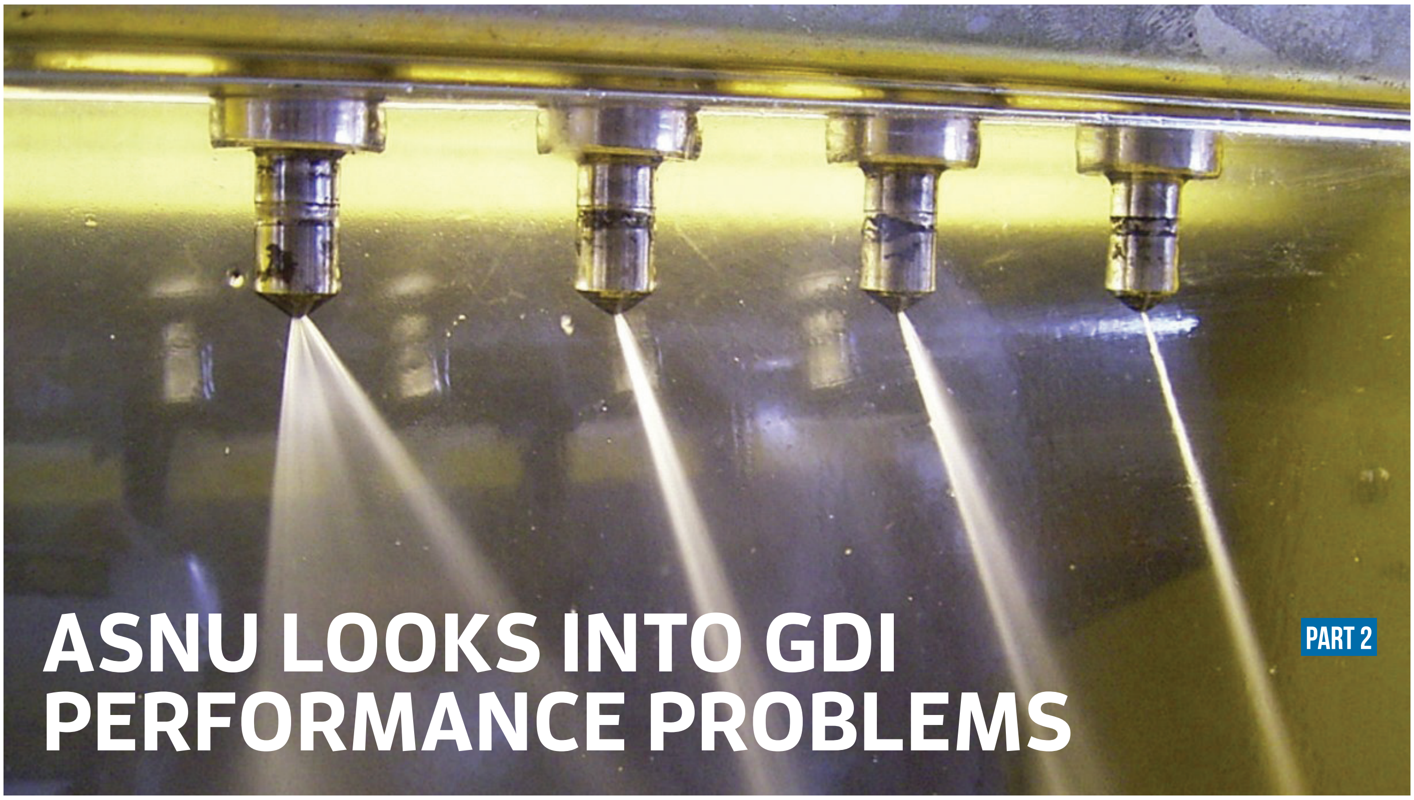
The Engine Management System determines when the system needs to switch between the Stratified Charge Mode and the Homogeneous Running Mode.

On a GDI system, the fuel is injected directly into the combustion chamber at a much higher pressure than manifold systems, up to 200 bar. These systems now require fuel pumps and injectors made of stainless steel and must be capable of performing at a much higher specification than ones seen on previous manifold injection systems. It delivers very precise quantities of fuel at extremely high pressures and in short periods of time, in some cases, for fractions of a millisecond.

To control these systems, the ECU is also of a higher specification and required to supply a higher current of up to 90V on some systems. There are many manufacturers of this type of system, but Bosch are recognised as one of the leaders in the development of GDI Technology.

0208 4204 494
phil@asnu.com

COMING UP: In the July issue of Autotechnician, ASNU investigates common GDI injector problems and how they can be safely diagnosed and fixed.



PART 2

ASNU LOOKS INTO GDI PERFORMANCE PROBLEMS

THE PROBLEMS WITH GDI ENGINES ARE WELL DOCUMENTED, BUT THE CAUSES ARE NOT. UNLESS YOU FIND AND CORRECT THE SOURCE, THEY WILL RETURN.

Problems are not caused by any one failure or feature. They are not due to the vehicle design or because of any design failure of the components used on the vehicle. Although the fuel does have an influence, that alone will not be the sole cause, however, add them to the driving conditions, traffic queues, speed humps, short stop/start journeys and the different fuels available, and you have the ingredients for failure. Solving problems requires the attention of a professionally trained workshop with the correct equipment, to diagnose the cause and provide the fix.

"Fuel trim adjustments are not correcting the cause of the problem, only compensating for it. You need to find the cause of the problem to fix it."

DELIVERY AND FUEL TRIMS

The injector's basic requirement is to supply a metered amount of fuel in a specific form at a time and for a duration requested by the vehicle's ECU. A port/manifold injector typically works to a 14:1 Air/Fuel Ratio, whereas a GDI injector is working to a 40:1 ratio and some of the Piezo injectors are working as high as 60:1 ratio.

The loss of any fuel at these levels can and will have an adverse effect on the engine. To counter this, the latest adaptive engine management systems have been designed to adjust the 'fuel trims', controlling the fuel delivery to each cylinder to maintain an equal delivery. An adjustment of up to 15% can be made to the fuel delivery of each injector on some systems but, as there are number of measurements that contribute to the fuel trim adjustment, these measurements cannot adjust or correctly compensate for poor fuel distribution and atomisation.

The fuel trims compensate for the difference in fuel deliveries; they do not correct what has caused the fuel delivery to change. Whatever has caused the change in the fuel will need to be investigated when the problem becomes a long-term issue for the system, highlighted by a warning on the dash panel.

The distribution and atomisation on a GDI injector is critical to maintaining the correct performance, fuel economy and exhaust emissions. They are now even more important than the quantity of fuel being delivered by the injector.

DIAGNOSIS BY REPLACEMENT IS OUT

For 90% of the motor industry, keeping fully up to date with technology is nigh on impossible. Technicians could spend at least 10 working days of a month being trained on the new technology and still have more to learn. It's just not cost-effective. Most technicians learn from a mixture of experience, the internet, 'having a go' and relying on the equipment they are using to do the job for them.

You have probably already removed injectors from a port/manifold engine without any major problems. Most are pretty simple and can be removed in 10 to 45 minutes. Information on these injection systems is quite easy to find and follow – many workshops employ the 'diagnosis by replacement' technique for this very reason. However, with GDI injectors, it's a different scenario. Firstly, their location is an issue, as a direct fit to the combustion chamber, they are not so easy to remove. Secondly, because of the engineering required for a GDI injector, they are not cheap. With GDI injectors, diagnosis by replacement is simply not cost effective.

SAFE REMOVAL OF GDI INJECTORS

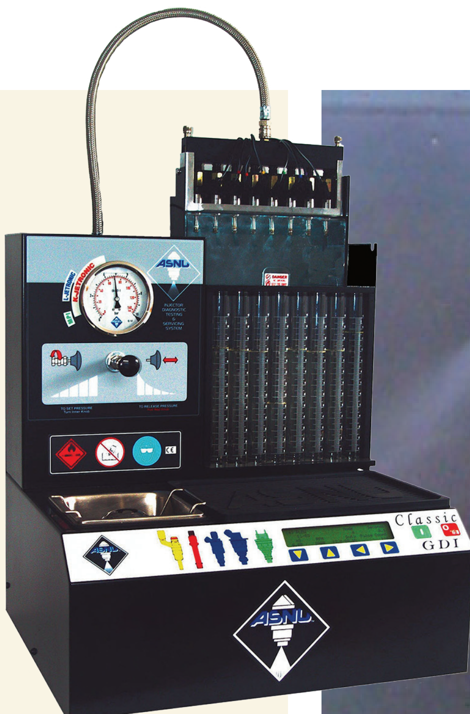
GDI injectors are, like all injectors, built with micron tolerances on the internal operation of the injector. The long shaft required to get the fuel into the engine is robust, but no match for a mechanic with a lever bar.

Over the years, the ASNU team have seen many different types of problems with GDI injectors. Some with broken pintles, broken springs, coil failure, seizures due to excess heat, misuse and abuse, carbon deposits and damage caused by either removing or refitting of the injectors. If the mechanic levers against the injectors to get them out they can twist or bend the shaft of the injector. Moving the shaft even just microns can stop the ball from returning to its seat, causing the injector to leak or even remain open.

Removing GDI injectors should always be carried out using specialist removal tools. It is possible to remove some injectors without these tools but the likelihood of damaging the injectors and the costs involved in replacing them, makes the use of specialist tools the only logical option.

ASNU'S CLASSIC GDI KIT

The ASNU Classic GDI Injector Diagnostic Testing & Servicing System allows you to compare injector performance safely. It can be used by apprentice level mechanics as well as Master level engineers.



On a vehicle fitted with a GDI system, the fuel pressure will operate at a potentially dangerously high level for the inexperienced, reaching anywhere between 75 and 200 bar. To enable a safe and easy examination of the injectors' performance, the ASNU kit runs the injectors at a lower and safer operating fuel pressure, up to a maximum of 10 bar. Testing at low pressure also makes examining the free movement of the pintle easier; high pressure can mask the free movement.

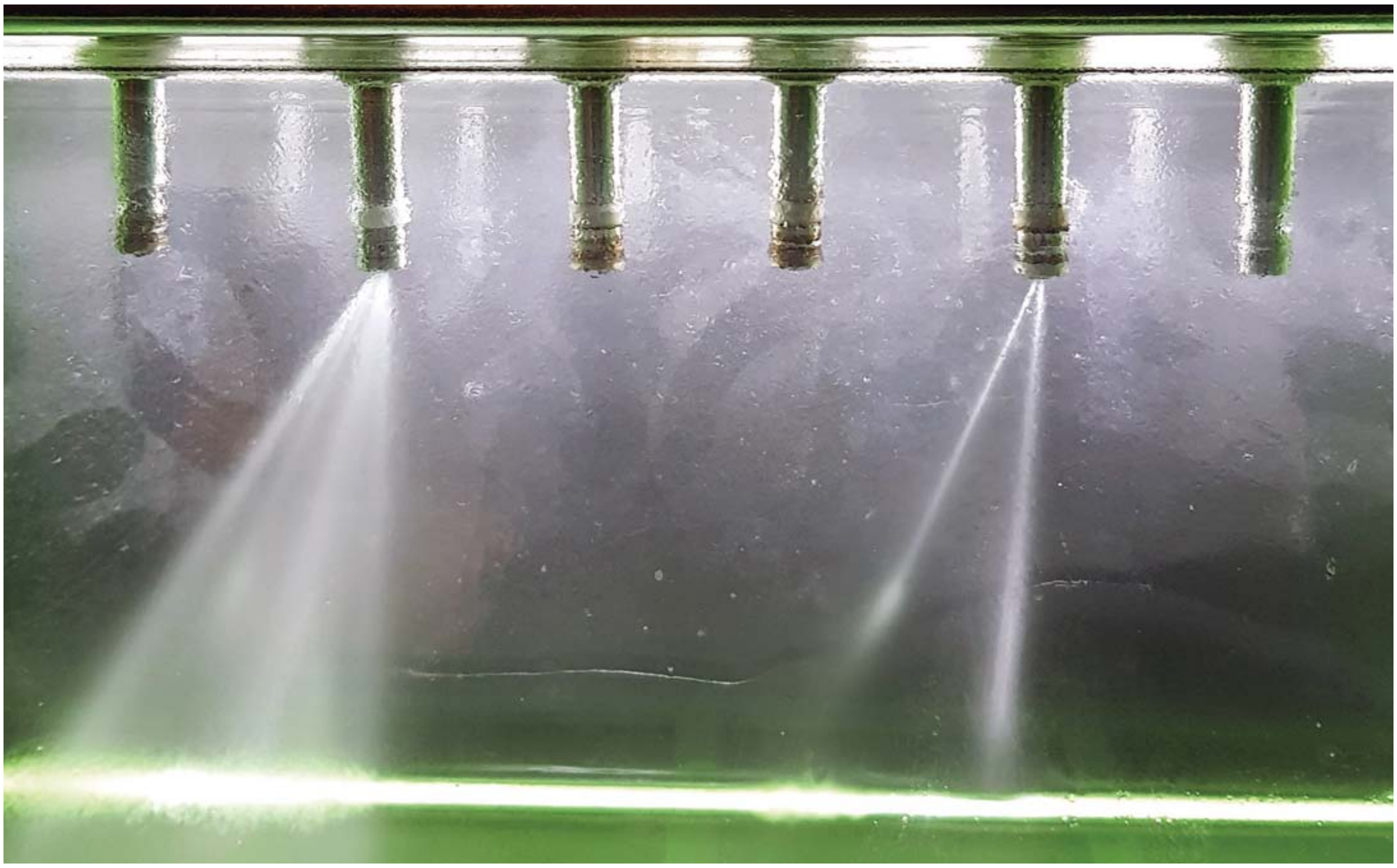
The Engine Management System of a GDI is designed to open the injectors for micro-second durations. With a maximum opening duration of only five milliseconds, any visual analysis of the injectors' spray patterns could be both difficult and dangerous. When mounted on the ASNU Classic GDI, the injectors are being supplied with the correct peak and hold currents and firing in sequential mode, simulating those of the vehicle's ECU.

The ASNU system allows the user to safely examine the injectors' spray patterns in greater detail, looking for any discrepancies in the fuel distribution and atomisation.

In some operating modes, the ASNU system opens the injectors for a much longer duration, thus exaggerating the spray pattern and making it easier to examine performance.

COMING UP: In the September issue of Autotechnician, ASNU considers GDI technology and injector diagnostics, with regards to flow rates and spray patterns. We'll turn theory into practice, featuring a case study on an independent garage who has already taken the GDI plunge to find out if the investment has been worth it.

✆ 0208 4204 494
✉ phil@asnu.com



THE TECHNOLOGY OF A GDI INJECTOR

PART 3

ASNU LOOKS AT INJECTOR FLOW RATES AND SPRAY PATTERNS AND WE SPEAK TO CLIVE ATTHOWE TUNING IN NORWICH, A VW & AUDI SPECIALIST WHO HAS ALREADY INVESTED IN GDI KIT, TO SEE HOW LUCRATIVE THE SERVICE AND REPAIR OF GDI INJECTORS IS FOR THE INDEPENDENT WORKSHOP

The most important feature of a GDI injector is not the flow rate of the injector but the fuel distribution and atomisation that form the injector's spray pattern. ASNU has experience of GDI injectors with differences of up to 15% in flow rates between the best and the worst delivering injector, yet the engine still runs without a problem. How is this possible?

Developments in the Engine Management System now allow the flow rate to be automatically adjusted to an individual injector to compensate for any deficiency in the injector's ability to deliver the correct amount of fuel. In theory this is ideal, in practice, it is not.

This feature is not correcting the problem, it is compensating for it and, although in the short term the vehicle is running fine, in the long term the problem will need to be addressed when the EMS reaches its compensation tolerance level and the engine's check light comes on.

GUESSWORK OR CORRECT DIAGNOSIS

As the injector's performance deteriorates and the EMS compensates for the lack of flow, how does it measure and compensate for the changes and deficiencies in the fuel distribution and atomisation?

FACT 1:
If you had six injectors with six different deliveries, with the help of the EMS, the engine would run correctly. With six different spray patterns and six correct deliveries, the engine would run badly.

FACT 2:
If you had six injectors and six different spray patterns, the engine would run badly and the engine check light would illuminate. If not addressed, the EMS would eventually put the engine in 'Limp Mode' to protect it from damage.

FACT 3:
The injector's spray pattern is designed for a very specific delivery angle and fuel droplet size. This ensures the fuel is directed to the correct location in the combustion chamber with a droplet size that will burn efficiently. Any disruption to the distribution or droplet size can and will have an adverse effect on the combustion process in that cylinder.

FACT 4:
The Fuel Trim Compensation for a bad spray pattern is to increase the fuel content. The engine's EMS sees a weak combustion stroke and believes that it needs more fuel. Usually, it has the correct quantity, it's just not atomising correctly. The cylinder now has excess fuel that is not only adding to the problem, but creating additional ones in the process.

FACT 5:
Now the cylinder has excess fuel, this can cause carbon build-up on the piston, excess burning on the piston crown, bore wash, gumming, sticking and slow response of any gas recycling valves and components, lacquering of the lambda sensor as well as clogging and damage to the catalytic exhaust.

YOU CAN'T FIX WHAT YOU CAN'T SEE

An EMS cannot analyse the injector's spray pattern. The spray pattern of a GDI injector is absolutely critical to the correct running, fuel economy and emissions.

There is no way to analyse the injector's spray pattern while it is still on the engine and the compensation actions of the fuel trim programme is not beneficial for the long-term good of the engine.

"Correct analysis of the injector's spray pattern is critical to the engine's long-term performance and should not be considered an option"

ASNU low pressure testing replicates the results of high pressure testing, offering a safe and detailed examination of injector function. To the aftermarket workshop, they are critical to efficiently resolving issues with an engine's performance, preventing the unnecessary replacement of expensive injectors that may only need servicing.

For more information on ASNU equipment, contact:

0208 4204 494
phil@asnu.com

IS GDI SERVICE AND REPAIR A GOOD INVESTMENT?

WE ASK CLIVE ATTHOWE, AN INDEPENDENT VW & AUDI SPECIALIST IN NORWICH, ABOUT HIS EXPERIENCE OF OFFERING THIS SERVICE TO THE PUBLIC AND TRADE CUSTOMERS

"Having the ability to test and prove the injector is faulty is for me a fundamental part of my diagnostic process"

WHEN DID YOU INVEST IN ASNU EQUIPMENT AND WHY?

"I have owned an ASNU Bench for over twenty years, upgrading to the Classic GDI when this became available. The reason for buying ASNU was that I was experiencing running issues on various engines that were found to be caused by injector spray patterns and poor deliveries. I had tried various methods of cleaning, mainly chemical treatments that weren't very effective, but I still had no means of accurately testing the injector itself. After seeing the ASNU injector bench demonstrated, I knew I had found the equipment I needed."

HOW OFTEN DO YOU USE THE KIT AND WHAT TYPES OF PROBLEMS HAVE BEEN RECTIFIED USING IT?

"I use the ASNU almost daily nowadays, predominately testing GDI injectors. Running issues and misfires on modern GDI is something we see often, having the ability to test and prove the injector is faulty, is for me a fundamental part of my diagnostic process. We have successfully diagnosed poor spray patterns across the entire RPM range, sticking and locking injectors, intermittent and permanent faults, delivery issues and faulty injector coil windings."

HOW HAS THE KIT AFFECTED YOUR BUSINESS?

"The ASNU bench has without doubt raised our profile and helped us keep our reputation as an injection specialist. We carry out a lot of testing of injectors for our local trade and this also enables us to establish the other services we provide. Sometimes when we test injectors we find no faults, we can then advise the best course of action for the customer. The equipment also sets us apart from other local diagnostic garages that don't have an injection bench, this makes it easier to sell ourselves above the opposition. We are an ASNU Injector Service Centre and receive enquiries from all over the UK to test and clean injectors."

MYSTERIOUS MITSUBISHI MISFIRE

By **Clive Atthowe**, Clive Atthowe Tuning

VEHICLE: **MITSUBISHI PAJERO EVOLUTION**

SYMPTOMS: **POOR RUNNING AND MISFIRING**

Although not a GDI engine, this job shows how useful the capabilities of the ASNU bench and ultrasound cleaning system are in diagnosing vehicle running faults and restoring injectors.

We had a rare Mitsubishi Pajero Evolution in our workshop back in February for diagnostics. The symptoms were poor running, a very rough idle and misfiring worst when cold. The vehicle had already been worked on, as is the case with most of the vehicles that come through our doors. Most ignition parts had been substituted and the fuel filter had been replaced but the fault remained.

Our initial diagnostics showed there were no fault codes present, although these could have been erased. All available live data looked normal and the ignition was tested on our Scope. We also tested the basic mechanical condition of the engine, conducting engine vacuum and compression tests. All proved to be correct and the only clue to the cause of its problems was high hydrocarbon content when the exhaust emissions were tested, indicating poor combustion.

After gaining approval from the customer, we removed the inlet manifold and the injector rail. The injectors were tested in-house on our ASNU bench and the results were quite dramatic.

As you can see in the top image, the spray patterns were poor with very uneven deliveries. This confirmed our suspicions of poor combustion.

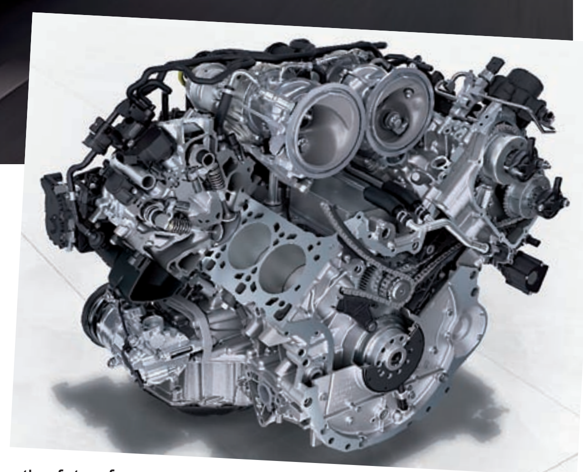
When we removed the injector filters before cleaning, there was a large amount of sediment inside, see above. Ultrasound cleaning would not bring these injectors back to life. These injectors are very rare and we were faced with trying a substitute or having some built to match. After consulting with ASNU, we decided to try a more radical approach, which involved further cleaning and making up some adapters to enable us to back flush the injectors under high pressure. Several cleans and flushes later we managed to restore the injectors back to a perfectly matched set.

We rebuilt the inlet after fitting the injectors and ran the engine again, all was well, restoring perfectly smooth-running, cold and hot.

Injectors are the one thing not normally tested during diagnostics but are the component that carry out the most essential part of the combustion process – injecting the fuel in an atomised spray in the correct quantity.

DANGER IN THE CITY

All post-2008 petrol-powered Porsches have direct fuel injection, or DFI. In principle it is a highly effective means of improving mpg and reducing exhaust emissions, but a growing number of primarily town- and urban-dwelling cars are beginning to suffer from unforeseen and potentially troublesome and costly driveability issues. Story and some photos by Chris Horton; other images supplied by Porsche and ASNU Corporation Europe



Car makers naturally paint an idealised picture of their products' place within the world, but this publicity shot of one of the latest Panameras driving towards Berlin's famous *Siegessäule*, or Victory Column, conveniently ignores the fact that many city streets are in near-gridlock for much of the time. And while modern DFI systems reduce exhaust emissions and fuel consumption to 'acceptable' levels, their frugality – and associated stop-start systems – come at a hidden price, especially once the vehicle has started the inexorable ageing process. Cutaway of petrol V8 (right) shows how fuel is now injected directly into the combustion chambers rather than – as before – the inlet tracts, upstream of the valves

It is often said that we humans have no real sense of our own mortality until the age of about 30. True or false? Well, consider some of the things you did back then that you wouldn't dream of today, now that you are older and perhaps a little wiser.

It's much the same with modern cars. Brand-new, fresh from the showroom, they have somehow acquired a go-anywhere, do-anything persona – and especially so these days, when the most basic small hatchback is marketed as some kind of high-tech, long-distance adventure capsule. Or when the largest and genuinely most sophisticated of luxury GT saloons and SUVs – or even near-200mph sports cars – are sold on their ability to survive and thrive in the urban jungle. Only after they have been around the block a few times do you suddenly become aware of their mechanical shortcomings and perhaps even frailties.

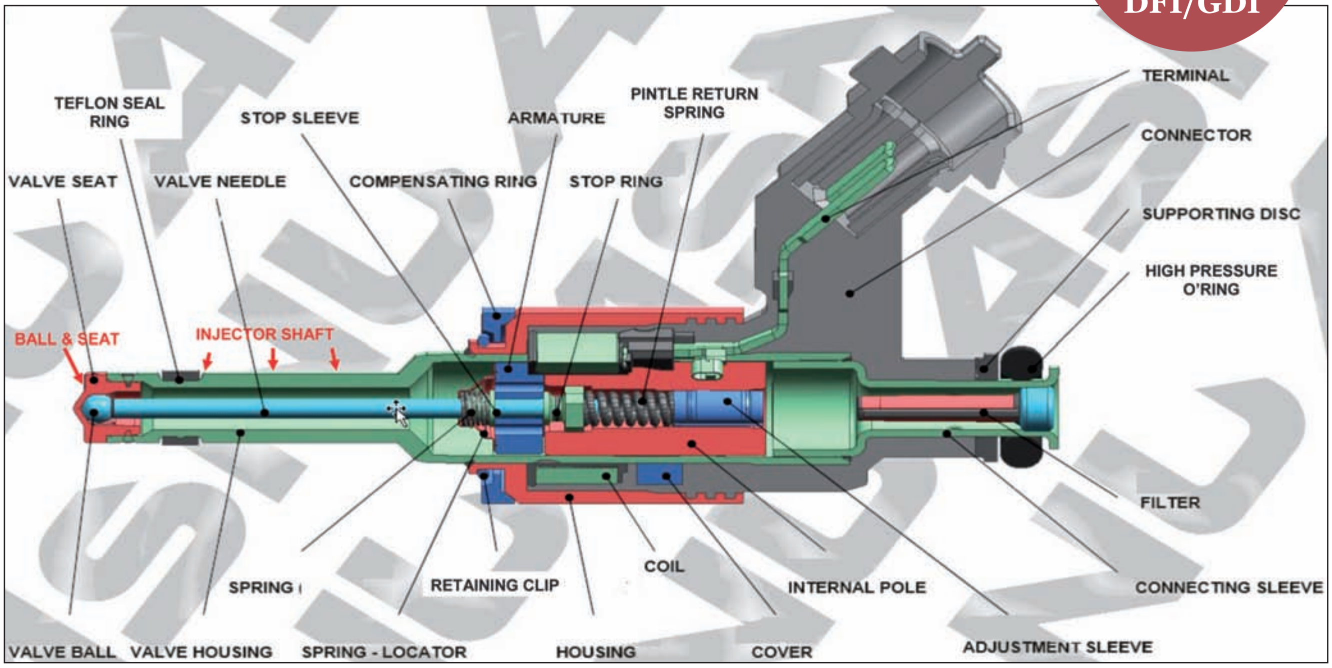
Ironically, however, it is arguably the relatively inexpensive city car that is ultimately the more versatile and resilient of the two genres. Drive a Volkswagen up! (and what a daft name that is) at more or less legal motorway speeds from central London to the middle of Glasgow and back once a week, and with regular servicing – or as regular as VW now deems necessary, anyway – it will probably serve you for 100,000 miles or more. Maybe twice that if you are genuinely interested in saving money by fully amortising your investment, rather than simply trading it in for one with an empty ashtray every year.

Confine your high-tech and high-performance modern Porsche to the UK's ever more congested urban areas, however – and such appears to be the fate of most Cayennes, almost every Panamera or Macan, and a depressing number of 911s and Caymans, especially in famously affluent London – and even with the occasional motorway journey you could soon run into some major technical issues that neither you nor possibly even the cars' designers envisaged. (And do remember that even at 90mph your 991 will still be travelling at only around half its designed maximum speed.)

To some extent those problems are inevitable; perhaps even their drivers' own responsibility for casually buying something so inherently unsuitable for the job. Ninety years ago, in 1927, Charles Lindbergh flew the Atlantic behind a simple Wright Whirlwind radial-piston engine producing all of about 200 horsepower. But asking a now typically 350–500bhp V8 to adapt faultlessly to life in almost permanent gridlock is a bit like using an English Electric Lightning to commute from London to Birmingham. (Which seems an appropriate analogy for the madness that is HS2, but that is another story.)

What we are leading up to here is that more and more modern Porsches – and, to be fair, many other petrol-fuelled cars, crucially all of them equipped with DFI, direct fuel injection – are now suffering from what might be called driveability issues. Misfiring, basically, leading to poor performance and poor fuel economy, and eventually to excessive – and effectively unlawful – exhaust-gas emissions. Which is all rather ironic, of course, since that is precisely what DFI, among various other frankly rather desperate measures, was meant to address.

Opinion is divided on the precise cause and



ASNU's schematic of a typical GDI/DFI injector reveals that it is essentially a simple solenoid-controlled valve. What you cannot tell from this diagram, however, is just how precisely it is manufactured, with tolerances down to mere microns. Clean, good-quality fuel is obviously vital to help avoid blockages (see also next spread), and likewise the regular servicing which, thus far at least, neither the injector manufacturers nor the car companies seem to consider worth suggesting. That is itself both relatively easy and inexpensive, but the design of modern engines – Porsche's in particular – is such that they could cost thousands actually to remove. And inevitably that process brings with it the danger of damaging the delicate mechanism by careless handling; ASNU has produced a special tool to aid removal, though

even nature of the problem, but Phil Ellisdon of fuel-injector specialist ASNU in Bushey, Hertfordshire, has absolutely no doubts. 'It's the injectors,' he states simply. They are fantastically clever devices, he continues, built to almost unimaginably tight engineering and electronic tolerances, and to function in the harshest possible automotive environment. 'But it's hard to ignore the notion that they were designed for some sort of idealised world,' he adds, 'and without much regard for the unintentional neglect or even abuse that, out here in the real world, they so often have to deal with.'

(Even so, continues Phil, it's worth pointing out that DFI petrol engines suffer fewer problems than the equivalent common-rail diesel engines – which also feature in many modern Porsches, of course – and cost garages and owners far less to service than oil-burners. 'Workshops equipping themselves to service gasoline direct injectors might spend around £10,000 to cover every unit currently in service,' he suggests, 'whereas someone tooling up to service every diesel injector might have to spend up to £100,000. And almost invariably the petrol injectors themselves are far less expensive to buy if they need to be replaced.' And as a Porsche owner himself, Phil concedes that DFI delivers the goods in terms of fuel economy. 'The best I ever got from my gen 1 997 was 22mpg, driving very carefully, and in normal use that was down to 17mpg. In the 991 that I have now I can easily get 33mpg when driving normally, and never less than 29mpg.')

And in truth, says Phil, it's not really the injectors themselves that are at fault, more a combination of the quality and the cleanliness of the fuel passing through them, the use to which the vehicle is routinely put (see above), and not least the car manufacturers' growing reliance on stop-start systems that cut the engine during momentary halts, supposedly for that little extra – but one suspects largely irrelevant – reduction in exhaust emissions. 'And to cap it all,' he says, 'you have ECU-controlled short- and long-term fuel trims making all kinds of compensatory adjustments to the fuel delivery, but not corrections.'

Certainly some of these latest-generation DFI injectors can, and do, develop internal electrical faults, and then the only answer is to fit new ones. But Phil is firmly of the opinion that much of what is now taking place on city streets around the developed world could be avoided by some relatively straightforward injector servicing. (Or straightforward servicing once the injectors have been removed, that is. In the Porsche V8s that means taking off the inlet manifold, and in a 911 will probably entail removing the engine. That is beyond doubt what Porsche itself would recommend.)

'I think it is extraordinary that these injectors are effectively fit-and-forget, supposedly able to last the life of the vehicle with no interim servicing,' argues Phil. 'They work in the most difficult of environments, just about the most unfriendly anywhere on the car. They are required to operate under extreme pressures and in extreme temperatures at millisecond durations, and to deliver millilitres of fuel with a highly specific spray pattern and droplet size. I have seen a great many of them, admittedly mostly from engines that have started to suffer from problems, but in all of those the tiny – and I do mean tiny – holes through which the fuel is sprayed are partially or even totally blocked with carbon. And that after as few as 20,000 miles.

'So, what should have been a carefully calculated fan of fuel mist that burns easily, even with air/fuel ratios as weak as 40:1 in stratified mode, becomes simply a jet – or several jets. In the same way that carelessly blasting your patio with a pressure-washer with the nozzle set to a narrow angle might

DFI OR GDI? OR EVEN SIDI? HOW IT ALL WORKS, ANYWAY

There is a wealth of detail to be absorbed for the fullest understanding of direct fuel injection, but for the purposes of this feature it can be boiled down to a few essential facts. (See also the useful Wikipedia article at https://en.wikipedia.org/wiki/Gasoline_direct_injection.)

Direct fuel injection, or DFI, and also known as gasoline direct injection (GDI), spark-ignited direct injection (SIDI) or fuel-stratified injection (FSI), works in much the same way as a modern common-rail diesel-injection system – although obviously with the ignition of the fuel/air charge by means of a high-tension spark rather than compression alone.

The fuel is pressurised, typically to between around 50 and 175 bar, and injected directly into each of the engine's combustion chambers, downstream of the inlet valves. In the previous multi-point or port-injection systems (such as in the gen 1 997 and its predecessors) the fuel is, as logic and the terminology suggest, injected into each cylinder's inlet tract, typically at only around 3.0 bar, and crucially upstream of the valves.

(Modern common-rail diesel systems operate at up to a staggering – and potentially highly dangerous – 2500 bar, or 35,000psi, at which point the liquid fuel itself is partially compressed, and certainly acquires a considerable amount of heat. Any jet resulting from external leakage at that pressure is sufficiently powerful to slice through steel plate.)

The first practical mass-produced application of GDI was in the Mitsubishi Carisma in 1997, with Porsche adopting it for the gen 2 997s and 987 Boxster and Caymans in 2008 for the 2009 model year. By 2015 the system was said to be a feature of around 45 per cent of all new cars sold around the world, and today that figure will surely be higher still, at least among those that still have internal-combustion engines.

The big advantages claimed for GDI are improved fuel efficiency and reduced exhaust emissions, together with potentially higher power outputs. These are achieved by the far more precise control of fuelling and injection timing than is possible with the older port-injection systems.

The engine can be made to operate with widely differing air/fuel ratios: stoichiometric, for moderate loads; full power, providing a slightly richer mixture for rapid acceleration and heavy loads; and ultra-lean burn or stratified charge for light loads and either constant or reducing speed. Under those last conditions the fuel is injected not during the intake stroke but toward the end of the compression stroke, and at an air/fuel ratio (up to 65:1 on some systems) that would be far too weak to sustain combustion in conventional carburettor-fed or even port-injection engines.

Another benefit of GDI is that the engine speed can be controlled entirely by regulating the amount of fuel passing through the injectors, allowing the elimination of the throttle flap – again as in common-rail diesels. This reduces what are known as pumping losses within the engine and offers further improvements in both power and exhaust emissions. (And it is the reason why modern Porsche engines – and others – require an engine-driven vacuum pump to operate their brake servos. As so often happens in physics, there is no such thing as the proverbial free lunch.)

Significantly, the Wikipedia entry concludes with a paragraph on GDI's 'drawbacks'. Chief among these is the absence of fuel passing over the inlet valves, and thus washing off any dirt in the intake air and carbon from the crankcase ventilation system. The resulting build-up can eventually restrict the port sizes, with an obvious effect on the engine's power and performance. It is also possible that a piece of this carbon will break off and, even if it causes no problems within the combustion chamber, might damage the vehicle's catalytic converter(s).

Cutaway above is of a VW DFI injector, but Porsche units, right, are similar. Ring at base of stem is a Teflon seal; staining above it indicates leakage. Note also deposits on nozzle plates. Microscopic before-and-after views (below) show how clogged the tiny drillings can become. DFI spray patterns are less symmetrical than in port-injection systems, so it's vital that all fuel goes to the right part of each combustion chamber

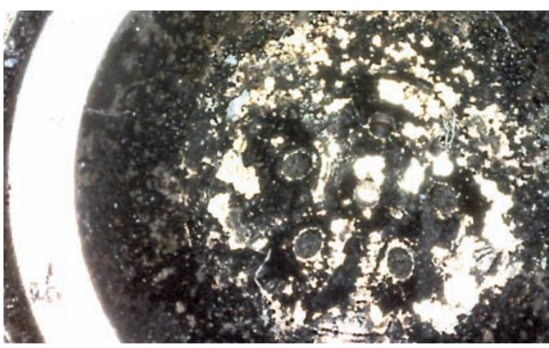
tear lumps out of the surface, so these jets of fuel can wreak havoc on the piston crowns.

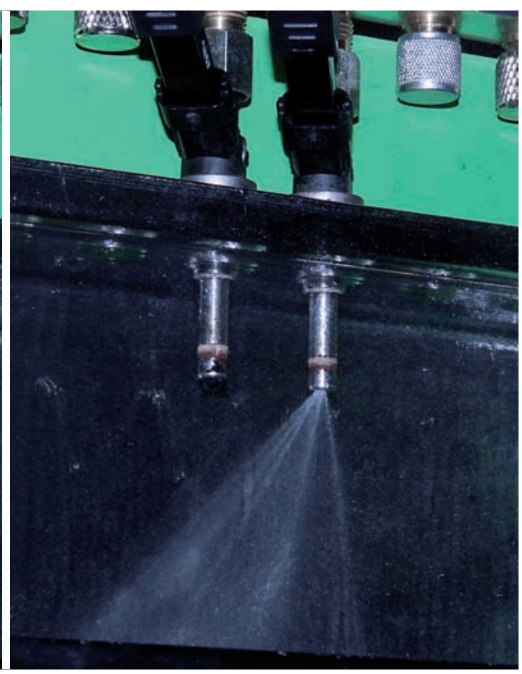
'Even if they don't damage those, there is always the danger of washing vital lubricant off the cylinder walls and eventually, by contaminating the engine oil, knocking out the main and big-end bearings. And the fuel that does get in certainly won't burn as efficiently as it is supposed to, with all of the obvious effects on consumption and emissions. This can also cause problems when the change in the oxygen content in the combustion chambers makes the coil packs work harder, thereby shortening their life expectancy. In my experience those are often changed repeatedly before workshops start to look for the underlying cause of the failures.'

Stop-start systems merely add to the problem, perhaps even exponentially, continues Phil. 'Think about it. The engine is hot, and inside the combustion chambers especially so. You halt at traffic lights, for however long or short a period is necessary, and each and every time you do so inevitably a small quantity of liquid fuel dries on the end of the injector nozzle. That leaves a residue of carbon, especially if you are using poor-quality petrol, which once again over a period of time can partially or even completely block one or more of those microscopic drillings.'

And the cars' highly sophisticated engine management systems aren't much help, it seems. 'They cannot detect a deteriorating spray pattern,' says Phil. 'What happens, in fact, is that as the carbon blocks some of the holes in the injectors, the ECU doesn't reduce the amount of fuel being delivered, just the shape and distribution of the highly specific spray pattern. But it continues to gather data from the various sensors in the combustion process, and through what are known as its fuel trims decides that the mixture is too weak. As a result it simply delivers more fuel, and so now is merely adding to the problem rather than actually resolving it.'

The answer, Phil believes, is the routine servicing we touched upon a few paragraphs ago. Plus some ultra-simple, back-to-basics diagnostics. And it is difficult to ignore the logic of his argument, whatever you might think about his plainly vested interest. 'Today, as always, you can tell a great deal about a petrol engine's general health just by looking at the spark plugs,' he says. 'We all know –





It's difficult to show in photographs – and the high pressures involved can to some extent mask all but the most significant carbon blockages – but 'dirty' and 'clean' injectors (above, left and right) highlight the effect of ASNU's ingenious ultrasonic tank. After just 15 minutes or so the nozzle plate is back to bright steel again. Interestingly, the collector tubes show that the overall flow rate of the cleaned injector remains slightly lower than that of the control item, but that is probably due to wear and tear, says ASNU's Phil Ellisdon – and is in any case far less significant in terms of engine performance and efficiency than it would be in an older power unit. All current Porsches have engine stop-start systems, and they will soon be mandatory in all new cars, but common sense suggests they might not be the panacea for urban air quality that the legislators seem to suggest. Photo near right shows a typical DFI injector pulse at cranking speed; image far right when the engine is idling. So cutting the motor for mere seconds at a time is arguably counter-productive – never mind the wear and tear on battery, starter and various other systems

or used to know, anyway – that if they are black and sooty, then the mixture is too rich, or not burning properly. And if they are chalky and white, then it is too weak. A brownish coffee colour is about right. That is just as relevant in a 2017 Panamera V8 as it was 40 and more years ago in a Rover V8.'

After that simple first step has confirmed or perhaps eliminated a problem in the combustion chamber – and fully aware that many of these modern units are by no means as easy to get at as they used or perhaps ought to be – Phil still recommends removing and overhauling the injectors themselves. How often? 'That's a tough question, because so much depends upon the car's "lifestyle".

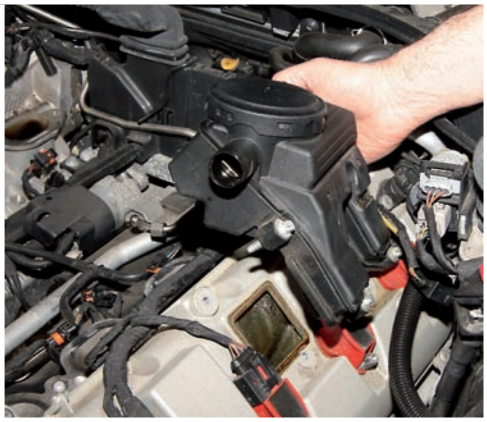
'Your service workshop should be able to identify an issue by diagnosis of the fuel trims, which, as I have said, tend to mask a developing problem until it become a more serious one. You can request to have them serviced as often as you feel necessary, perhaps if the vehicle is lacking performance, or has other driveability issues. But it should certainly be more often than the simple "never" that the manufacturers seem to endorse. Perhaps it should be based on engine-hours, as in aircraft and boats – and bearing in mind that running at or near idle speed for long periods is far harder on the injectors than working them under load at higher speeds. It wouldn't be impossible to incorporate some kind of warning into the engine management system, based on time elapsed and average engine speed.'

Fortunately, continues Phil, injectors can quite easily be checked, in situ, for those internal electrical problems we mentioned earlier by a good specialist with the right knowledge and equipment – something we shall come back to in a future how-to story, we hope – but to do a proper job there is no alternative but subsequently to remove them, whatever pain that might entail.

'In some ways, they are little different to the simple, old-fashioned devices you see in 944s, 928s, 993s and the like. We run them through our standard ultrasonic cleaning tank, and that deals with the carbon and other dirt, both inside and on the nozzles, and naturally we test them all for both the correct spray pattern and their overall delivery – although surprisingly the latter is far less crucial than it was in older-style port-injection engines. We also replace the Teflon sealing sleeve around the stem of each nozzle. Otherwise there's a chance of combustion gases escaping. You can tell if that's been happening previously, by the way, if there are brown stains in evidence on the stem.'

That is never going to be an inexpensive process. Remarkably, even for these highly sophisticated DFI units ASNU charges just £25 plus VAT per injector for the company's standard spray/delivery test and cleaning process, and then another spray/delivery test to verify the work. So even for a Cayenne or a Panamera you are looking at only £240 including VAT. But there is nothing to be done with those that still fail to spray correctly other than fit new ones – at around £250 apiece – and in any case the labour charge alone to remove and refit them is likely to run into many hundreds of pounds, if not several thousands. In the V8s, as we've said, you need to take off the inlet manifold, and in the 991 and Boxster/Cayman ranges you are almost certainly looking at having the engine removed. And that, as ever, will surely lead to expense in several other areas.

Phil urges extreme caution, however, to anyone planning a DIY injector removal – and even to those independent Porsche specialists who don't (yet) know exactly what



In all of the later Porsche petrol engines it is necessary to remove the inlet manifold for access to the injectors for servicing or replacement – and in the sports cars (911, Boxster, Cayman) that is most likely going to mean taking out the engine. Such fun... In this Panamera at JZM a number of – but perhaps significantly not all – the inlet valves were caked in a thick layer of oily carbon. In truth, it's a scenario that seems to be affecting an increasing number of GDI/DFI engines – perhaps because of the sedentary lifestyle that many urban-dwelling cars lead, and almost certainly because the backs of the valves are no longer kept clean by the passage of petrol across them. Either way, the deposits can be removed by blasting them with crushed walnut shells, and it's a process we hope to show soon with JZM's newly acquired machine. Photo on the far right shows V8's air/oil separator, which is conveniently mounted on left-hand camshaft cover. At least that's a bit easier to get at than in the 996/997

they are doing. 'We have produced a special tool – a small slide hammer specifically for GDI/DFI injectors, basically – which you carefully attach to the top of the injector, and thus pull it out perfectly straight. The trouble is, some people simply lever them out with one or more screwdrivers, and that risks bending the stem. Even just a one micron discrepancy will most likely prevent them ever working properly again. That's how accurately they are designed and built. For the same reason they don't like being dropped, either.'

Even after all that, however, the travails of the modern DFI Porsche owner are far from over, it seems. Go to all the trouble of removing the manifold for access to those troublesome injectors, and it is only natural to peer down into the ports at the backs of the inlet valves to see what's going on. But some or even all of them will almost certainly be coated with a thick, black, oily residue that looks a bit like charred wood. Indeed, such was the situation in the 2012 Panamera that, after visiting Phil Ellisdon at ASNU, we saw later the same day at JZM in nearby Kings Langley, Hertfordshire.

Quite where this stuff is coming from is so far a bit of a mystery. Certainly in DFI engines there is none of the fuel present in this area that you get with old-fashioned port-injection systems, and which naturally tends to keep the valves clean. And arguably the deposits might have no great bearing on the way the engine runs, unless perhaps they become so thick that they prevent the inlet valve(s) seating correctly. (And it is both interesting and perhaps potentially significant that in the engine we witnessed only about half of the eight such pairs of valves were thus affected.) But it isn't very nice to look at – or to know that it is there, especially in a vehicle of this nature and value – and again its presence on only some of the valves could itself be indicative of a rather more serious problem. Perhaps it is related simply to faulty injectors – but at this stage there is once again no overwhelming consensus.

Phil Ellisdon, not unreasonably, blames the presence of the unburned fuel that is the result of a faulty injector(s) – and that would certainly explain the seemingly partial nature of the phenomenon. In certain engines it could be a fault in the EGR (exhaust gas recirculation) valve, but the Panamera's V8 doesn't have one, points out JZM's Steve McHale, just the usual air/oil separator to deal with crankcase fumes and pass those – minus, one hopes, the oil – back into the combustion chambers. Perhaps, then, it's a problem in that area, and perhaps in those cylinders which, having been adversely affected by faulty injectors, are suffering from excessive combustion-gas blow-by. But then the same single air/oil separator ultimately feeds all the ports, and so logic suggests that all the valves would be affected equally.

Either way, all are agreed that it's best eliminated, and to that end JZM has ordered an ingenious German-made machine with a special nozzle that simultaneously blast-cleans the ports – with crushed walnut shells – and vacuums out both the soiled medium and the contaminant. 'It's a simple enough job,' says Steve McHale, 'although naturally you have to rotate the crankshaft such that each pair of inlet valves is closed before you clean them. The engine won't run at all well if the cylinders are full of crushed walnut shells... But you would surely carry out the job only in conjunction with attending to the injectors, and even then there's nothing to say that it won't happen again in the near future.'

So there you have it. Yet another nightmare scenario for the hard-pressed modern Porsche owner. Or perhaps not. The simple fact of the matter is that, dealt with soon enough, all of the issues discussed here are far more easily fixable than any bore-scoring or intermediate-shaft-bearing collapse – and, viewed in the context of a vehicle of this nature, not overly expensive. (Or not yet, anyway. That will surely change when your 2014 Panamera is 10 or even 15 years old.) They are also quite easily avoidable, one suspects, simply by using the car for its intended purpose, rather than indulgently driving the kids half a mile to school each day. And, thus far at least, you can always turn off that annoying stop-start function – although we understand that even that may eventually become impossible. First-world problems? It's hard not to think so. **PW**

● We were hoping to show JZM's brand-new port-cleaning machine in action on the engine whose inlet port is shown in the photo above middle, but unfortunately it had not arrived by the time this issue closed for press. See – we hope – *Technical Topics* in the July edition. Watch out, too, for a future story on the common-rail diesel problems hinted at here.

CONTACT

Thanks to Phil Ellisdon at ASNU Corporation Europe Ltd, 65–67 Glencoe Road, Bushey, Hertfordshire WD23 3DP; tel: 020 8420 4494; asnu.com. Also to Steve McHale at JZM, Unit 1, Langley Wharf, Railway Terrace, Kings Langley, Hertfordshire WD4 8JE; tel: 01923 269788; jzmporsche.com

KEEPING UP WITH THE TIMES

Our first contact with ASNU was in 2002, when we showed how the company, based in a quiet suburban street in Hertfordshire, had developed a machine, originally designed in Australia, for testing and ultrasonically cleaning what would now be considered the relatively low-tech and low-pressure injectors then in widespread use. Established in 1990, it now has distributors and agents in over 60 countries, who between them test and service around 600,000 fuel injectors a year from car and motorcycle and even boat engines.

In January 2013 we examined how in light of changing technology the company had cleverly re-engineered a small number of modern injectors, such that they could be used in older engines. And more recently still this writer had the partially blocked injectors from his own 944 project car overhauled by proprietor Phil Ellisdon himself. See pages 110–113 of the April 2017 edition.

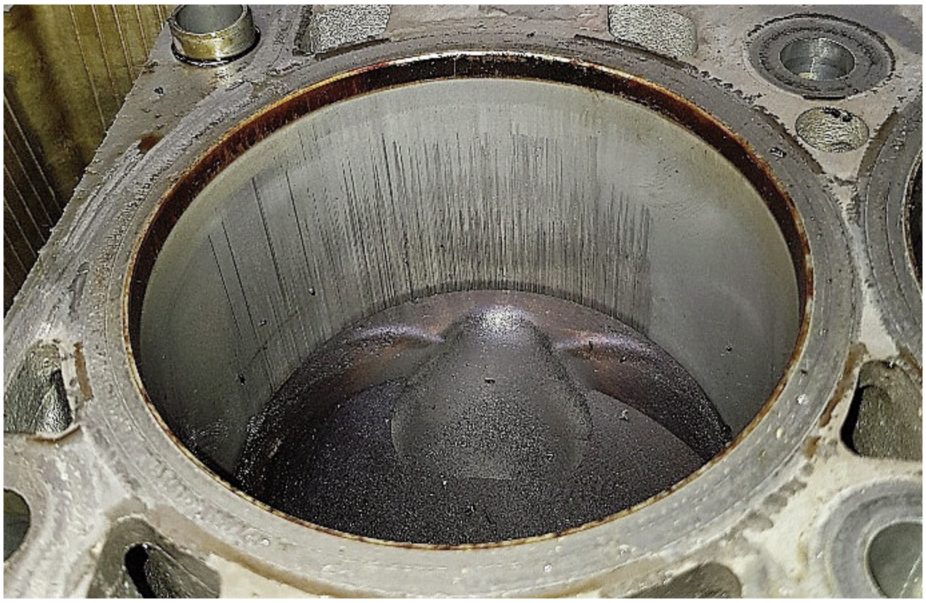
The company has routinely responded to developments within the industry. It was the first in the world to devise (in 1997) a system for testing GDI injectors, crucially realising that a machine running them at their normal working pressure would not only be expensive and create a potentially dangerous working environment (GDI engines' fuel systems typically operate at between around 50–175 bar; that's 700–2450psi), but would even be counter-productive.

'Understandably, the injector manufacturers have to be able to test new units at full system pressure,' admits Phil, 'but out here in the after-market it's a different story. Experience has shown us that the higher the pressure, so the tighter the pintle – the valve at the business end, basically – is forced into its seat, and any visible evidence of a leak because of wear tends to be masked.'

Phil has also concluded that the most important aspect of a GDI injector is not, as in port-injection systems, its flow rate – and their evenness from one cylinder to another – but the distribution and atomisation that between them form the spray pattern. And that pattern itself, created by the fuel blasting through microscopically small holes, may well appear 'wrong' to anyone accustomed to looking at the older units. 'You have to think of each spray cone as a number of individual jets working in unison, each one directed at a particular part of the combustion chamber. They really are the most extraordinarily precise devices.'

Trouble is, continues Phil, engine management systems are now so 'clever', for want of a better term, that they can instantly adjust the amount of fuel delivered to any one injector in order to compensate for any differences. 'Sadly, though, they still cannot correct what has caused that difference, which here, as we have seen, is most likely to be that carbon build-up on the end of the injector. As always, you have to go for the root cause of the problem, not just its consequences.'

GEN 2 BORE SCORING: THE SMOKING GUN?



The precise cause of this Gen II 997 failure is – inevitably – debatable, but ASNU's Phil Ellisdon is convinced it's down to something as small and seemingly insignificant as a fuel-injector stem seal

Everyone loves a 'whodunnit'. And in automotive terms they surely don't get much better than the cylinder-bore scoring that seems to have bedevilled so many of Porsche's flat-sixes these last 20-odd years, since they famously adopted liquid cooling in the mid-1990s. (With IMS-bearing failure a very close second, of course.) We present, then, the latest nerve-jangling, edge-of-your-seat episode: further graphic evidence that even the gen 2 997 is by no means immune to this distressingly expensive condition – albeit for probably rather different reasons than in earlier instances.

Previously – as they say in all the best TV dramas: two years ago, in the July 2016 edition of *911 & Porsche World*, I reported on what then appeared to be an isolated and certainly rather odd case of cylinder-bore scoring in a 2009-model 997 Carrera 'S' at Porsche-Torque in Uxbridge, Middlesex. It was a gen 2 car, and thus equipped with the largely redesigned (and by inference significantly improved) type MA1 engine, with its so-called closed-deck cylinder design. (Which pretty massive change to the engine architecture tells its own story about the earlier iteration. Porsche would not have made such a radical and costly alteration without a very good reason.) Remarkably, the story elicited only a deafening silence from the wider Porsche community, although as I recorded almost a year later, in the May 2017 edition, I was soon having a long correspondence about it with Barry Hart at Hartech, who I still believe to be one of the most knowledgeable and experienced specialists in the molecular-level metallurgy of these engines outside of the Porsche factory.

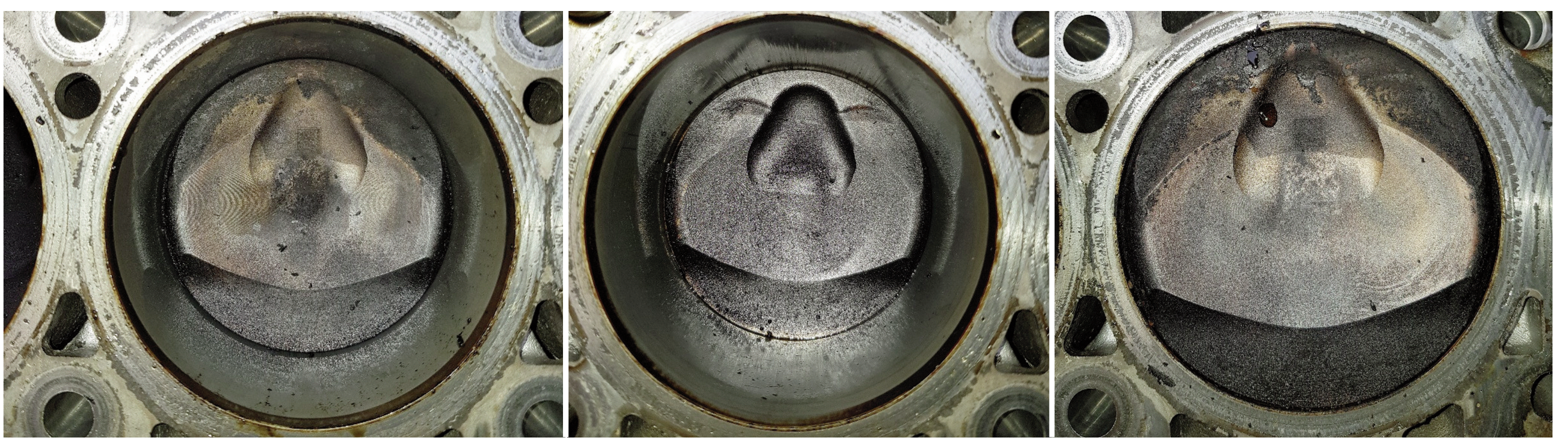
My own view of that Porsche-Torque case, based on empirical experience of other engines over many years, and the precise location and nature of the damage to the bore and piston – and cautiously endorsed by Barry Hart – was that this particular problem was caused not by the chronic but essentially very localised overheating that was (and I suspect remains) the most likely culprit in the earlier M96 and M97 units, but by good, old-fashioned partial seizure. Back in the 1970s I ran a 650cc BSA Lightning that suffered pretty much identical damage to both (air-cooled) cylinders, probably due to overheating caused by excessively retarded ignition timing. (I got it running again and then sold it, in case you were wondering…)

Initially, Barry Hart believed that this seizure might have been the result of the owner driving his car too hard before the engine had reached full operating temperature, with piston profiles and necessarily minuscule piston-to-bore clearances as significant contributing factors. (And a management system that necessarily insulates the modern driver from the way an older, lower-tech engine would naturally behave during that warm-up process. Think 356, 911S, perhaps even 944. They all have an innate resistance to being 'woken up' first thing in the morning, such that it is almost impossible to drive them too hard, too soon.) The pistons were expanding faster than the cylinder bores, basically. Eventually, though, and having forensically examined several other similarly failed gen 2 engines, Barry concluded that it was probably due to stresses almost unavoidably formed within the cylinder-block castings during manufacture, and which eventually caused them microscopically to distort and shrink across the bores in the thrust direction.

Whatever, as they say. The jury is still very much out on that one, and with no further reports coming in from anguished gen 2 997 (and later Boxster and Cayman) owners, out there in the harsh testing ground of the real world, it seemed reasonable to suppose that any problems of this nature were relatively few and far between; just one of those things. No news is good news, and all that.

Meanwhile I was having conversations with both Steve McHale at JZM Porsche in Kings Langley and Phil Ellisdon at Watford-based ASNU about the different problems that were likely to arise in these later engines (and in the V8s, as well), thanks in part to the natural characteristics of their ultra-lean-burn direct fuel injection, or DFI, but also to the fact that – absurdly – so many high-performance cars now spend so much of their time in stop-start urban traffic, with their massively powerful engines running at little more than idle. And not least because there appears to be absolutely no provision for their necessarily hard-working fuel injectors ever to be serviced. (Perhaps unsurprisingly, this is a particular concern of Phil Ellisdon.) The result was my five-page *Danger in the city* story in the June 2017 edition of the magazine.

I am pretty sure that you will understand, then, my immediate interest in a batch of photos e-mailed to me by Phil Ellisdon in early May this year. They show the inside of the MA1 engine from a 2010 997 Turbo: one careful owner from new, 23,000 miles, full service history, and apparently used mostly for long journeys after being warmed up from cold with all due care and consideration. It ended up at JZM for investigation into a loud knocking sound from the engine, especially after a cold start, and at which point there were found to have been more than 60,000 misfires on cylinder number four. Inspection with a borescope showed the unmistakable signs of scoring inside that



Three piston crowns from the same 23,000-mile, 2010-model 997 Turbo show the washing (or in one case not) effect of markedly different injector spray patterns, argues Ellisdon. Combine this misdirected and possibly excessive flow with reduced lubricity and perhaps increased water content of ethanol fuels, and you have the perfect storm

TECH TOPICS

With *911 & Porsche World*'s consultant editor, Chris Horton

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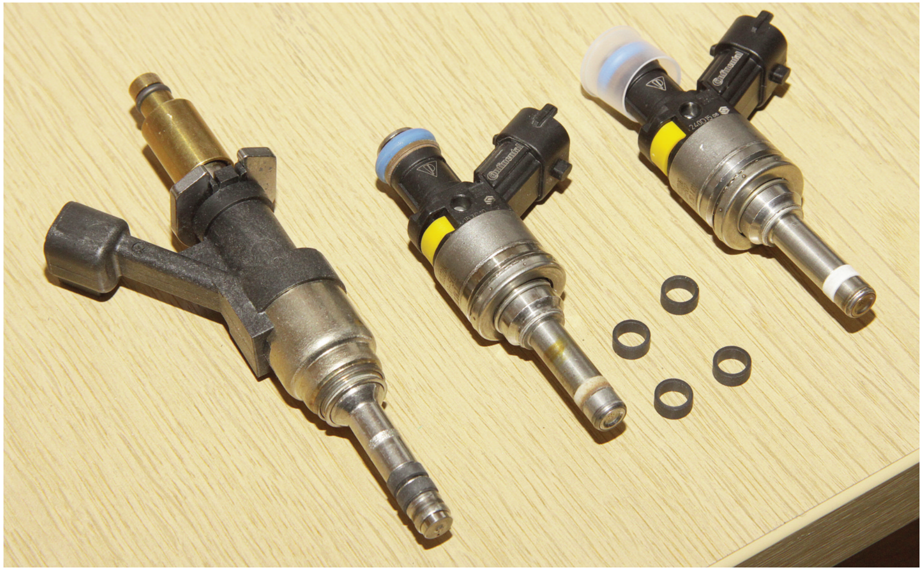


From right to left: new 997 injector, showing white Teflon stem seal; a used injector from the affected engine, showing discolouring, and staining of stem; BMW injector, with *two* grey graphite-based seals

same cylinder, and so the engine was removed and partially stripped for further examination. And, by the time you read this, for replacement with a new 'short' engine from Porsche. Curiously, there was no obvious sign of any oil smoke in the exhaust.

'The short block costs around £10,500 plus VAT,' says JZ's Steve McHale. 'But we priced up our usual alternative – completely stripping the old engine, sending it away to Capricorn for machining and pistons, and then rebuilding it with all the many other new parts that would be needed – and there was so little difference that it would have been a false economy not to use a brand-new one. And although Porsche Cars GB told us that it knows of no other failures of this nature, the fact is that the new block and pistons may well have been superseded by subtly improved components. You just never know with something like that.'

Indeed. But precisely what caused the problem in the first place? And, no less crucially, what is to stop it happening again, perhaps after just another 23,000 miles? For Phil Ellisdon the classic smoking gun has to be the injectors, combined with the relatively poor lubricity of modern ethanol-based petrol (which also contains a not insignificant amount of water, in part for its anti-detonation properties). 'When we tested them, we found the flow rates and spray patterns were far from ideal – and you can clearly see that from the different witness marks on the piston crowns. And I believe this is due in no small measure to overheating that has affected their electrical resistance. There is a tiny Teflon seal at the lower end of each injector stem, where it enters the combustion chamber. All six from this engine were showing signs of blow-by, with two particularly bad examples, and I think it is inevitable that the very high temperatures will have travelled up the stems to the delicate electronics inside the body of each unit.

'That, together with a carbon build-up on the six nozzles themselves – the natural product of the exhaust-gas recirculation system, and the engine stop-start function in traffic – will have adversely affected the spray pattern, and the management system, the so-called fuel trim, will have pushed more fuel through them to compensate for what the oxygen sensor tells it is too weak a mixture. That washes the necessarily thin film of oil off the cylinder walls, and there you have it. The perfect storm. Metal-to-metal contact and, very soon after that, bore scoring. It can surely be no coincidence that replacement injectors now have dark-grey, graphite-based seals, presumably better able to withstand combustion-chamber gases, instead of the original off-white Teflon jobs.'

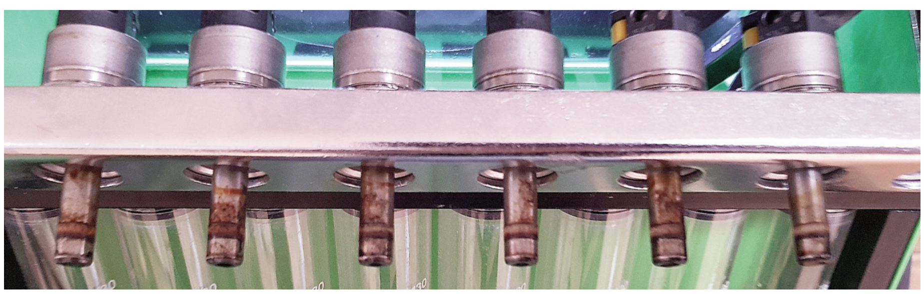
It's fair to say that Steve McHale is less certain about the bore-wash theory – the scoring is not in quite the right place for that, he argues – but he agrees that the injectors are probably the underlying source of the problem, and with the situation exacerbated by those supposedly high-tech modern fuels. 'DFI injectors work in a completely different way to the older Motronic-style units,' he says. 'Fuel pressures in these later engines can be anything up to 150 bar, and so while the injectors need only five volts to pulse them on and off as rapidly as necessary at anything up to 7000rpm, they need 60 volts to open them in the first place. So their electrical resistance is, indeed, critical – and the one from cylinder four in this engine was in effect short-circuited.'

Quite what might be the longer-term answer to this seemingly new and disturbing scenario is difficult to say. Careful, more considered use of your car, perhaps – not using it for a two-mile trip to the shops or the station, for a start, despite its ability to cope with that in the short term – and certainly constant, eagle-eyed vigilance. Turning off the stop-start function – while you are still allowed to, anyway. Regular testing of the injectors' resistance (which can be done by a specialist such as JZM without any mechanical interference), and possibly a full fuel-injector service (and stem-seal replacement) every 20,000 miles – although since that might by definition require the removal of the engine from the car, and then the removal of the induction system from the engine, it's hard to see that happening too often. Perhaps even – at the obvious risk of contaminating the catalytic converter – giving the engine an occasional dose of upper-cylinder lubricant, just like we used to way back in the 1960s. *Plus ça change…*

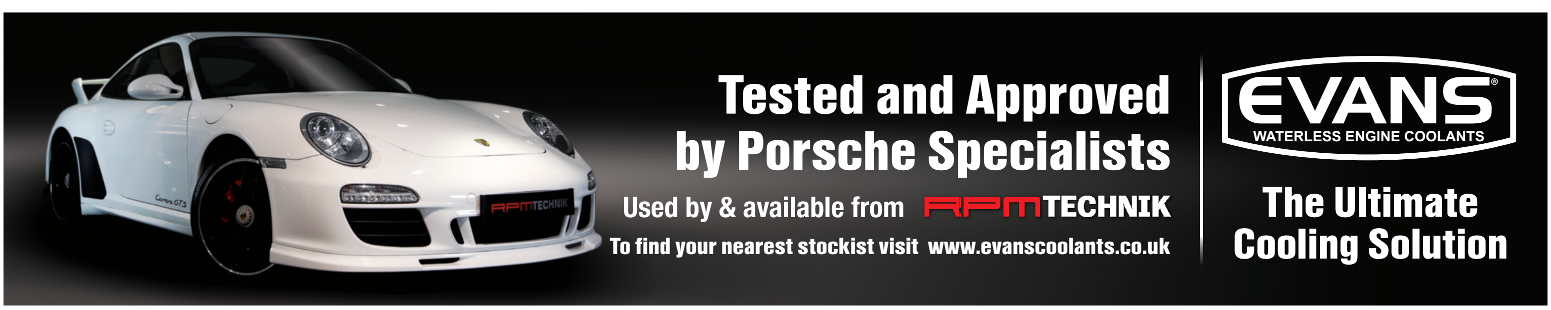
Either way, cylinder-bore scoring seems to have become an unfortunately random fact of 21st-century Porsche life, an unintended consequence of the industry's frankly misguided drive toward ever more 'performance' from ever smaller quantities of fuel (as a nation, perhaps even as a species, we should surely be looking at more sensible ways of using any of our cars than, say, the twice-daily, perhaps 100-mile commute), and I can't help feeling that we shall soon be hearing about 991s with the same issues, and in time even the still-to-be-launched 992. Perhaps the all-electric 911 won't be too heavy a cross to bear, after all. **PW**

CONTACTS

JZM: jzmporsche.com
ASNU: asnu.com
Hartech: hartech.org



Set of injectors from the affected engine, on test in ASNU's rig, graphically demonstrates the staining on the stems that comes from combustion-gas blow-by. Even the 'best' (1 and 6) have partially failed



Story by Chris Horton; photography by Peter Robain

BEST OF BOTH WORLDS

Ten years ago we featured ASNU's fuel-injector testing and cleaning machine. Now meet the company's no less ingenious or cost-effective high-performance injectors. And prepare to want some. Today!

Roger Friend, the tirelessly enthusiastic global sales manager at Bushey, Hertfordshire-based ASNU, has an engagingly simple way of explaining the principle behind the company's innovative new range of high-performance fuel injectors – which in our carefully considered opinion could be about to take the Porsche world by storm, if not even the wider performance-car industry. 'Think of an ordinary, common-or-garden jam jar,' he suggests helpfully. 'Then pretend that you are trying to fill it with golf balls. You'll be lucky to get two in, or maybe three at the most. OK, so now fill it with marbles. See what I mean? There must be two or even three dozen in there, and there's much less space between all of them.'

The point he is so elegantly making is that for optimum combustion efficiency – power, torque, driveability, and now most importantly the great god of fuel economy – small droplets of fuel will fill a given space far more effectively than large ones. And the more completely (and also accurately) your engine's combustion chambers are packed with those droplets of life-giving gasoline, so the bigger the bang, and the more convincingly – in theory, anyway – you should be able to outpace the guy behind you in that Audi R8 or Nissan Skyline. Or, should you choose not to use all of the available performance, the less petrol you will use, and thereby save the planet.

There is, needless to say, just a little more science to this scenario – and, as we shall see, to these cleverly adapted Bosch-based injectors – than that. Overall flow rate, for a start – the number of marbles you can squeeze into that notional jam jar during a given period, in other words – and not least the spray pattern of said marbles – sorry, the fuel droplets – as they are blasted into the cylinders under very high pressure. (More on both of these vital factors in a moment.) But that is basically it. And it's all achieved with a single 'core' injector originally designed for, well, let's just say more of an industrial application, rather than a purely automotive one. Again, more on what we believe to be this hugely exciting development in a moment.

We were last at ASNU exactly a decade ago, for the December 2002 edition of *911 & Porsche World*. (Pages 39–41, for those of you with back issues, but failing memories.) In those days the company's primary activity was building and marketing – the latter throughout the world – its own fuel-injector test-rig, first launched during the late

Injector in the background here is Bosch's EV1, familiar to the owner of many a Porsche built from the early to mid-1980s through to the mid-1990s. It's effective and reliable, often working satisfactorily for well over 150,000 miles, but servicing, using one of ASNU's machines, can make a big difference to the car's driveability. In the foreground, meanwhile, is the latest EV14 unit, clearly showing the add-on top and bottom 'caps' that enable it to fit an engine designed for the earlier injector – and with the right internals and delivery pressure it can flow up to 2300cc of fuel per minute

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Heading photograph on the opposite page shows a typical selection of the so-called orifice plates built into the ASNU lower caps; it's these, with their often microscopically small holes, that determine the all-important spray pattern, and to a certain extent the flow rate, as well. Coloured bands aid easy identification during the production process. The tiny projecting pins are pushed into the body of the cap to lock it to the injector; it's glued, too, for a permanent joint. Alloy upper caps (this pic) are inherently simpler, being merely trapped between injector and fuel rail. Coloured 'O'-rings denote different sizes

1980s, together with the associated tools and other essential hardware. 'I still go through those special, extra-thick passports like most other people fill pocket diaries,' says Roger Friend, the day after a week-long trip to the US. Inevitably that original machine, designed by Australian fuel-injection specialist Alan Skovron, and first brought to the UK by ASNU managing director Phil Ellisdon, has undergone a more or less continuous process of development, and has now been joined by one also capable of testing the very latest GDI, or gasoline direct injection, units. But the basic principle remains exactly the same. (And, before you ask, the company currently has no involvement with diesel injection systems.)

At the heart of each ASNU machine, which is about the size and weight of an old-fashioned TV set, and powered by an ordinary domestic mains supply (reduced in part to the 12, 90 or even 170 volts required by modern injectors), are a specially made high-pressure pump and an electronic switching system. Between them these equate to the vehicle's own fuel pump and ECU, and allow it to replicate, or if necessary even comfortably to exceed, the conditions found within the engine itself in terms of both supply pressure and the speed at which the injectors open and close. 'For obvious reasons the only major parameter we can't duplicate is the heat inside the combustion chambers,' says Roger, 'but that's not really an issue given what we are trying to achieve here.'

A plastic window allows the injectors – up to eight at a time, mounted side by side in a special quick-connection holder – clearly to display their spray patterns. (For no less obvious reasons the liquid passed through them during this process is a specially formulated testing and cleaning fluid, rather than flammable petrol.) By easily moving the holder down to the next 'stage' on the machine the operator can then accurately measure the quantity of fluid passing through each injector nozzle during a given period, into a row of calibrated glass tubes that are accurate to within 1.0cc. For both of these tests each injector's solenoid-controlled internal valve is routinely pulsed open and shut, as it would be during normal use. The machine's circuitry also allows the valves to be held in the fully open position, if necessary, in order to compare the so-called static flow against OE specifications.

Inevitably there is much detailed information that can be drawn from the test results by a skilled and experienced operator, if necessary with reference to the injector and/or vehicle manufacturer's own data. In some ways, though, it's a simple and in truth endearingly unscientific (but obviously still perfectly valid) visual comparison between the units' performance that is the overall key to the machine's effectiveness, and thus its popularity. (There are some 7000 ASNU units around the world, hand-built first in Australia and now here in the UK, with over 4500 sold since 2000. Perhaps inevitably there are a growing number of cheap Far Eastern copies, or even fakes, on the market, too.) You can instantly see, in other words, if one or more injectors is delivering a single and perhaps rather erratic jet, rather than a nice, broad cone of fuel mist. Or whether, over the course of the flow test, one device delivers significantly less fuel than its neighbours – or even, perhaps, quite a lot more.

Any offending injector may, of course, be worn or damaged beyond repair, but the chances are that it will respond at least in part to thorough cleaning; it's certainly well worth a try. Hence, over on the left-hand side of the machine, a special detergent-filled ultrasonic bath, which by once again pulsing the injectors open and shut at the same time as subjecting them to very high-frequency vibrations can extract truly amazing amounts of dirt, rust and sediment from deep within the often microscopically small internal drillings. (Use anything other than top-brand fuel at your own peril, says Roger. You have no idea what may – or may not – be in it.) And if even that cleaning process fails significantly to improve matters, then the injector can with the correct ASNU-developed tools be partially dismantled for the fitting of certain vital new components – notably seals and the so-called (and implausibly tiny) filter basket.

So far, so simple – and deservedly successful, too. By about 2008, though, and no doubt spurred on by long hours spent travelling to trade shows literally all over the world, managing director Phil Ellisdon had come to realise that, while most mass-produced injectors do a pretty reasonable job in standard, run-of-the-mill engines, there was beyond doubt a market for something capable of delivering just that little bit extra in terms of flow rate and spray pattern. Back to our jam jars, golf balls and marbles, in other words – or, rather more prosaically, what the company calls the ASNU Performance Injector. The key would be finding a single basic mechanism that could with the minimum of work and

ASNU-adapted EV14 injectors, as described elsewhere in this feature, can be a very cost-effective performance upgrade, we believe, at just £85 each plus VAT – but don't necessarily condemn your old EV1s (left). New replacements no longer available, but ASNU – and its agents around the world – carries stocks of the tiny components needed to service them effectively

thus expense be made to suit as many different applications as possible.

'Fortunately, we've long had an excellent working relationship with Bosch in Germany,' says Phil. 'In fact, we even supply them with our diagnostic machines. To cut a long story short, we looked at their full range of injectors, and decided that what's known as the EV14 would do the job perfectly. EV stands for nothing more than electronic valve, by the way. We could take a very specific version of this injector, and then, using our range of specially designed adaptors, offer combinations of flow rates and spray patterns that would between them work with the vast majority of engines that owners might realistically want to modify. In fact, Bosch now supplies us with a purpose-made injector body, all ready for us to fit the end-caps we want.

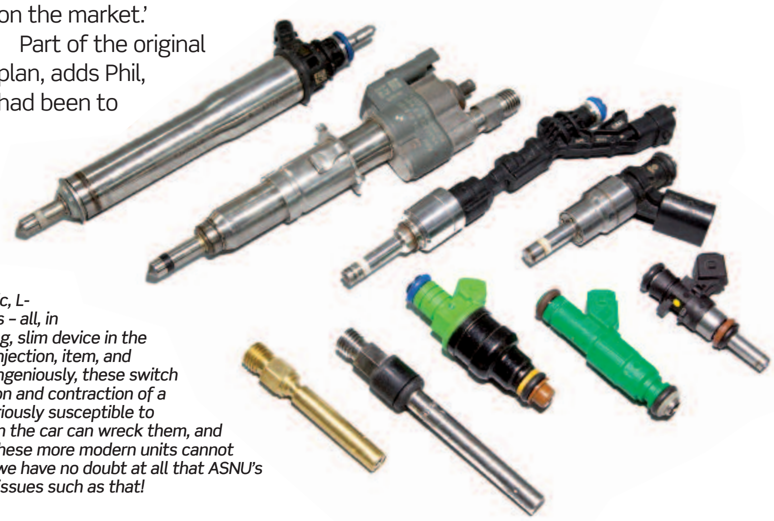
'But that was just the start of it. Next, we had to come up with a range of orifice plates that would give us the required combinations of both the spray patterns we needed – with typically 10-, 20- and 30-degree cones – and then the various flow rates, as well. Just to give you an idea of the scale of the task, and also the versatility of our system, the original Bosch EV1 injector – the sort of thing you'll find in many Porsches from the mid-1980s through to the mid-1990s – was available with a maximum flow rate of just 500cc per minute. The ASNU concept was to produce a whole range of injectors, with flow rates from 300cc up to 1100cc, in 50cc per minute increments, and this was achieved with our specially designed adaptor caps. Our latest version of the EV14 can at the standard 3.0 bar working pressure deliver between 1200cc and 1800cc, in 200cc increments, 2000cc at 4.0 bar, or as much as 2300cc at 5.0 bar. Even so, it still meant first designing and then manufacturing many tiny and necessarily very precise components.'

Chief among those, not surprisingly, are the aforementioned orifice plates, which as you can probably imagine from their often microscopic holes are genuinely high-tech, aerospace-grade items, produced to mind-bogglingly tight tolerances.

'Orifice-plate holes were originally drilled using a technique known as spark erosion,' says Phil, 'but we needed something even more accurate, and which could if necessary make still smaller holes to give us our 50cc increments in flow rates. We came up with the idea of using laser technology, but then we had to find someone capable of actually doing it. Sadly, for commercial reasons I can't tell you any more than that, because this is what makes the atomisation characteristics of the ASNU units so much better than those of other high-performance injectors on the market.'

Part of the original plan, adds Phil, had been to offer even end-users the option of self-assembly performance injectors for those who wanted them, but that was fairly quickly abandoned, and now units leave the factory with flow rates and spray patterns calibrated with reference to the original Bosch and/or Porsche data, or else to the customer's stated requirements; ready to plug and play. 'We realised it could be fraught with difficulties, and even dangerous, if people got it wrong when they assembled the parts.'

So now, says Phil, the upper adaptor is still essentially simply 'trapped' between the top of the injector and the fuel rail, with 'O'-ring seals to keep the fuel in its rightful place. But the lower cap, which has three seals, is both pinned and glued into position, either at Bushey, or else by those API distributors, such as Neil Bainbridge at BS Motorsport in Westcott, Buckinghamshire, with the relevant expertise. And at this point it's worth noting that Neil is not only an enthusiastic proponent of this new 'system', but has also proved its credentials on his engine dyno (more on that remarkable



Electronic fuel injectors through the ages. Anti-clockwise from below right: K-Jetronic, L-Jetronic, then four different Motronic units – all, in theory, replaceable by ASNU APIs. The long, slim device in the middle is a typical GDI, or gasoline direct injection, item, and finally there are two piezo-electric units. Ingeniously, these switch the fuel supply on and off by the expansion and contraction of a special internal crystal, but they are notoriously susceptible to damage – even a minor front-end impact in the car can wreck them, and they are expensive to replace. Currently these more modern units cannot realistically be serviced or upgraded, but we have no doubt at all that ASNU's ingenuity will eventually overcome minor issues such as that!

THE KNOWLEDGE

ASNU Corporation Europe Ltd is based at 65-67 Glencoe Road, Bushey, Hertfordshire WD23 3DP; tel: 020 8420 4494; www.asnu.com – and needless to say that website will give you stacks of extra information and fascinating detail that we simply don't have the space for here.

A number of established independent Porsche specialists have the company's diagnostic machines, and can as a result service older-style injectors, as well as supply and fit APIs. These include Tognola Engineering in Datchet, Berkshire (01753 545053); JZM in Kings Langley, Hertfordshire (01923 269788); Jaz in Wembley, north London (020 8903 1118); and BS Motorsport near Aylesbury, Buckinghamshire (01296 658422).

Other UK distributors and servicing centres include Mr Injector in Stevenage, Hertfordshire (07860 350390); EPS in Northampton (01604 726437); Hypertech in Falkirk, Scotland (01324 812212); and not least Auto Extreme in South Croydon (08450 095641).

What's more, the company is active in more than 60 countries around the world (and especially the US), so the chances are that you won't ever be too far from either a diagnostic and injector-cleaning machine or else a source of APIs – see the website again, or contact head office for details.

Those machines themselves, by the way (see right), are currently priced at £4250 and £5900, both plus VAT, for the earlier non-GDI and newer GDI-compatible unit, respectively. So while plainly not intended for the DIY market, neither might they be prohibitively expensive for, say, car clubs, or those wishing to start up their own small business. The going rate for cleaning and overhauling an EV1 is currently around £20 a time, we're told.

Most older Porsches with electronic fuel injection will be suitable for conversion to APIs. The only requirement – unlikely to be an issue in this context – is that the ECU is sequential in operation, and ideally fully mappable in order to take full advantage of the potential gains in combustion efficiency, and thus both power output and overall economy. Adaptors are now available even for those Porsche engines that have been fitted with Jenvey throttle bodies; details on request.

machine in the March 2012 issue). Using a customer's 3.6-litre air-cooled RSR engine, and having chosen and then fitted the relevant adaptors from his now extensive stocks, he raised peak power from 298.4bhp at 6800rpm to 308bhp, and peak torque from 230.4Nm at roughly 5700rpm to 237.8Nm.

There is, as you have probably realised by now, much else that we could tell you about this ingenious new system, and we hope that over the coming months and years, as it becomes a familiar element of the Porsche-tuning 'scene', we shall be able to do just that. For the moment, though, suffice it to say that for any relevant Porsche owners still not quite convinced, the final deciding factor must surely be a mix of pragmatism and cost. The fact is that the EV1 injectors in, say, your Carrera 3.2, your 944 Turbo, or even your 964 or 993, are no longer available new; the lines that made them have closed down. Even that may not be a problem for some time to come, because there is no doubt that an ASNU machine and the spare parts still available could keep them working for at least the next 20 years.

How much better, though, to upgrade and update wherever possible – in the same way that you might your suspension, brakes, tyres, or any other aspect of the engine itself – and fit something rather better suited to the second or third decade of the 21st century than the end of the 20th. And not least because, remarkably, an ASNU Performance Injector, or API, will cost you just £85 apiece plus VAT. And at that rate even my newly acquired 924S will warrant a set. **PW**

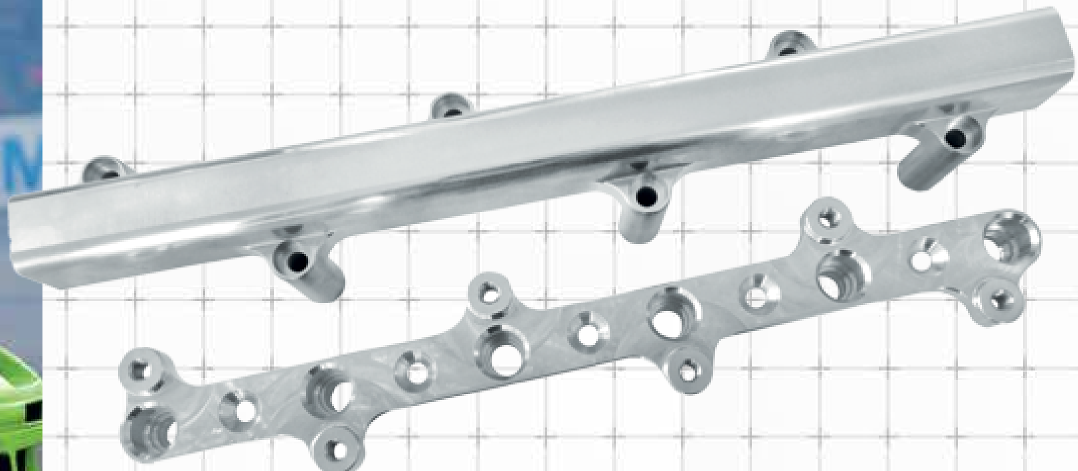
ASNU

With a brand that has become almost synonymous with aftermarket fuel injection over the years, the guys at ASNU work hard to constantly push the bar, so we caught up with them for a chat...

Words and pics: Sam Preston

From creating unrivalled performance products in-house to providing invaluable cutting-edge diagnostic technology across the globe, ASNU has undoubtedly become one of the world-leading names in aftermarket and motorsport fuel injection systems in its three decades of operation. It therefore might surprise you to learn that rather incredibly, the company is still run from its modest British HQ with less than ten core staff.

To find out more about the compnay, we caught up with founder and MD Phillip Ellisdon at the firm's Watford-based offices to discuss the past, present and future of all things fuelling related…



How did ASNU come about?

I've been immersed in the fuel injection industry for almost 30 years. During this whole time, I've had people approaching me saying things like 'I can't find myself a set of 500cc injectors that are the correct fitment or spray pattern for my car, can you help?'. So in the end, I decided to start making my own injectors to solve this seemingly large problem.

I spoke to Bosch and began the long and expensive process of developing my own units based on theirs, but with my own adaptor caps and spray units. I started out by offering the customer to pick their own flow patterns and spray rates for each injector, but this turned out to be a bit of a minefield with almost too many options being available, often confusing the customer.

We then changed it around and began to offer more tailor-made injectors for each application, as it was clear we knew more about things like spray patterns than they did! Since then, we've also developed much larger flow-rate injectors with the help of Bosch (now up to 1500cc).

We also created our twin-colour band system which is found on the end of all of our components to not only quickly denote that they're ASNU items, but also for quick reference on the spec of that particular part.

We've really set the standards for big-power aftermarket and motorsport fuelling systems across the world now, which is reflected on the huge amount of successful machines our products feature on.

What else are is ASNU well known for?

We've seen countless cases of garages and tuners resorting to replacing large parts of the engine to try and resolve a problem that's actually being caused by a faulty injector. The problem is, there's not an easy, quick way for someone working on a car to inspect the health of an injector while it's doing its job, and even the engine itself can't identify whether a spray pattern is correct or not.

This is why I developed our range of injector diagnostic machinery that's gone onto feature in workshops around the world for race teams, private garages, tuning houses and even in major car manufacturing plants. By being able to easily see exactly how each injector is performing can save vast amounts of time and money down the line, by diagnosing specific injector problems before they cause more issues with other parts of the engine.

What patterns have you seen in the aftermarket industry that you'd like to change?

It amazes me how many people still seem to believe that the key to creating an effective performance car is solely down to the flow rate of their injectors. Whereas in reality, it's not all about how much fuel is used, but how you use it, too. We've spent countless hours developing tailored injectors with not only specific flow rates, but also with specific spray patterns, which is definitely equally as important when creating an effective and efficient engine.

It's worth noting that people are becoming more away of the importance of spray patterns, though, especially in recent years with the introduction of hi-tech cars such as the R35 Nissan GT-R, which have put a big dent in the popularity of more old-fashioned

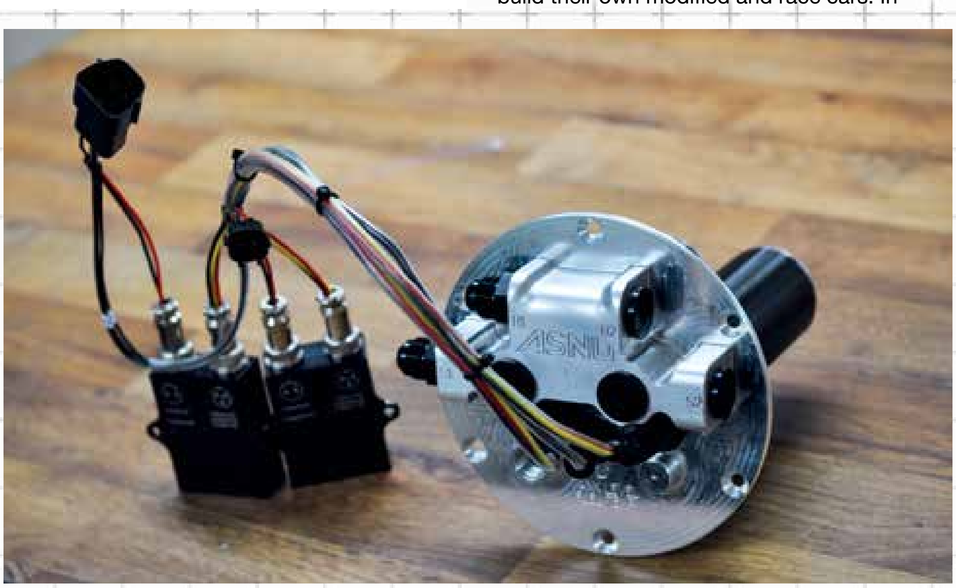
technologies such as big American V8 powered drag racers.

How have you seen trends change recently when it comes to what people want from their performance cars?

Our work recently has revolved around educating the market on how to create cars that not only perform well, but also retain their usability. People not only want cars that can perform well on the track or drag strip; they also want to use them for the more sensible stuff in between, too. For example, I've spent a lot of time in America, where it's clear the technology they're finding on the Japanese cars is having a big influence on how they build their own modified and race cars. In fact, it seems that the more exposure people around the world are receiving to Japanese cars, the more educated they're becoming on more advanced fuelling systems.

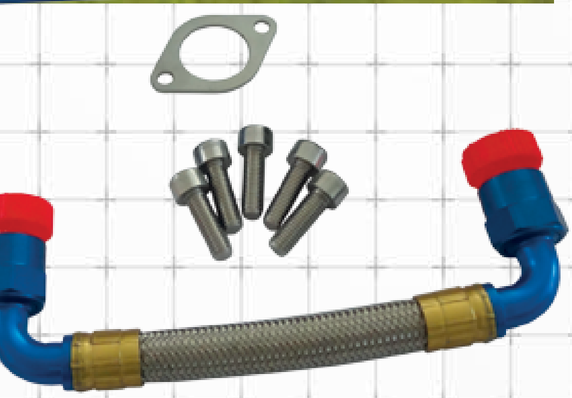
We recently created our 12-injector upgrade kit for the R35 Nissan GT-R. If you've got a 1500bhp engine, you need a whole lot of fuel to power it when it's producing peak power. The problem is, it's difficult to reduce the amount of fuel flowing through at the lower revs, which often causes issues such as problems at idle.

Our 12-injector setup, with two injectors per cylinder, allow the driver to still have a useable car when it's not being driven hard, by only using half of the injectors during these times. But when they decide to go drag racing in the evening, all 12 injectors fire up when they put their foot down. This kit is likely to be available for a number of other applications very soon.



Why have you decided to put a lot of attention towards the R35 Nissan GT-R recently?

If you look at Japanese cars that're more affordable to buy than GT-Rs, usually there's only a limited amount of money people are willing to spend modifying these vehicles.



We do sell a lot of things like fuel rails to the drift community for cars like Nissan Silvias, but it's unusual for them to want to splash out on something as comprehensive as the components we're creating for the GT-R.

What're the most common mistakes people make when it comes to fuelling?

People are keen to increase the performance of their injectors and not necessarily think about the rest of their fuel system. If you get injectors with 30% more flow, for example, the lifespan of your standard filter is likely to be 30% less. You need to really think about the whole system when upgrading one aspect.

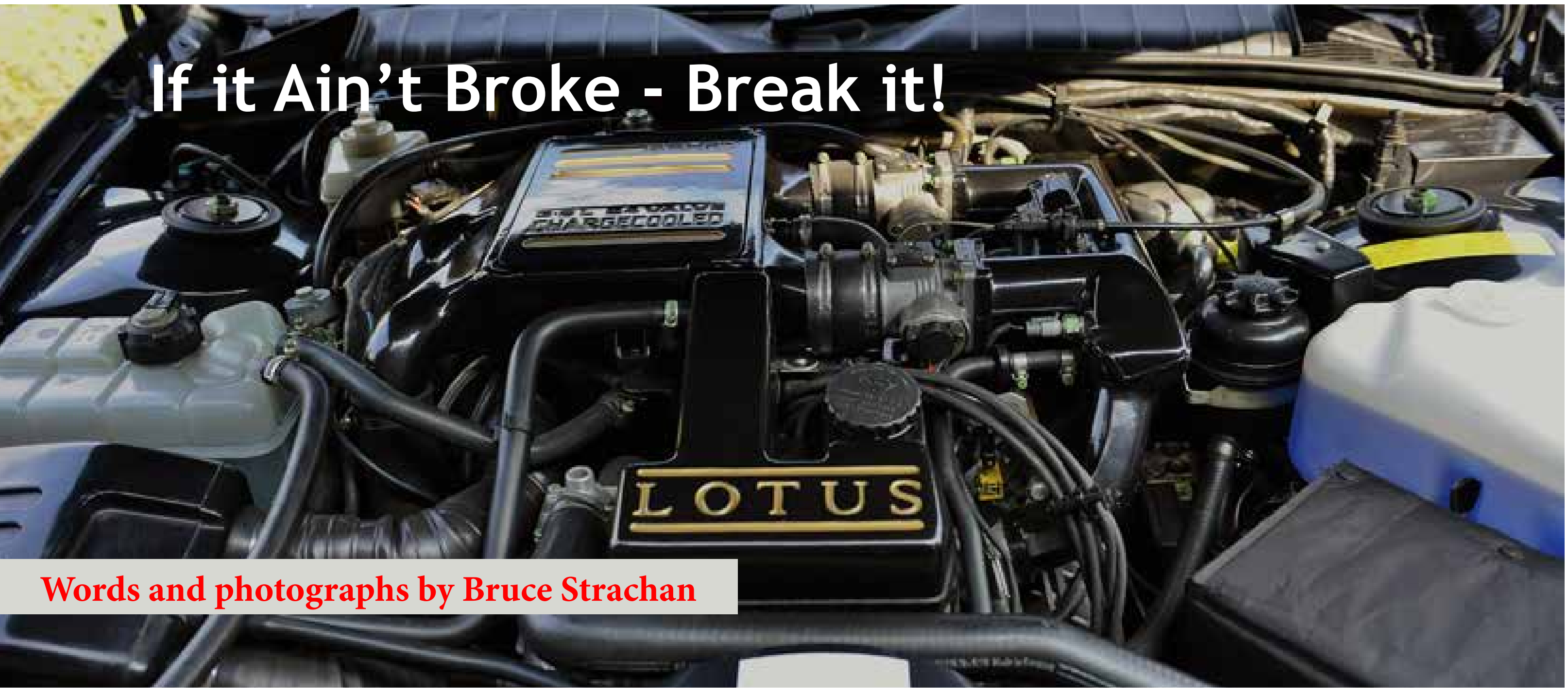
Because of this, we've developed improved components for the whole fuelling system for a number of cars, such as our 'Battleship' filter/pump unit, enlarged braided lines and performance fuel rails for the GT-R.

We've also seen people using LPG injectors for big-power builds. Our injectors all feature metal-to-metal seats, whereas an LPG unit has a metal-to-rubber seat. When the rubber comes into contact with the oxygenated fuel it swells up, meaning what was once a 2000cc injector becomes something like a 1600cc injector once its swelled up. This is something that needs to be considered when spec'ing the right components for your engine.

What's the future for fuel injection?

Emissions. Emissions is about unburnt fuel, and if you deliver the fuel in a format where it won't burn correctly, this is where your problems begin. With more advanced technologies being incorporated by the manufacturers now such as direct and twin injection systems, being educated on how injectors work has been more critical than ever to put a stop to bigger problems and unnecessary costs down the line.

If it Ain't Broke - Break it!



Words and photographs by Bruce Strachan

Ever since I have owned my Lotus Carlton I have not been happy with its under bonnet appearance.

Not because it was scruffy in any way, it is quite the opposite, the previous owner had spent a lot of time and money making it look very presentable. However the valve cover, chargecooler and inlet manifold were painted in JPS colours (Black and Gold). The black and gold didn't look out of place and some observers even thought it was better looking (and more in keeping with the Lotus look) than the factory metallic grey and red. But to satisfy my OCD I had to change the offending items. Not a massive task in itself and one that should have taken no more than a weekend to complete.

Everything on the engine dismantled very easily, apart from the grommet that sealed the charge cooler level sensor that was very hard and brittle and fell apart when I prised it out. But there were no seized nuts or bolts and nothing else broke. I had managed to purchase a new valve cover and a new chargecooler but couldn't find a new inlet manifold so had to have the original one painted to match.

I had the old paint chemically removed and carefully masked all of the areas that were not to be painted. Finding a replacement grommet for the coolant level sensor proved to be a bit of a problem. I could find one that fitted the charge cooler quite snug but the sealing around the sensor was not as tight as I would have liked. However I assembled it using the black silicon sealer.

I took the manifold to a local company that offered Powder Coating, Enamelling and Wet Spraying. Any local spray shop would have sprayed it quicker and cheaper than this company but they were going to scan the valve cover so that I got a perfect match and select the correct paint for the job. After two weeks the manifold was ready to collect and to my horror it was nowhere near the correct colour and to make things worse the man in charge tried to justify it. When I told him I could get a closer colour match with an aerosol can he agreed to paint it again.

While the manifold was off the car I thought it would be a good idea to have the injectors cleaned. They had not given me any cause for concern but I couldn't see looking through the extensive service history that they had ever been cleaned or replaced. I looked on the forum and found that a company in Hull seemed to be the one that other members had used.

'While the manifold was off the car I thought it would be a good idea to have the injectors cleaned'.

The re-assembly was fairly straight forward and uneventful; until that is, I fired it up. It began firing what seemed like one cylinder at a time finally settling for running on five. I isolated it to number five cylinder not firing, although I could hear the ignition lead sparking. I removed the inlet manifold again and swapped number

five and number one injector, re-started and it was now misfiring on number one cylinder.

I removed the injectors again and sent them all back to the cleaning company. They were returned to me without any explanation as to what had been found; I re-fitted them and started the engine once more. This time it was number four cylinder that was not firing so I again swapped it for number one and restarted the engine and now number one cylinder was not working. I contacted the cleaning company and he asked me to return just that one injector, which I did and when I got it back and fitted it, the engine then ran on all six cylinders. Great!

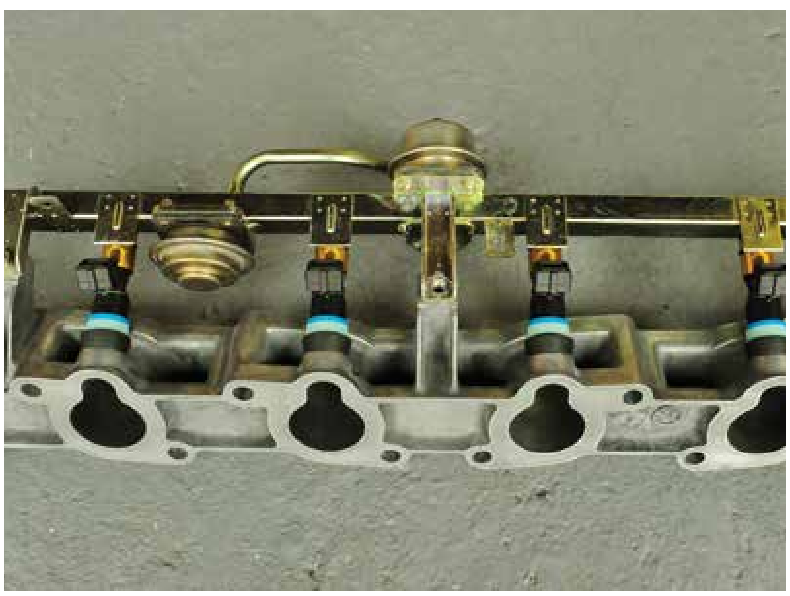
I then re-fitted the chargecooler and the power steering reservoir etc. I checked the engine over while it was warming up and then discovered the new chargecooler level sensor grommet was starting to leak! Feeling a bit frustrated I left it for a couple of days. When I went back to start it again it was difficult to start and this time it only ran on four cylinders. I contacted the injector cleaner again who said he had no answers and I should contact a company called ASNU in Bushey Hertfordshire, which incidentally is closer to where I live. So now I had gained

'So what could be done? My old injectors could not be repaired and new ones were now obsolete'.

two problems that I didn't have before I started; a leaking Chargecooler and a misfiring engine.

First I phoned my local Lotus dealer to see if he had any solution regarding the level sensor grommet and he suggested I use the grommet from a Lotus Esprit and although it was a slightly different design it was a tighter fit than the one I had so I assembled this one and again with the black silicon sealer.

Then I phoned ASNU and spoke to Phil Ellinson who suggested I took the injectors over to him to run on his machine. When I arrived at Bushey it didn't take long for Phil to find the problem, in fact he could immediately see



that anything over 2.5 Bar fuel pressure one or two of the injectors would start to fail. The factory standard pressure is 3 Bar so there was my problem. I asked why they worked fine before the cleaning process and Phil told me the fuel gum that was cleaned off was actually helping to take up some of the slack/wear in the injector pump. The injectors that Lotus used were Rochester (favoured by GM because of cost rather than the more expensive Bosch injectors used by some Opel cars) and were not a very high quality (to put it mildly).

So what could be done? My old injectors could not be repaired and new ones were now obsolete. I explained to Phil that I didn't want to scrap the car because of failed fuel injectors. So Phil checked the coil resistance the flowrate and volume of one of the injectors that was still working and told me he could build me a new set; brilliant!

The next day I was back down to Bushey with my injector manifold and fuel rail so that he could build the injectors with not only the right spec but also they would fit. Phil selected a Bosch pump body that had the same resistance as the original injector and the same connector. Simon who is the ASNU technical guy (an ex-Bosch employee who at one time was seconded to Lotus to sort out their injector requirements) suggested the components required to bring the Bosch pump to match the Rochester spec. It was a good starting point and further discussions between Phil and Simon resulted in an exact match. Phil then selected the seals and spacers necessary to achieve the same fit as the originals.

Having decided on the correct components required they were then handed over to Bob who would hand build the six injectors. Bob has his own little area in the factory where he has injector bodies, caps, plates, seals and spacers and can build an injector to fit any application. It is good to know you are in the hands of the professionals so often in the Motor Trade there is so much negativity especially if the part you need is not made by the original manufacturer. The team at ASNU know injectors inside out and have the knowledge and enthusiasm to solve all injector related problems.

During the two mornings I spent over at ASNU I discovered the company was started by Phil 25 years ago manufacturing the cleaning and testing machines. Keith, who is now the General Manager at ASNU was one of Phil's first employees. There are now 60 countries around the world using the ASNU cleaning machines and having built a successful company manufacturing the machines Phil then started building performance injectors for private owners and racing teams and he now sends around 60,000 injectors out each month all over the world.

I reassembled the inlet manifold and chargecooler with renewed confidence and guess what?..... It Worked!!

It fired up on all six cylinders straight away and when warm settled down to a nice smooth even tickover at about 700rpm. Also there was no coolant leak from the chargecooler! On the road it felt fast; but it always did. However now in sixth gear it is much more flexible than it was. The iridium plugs I had previously fitted allowed me to use sixth gear below 80mph (on private roads officer) but with the new injectors fitted it pulls away from 50mph in sixth gear quite happily.

The difference is probably more noticeable on my engine due to its high mileage. Compression pressure would have suffered over the years and a stronger spark and more efficient fuel delivery will help to improve combustion. On an engine with more combustion pressure there will still be an improvement albeit less noticeable.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ASNU™
Put life back in your engine
Are you fed up with your cars lack of performance?
Has the pleasure gone from driving a car with a tired engine?
Have your petrol costs increased without any performance benefits?
When did you last have your injectors serviced?
The injectors are responsible for firing the fuel into your engine,
if they do not perform correctly, then neither will your engine.
This garage is equipped with the
ASNU Injector Testing & Servicing Equipment.
Ask here for details on how ASNU can save you money and . . .
Put life back in your engine
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ASNU - World Leaders in Injector Diagnostic Testing & Servicing

ASNU Injector Diagnostic Testing & Servicing Systems

ASNU Performance Injectors, Fuel Pumps & Fuel Systems & Fuel Rail Kits

ASNU Corporation Europe Ltd
65-67 Glencoe Road, Bushey, Herts, WD23 3DP, UK
Tel: +44 (0) 208 4204494, Email: enquiries@asnu.com, Web: www.asnu.com