A visit to: 213 Performance

Dashboard instruments are a driver's vital tools to monitor the health and performance of a car and its engine. Lowflying visited 213 Performance, STACK's official European service partners, to get the lowdown on the selection, installation and maintenance of sensors and instruments from company director **Andrew English**.

Thank you for inviting Lowflying to visit you. I suspect that most of our readers will be familiar with STACK as a supplier of instruments, dashes and the like, but may not be familiar with 213 Performance. Could you tell us a little about the history of the company, your relationship with STACK and the services you offer?

STACK was founded in the mid '80s by two engineers who had been doing consultancy for a company designing electronic devices for the motorsport industry, one of which was an air core tachometer. Because of STACK's location in Bicester, right in the heart of "Motorsport Valley", they became product distributors for a while. One day however, they realised that they had a number of ideas for their own product which would offer significant performance improvements. Out of the design work that followed came the stepper motor needle control system, unique at the time and which won them a British design award. STACK's business grew rapidly as the industry had been crying out for a more accurate product in this space. As a privately held British company, STACK ended up supplying most of the F1 teams of the time as well as GT racing teams and many manufacturers.

The business continued to expand; STACK went on to design the first commercially available data acquisition system used on an F1 car while at the same time building relationships with OEMs, supplying Lotus with the Elise dash for example.

In 2007, STACK was acquired by American company Autometer Products because it complemented their existing products. STACK's founders stayed on and business continued as before for a while. However, the company was doing a lot of work on video capture systems for OEM and aerospace applications where ISO manufacturing standards were required. Autometer therefore decided to move STACK's manufacturing to its ISO approved factory in Chicago, although design and support continued from the UK. In 2016 however, Autometer decided that a UK satellite operation could no longer be justified, so consolidated everything in Chicago.

Pete and I were going to be made redundant, so we decided to go into business; we had plenty of contacts in the industry, but no clear idea of what we were going to do. It turned out to be a wise decision; having taken the business to the US, Autometer realised the challenges they were going to face offering support to European customers – they would need to run split shifts with staff starting work at 04:00. They approached us to see if we were interested in looking after their European clients and as a result, we became their factory authorised service partners for Europe, also providing support to their distributors across the region. We offer technical support to their end users and do all the service work, including warranty. What de don't do is sell direct, except for "specialist" products in the non-consumer market. Despite this close relationship with STACK, we don't work exclusively with them and have a good knowledge of many other systems including AIM, VBOX etc. and often help customers integrate different makes of ECUs, dashboards, video systems etc.

You've already mentioned a couple of terms relating to instruments that we should explore further including "air core" and "stepper motor". Can we go back to basics and discuss some of the different instrument technologies on the market please?

There are a raft of different types of sensor and gauge in a performance car like a Caterham,

Electric Pressure Sensor, recommended not to have mounted directly on block.

Solid state pressure sensor much smaller, more accurate and reliable with greater mounting flexibility.

but let's start with two key measurements - pressure and temperature.

Starting with pressure gauges, oil pressure being the prime example. There are three main types of gauge typically used in automotive applications, each of which has different advantages and disadvantages. The most basic type, at the bottom end of the price range is a mechanical gauge, connected to the engine's oilway via a capillary tube. Mechanical pressure gauges are a perfectly satisfactory solution for many applications, and because the setup is so simple, some consider them particularly trustworthy. An advantage is that they do not need electrical power, particularly useful for historic cars running magnetos and the like. However, a downside is that you have pressurised hot engine oil in the cockpit, with the obvious risks to the driver were something to fail.

Electrical options were therefore designed which have a remote sensor, keeping hot fluids away from the driver. The needle in an electric pressure gauge moves based on the resistance in an electrical circuit. At a highly simplistic level, inside a traditional electric pressure sensor is a set of bellows which inflates as the pressure changes, with an arm which moves up and down a resistor. This type of sensor can be quite large and heavy; one installation consideration is that if such a sensor is mounted directly on the side of an engine (as we often see), vibrations can cause reliability problems either because the bellows mechanism fails, or because where the variable resistor spends its time reading similar pressures, the vibrations flat-spot the wire windings. To minimise these risks, we recommend remote mounting the sensor via a braided line, securing it to a chassis rail or bulkhead. Wrapping the sensor with some hose can also help take out the worst of the high frequency vibrations. These steps can also make the sensor less vulnerable compared to having it sticking out the side of engine where a knock could mean a big hole and lots of trouble!

To overcome the limitations of these resistive sensors, smaller solid state sensors were developed. With no real moving parts (measurement is done via a strain gauged stainless element) they are smaller, lighter and much more reliable and accurate over their entire life. They may be more expensive to purchase, but you can mount them directly on the engine. These sensors require a regulated 5 volt supply, so have a 3 wire connection and the signal is conditioned (temperature compensation, for instance) and amplified to provide an "analogue" output.

OK, so that's pressure measurement, what's next?

Drivers will typically next want to measure their water and oil temperatures. Again, there is a choice between mechanical and electrical systems. STACK's mechanical systems rely on a bronze Bourdon tube containing two bonded strips of different metals; their varying thermal expansions cause the needle to be deflected. Again, mechanical temperature gauges can be sufficiently accurate for many applications and are ideal for vehicles with no, or low powered electrical systems. A downside however is that because the systems are designed for all sizes of vehicles, they come with a 6' tube that can't be shortened, which you have to "lose" somewhere when used in a Caterham.

Electrical temperature sensors operate the same for oil and water, although the gauges are likely to measure different ranges. The sensors rely on an element in a copper tube whose resistance changes with temperature. A design difference of note between different temperature sensors is whether they are single or double pole. Cheaper single pole sensors rely on the car's chassis for an earth - OK if properly installed, but we see a lot of people putting plumber's tape around the threads, great to prevent leaks, but also an electrical insulator so it's no surprise when it doesn't work… We also see customers mounting their sensors using fittings cut into radiator hoses... Not a bad idea in itself, but again you don't have the required earth. So, for either of these setups to work, you need to choose a sensor with connectors for both earth and signal. They may be slightly more expensive, but they provide the flexibility to mount them pretty much anywhere.

The key to getting accurate, responsive temperature readings is to ensure that the tip of the sensor is right in the flow of what you are measuring. Sensors have a relatively large thermal mass on their own, and in a larger fitting, it becomes bigger still. Get the sensor tip into the flow and measurements will be more responsive.

So, what about gauge types?

We've already touched on mechanical gauges, so let's now focus on the electrical types. Traditionally, electrical gauges were based around what we call "air core movements"; inside is a precision wound coil inside a magnet, with another coil around the outside. A varying resistance creates a varying current flow in the coil which deflects the needle. It's a tried and tested solution which can work very well.

Again however, there are some limitations, the main one being that vibrations and G forces can affect the reading. STACK employs a number of techniques in its designs to make air core gauges as immune from vibration as possible, but you can't get away from the fact that external forces will have some effect, particularly in high performance applications.

So is this where the stepper motor design comes in?

Yes, absolutely. Here, the needle is driven by a microprocessor-controlled stepper motor. From a motorsport perspective, it's a much better solution; you can be sure the needle will go exactly where you want it to, accurately and repeatably. The easy way to recognise a stepper motor gauge is that when you power one up, the needle starts by going back below

0 where it pulls against a reset pin so the microprocessor knows its exact starting point. It will be programmed that, for example, 90psi is a certain number of steps up from the pin.

Convention says that for instrumentation, accuracies are quoted as a percentage of full scale. STACK electric gauges have a quoted accuracy of +-5% full scale, whereas their stepper motor gauges are +-2%. As previously stated, air core gauges are also more likely to be affected by vibration, G forces etc. whereas a stepper motor puts needle right where it should be each time.

Stepper motor pressure gauge (L) and electric version (R)

Any downsides?

Well, a stepper motor system is likely to be a more expensive set-up, but apart from that, no. The main installation consideration is that because it uses a microprocessor, you need to pay particular attention to a good power supply. It's here that earthing / grounding issues tend to come in. If you've trying to use a rivet on a powder-coated chassis rail as ground, you're likely to have problems. Stepper motors, LCD dashboards etc. all hate bad earths. In fact, I'd probably say that the majority of problems customers report whether on the most basic systems or the most advanced can be traced back to bad earths. Always observe the product manufacturer's advice about how to ground your sensors and be wary about making modifications to the looms supplied with them. If you need to, and have access to decent crimping tools, then shortening wires is OK, but don't be tempted to make changes.

You mentioned crimping wires, isn't soldering OK?

I'll admit there are different schools of thought on this, but in my experience, it's better never to solder a wiring loom, just crimp. You may hear people advising you to crimp and then solder, but I've seen that leading to so many problems. Let me explain; when you solder a joint, you heat the wires up then run the solder in. The solder wicks up the wire and makes a nice-looking joint which you then cover with heat shrink. What I can almost guarantee however is that 80% of soldered wiring failures don't happen at the joint, they happen just before or just after it, because the solder has wicked further up and made the wire brittle. Crimping is far better– you just need to use the proper kit for the job, select the right crimp for the gauge of wire, then support everything correctly whether it's with heat shrink, convoluted tubing or even tape (which I hate, but is better than nothing!) Ensuring that your wiring is properly supported is really important in a car like a Caterham as vibration will find a weak spot, wherever it may be.

What about other key instruments that owners will want to consider?

Tachometers (rev-counters) typically measure the pulses from your ignition system. There are a few things you need to think about in a high performance environment however… Most tachos can connect directly to your ignition coil, a nice easy way to source a signal. What you then find is that everything works perfectly until you hit the rev limiter, which controls engine speed by cutting the signal to the coils. When this happens, the tacho needle drops to 0, then jumps back when the signal returns, thrashing around. Most ignition systems offer a specific tacho output upstream of the rev limiter, which is where you want to take your feed. Some more complex rev limiters are designed to "stutter" the ignition, which can create an apparent higher rpm signal than the engine is actually turning, equally unhelpful if you want to recall the actual maximum.

Technology now also provides a number of options when it comes to the speedometer. The traditional approach is to take a mechanical drive or electrical signal from the drive train (gearbox, input flange to diff, output shaft, bolts on brake disk…) This works well, the only possible downside being false readings through wheel spin, lock up etc. Some more modern systems use GPS. It's an easy system to install - bolt the antenna on and away you go. The only downside is that the antenna needs to see the sky, not often a problem for track cars but sometimes an issue for street cars driving through tunnels or between tall buildings. Some dash systems are already designed for GPS, but STACK also offers a product which converts GPS speed measurement to electrical pulses to feed a traditional display.

Fuel gauges work by measuring the resistance from a variable resistor connected to a float arm. Most fuel level gauges allow a simple way to calibrate the empty / full levels, and as long as the tank is relatively regular, there should be a reasonably linear relationship between these points. Problems only occur if you are using an odd shaped tank as you sometimes see for packaging reasons in race cars. Some STACK dashes allow you to calibrate in 5L increments throughout the range to deal with this. If you're not using a foam-filled tank or a cell, the fuel moves around under G forces and if you have a responsive gauge without damping, you'll see the gauge measuring the slosh. However, modern stepper motor gauges use software damping to filter this out.

Caterhams are open to the elements. What is the deal with the waterproofing of gauges and electronic dashboards?

Here, you have to differentiate between dashboards and gauges. Dashboards are typically designed to be fully sealed; STACK dashboards are sealed to IP67 standard which requires them to withstand 1 hour under 1m of fresh water. In fact, at trade shows, we often have a working dash submerged in a goldfish bowl for days on end! Having said that, being designed to withstand water is not the same as being able to handle direct pressure washing or steam cleaning. I compete in Autograss and that's how some drivers clean their cars, but you have to be really careful as it can be a sure fire way to damage ECUs, data loggers, video systems, dashboards etc.

Gauges are typically designed differently and are made to breathe, so although they may be sealed reasonably well from the front, they are not from the back. It's therefore important to mount them in a well designed panel, with everything as well protected as possible from behind.

Display Tachometer

What other considerations are there at the installation stage?

Getting the wiring right is absolutely key of course. The supplied wiring is likely to be longer than required for a Caterham. Shorten it by all means, but as previously discussed, use the right tools to make nice crimp connections, seal them with heat shrink and ensure that the wiring is well supported. The alternative to shortening is just to coil the excess away tidily. Best practice to avoid the risk of creating interference is to coil the wire, then twist and cable tie it into a figure of 8.

Be careful with cable routing. To avoid chafing, you definitely don't want wires anywhere near sharp edges and always use gromets when passing through panels. Keep them well away from coil leads, both HT and power. We saw this recently when mapping a 2L Vauxhall on the rollers. Half way through, the engineer pointed at the real time display which showed water temperature jumping all over the place. He assumed the sensor was faulty, but it turned out that the wiring was running alongside the HT leads. Equally, if you run fuel injectors, keep instrument wiring well away from their leads too, as the solenoids radiate electrical interference.

Is there any preventative maintenance owners should carry out on their gauges, sensors and the like?

Like pretty much everything on a performance car, good preparation is key. Doing a good job at the installation stage goes a long way towards making sure everything works reliably and accurately for years to come. We've already talked about crimping vs soldering, but one other thing - please don't consider Scotchlok connectors. If I meet the person who invented those abominations, I'll have a few words to say… Other than that, keep everything clean, inspect your connections, check your crimps regularly and everything should be fine.

Practically, how do you go about checking crimps?

Assuming you've used the right tool and selected the appropriate crimp for the gauge, once you've made a new crimp, give it a pull to make sure the wire won't move. It's the same when checking at a later date, you just want to make sure there's no give. The tell-tale sign is when you see some conductor showing; with a good installation job, you shouldn't be able to see any so if some is now visible, something's moved.

Is there anything we haven't discussed that you think our readers should know?

There's one piece of preventative maintenance particularly relevant to Caterham owners which relates to the "Triangular" STACK dash that was original equipment on some models and retrofitted to many others. There have been a number of different models over the years; they all look the same and can only be differentiated through the part number. One thing they have in common however is an internal battery on the circuit board. This was specified to last approximately five years. We test the battery on every unit we have in for work and see a huge variability in the current drawn by the memory chips. Consequently, some batteries will last 5 years, whereas others we forecast still to be running in thirty… However, if the battery does fail, the unit resets to factory defaults, loses its calibrations and needs to come back to us for replacement.

Murphy's Law says this is bound to happen just as you cross the Channel on a tour, or head out for qualifying. If you

The "Triangular" STACK dash that was standard fitment on many Seven models.

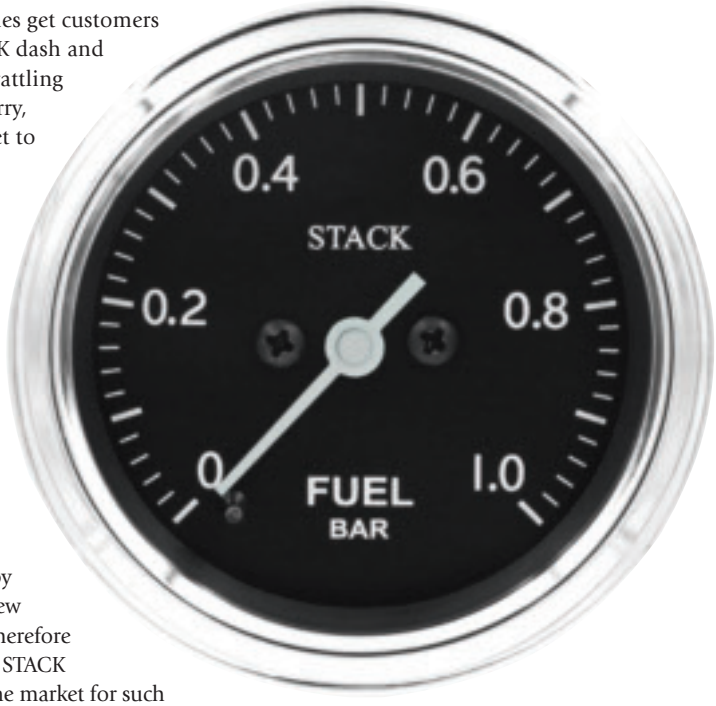
think you have a battery which may need replacing, we can advise from the serial number when the unit was manufactured and we have access to STACK's service records so we can track whether it has been through repair before and what work was done. If the battery is less than five years old, there is no reason to do anything at this stage. If it's older, we have a non-invasive test method so we can advise either that it's got plenty of life left, or suggest it should be changed. For an inspection fee, as well as the battery check, we complete the same full set of tests as when the unit first left the factory. If it turns out that any work is required, we will provide a no obligation quote.

Does this include checking the waterproof sealing?

Yes, absolutely. Over time, waterproof seals can fail and then you get misting. We follow many of the popular internet forums and I am disappointed when I sometimes see people saying "They all do that…" They certainly shouldn't, and electronics and moisture really shouldn't mix. The original misconception may come from the fact that the very first units were machined from solid aluminium and could not be sealed. Since then however, the bodies have been made from carbon composite and are fully sealed front and back. If you do have one that steams up, we'd love to sort it. One word of warning; we sometimes get customers who remove their STACK dash and ring to report "a funny rattling noise" inside. Don't worry, it's just a bag of silica get to absorb condensation.

So, can you service and repair any STACK products?

STACK's official policy is that any product that hasn't been manufactured for five years is out of support. However, we acquired all the fixtures, fittings, parts and test equipment and luckily, as it was a business run by engineers, they never threw anything away! We can therefore repair most things. Since STACK products have been on the market for such a long time, we are actually seeing more and more demand for us to help recommission historic cars which had STACK products as original fitment. Even the triangular dash, still a current product in its latest version, was actually introduced 25 years ago which is significant as that's the cut-off date for many historic championships, so the STACK dash is period correct.



Stepper motor technology is available in classic-styled gauges

Many thanks for your time Andrew. 213 Performance can be contacted via www.213performance.co.uk and it is offering Club members a 10% discount on STACK servicing and repairs until 28th Feb 2019. ***LF***