General V-Twin Motor Information

Definitions

1 ~ Thermal Efficiency: Ratio of "heat produced" to "heat that produces work"

2 ~ Volumetric Efficiency: Ratio of "the amount of actual air/fuel mixture in a cylinder" to "the amount of air/fuel mixture the cylinder can hold at 100% fill"

3 ~ Mechanical Efficiency: Ratio of "power produced" to "power actually doing work"

4 ~ Combustion Efficiency: Ratio of "air/fuel mixture actually burned in a cylinder" to "air/fuel mixture in a cylinder available to be burned"

Altitude (elevation)

Altitude directly affects engine power. As elevation increases, air density decreases, which means there is less oxygen available to support the combustion of fuel. Thus, Less air = Less horsepower, or, the higher you go, the slower you go........a classic case of running out of breath.

Air Filters, Carburetors & Jetting

Harley's late model air filters do a good job of filtering in-coming air and silencing intake noise, but they restrict air flow. A free-flowing air filter will allow a V-Twin to pass more air for improved combustion. Flow bench tests have shown that the H-D Screaming Eagle air filter is capable of flowing all the air that a stock CV carburetor can flow. S & S also has an efficient air filter and there are many others available to suit individual taste. Due to the passage of more air, the installation of a free-flowing air filter may cause the air/fuel ratio to become "lean" (too much air for the amount of gas that the carburetor meters into the engine) which means that jetting adjustments should be made to the carburetor.

Changing the carburetor jetting is not difficult but it does require some tuning experience for accurate dial-in. Proper jetting can transform an average, sluggish engine into a highly responsive powerplant that if a real delight to ride. The sad truth, however, is that the majority of bikes on the road today are not properly jetted, especially factory-stock bikes. In the case of late models, this is not the fault of Harley-Davidson, but rather the E.P.A. who mandates very strict emission controls.

For maximum power, the proper air/fuel ratio for normal engine operation is between 13:1 and 14:1. This is slightly rich and is not the "stoichiometric" ratio 14.7:1 (ideal chemical mix). The "ideal chemical mix" does not produce max power in most engines. The ratio simply means that every 1 part of gas requires 13 or 14 parts of air for optimal combustion. More than 14 parts of air results in lean mixtures and less than 14 parts of air results in rich mixtures. Newer engines that spit, cough, hesitate and backfire through the carburetor are suffering from "EPA" jet settings.

Most late-model Evo Harleys are factory-equipped with CV (Constant Velocity) carburetors that are adequate for normal street operation and for mildly hopped-up engines, but major horsepower increases require changing to a higher capacity carburetor. For example, if you add a "hotter" cam, have the heads "ported" for increased flow and add an efficient exhaust system, the factory carburetor may bottleneck air flow and limit the power gains that the modifications could produce. All components must work in harmony for optimal power output. Conversely, if you just add a larger carburetor to a stock engine, there will be little, if any, power gain because stock heads don't flow well enough to measurably benefit from the carburetor's higher flow capacity (certain Buell models are exceptions).

The carburetor must be "matched" with the engine's air flow abilities. Engine air flow velocity is equally important with air flow volume. The flow velocity must be as high as possible for re sponsive torque at low-to-mid rpm while the flow volume must be sufficient to supply the engine with all of the air it needs to attain maximum high-rpm power (these two flow factors are at odds with one another and cause design compromises). In other words, the size of the carburetor venturi, or opening, must be large enough to flow the required volume without causing low flow velocity. This also applies to the intake manifold, both head ports, valves, combustion chamber and the exhaust system. They all must function in harmony for optimal power throughout the powerband (the engine's operational rpm range). Regardless of the flow volume, if flow velocity drops below a critical level, throttle response and torque will suffer.

Any biker of modest experience who is contemplating a carburetor change is urged to carefully research the available options before taking a plunge that might result in disappointing performance. For power purposes, a carburetor should not be selected on the basis of cool appearance, slick advertising or as a mimic of another bike. Many bike professionals will share their experience with others just for the asking. Enlightened decisions equal desired results.

Bore & Stroke

Harley V-Twin engines are undersquare by design. "Undersquare" implies that the piston stroke is larger than the bore diameter. By contrast, high-revving Japanese four cylinder engines often have an oversquare bore and stroke relationship (the bore is larger than the stroke). If bore and stroke are the same, the engine is said to be square. Oversquare engines rev higher than undersquare engines and they can make impressive horsepower at top rpm. Undersquare engines produce strong torque at low to mid range rpm's because of the "leverage" advantage of a longer stroke. This longer stroke, however, increases piston speed per engine cycle, causes greater side-loads on the cylinder walls and decreases maximum rpm's. V-twin engine displacement can be increased by a bigger bore, a longer stroke or a combination of both for *really* BIG cubic inches. If you are a torque devotee, increase your stroke. If you are a horsepower (rpm) junkie, increase your bore. If you believe that too much power is just the right amount, you can increase both!

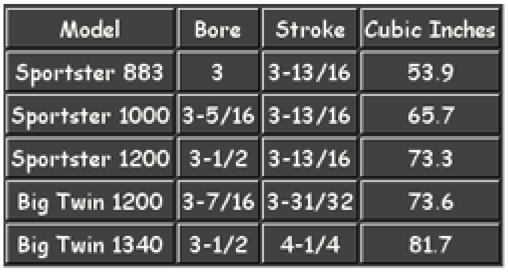
V-twins with factory aluminum cylinders have steel cylinder/head bolts. Steel and aluminum have different thermal expansion properties and this trait causes the cylinders to elongate more at operating temperatures than the steel bolts that hold them in place. The net effect of this design is that, when the engine reaches operating temperature, the cylinders are squeezed by the bolts and distort out-of-round, resulting in some loss of ring seal, and therefore, loss of power due to compression/combustion blow-by. This problem can be largely corrected by the use of aftermarket cylinders made of heavier cast iron (Axtell) which are stiff and have expansion properties closer to the steel bolts, or reinforced aluminum cylinders (S&S and Sputhe) which are more rigid than factory cylinders and have better resistance to distortion. These brands of cylinders, and others, can also increase engine displacement since they are available in larger bore sizes.

V-twins built for racing must sometimes rev beyond 7,000 rpm to be competitive, but they are also frequently rebuilt, a scenario that few street riders would tolerate. The razor-edge life span of a race engine can be very brief indeed. By comparison, a properly modified and tuned V-twin can have excellent street longevity if it is not flogged by lugging or over-revving. The practical (safe) rev limit varies with different V-twins depending on engine configuration, particularly stroke length. For example: An Evo Sportster of stock-stroke will experience extreme wear on the crank pin and other stressed components when revved beyond 6,800 - 7,000 rpm.

The added torque of a stroked engine makes it tons of fun to ride, and if that's what you want, more power to you (pun intended). But, there are other viable approaches to high power that yield greater longevity and efficiency. Veteran bikers often quote an old hot rod adage....."There is no substitute for cubic inches." and there is truth in the saying. On this page, however, that adage is amended to read "There is no substitute for cubic inches, except more efficiency."

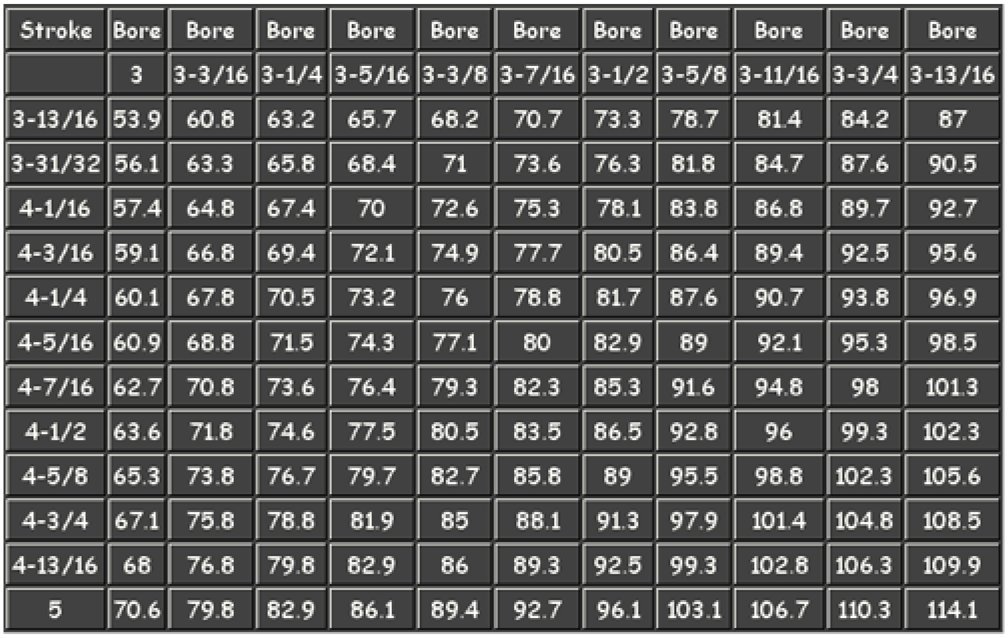
If you increase your bore size for "more horsepower", keep in mind that horsepower is not proportional with displacement. Horsepower is proportional with air flow volume. Factory Evo heads have marginal flow ability even with the stock bore and stroke. Therefore, an excellent reason to increase bore size is to allow the use of a larger combustion chamber that can accommodate larger valves, which in turn, can flow more air/fuel mixture for greater volumetric efficiency.

Factory Displacement



Model	Bore	Stroke	Cubic Inches
Sportster 883	3	3-13/16	53.9
Sportster 1000	3-5/16	3-13/16	65.7
Sportster 1200	3-1/2	3-13/16	73.3
Big Twin 1200	3-7/16	3-31/32	73.6
Big Twin 1340	3-1/2	4-1/4	81.7

Other Displacement Combinations



Stroke	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore
	3	3-3/16	3-1/4	3-5/16	3-3/8	3-7/16	3-1/2	3-5/8	3-11/16	3-3/4	3-13/16
3-13/16	53.9	60.8	63.2	65.7	68.2	70.7	73.3	78.7	81.4	84.2	87
3-31/32	56.1	63.3	65.8	68.4	71	73.6	76.3	81.8	84.7	87.6	90.5
4-1/16	57.4	64.8	67.4	70	72.6	75.3	78.1	83.8	86.8	89.7	92.7
4-3/16	59.1	66.8	69.4	72.1	74.9	77.7	80.5	86.4	89.4	92.5	95.6
4-1/4	60.1	67.8	70.5	73.2	76	78.8	81.7	87.6	90.7	93.8	96.9
4-5/16	60.9	68.8	71.5	74.3	77.1	80	82.9	89	92.1	95.3	98.5
4-7/16	62.7	70.8	73.6	76.4	79.3	82.3	85.3	91.6	94.8	98	101.3
4-1/2	63.6	71.8	74.6	77.5	80.5	83.5	86.5	92.8	96	99.3	102.3
4-5/8	65.3	73.8	76.7	79.7	82.7	85.8	89	95.5	98.8	102.3	105.6
4-3/4	67.1	75.8	78.8	81.9	85	88.1	91.3	97.9	101.4	104.8	108.5
4-13/16	68	76.8	79.8	82.9	86	89.3	92.5	99.3	102.8	106.3	109.9
5	70.6	79.8	82.9	86.1	89.4	92.7	96.1	103.1	106.7	110.3	114.1

Engine Displacement = bore X bore X .7854 X stroke X 2 (no. of cyl.)

Cubic Centimeters = cubic inches X 16.39

Cubic Inches = cubic centimeters / 16.39

Camshafts

The whole point of an engine is to produce power by getting a measured amount of external air, mixed with a fine spray of fuel, into the combustion chamber and keep it there long enough for controlled ignition. Four-stroke engines achieve this feat by their reciprocating piston movement through the four cycles of intake , compression , power and exhaust . Camshafts open and close the intake and exhaust valves during this cyclical process and determine the timing of each valve event. A V-twin valve train assembly consists of a camshaft(S), lifters, pushrods, rocker arms, valves, valve springs and valve spring retainers (keepers). Camshaft designs range from mild to wild and they determine the running characteristics and nature of an engine. The standard factory cams are very mild in terms of peak power but they provide a broad (torquey) powerband. Evolution 1200 and 1340 engines make roughly 50 H.P. from the factory (excluding California models and 883's which make closer to 40) and many bikers simply *need* more power, particularly heavy riders who carry passengers. But most of us probably want more power for the sheer rush of white-knuckle acceleration! It is very addictive.

Many people tend to "over-cam" their engines. By that, I mean that the chosen cam is too racy for the rest of the engine which almost always causes disappointing performance at low-to-mid range rpm's. For example, if an otherwise stock engine is modified with straight drag pipes and a racy cam, the engine response below 4,000 rpm's will be very flat as many bikers have sadly discovered. It may have a brief horsepower "hit" at high rpm but getting to high rpm may be a challenge in itself. One reason for this torque loss is the reduction of cranking compression due to the racy cam's longer valve duration which lets air/fuel charge escape the cylinder and then........adios torque! For street use at normal rpm's, a conservative cam choice is more practical than a radical top-end cam and it will often out-perform a hotter cam because of it's superior powerband. The subjects of camshafts and valve timing are deep ones. Too deep, in fact, for thorough discussion within the space available for this page. There are some excellent books on the subject available through most motorcycle magazines and a visit to the Comp Cams web site may also be helpful.

Several reputable cam brands such as Andrews, Red Shift, Crane, Sifton, V-Thunder and others, offer cams and related valve-train gear for virtually any application and they can help you select an appropriate grind for your purposes.

Cooling & Lubrication

V-Twin engines are designed for external air-cooling and internal oil-cooling. One feature of this scheme is that the front cylinder tends to run cooler than the rear cylinder because it receives more cooling air flow when the bike is moving. Air cooled engines span a range of operating temperatures due to state of tune, riding style and ambient air temperatures. Clearly, a V-Twin powerplant will run cooler in a Chicago winter than in a Florida winter, and that's okay as long as it is running within the *proper* temperature zone. It is wise to patiently warm-up a cold engine to allow all working metal parts to expand to their proper fit with one another since racing a cold engine dramatically increases wear and causes premature rebuilds.

There are several aftermarket oil coolers available that lower the average engine operating temperature by 20 degrees or more which is desirable for summer operation, especially in southerly climates. When oil reaches a critical temperature, it breaks-down and loses it's lubricating qualities. Much debate continues about the use of synthetic oils that have a higher resistance to thermal decomposition than petroleum-based oils, but, there are numerous high-powered Harleys that enjoy excellent longevity using synthetics. The synthetic oils tend to be "slicker" than petrol-oils and they should not be used during engine break-in or the moving parts may not seat properly. Also, proper oil levels should not be exceeded or problems may occur with blown gaskets and excessive seepage from engine breathers.

V-twin engines are pressure-driven devices that are sometimes referred to as heat pumps. Of all the heat produced from combustion, approximately 1/3 goes out the exhaust, 1/3 is dissipated through cooling and the remaining 1/3 is used to overcome friction and produce mechanical power. These percentages make it very clear that there is plenty of room for improved thermal efficiency.

Exhaust

Harley engines are "bottle-necked" by their factory exhaust pipes to comply with EPA emission requirements. Fortunately, this flow restriction can be improved by replacing the factory system with aftermarket pipes and there are hundreds to choose among for various applications.

Unmuffled "drag pipes" are commonly seen on street Harleys, and although tuned drag pipes of proper diameter and length are lightweight and work for maximum power at high rpm, they present some problems for street use. Most street riders use drag pipes for their clean appearance and wicked exhaust sound. Ah, that sound .... music to the ears. Terrific, if that's what you want, and although a loud exhaust may be offensive to some people, loud pipes do add a measure of safety for street riders by alerting zombie cage (auto) drivers to their presence. The bad news is that, all other things being equal, drag pipes cause a significant loss of torque at low-to-mid rpm. If you replace the factory 2-into-2 pipes (and crossover pipe) with drag pipes, you may have a few more horsepower at high RPM, but you will lose measurable power (torque) at lower rpm where it is most often needed. This begs the question - How often do you ride above 4,000 rpm?

Many bikers and mechanics talk about having "proper back pressure" as though the term possessed some mystical significance that only a few engine wizards understand. As it is commonly understood, back pressure is an ambiguous, rhetorical misnomer that only confuses the complexities of exhaust theory. Assuming that an exhaust system has sufficient chamber volume (small mufflers do not have sufficient chamber volume), it is the control of reversion waves and flow velocity within the system that is important for efficient flow. Presumably, this is what so many people call back-pressure.

Exhaust theory arises from the physics of wave dynamics.

Briefly stated, the main objective of a performance exhaust design is, or should be, to reduce engine pumping losses . Strictly speaking, an exhaust system, in and of itself, can not create more engine power (more fuel must be introduced and burned for more power). An exhaust system of proper design increases efficiency by freeing power that is otherwise lost to flow restrictions (pumping losses). It accomplishes this by scavenging spent combustion gases and (ideally) by contributing to the laminar (ordered) movement of all flow events starting at the air intake, through the head, and ending at the exhaust discharge. When the exhaust valve opens, two things enter the head pipe - pressure waves expanding at supersonic speeds and the burned combustion gases which move somewhat less rapidly. These pressure waves can be likened to the concussive shock waves seen spreading outward, from the center of an explosion, or like the concentric waves caused by a pebble thrown into calm water, only much faster.

The escaping pressure waves move into the exhaust chamber (diffuser or megaphone) and are reflected off of it's inside walls, baffles and/or ambient atmospheric pressure as reversion (reversed) waves. Some of these waves will reflect all the way back to the still-open exhaust valve, and depending upon the timing of their arrival at the valve, they either help flow or impede flow.....this is where the exhaust designer's skill is tested.

The savvy designer can tune the timing of reversion wave arrival at the open exhaust valve by manipulating the effects of wave cancellation, wave resonance, head pipe diameter and length, diffuser shape and other system variables, to result in an engine that is effectively "suck-charged" (no jokes please) at a specific rpm range! This technique, along with similar intake track tuning, makes it is possible to "ram" up to 25%(+/-) more air/fuel mixture into the cylinder than the chamber volume would normally hold. When an engine enters this tuned rpm range, the increased flow efficiency can be felt as a definitive surge of power and is often referred to as being "on the pipe". However, even the best exhaust design is a compromise that yields optimal power only across a narrow rpm range, usually at high rpm's, but not at all rpm's. For the widest powerband, some of the 2 into 1 collector pipes that are available represent an acceptable compromise of pipe design by retaining reasonable low rpm power without restricting high rpm power. Also, for the record, exhaust loudness does not necessarily equate with engine power.

So, how do you choose the best pipes for your purposes? Unless you are prepared to endure the time and expense of empirical dyno-testing, the best answer you will find here is.......research and/or trial and error. Even published exhaust tests on dynamometers can be misleading unless performed on an engine identical with yours.....same heads and/or head mods, same pistons, same cam(s), same air filter and carb, etc. Very tiny mechanical differences can have very large effects upon flow efficiency. This is not meant to discourage anyone who is pondering pipe selection but exhaust theory is rather convoluted and, because of that, a challenging issue.

Fuels, Octane, Pre-ignition & Detonation

High-octane or premium gas burns slower than low-octane gas (regular gas). Therefore, combustion is slowed with premium gas. Slower combustion can prevent pre-ignition, or "pinging". Pre-ignition is ignition of the fuel/air mixture before the spark plug fires. The ping of pre-ignition sounds like marbles bouncing around inside the engine. The term "pre-ignition" is sometimes incorrectly used interchangeably with "detonation". The death rattle of detonation is an erratic and intense pressure wave that occurs shortly after TDC (top dead center) of the power stroke. When the air/fuel mixture is ignited by the spark plug, a combustion flame front spreads outward from the plug accompanied by pressure waves created by the combustion. Detonation is caused by the amplification of two pressure waves combining to form an intense wave "spike", which then bounces around the combustion chamber surfaces, causing very-high temperature spots that ignite a second flame front. The "knocking" sound of detonation results from this secondary ignition and it's pressure waves which greatly shock-stresses pistons, piston lands, rods, crank and bearings. Schlieren photography of Harley combustion chambers during actual engine operation has revealed that detonation is not the result of "colliding flame fronts" as some believe. Most everyone does agree, however, that severe detonation will quickly destroy an engine.

The octane rating system used in the USA is RON + MON/2, where RON is the Research Octane Number, and MON is the Motor Octane Number. The ratings are determined on a dynamometer for a particular fuel. The RON dyno test is done without a load on the motor, and the MON dyno test is done with a load on the motor. The two results are then summed and divided by 2 to determine the rating of the gas which is displayed at the gas pumps.

An engine's octane needs are influenced by several factors, especially the configuration of the engine (state of mechanical tune, i.e. - cranking pressure, valve timing, ignition timing, operating temperature, plug heat range, carbon deposits, etc.) and each engine has it's own distinct octane requirements for optimum operation. For example: If your engine only needs 89 octane to run properly without pre-ignition, the use of 91 octane will not increase performance! Conversely, the use of 87 octane, when 89 is needed, will result in preignition, overheating and poor performance. Once you have established the actual octane needs of your particular engine for ping-free operation, the use of higher octane gas is only wasted money!

Gearing Equation

MPH = rpm X rear wheel radius / [final gear ratio X 168]

RPM = mph X final gear ratio X 168 / rear wheel radius

Final Gear Ratio = rpm X rear wheel radius / [mph X 168]

Rear Wheel Radius = mph X final gear ratio X 168 / rpm

Note: For rear wheel radius measurements, the tire pressure should be correct and the rider's full weight should be on the seat. Tire expansion caused by heat and centrifugal forces at high speeds will cause a slight error in the accuracy of these formulas.

Heads

Heads make or break an engine. A head must pass the air/fuel mixture into the cylinders, accommodate spark plugs and reciprocating valve parts, contain combustion, pass the exhaust out of the cylinders and transfer heat away from the engine (and most people want them to look good too)........no small task. During the last few decades, more work has been focused on head development than any other aspect of the Harley engine. Why? Because that's where the greatest power limitations and potential exist.

A reality, and limitation, of the V-Twin engine is that maximum horsepower is directly dependent upon the volume of air that flows through the engine (excluding the use of oxygen-bearing nitromethane and/or nitrous oxide). This fact means that, a 883cc engine that can flow a maximum of "X" amount of air, can theoretically make as much peak horsepower as a 1340cc engine that flows the same amount of air. These two hypothetical engines would have very different running characteristics, but they would share the same approximate power potential. Some people resist this concept but it is none-the-less true. Swift sleds have efficient heads.

The main flow impediment to Evolution heads is valve "shrouding". When an Evo valve is lifted from it's seat into the combustion chamber, part of the area around the valve opening is restricted, or shrouded, by head material that interferes with air/fuel flow. This is because the combustion chamber shape is not large enough to unshroud the valves and the result is intake flow turbulence. Paradoxically, air/fuel turbulence inside the combustion chamber is desirable and promotes a good burn due to better vaporization of the fuel. Head-porting to the rescue.....!

Porting is the reshaping of the intake and exhaust passages for improved flow. The art of porting is a skill possessed by few and sought by many. The success or failure of porting work is usually measured on a flow bench and flow results are expressed in C.F.M. (cubic feet per minute). Porting is not for the novice engine builder. Taking a die grinder in hand and arbitrarily enlarging the intake and exhaust ports rarely produces the desired power gains! Modifying a port for improved flow is a delicate balance of flow velocity and volume, the two traits being mutually opposed. The flow velocity must be as high as possible for responsive torque at low-to-mid rpm while the flow volume must be sufficient to supply the engine with all of the air/fuel mixture it needs to attain maximum high-rpm power. Attaining adequate laminar flow volume while maintaining high flow velocity across the rpm spectrum is the trick that results in a proper flow curve and broad powerband.

The issue of port polishing often stirs considerable debate among bikers. One school of thought maintains that fully polished ports present less resistance to the flow of air/fuel mixture and exhaust gasses. Another school of thought favors polishing the intake ports only to a satin finish and fully polishing the exhaust ports to a mirror finish. A side benefit of mirror-smooth exhaust ports is greater resistance to carbon deposits. The latter of the two, satin intake and polished exhaust, is preferred by many professionals. In reality, port contour is more important to flow than mirror finishes.

The wizards of porting - Dave Mackie, Jerry Branch, Dan Fitzmaurice, Carl Morrow and others, offer ported heads that are profound improvements over mass-produced factory heads, and there are new, redesigned heads available from the likes of S&S, STD, Hemi-Designs, Pro-One, Patrick Racing, Edelbrock, etc. (sorry, I can't list everybody in the head business). Before you spend your money, just remember that even these advanced heads won't perform to their potential if they are not coupled with compatible cams, pistons, carburetors and other engine components. Each of these brands have serious investments in research and they know what works with their products and what doesn't. Talk to them and compare. Randomly mixing unproven combinations of engine parts universally causes unpredictable effects unless you really know what you're doing.

Ignitions, Timing & Spark Plugs

The job of the ignition system is to "light the fire" of gasses within the combustion chambers at the proper time. This can be accomplished mechanically, electronically or by a combination of both. When the factory double-output coil discharges, it fires both spark plugs at the same time which results in wasted spark energy going to a cylinder that is not yet ready for ignition. This "double-fire" design contributes to idle roughness and carburetor backfiring but apparently does little harm to the engine. Replacing the double-fire setup with a "single fire" ignition can smooth engine idle and improve low-speed throttle response but dyno tests indicate little, if any, horsepower advantage from doing so.

Some people have a second spark plug hole machined into each engine head which requires an aftermarket ignition system for firing four plugs instead of two. This practice began on pre-Evo engines as a solution for detonation problems and is still extensively used, especially on high-performance machines. The potential benefits of dual spark plugs depends upon the configuration of the pistons and combustion chambers. Engines with high-dome pistons respond well to dual plugs because, near TDC, the piston dome tends to separate the mixture charge, part of which, may not ignite at the proper time from a single plug.

The optimal settings for ignition timing and advance curves are passionate subjects among tuners. Due to the multitude of variables involved, dyno-testing is the most effective method of determining ideal timing and advance curves for a particular engine. The word "curve" is inexact and not actually a smooth curve, but rather a stepped slope comprised of several sequential timing increments.

Spark plugs must be of the correct length, heat range and end-gap. The ceramic insulator that surrounds the center electrode collects combustion by-products that have color and shape. "Reading" the color and type of these deposits can reveal a cylinder's operating conditions for tuning and other diagnostic purposes. Black, sooty deposits indicate air/fuel mixture richness. Whitish or very light gray deposits suggest leanness. A light beige color indicates optimal air/fuel mixture. If plugs are wet and smell of gasoline, the engine is probably flooded. If they are oily, there may be bad rings or leaky valve seals. If the plug heat range is too hot, the electrode tip may be partially burned away and may be accompanied by preignition or detonation. If they are too cold, they will foul easily and may make the engine hard to start. When plug-reading is mastered, some of the mystery of tuning is revealed. Spark plug color charts are often available at auto supply houses and such charts can ease the rigors of tuning.

Spark plug wires should not be overlooked in the search for power. The high-tension wires installed by the factory are prone to electrical leakage and can be easily replaced with higher capacity wires of less resistance and greater insulation. The factory coil is also less-than-stellar in terms of discharge voltage and can likewise be replaced with a high-energy coil(s) of 30,000+ volts to assure hot sparks for ignition. Once the resistance of the spark plug gap is overcome by the coil's discharged voltage, the propagation, or duration, of the electrical arc requires substantially less voltage. This is because the arc is a plasma of ionized particles with less electrical resistance.

Nitrous Oxide (N2O)

The use of a nitrous oxide injection system is one method of increasing power by 30% or more, depending on how it is setup. For street use on late model bikes with factory lower ends (pistons, crank, rods, etc.), a 30% power boost should not over-stress the engine too much if reasonable rpm limits are observed. Nitrous comes in two flavors, U.S.P. for medical use and Nitrous Plus for "off road" engine use. Many speed shops keep Nitrous Plus in stock for refills, but be aware that, if you are tempted to "cop a high" by breathing nitrous, it contains a nasty toxin (sulfur dioxide) that is specifically added to discourage such use. Put it in your engine, not your lungs.

Nitrous oxide is an oxygen-bearing compound, or oxidizer, that allows additional fuel to be burned during combustion. That "additional" fuel must be injected along with the nitrous or the engine will become dangerously lean and may self-destruct. Several kits are available with varying bike-sized nitrous storage tanks and most systems use a button on the handlebar to actuate a quick dose of extra horsepower. Refills can be a hassle, however, and certain carburetor and/or intake manifold modifications have to be made during installation to accommodate the injection of more fuel. Unless you have competent mechanical and tuning skills, the setup of a nitrous system should be done by professionals.

Nitrous tanks should be mounted in a location where they are protected from rupturing if the bike goes down (the sudden release of a nitrous cylinder pressurized to 1,000 PSI could greatly complicate an accident). Most bikes are short on such space, but, if possible, the container should be mounted on the inside of a frame tube or other protected location.

Once installed and dialed-in, a nitrous bike can be a strong street machine, capable of surprising bursts of acceleration, especially if it is equipped with a hot ignition, a free-flowing air filter and an efficient exhaust system. But, it is not quite a Ninja-killer yet. That requires internal engine modifications but it can be done and still retain street reliability. It's mostly a matter of dollars..... like the speed shop sign says, *"We sell horsepower, how many do you* *want?"*

Pistons & Rods

Because of the inherently long stroke of a Harley engine, it's piston speed is unusually high for any given rpm. It must simply travel farther per engine cycle due to it's undersquare bore/stroke relationship. In spite of this disadvantage, good engine longevity is common on well-maintained bikes which is a testament to factory lower-end components but there are limits to how much loading the stock pistons, rods and crank can withstand. Consider this for example: The loads on connecting rods do not increase in a linear fashion with rpm. Connecting rod loads increase at the *square* of their velocity! This fact is a compelling reason not to over-rev. When power levels get up around the 95 HP region (which means high rpm's), it is time for forged pistons (as opposed to cast pistons), heavy-duty rods and precision crank blueprinting. Yes, there are 100+ HP bikes with stock lower ends, but it's risky if they are pushed hard, especially when all of that high-energy activity is just a few inches away from your crotch! At extreme rpm's, the hardened crank pin surface begins to spall (separate or flake) and this is soon followed by major disaster.

Changing to higher compression pistons is one of the easiest ways to increase torque throughout the powerband but it must be done carefully to avoid detonation. Depending upon their design, some aftermarket pistons will require head modifications for valve/combustion chamber clearance. If "high-compression" pistons are installed, it should be understood that advertised piston compression ratios are static compression, not cranking compression. Valve timing, controlled by the camshaft(s), directly influences actual cranking pressure within the cylinders. For example, a set of so-called "11 to 1" compression ratio pistons may become 9 to 1 compression in the cylinder because valve timing may allow some air/fuel charge to escape the combustion chamber during the compression stroke. This is another reason why engine parts must work in harmony.

The use of "squish" bands can increase combustion efficiency. A squish band, or zone, is an area of the piston surface that is fitted to within .020" - .040" clearance of the head at top dead center. This close fit is achieved by deck height adjustments (varying the head and cylinder gasket thickness' for the desired clearance). A squish band increases power by squeezing the air/fuel mixture toward the center of the chamber which promotes turbulence and further vaporizes the mixture for improved combustion efficiency.

Weight

Physics tells us that an object at rest tends to remain at rest. It logically follows that the amount of energy required to move a motorcycle at "X" velocity is proportional with the mass of the motorcycle. In other terms, the lighter the bike, the quicker it will accelerate with "X" amount of applied force.

Horsepower and torque are inextricably math-related. Torque is the amount of force produced. Horsepower is the amount of work produced within a unit of time.

Torque = horsepower X 5252 / rpm

Horsepower = torque X rpm / 5252

Most Harley bikers recognize that a factory 1200cc Sportster has quicker acceleration than a factory 1340cc Low Rider because of it's superior power-to-weight ratio. Both engines make roughly the same amount of horsepower (50 some-odd) but the 1200 weighs considerably less. Hypothetically, lets say that a 1200 Sporty weighs 550 pounds wet: > 550 LB divided by 50 HP = 11 pounds per horsepower. If the Low Rider weighs 650 pounds: > 650 LB divided by 50 HP = 13 pounds per horsepower. More dramatically, consider a top fuel drag bike that weighs only 400 pounds and makes 300 HP: > 400 LB divided by 300 HP = 1.3 pounds per horsepower...........no wonder they haul-ass!

Let's go back to the 50 HP Low Rider. If we install an efficient exhaust system and air filter, a hot ignition and coil(s), and carefully jet and tune the beast, we could end up with near 70

HP. The Low Rider still weighs 650lbs: > 650 LB divided by 70 HP = 9.3 pounds per horsepower - superior to the stock Sportster's 11 pounds per horsepower. Now the Sportster owner is pissed because our Low Rider has better acceleration, so he makes the same engine mods and also gets 70 HP: > 550 LB divided by 70 HP = 7.8 pounds per horsepower and the race is on. This sort of competition can push reasonable men to seemingly unreasonable measures in pursuit of horsepower and it is what drives the sport of drag racing!

Engine components are also subject to the power-consuming effects of weight. Any engine will be more responsive if it's rotating and reciprocating parts are as light as possible while retaining enough strength for their function. Lighter parts simply have less inertia to overcome during engine acceleration and deceleration.

Drag racers are particularly well-acquainted with the virtues of lightness and go to great extremes to lighten their race bikes. Some even inflate their tires with helium instead of air. The benefits of lightness also apply to street bikes. One method of reducing bike mass is the removal of superfluous components. Another method is to replace heavy steel and/or cast iron parts with lighter aluminum, magnesium, fiberglass, carbon fiber and plastic. If you want more acceleration, put that Hog on a diet and enjoy the added bonus of more responsive handling and quicker braking.