PART 1

COMPRESSI ON RATIO

This month Stu explains the principles behind compression ratio, and how to work it out.

Here we see the volume of the combustion chamber being calculated using a burette

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, in the past Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Then seven 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's also jointly responsible with Webmaster, Petrucci for **www.passionford.com**. Started in 2003, it's grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web. His new forum, **www.fordrsforums.co.uk**, is also up and running.

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 most importantly how they can be improved.

Hope you enjoyed last month's article. This month we are going to take on a far more complex subject. It's one I've wanted to do for a long time but I couldn't quite get to grips with how to approach it in an easy to understand manner, and so as not to bore you all to death. I think I've worked out a good format now so let's get going and see if I can teach you all a little about compression ratios, without you nodding off at the back there...

WHAT IS COMPRESSION?
You need to know what the compression part of the story is when you are dealing with an internal combustion engine. Compression is simply the act of squeezing a gas (or a solid for that matter) into a space smaller than it normally occupies.

As far as our engine goes, we open up our inlet valve and draw the piston down to the bottom of its bore, introducing lots of air as we go. When we have a cylinder full of air, we close the inlet valve, thus sealing off the cylinder and making it airtight. We then move the piston all the way back up the bore to the top, compressing the fuel and air that was once filling the whole cylinder until it is all squeezed into a much smaller space right at the top of the cylinder, commonly known as the combustion chamber.
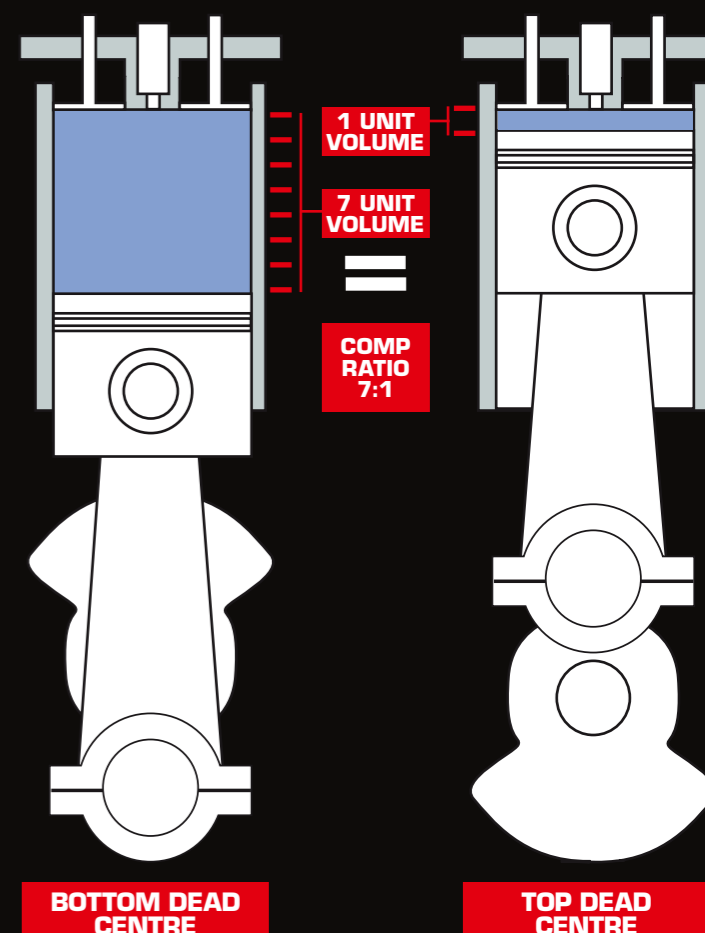
WHAT IS COMPRESSION RATIO?
Now you know what compression is and how we compress our fuel and air mixture, you need to know just how compressed something is.

To explain this we commonly use what's known as a ratio. Let's imagine that we have compressed 2 cubic feet of air into a 1 cubic foot space. This is known as a ratio of 2:1 as we have compressed something into a space half its size. If the original air occupied a space of 4 cubic feet, we would have compressed it by a ratio of 4:1.

As far as our engines go, the compression ratio is the total volume of the cylinder and combustion chamber when measured above the piston crown while the piston is sat at the bottom of its travel, this is referred to as bottom dead centre (BDC), divided by the combustion chamber volume above the piston when it's sat right at the top (known as top dead centre, or TDC).

WHY CHECK IT?
Whenever you are building

1 UNIT VOLUME

7 UNIT VOLUME

COMP RATIO 7:1

BOTTOM DEAD CENTRE

TOP DEAD CENTRE

You need to work out the capacity of your cylinders if you alter the dimensions with liners

when it's at TDC. This is the area where the gas will sit once compressed to its maximum and is essentially the combustion chamber area in a fully assembled engine. To get this figure in an un-built engine, you need to add together your combustion chamber cc, head gasket cc and above piston cc. It's worth mentioning that on some engine's you can grease the pistons in the bores at TDC and fit the head and gasket temporarily and cc the clearance volume with the engine assembled, using fluid and a burette via the plug hole.

Now you have the clearance volume and cylinder volume in ccs you can work out your compression ratio. Add the cylinder volume and clearance volume, then divide that answer by the clearance volume – cylinder volume + clearance volume ÷ clearance volume.

A standard Cosworth YB has a clearance volume, with gasket, of around 71.2cc so let's use that as our example. Cylinder volume (498.497) + clearance volume (71.2) = 569.698 ÷ clearance volume (71.2) = 8.00, so the compression ratio of a standard Cosworth YB is 8.0:1.

I know that was a lot to take in, but keep at it and it should come together. All you're trying to do is work out two areas inside your engine and do some maths. Those areas are basically the area the piston covers under normal travel, and the area that it doesn't.

We can work out what clearance volume is required for a given compression ratio before

Knowing that the standard volume is 71.2cc means that we also know we need to remove 5.49cc of material from the combustion chamber/top of piston area to achieve our desired compression ratio on this engine.

And that, in a nutshell, is all you really need to know about compression ratio. Apart from

"All you're trying to do is work out two areas inside your engine and do some maths."
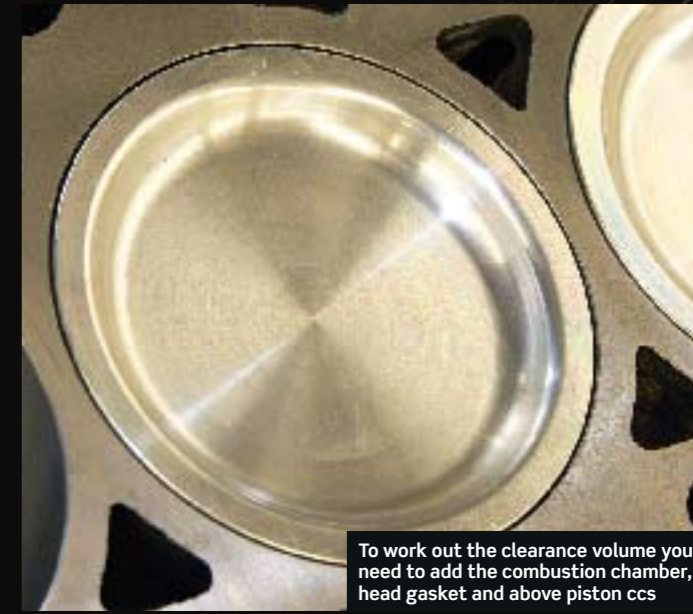
we start. If we have already chosen our bore and stroke, then we can work out what clearance volume will be required to achieve our chosen compression ratio by simply dividing our bore area by 1 unit less than our desired compression ratio.

Let's say with our Cosworth YB we wanted to achieve 7.5:1 then we would divide our bore area (498.497) by 6.5 and the resulting number will be the ccs we require our clearance volume to be. In this case, it's 76.69cc.

maybe why different engines have different compression ratios, why we would use high or low for certain applications and what factors affect the outcome. If you join me same time and place next month, we will deal with all that as well.

To work out the clearance volume you need to add the combustion chamber, head gasket and above piston ccs

NEXT MONTH

Why different engines have different compression ratios.

an engine, especially a performance one, you need to measure your compression ratio. It must be done a few times in most instances, as if you're boring the engine out or changing its stroke then you will need to modify the pistons to get the compression ratio back to where you want it, and keep modifying things until you have got it perfect.

You must do this on each cylinder to be certain that everything is balanced perfectly. Even unmodified engines can have compression ratio problems if they've had too many head

how much fluid it holds. A thin layer of grease seals the plate against leaks.

When the combustion chamber is completely filled with no air bubbles showing, read the burette and note down how much fluid was used to fill it. This figure represents your combustion chamber's capacity in cc.

MEASURING THE ABOVE-PISTON VOLUME
Ccing the cylinder heads is easier than ccing the area above the piston at top dead centre. If your pistons are flat tops or dished, and are below the deck surface of

length of the stroke. First you need to work out the cylinder's bore area by using the following calculation:

Bore area calculation = bore x bore x pi divided by 4 (pi has a value of 3.14159)

Normally we measure engines' internal volume in cubic centimetres, but be aware that engine dimensions are often shown in millimetres so don't forget to convert any measurements into centimetres before starting the calculations.

Let's use the Cosworth YB as an example and work out the compression ratio. The bore is 90.82mm and the stroke is 76.95mm. So, if we convert that into centimetres we get: bore = 9.082cm and stroke = 7.695cm.

Bore area is therefore 9.082x9.082x3.14159(pi) divided by 4 = 64.782 sq cm.

The volume of 1 cylinder is bore area x stroke, so 64.782x7.695 = 498.497cc per cylinder.

There are four cylinders in the engine so the total engine volume is 498.497x4 = 1993.988cc

The final figure we need for our compression ratio calculations is the head gasket's compressed thickness. You can do this by measuring an old gasket of the same type you are using or by consulting the manufacturer's specifications for that gasket. You need to work out how much fluid will be held by the head gasket when it's fully compressed. You can calculate it as above or use the Perspex and fluid method.

"A standard Cosworth YB has a clearance volume, with gasket, of around 71.2cc."

and/or block skims, as the increased compression ratio can lead to detonation problems.

HOW IS CR CALCULATED?
The measuring process involves ascertaining the volume of fluid held by the combustion chamber. We have to determine the capacity (measured in cubic centimetres (cc) so we call it "ccing") of our combustion chamber and the combustion area built into the tops of most pistons, as well as work out the bore capacity of our engine.

To measure the combustion chamber capacity we use a flat piece of Perspex or glass plate placed over the combustion chamber and then release fluid into the chamber through a hole in it. We use an accurately graduated burette to release the fluid so we can measure precisely

the cylinder block at TDC, grease the piston ring area to stop fluid escaping past the pistons. Bring the piston up to the top of its travel (TDC) and place the Perspex plate over the top of the piston.

However, if the piston has a large dome and any part of the dome extends above the cylinder block at TDC, you must cc the piston with it positioned exactly 25mm down in the cylinder bore. Fill the area above the piston with fluid, then subtract this volume from the calculated cylinder volume at 25mm and you get the piston dome displacement in ccs but don't worry about complications like that for now.

MEASURING THE CYLINDER CAPACITY
The volume of a cylinder is calculated by multiplying the area of the bore of the cylinder by the

WORKING OUT CLEARANCE VOLUME
Clearance volume is the amount of space at the top of the piston

Measuring the bore is the first step in working out the cylinder capacity