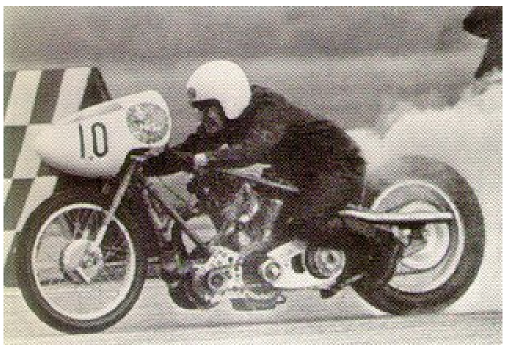
CHAPTER ONE

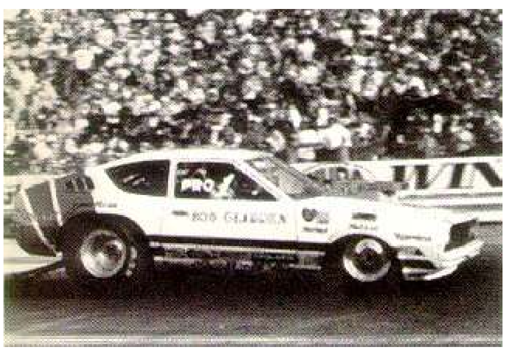
POWER!

Horsepower.... What exactly is it?

Wherever people gather to talk motoring, motorcycling or motor sport of any kind it is only a matter of time before the word ‘power’ comes into the conversation.

But very few people really understand what horsepower is.





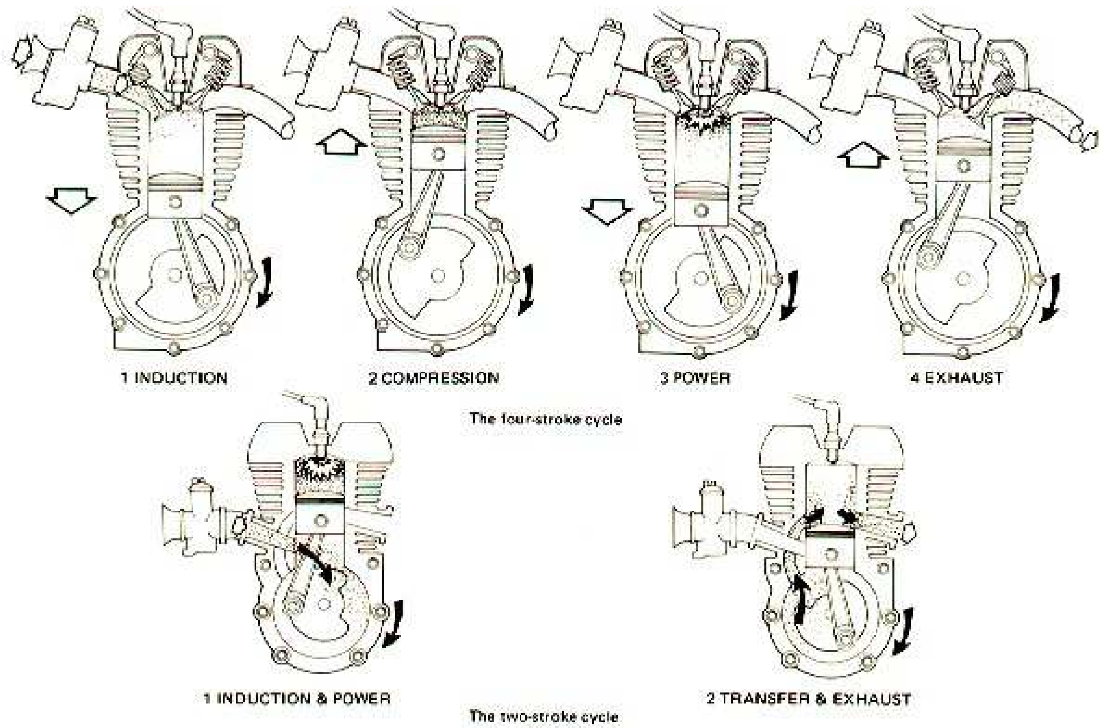
The dictionary definition is....

“A unit to measure the rate of doing work...”
Not a lot of help for someone trying to make crucial decisions on how to tune an engine!

Yet every rider and driver knows the feel of power...
The surge of acceleration as the throttle is opened, the clutch dropped, and suddenly the wheels are spinning - that’s the feel of high power.
Even as you wind back the twist grip of your 50cc moped, it’s power that gets you moving, even though not quite so sexy.

In fact, nothing moves without power - clockwork toys, elastic band propelled pellets, human beings on bicycles, Harrier jump jets... all need power, large or small, to move at all.
A simple falling stone uses motive power from the kinetic energy imparted when someone or something lifts it against the pull of gravity.
So power can also be defined as the result of converting work into movement.
And the internal combustion engine happens to be one of the most convenient ways of producing movement.
All you need to do is pour the fuel in at one end, pull the right knobs and levers... and instant power comes out the other end.
The engine thus converts fuel into movement.

But what exactly, is fuel?
Fuel is neatly packaged heat...
Anything that burns when a match is applied is potentially capable of producing power, in this case petrol/gasoline or methanol.
So the engine is a heat converter and of course this is why, when this subject is studied in college, it is entitled ‘heat engines’.



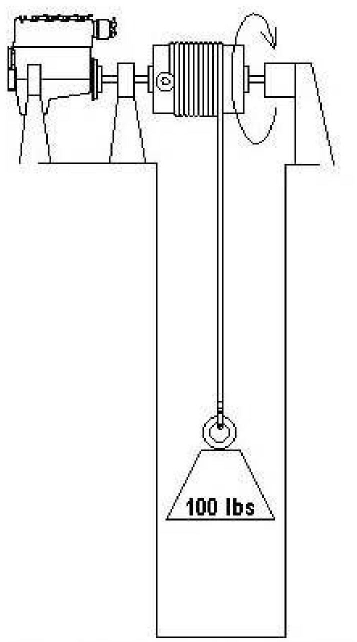
Two stroke or four stroke, one cylinder or sixteen, the conversion process is always carried out in the same way - by drawing in a mixture of fuel and air, compressing it, igniting it and using the resultant combustion to drive a piston or turbine down or round, and rotate a crank.
When the engine converts fuel into power, the process is rather inefficient and only about a quarter of the potential energy in the fuel is released as power at the flywheel. The rest is wasted as heat going down the exhaust and into the air or water.

This ratio of actual to potential power is called the “THERMAL EFFICIENCY”, of the engine.

The machine we use to measure engine performance is a dynamometer and the way in which it works is closely tied to the explanation of power.

MEASURING POWER
The term “Horsepower, was evolved during the 19th century to describe the capability of engines to carry out a measure of work related to the conversion of energy into motion by the horse.
At that time it was a realistic way of comparing mechanical power to “horse power”.
The unit of engine horsepower, which used to be called B.H.P, the abbreviation of Brake Horse Power, is now being replaced with the “Watt”, hitherto used to quantify the power of electric motors and other appliances.
One B.H.P is the equivalent of 746 Watts.
Both of them are a measurement that describes the power that is actually measured at the flywheel.
A dynamometer is not actually capable of showing power as a direct reading, but measures torque

and R.P.M, from which power is calculated.
Engine Data Acquisition Systems are electronic measuring system that captures information from an engine or chassis dynamometer, then automatically calculates the power.
Torque is the amount of work that an engine is actually doing at any given moment, that is, the turning force being exerted at the crankshaft, and is measured in "Foot Pounds, or "Newton Metres", depending on whether you are using the British Imperial or the International Metric System.



Imagine an engine sited at the top of a deep well turning a drum, which is four feet in diameter, i.e. 2 feet radius.
A rope attached to the drum is hanging down the well with a weight of 100 lbs. on the end.
As the engine turns the drum it will lift the weight. The drum is four foot in diameter and the rope is being pulled in at two foot from the centre of rotation; therefore the work being done or torque is measured as 2ft x 100lbs = 200 foot pounds
The speed at which the drum is rotating is measured as Revolutions Per Minute (R.P.M).

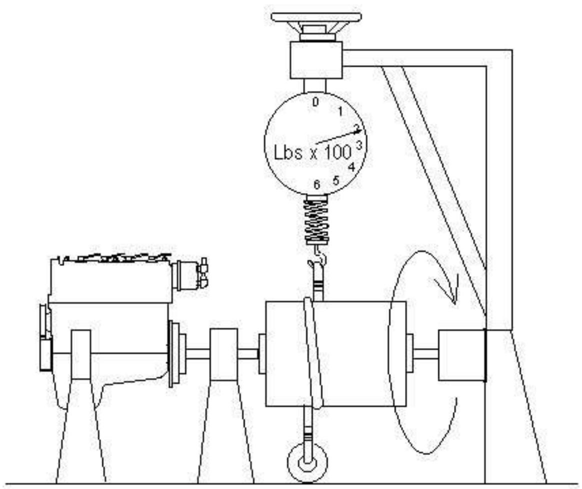
B.H.P is calculated as follows

$$\text{B.H.P} = \frac{\text{TORQUE X R.P.M}}{\text{CONSTANT}}$$

The constant depends on the units of torque, which are being measured. As we are using ft.lbs it will be 5250, so if we say that the engine is turning at 1000 R.P.M then:

$$\text{B.H.P} = \frac{200 \times 1000}{5250} = 38$$

Because we cannot calculate B.H.P without knowing the R.P.M, it means that B.H.P is a measure of the speed at which work is done as previously mentioned, a unit to measure the rate of doing work.



To understand the way in which the dynamometer works, imagine anchoring a spring balance to the ground, with a rope attached to the top eye and wrapped around a drum with a slipknot is tightened as the drum is rotating, the rope will be tensioned and the balance will extend to indicate this tension as a 'weight'. As the knot is further tightened, friction between rope and drum will slow the drum and its driving engine until, at 1000 R.P.M, the spring balance reads 100 lbs.

The weight being lifted is 100 lbs and the speed of the drum or engine will then be used in the formula to calculate the horsepower. If the speed of the engine/drum were 1000 R.P.M the B.H.P being exerted would be 38. If the speed were 1500 R.P.M this would mean the engine was lifting the weight faster and exerting more power to do it. The calculation would then be:

$$\frac{200 \times 1500}{5250} = 57 \text{ B.H.P}$$

THE DYNAMOMETER

So a piece of rope, a spring balance, a rev counter and an engine fitted with a flywheel or drum to take the rope is all you need to make a dynamometer…

Well, yes… but! if the throttle is wide open and nothing is moving where is all the power going?

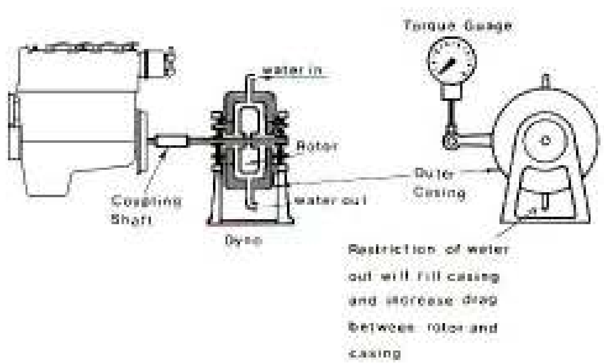
The answer is, that it's turning back into heat again.

Where?

You've guessed it! Between the drum and the rope - as friction.

So although the idea of a cheap dyno sounds good, in fact the power being used, turning into friction heat, would set fire to the whole lot.

Unless, of course, we cool it by pouring water over it, and that's just what the modern dynamometer does.



It uses a device like the torque - converter of an automatic transmission to do the job of the rope and drum and is running in a continuous flow of cooled water to absorb the heat.

The engine turns the inner part of the torque - converter and the water drag thus created tries to turn the outer casing, which is coupled to a big accurate weighing machine reading torque.

Now that we understand the meaning of power and how to measure it just how important is it?

Does an increase in power automatically mean higher speeds?

Not necessarily… power is only of value when applied with suitable engineering skill. Smooth, controllable power will often return better results than ultimate B.H.P peaking over a narrow rev band. This is often the secret behind the out-performance of many smaller racing machines over their more powerful contemporaries.

WHAT CONTROLS POWER?

HOW CAN IT BE IMPROVED?

An engine very much like a human being. It takes in air and fuel(food).

It burns the fuel (digestion). It converts the energy released into power (muscles).

Discharge of exhaust (bowels). Oil pump and circulation (heart).

Cooling system (pores). Pistons and cylinders (lungs).

The camshaft (brain) coordinates of the whole sequence of operations in the same way as the brain.

The efficiency of these individual functions effects engine performance in the same way they would affect a human.

Poor or contaminated fuel will have low energy content.

Bad ignition or combustion chamber shapes will reduce the ability to digest the fuel fully, resulting in an unpleasant and dirty exhaust.

Clogged or inadequate oil filters or a worn oil pump will result in component failure.

A dirty cooling system with clogged radiator pores will result in overheating.

A poorly designed camshaft will result in erratic breathing.

They all work together to produce the final flywheel muscle power, however good or bad.

To understand the process we'll start with the breathing cycle.
If we think of the engine as an air pump then theoretically it should draw in and exhaust its own volume of air each time it cycles - that is, once every revolution if it's a two stroke and once every two revolutions if its a four stroke. In fact, ordinary production engines don't achieve this and only manage to shift about 80% of their volume.

This ratio of possible air pumped to actual air pumped is called Volumetric Efficiency and this is what we have to improve to get more power. The difference in appearance between two engines of similar type, one of which is in standard road trim and one in full race trim can be seen on the left.

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Fig.11 is a standard street Honda 750 four and Fig.12 is a full race version of the same model. The noticeable external differences in the engine preparations are to increase the VOLUMETRIC EFFICIENCY.

Volumetric Efficiency = Breathing Ability = Power

A chain of parts controls the breathing cycle, each one of which depends on the others to work at it’s best.

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The process starts right back at the air cleaner which varies from being a large box containing a large paper filtration and silencing element, necessary for silent operation and engine protection under a variety of dusty and sandy conditions, through to the light and minimal filters of rally cars and speedway bikes, to the completely open bell mouths of full circuit drag machines.

The next link in the chain is carburetion. The process of mixing the fuel and air and feeding them to the engine in balanced doses, that is about fifteen times as much air as fuel.

Fifteen to one - air fuel/ratio - another important controller in a final power output!

Although we call it ‘carburetion’, here it can also include fuel- injection, just another method of delivering fuel to the engine.

So, via inlet manifolds or stubs we move to the next link and here it is where the two stroke and four stroke engines divide.

FOUR STROKE | TWO STROKE

AIR BOX OR CLEANER

RAM - PIPE

CARBURETTOR

FUEL - INJECTION

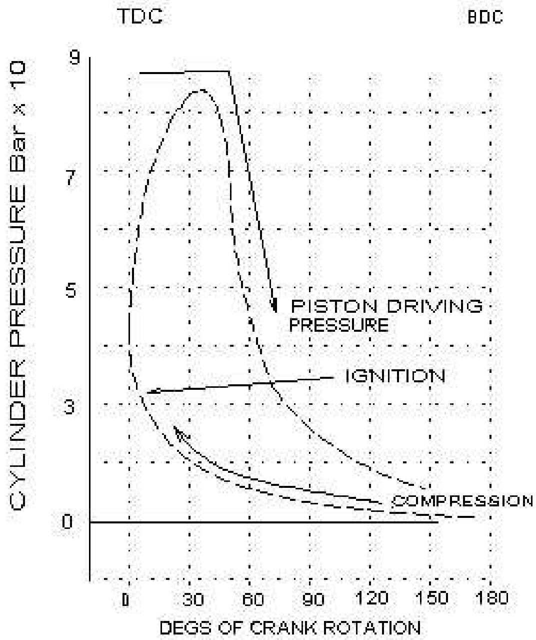
INLET MANIFOLD

FOUR STROKE	TWO STROKE
CYLINDER HEAD	CRANK CASE
PORTING	PISTON VALVE
INLET VALVE	PISTON SUPERCHARGER
CAMSHAFT	TRANSFER TIMING

COMBUSTION

FOUR STROKE	TWO STROKE
EXHAUST VALVE	EXHAUST PORT TIMING
SIMPLE PARALLEL PIPE EXHAUST SYSTEM COUPLED WITH MULTI CYLINDER ENGINES	COMPLEX MULTI-TAPER SYSTEM ONLY COUPLED WITH 3 CYLINDERS
POSSIBILY A SIMPLE MEGAPHONE	EXPANSION CHAMBER, REVERSE CONE RESTRICTIVE TAIL PIPE
150+ BHP / LITRE	200 BHP / LITRE

The four-stroke chain of power

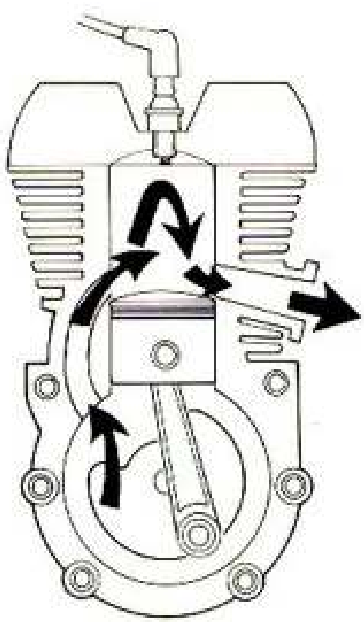


The mixture enters the cylinder head and is induced through the inlet valve into the combustion chamber. The way in which it enters the chamber is controlled by the port shape and finish inlet valve timing, which in turn is controlled by the camshaft.

The camshaft is probably the most important single component in the four stroke engine, as far as power production is concerned, and it is certainly the most complicated piece to design and produce (P.17).

Compression takes place followed by ignition and combustion - the point at which four- and two-stroke reunite in a common process.

Exhaust in a four-stroke engine is again first controlled by the camshaft operating the exhaust valve, and then by the design of the port and the exhaust system, which in turn, has a considerable effect on exhaust efficiency (P.18).



The two-stroke chain of power.

There are several ways in which the two-stroke engine will work but we will consider the modern loop-scavenge design, which is the most commonly used production version. (Fig.19)

As the piston rises, a depression is created in the crankcase and the mixture is drawn in at the point where the piston skirt starts to uncover the inlet point. As the piston comes down, the inlet port is closed and the charge is compressed and driven up the transfer port into the combustion chamber. Because the mixture is being forced into the chamber under pressure, this is really a form of supercharging and is one of the reasons that this type of engine can produce so much power relative to its size.

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As the piston rises again, compression takes place, followed by ignition and combustion, driving the piston down which opens the exhaust port and drives a new charge into the combustion chamber at the same time. Because these two happen together, the design of the transfer port and the exhaust system must be just right in order to clear the foul gases and ensure a full charge of new mixture without wasting any down the exhaust port.

Although the two designs appear to be very different, the overall function of both is the same - fuel into power, the level of which is governed by volumetric efficiency.

The significant part of the power train chart is the point where the two engines coincide at combustion. The key to high power output is fast, controlled, near total burning of the compressed mixture. This key is common to all types of internal combustion engine and is dependant on all the parts around it.

Next we’ll start to look at those parts in detail.