CHAPTER 3.
COMBUSTION - THE POWER STROKE.

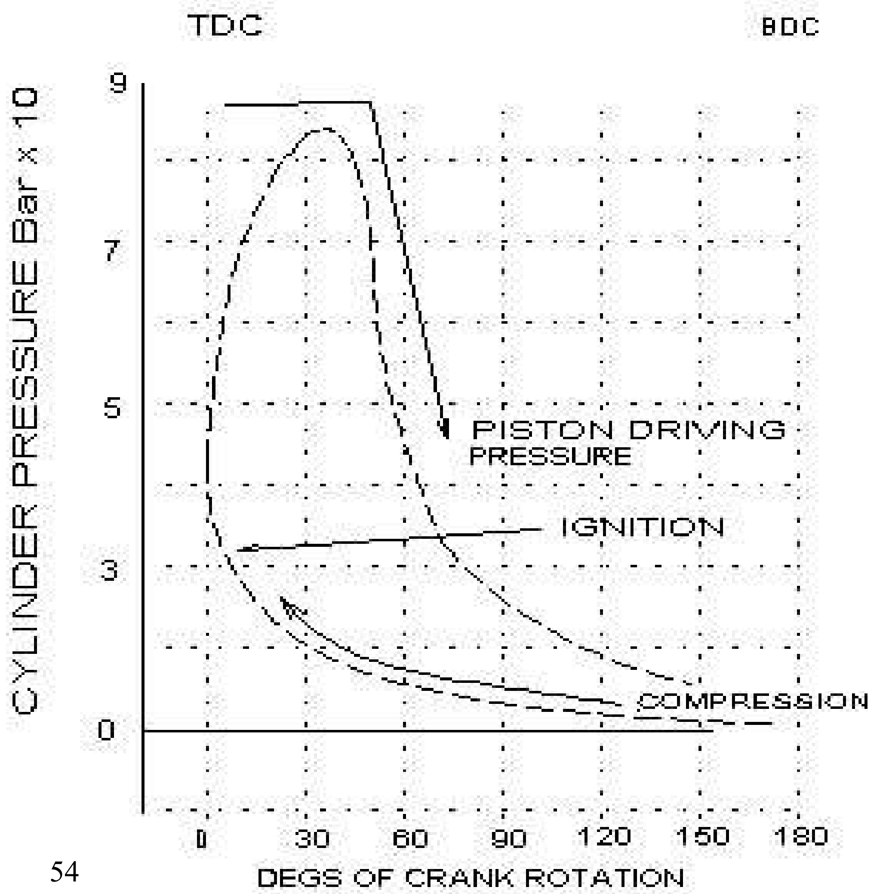
Four-stroke and two-stroke characteristics re-unite during the process of combustion.
In both cases, a fast efficient burn is **THE** major key to high power output, and the factors that control it are common to both.

As the piston rises, the mixture is compressed and consequently undergoes a rise in temperature.
As the cylinder pressure rises to about 13.6 bar (13.6 x Standard Atmospheric Pressure), which will occur somewhere between 20 and 40 degs. before T.D.C., the plug fires and the combustion process starts.

Once again, it must be stressed.....

IT IS A PROCESS OF BURNING! - IT IS NOT AN EXPLOSION!

An explosion is the result of uncontrollable detonation, which does occur in the internal combustion engine occasionally and, if allowed to continue unchecked, produces disastrous results.



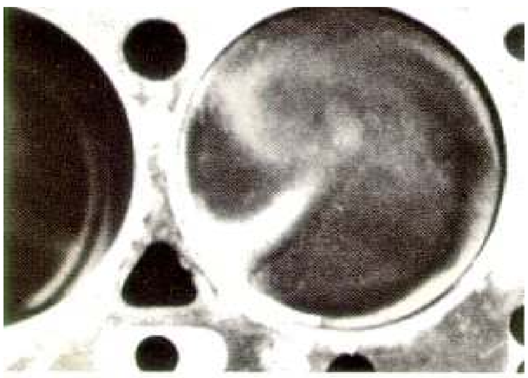
54

As combustion continues, the cylinder pressure rises to between 54 to 68 bar (Fig. 54), to create the driving force on the piston crown.
This maximum pressure varies with engine design, but a good thumb rule is that it will be about one hundred times the compression ratio.

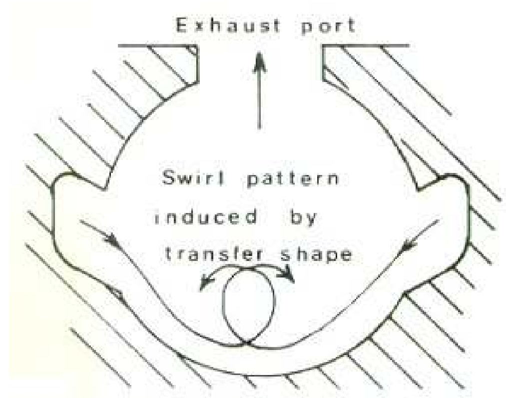
The efficiency with which combustion takes place is controlled by a number of important factors that readily respond to adjustment or modification and are equally applicable in both two- and four-stroke engines.

They are as follows :

Swirl - Control of movement of the inlet mixture as it enters the combustion chamber, as a result of the correct shaping or reshaping of the inlet port and valve, or the transfer port.



55 *Carbon formation on piston showing swirl pattern of inlet charge.*



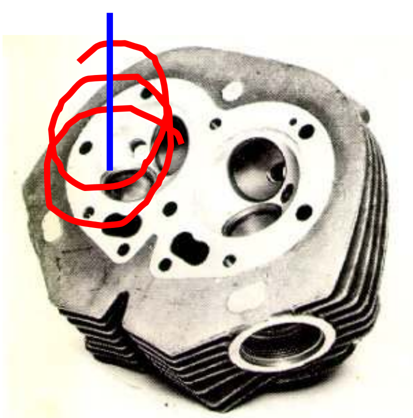
2-stroke Swirl pattern.

55a

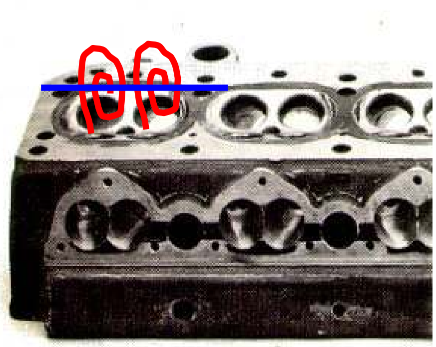
This results in a turbulent pattern within the inlet charge, which in turn creates a pre-mixing effect on the richer and weaker portions of the charge and assists even burning.
Fig. 55 shows an example of perfect swirl control imprinted in the light carbon on the piston crown of a well-modified engine.

Fig 55a shows a graphical example of the same effect, as it would be created by the correct shaping of a two-stroke port layout.

In engines with two valves per cylinder, swirl will take place around a vertical axis, forming layered pancakes or doughnuts of mixing gas.
In engines with four valves, the swirl is created around a horizontal axis forming wave-like rolls of mixing gas.



56



In either case, the object is to induce a gas movement that holds the fuel vapour in suspension with the air and packs it evenly into the cylinder space, ready for compression.

Combustion chamber shape and finish - A neat, minimum combustion chamber area, ensures that flame-spread is rapid and progressive, permitting the ignition process to be delayed as long as possible, i.e. a minimum of spark advance. (See section on ignition control)

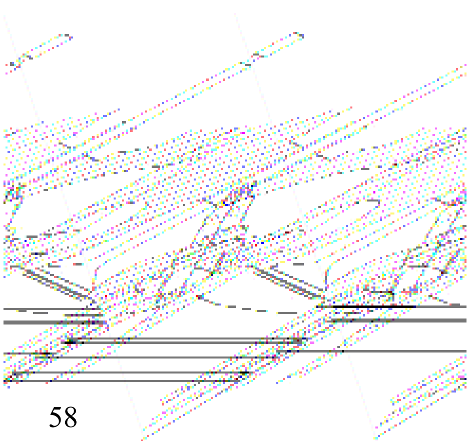
57 *2-stroke combustion chamber with central spark plug.*

This is one area in which the two-stroke engine really scores, because its' lack of valve head intrusion in the combustion chamber means that the chamber can be of near perfect, small part spherical design, with the plug in the centre. (Fig. 57)

In all cases combustion chamber surface finish should be smooth and highly polished to reflect heat back into the chamber and to retard the build-up of carbon related deposits that can cause detonation or run-on.

Having selected the desired compression ratio, chamber volumes should be balanced to within half a c.c. between all cylinders.

Squish - The final compressive shock received by the charge, immediately before the start of combustion.

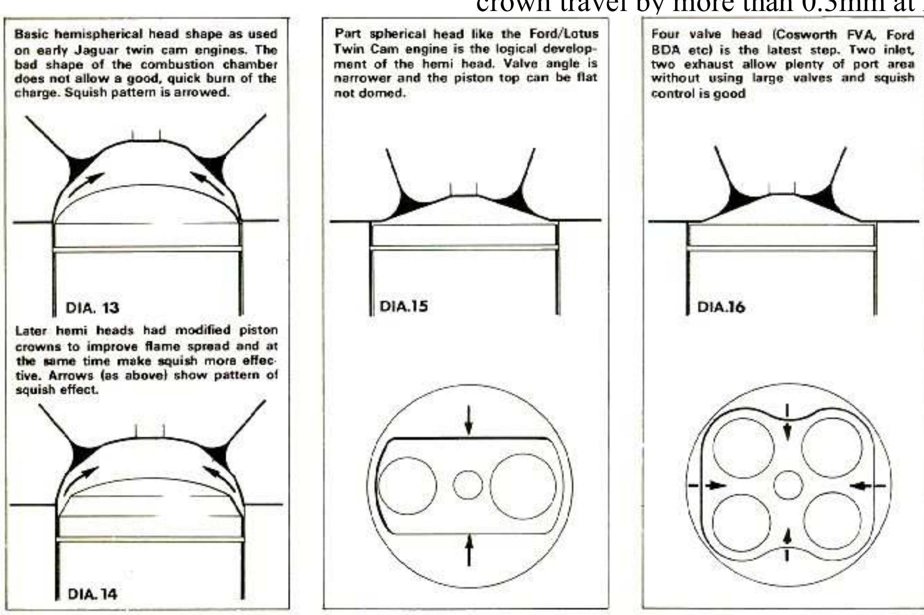


58

Created by close proximity of certain areas of the piston crown to the cylinder face at T.D.C. (Fig. 58), squish is used to drive the compressing charge into the most suitable area for start of combustion.

The squish gap should be as small as is practically possible, and can be as little as 0.5 mm or less, depending on crank and con-rod stretch at high R.P.M.

Remember that the "inertia weight"... that is the effective weight of the piston and connecting rod small end at high engine RPM, is enough to stretch the upper limit of piston crown travel by more than 0.3mm at high speed.



59

Good squish control allows mixture that otherwise may be trapped in the "dead areas" of the combustion chamber, to be driven towards the combustion chamber centre, and closer to the ignition point.

Compression ratio - The ratio of the swept volume of the cylinder to the compressed volume of the cylinder.

Calculated as follows:

$$\text{Compression ratio} = \frac{\text{Swept volume} + \text{Clearance volume}}{\text{Clearance volume}}$$

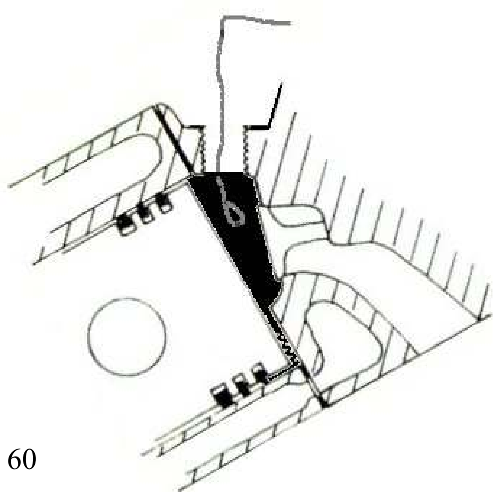
Compression ratios vary from 8 to 1, used for standard engines, up to 12 to 1 for petrol burning race engines and 15 to 1 for alcohol burning race engines.
Compression ratios for two-stroke engines are often calculated using trapped volume above the exhaust port, instead of true swept volume. This means that C.R. varies with exhaust timing and, calculated on this basis, the results are much lower and vary from 7 to 1 up to 9.5 to 1.

Measuring Compression Ratio.
This apparently simple task is often carried out incorrectly, to the considerable detriment of the maximum power output.
If the engine is a twin cam 2 or 4 valve layout, the combustion chamber will usually finish up as a part spherical or pent-roof shape. (Fig. 59)
The piston may have a slight rise on the crown and may also have valve clearance pockets, and the flat area above the top ring land, will probably not reach the top of the bore at TDC.
Cylinder head gaskets will vary in thickness and valve heads will protrude into the chamber.

This complexity of layout often means that the simplest way to check the compression ratio, is to set one cylinder to TDC, smear a thin seal of grease around the top ring land, then build the cylinder head into place in the normal manner and torque it down.

Then, if the spark plug is not upright, tilt the engine until the plug axis is vertical and, using a pipette or measuring cylinder, fill the chamber with water until it is half way up the plug thread.

Remember, when using water as the measuring liquid, to allow for the meniscus curve caused by the surface tension.
That is… always measure to the top or bottom of the curve. It doesn't matter which as long as you are consistent.



60

This should have then fully filled the combustion chamber and allowed for the plug body volume, but just to be sure, use a piece of thin wire to agitate the liquid through the plug hole, to help shift or burst any air bubbles that may still be trapped. (Fig. 60)
This method should give you a fairly accurate measure of the true clearance volume, and of course, the swept volume is the bore area times the stroke.

If you decide to measure the head and block volumes separately, then make sure you allow for the volume of the compressed head gasket as well.

This can typically represent one complete ratio on a "square" bore/stroke ratio 400 c.c. cylinder.

FUELS.
The type of fuel in use obviously heavily influences the combustion process.
As previously mentioned, power is derived from the conversion of heat, and fuel is merely neatly packaged heat.
The amount of heat (and consequently power energy) in a particular type of fuel, is quantified as its' "calorific value".
Just as consumed calories from food, release body heat, so consumed calories from fuel release combustion heat.
One calorie is the amount of heat required to raise one gram of water one degree centigrade.

Straight petrol (gasoline), regardless of octane level, has a calorific value of around 44 KiloJoules/Kg or 19000 British Thermal Units/Lb.
However, in order for a fuel to give out its' maximum energy potential, it must also be resistant to knock.

Knock or detonation is the uncontrolled process of combustion that occurs due to the presence of trapped gas in hotspots.
So although fuel additives don't actually increase a fuels' calorific value, they do enable it to deliver more of its' potential by holding off the onset of knock, thus allowing suitable amounts of spark advance to be used for maximum power.
In effect therefore, the fuel additive is giving an energy or heat conversion boost.
As well as boosting effective heat content by reducing spark advance knock, fuel additives can also enhance the power output of a particular fuel by allowing the use of higher compression ratios.

Table of fuel properties :

	Effective Energy Value	Octane Rating
2 - star pump petrol	80	92
4 - star pump petrol	100	97
Unleaded petrol	95	94
Avgas aviation petrol	110	104
4 - star with fuel booster	108	102
Methanol	118	110
4 - star/Nitromethane	120	100
4 - star/Nitrous Oxide	120	97