THE EXPERT
STEWART SANDERSON

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

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

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

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

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

PART 1

ROAD TO RACE CAR

Words: Stewart Sanderson and Will Pedley

IT'S ALL ABOUT THE ENGINE FOR THE FIRST PART OF OUR GUIDE TO TRANSFORM YOUR ROAD CAR INTO A RACER.

We're sure you'll have seen some sort of racing either at a show, track day or specific race series. Have you ever considered what's involved in taking the car parked on your driveway and converting it to a reliable racing car?

In 90% of cases, your road car most probably has an engine and transmission set-up that is designed as a compromise between smoothness, fuel economy, driveability and performance. This component compromise will give great service on the road where maximum performance is not usually required for more than a small percentage of the time. So, let's look at what will need to be altered in order for full power to be available reliably for racing use and why...

ENGINE

The first thing that needs to be considered is what type of racing the engine will be involved in, this will dictate the area of power band required. For example, a drag racing car may need a power band high up in the rev range whereas an auto cross racecar may need a power band low down in the range.

This power band target can be used to aid the rest of the engine spec in terms of camshaft selection, valve train, turbocharger/throttle body/carburettor selection, cylinder head porting, compression ratio, inlet and exhaust manifold selection. All of these aspects and more will affect the engine's useable power band.

Camshafts need to be carefully selected to achieve the correct powerband

CAMSHAFT SELECTION

Standard camshafts in most factory petrol engines have a power band from around 1500rpm through to 5500rpm. Let's assume we're building a circuit racing car which will need a power band at the top end of the rev range.

With a new rev limit of 8000rpm, we need to choose our camshafts to ensure that the power band works with our gear ratio choice, so that every gearchange lands the engine speed back in the power band. By increasing various aspects of our camshaft spec we can alter the actual engine speed that our engine develops most useable power in.

For more info see my camshaft feature in issue 246, available at **www.fastfordmag.co.uk**, and 286's Lowdown feature.

VALVE TRAIN

With the selection of our new camshafts we need to consider our valve train. Normally the valve springs are stiff enough in a standard car to support the factory rev limit of 6500-6800rpm. If we intend to rev higher than that, or use aggressive profile cams, the valve springs will need uprating.

They need to be chosen carefully to ensure they are strong enough to return the valve to its seat in the shorter time available at the higher engine speeds, and designed so they don't become coil bound (where the spring compresses solid) at peak lift from the camshaft. If a sufficiently strong single spring isn't available, it may be necessary to use a double valve spring. However, in some cases, this can involve additional machining of the cylinder head.

We must also consider the lifters used between the lobes of the camshaft and the valves. A lot of factory vehicles run hydraulic lifters to provide smooth and quiet engines. At high revs these hydraulic lifters can struggle to cope depending on camshaft profile, valve spring selection and power band. You may need to upgrade to solid lifters to avoid engine speed-related problems.

INDUCTION

Depending on whether the vehicle is forced induction or N/A, you'll need to select a turbocharger or carburettors/throttle bodies for your racecar.

If your target power band is at lower engine speed, then a smaller turbocharger or set of carburettors/throttle bodies can be used to give sharper response and more power/torque at lower engine speeds.

For high revving applications a larger turbocharger or set of carbs/throttle bodies can be used, although low speed driveability can be compromised.

When talking about induction, it's also worth mentioning filtration. On a standard road car, it's vital that the filter set-up can cope with any conditions, up to and including driving through a dusty desert! On a racecar, filtration can be tailored to the conditions the car will be exposed to. On a drag car for example, it is not uncommon to leave the intake to the turbocharger completely exposed to reduce the restriction posed by an air filter.

FASTENERS

Fasteners used in the standard engine were probably not designed to deal with the extra stresses of racing, or vibration levels created by extra engine rpms. For ultimate reliability upgrade critical fasteners such as con rod bolts, crankshaft main cap bolts and cylinder head bolts to high tensile items such as ARP ones. Torque them to the specific settings supplied by the manufacturer.

Vitally important bolts should be lock-wired so they can't come free on items subject to high vibration, and certainly anything that can cause an accident by dumping fluids, such as sump and transmission drain plugs.

Throttle bodies can be tailored to give a race engine the desired characteristics

Race engines typically run higher compression ratios than road car engines

COMPRESSION RATIO

The compression ratio on standard vehicles is a compromise in most cases to allow a smooth drive without placing undue stress on the engine, while allowing use of varying qualities and octane of fuels. For a racecar there are gains to be found by changing the compression ratio.

For an N/A engine we can look to raise the compression ratio to work with the selected camshafts and throttle bodies/carburettors as well as high-octane fuel. For a turbocharged engine we can use the compression ratio in different ways, depending on the application. For low engine speed power bands, we could increase the compression ratio from standard and for high engine speeds and power we could reduce it. Using higher-octane fuel with these engines can pay dividends in power once everything is optimised.

CYLINDER HEAD PORTING

On most vehicles, the standard cylinder head, as with other areas of the engine, was produced on a budget to provide acceptable performance while concentrating on fuel economy and emissions. When converting a standard engine to a race engine, there are very few circumstances when it is detrimental to optimise the cylinder head ports.

Keeping the port size small can benefit vehicles that need to maintain good gas speed entering the cylinder head at low engine speeds. Enlarging the port is more beneficial to engines with their power band at high engine speeds. Cleaning the casting marks out and matching the inlet manifold port to the cylinder head port is usually advantageous at all levels of tune.

"IT'S WORTH EXAMINING THE MAXIMUM SAFE PROVEN LIMITS OF YOUR ENGINE'S COMPONENTS."

Porting the cylinder head improves airflow, making it suited to high revving applications

COMPONENT MATERIALS

Components within the standard engine are made on a budget in most cases, and as such aren't up to the job in a race engine. Con rods are a prime example. When pushed 1500rpm over their intended maximum speed for sustained periods they can be prone to failure.

It is worth examining the maximum safe proven limits of components in your engine and establishing what components would benefit from upgrading. For example, forged H-section con rods could be used to ensure reliability.

This goes for gaskets too, a standard fibre gasket would usually benefit from an upgrade to a multi-layer steel (MLS) item to cope with additional cylinder pressures created by your increased power outputs, unless its performance has been proven reliable at the power level and race length you are building for.

ENGINE LUBRICATION

In most cases, the standard engine's lubrication system is adequate for road and occasional track use. Once you raise the power you'll raise the lubrication demands on the oil. Also, if you fit slicks you'll be generating more cornering force than your oil system was designed to cope with and you run the risk of pushing all the oil away from the standard oil pick-up pipe. This can easily result in picking up air and damaging the engine. If you are racing with these tyres we would strongly suggest you invest in either a baffled sump or a dry sump lubrication system.

Standard engine oil will have ideal properties for road use. The service interval is probably around 10,000miles and up until now probably hasn't proved an interesting point for conversation. If the car is going to be raced, that will change…

Depending on the application and your budget, the key is to ensure suitable lubrication throughout the engine under the more strenuous conditions it will be subjected to. In drag racing, the car's engine will only normally be running for a short period of time before it is used at full load, this is usually because it keeps engine bay temps down. This short period of running will allow minimal oil temp build up, then a hard launch will most likely stand the oil against the rear of the sump. Add in rev limits exceeding 8000rpm, sometimes 9000rpm, and we see that the standard system will need work!

Check the grade of oil. Depending on the type of work the engine will be doing, it may be better to run thicker oil for greater protection and resilience to raised operating temps. Speak to an oil expert before you change the grade.

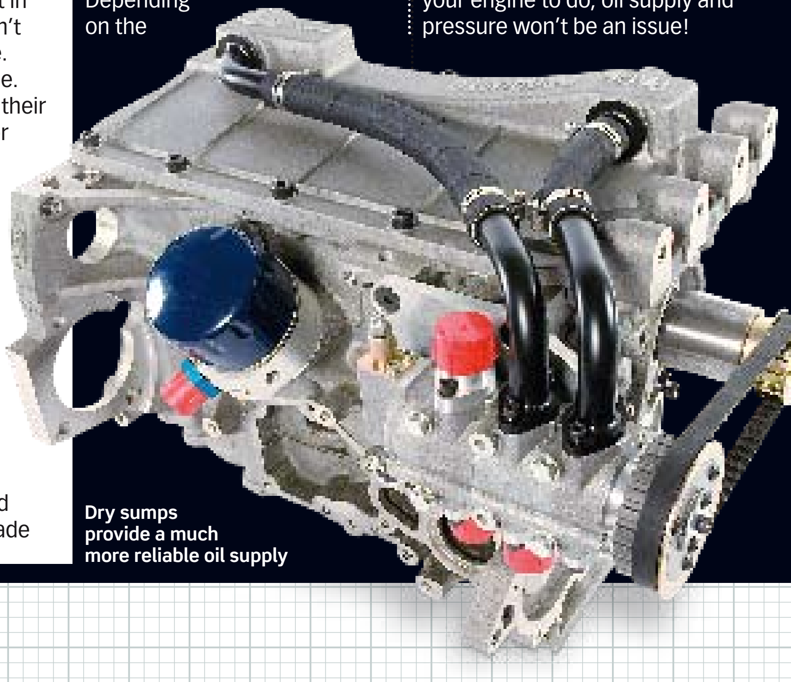
Ensure the oil pick-up in the sump is always able to draw oil and not air! Have baffles or gates fitted into the sump pan to restrict movement of oil within.

The standard oil pump's pressure may not be suitable for your intended use, so look into high-pressure items. If the engine's going to work hard for periods of time make sure the oil doesn't drop out of its efficiency range by overheating, which is where an oil cooler is useful.

Oil coolers come in a couple of forms, oil to water and oil to air. If you choose an oil to air cooler, it's worth fitting it thermostatically to only allow oil to pass through it after a certain temperature. This avoids overcooling the oil and compromising its properties.

If your budget will stretch to it and the type of racing necessitates it (such as drag racing), the ultimate option is a dry sump set-up. A dry sump set-up is a system where the oil is stored remotely in a tank and pumped into the engine and sucked out again, as opposed to the oil being sat in the engine's sump as in a regular system. See the Lowdown feature, page 122.

This requires a significant amount of extra parts, such as the dry sump pan, the pump, mounting brackets, belts to drive the pump, reservoirs, breathers, remote filters, coolers and a good few meters of hose! This set-up doesn't come cheap, but you can be assured that whatever you ask your engine to do, oil supply and pressure won't be an issue!



Dry sumps provide a much more reliable oil supply

Forged con rods are a must for high revving engines

FLYWHEEL

Standard vehicle flywheels are designed to be heavy to maintain large amounts of inertia on the crankshaft. This allows for a nicer driving experience and makes pulling away using the clutch more controllable at low engine speeds. The compromise is that the engine is more lethargic to pull through the rev range than it could be.

On a racecar, a lightweight flywheel can be fitted to allow the engine to pull through the rev range in a crisper and faster way. This makes the mod beneficial to most types of race engine. Be aware though that setting off from a standstill with a race clutch and lightened flywheel can take some getting used to before you stop stalling the motor.

OIL BREATHER

Most factory vehicles have an adequate oil breathing system, but with the extra crankcase pressure produced on a tuned engine we need to look at upgrading the breather system. Ideally, breathing from the crankcase and the cam/rocker cover into a breather tank with a return to the sump and a suitable diameter filtered vent hose to atmosphere. Failing to do this can result in excess crankcase pressure creating oil leaks or oil loss and consumption during hard cornering.

ENGINE COOLING

The standard engine cooling system is adequate to cope with nominal power increases and hard use, but make sure pipes, thermostat, pump and radiators etc are in good condition, with the radiator free from flies and debris. The water must also be spotless and free from corrosion while being of the correct water/anti-freeze mix too.

Larger intercoolers help keep the ACTs down

INTERCOOLING

If your car has a turbo or supercharger, to prepare for racing a boost increase will be on the cards. Most factory vehicles have an intercooler that is fine at standard boost pressures, but once you start increasing that pressure it's time to upgrade.

Increasing the size and core thickness of the intercooler is important, but locating it so as to expose it to lots of cool air is critical. Most standard systems can become heat soaked with prolonged periods of full power output so fitting an aftermarket upgrade is essential, even for cars running standard boost.

CRANKSHAFT

In a lot of cases the factory crankshaft is substantial enough to take a noticeable power increase. However, we can still improve it before we need to upgrade, as upgrades tend to be billet steel items with hefty price tags!

We need to make sure that the crankshaft is correctly balanced as part of the rotating assembly (crankshaft, con rods, pistons, pins, rings, pulley, bolt and clutch). Correct balancing will allow the engine to rev faster, cleaner and higher.

We can also look into 'knife edging' the crankshaft before the balancing work is carried out. This is where the counterweights on the crank are machined down to, as the name suggests, a knife edge! This reduces the windage losses as the crank runs in and out of the oil and also lowers the weight of the rotating mass, which in turn can increase bhp output and make the engine rev faster.

VALVE MATERIALS

The standard inlet and exhaust valves are fine from the factory and can take an element of tuning before they need to be looked at. However, on a big-power engine, they may well need replacement to aid reliability.

Exhaust valves are normally the first to present a problem. Not surprising when you consider what they have to go through. Slamming shut against the valve seat 30 times a second at high revs and in temps often exceeding 800°C is a hard job for any component.

Upgrade options include sodium filled valves that use sodium in the valve stem to draw heat away from the valve head. These are used on a number of performance cars from the factory.

From here, it gets more expensive. Titanium valves are heading towards F1 technology and provide great features such as incredible lightness and strength. For exhaust valves we have the option of an alloyed material called Nimonic. These are the best upgrade for exhaust valves, offering the highest heat resistance but don't add weight to the valve train.

NEXT MONTH
TRANSFORM YOUR CAR'S TRANSMISSION