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45 Performance

Introduction

Thank you for selecting this booklet. It represents roughly 35 years of curiosity, research, and experimentation with the Harley-Davidson 45 engine.

I assume that the reader is already familiar with motors in general, and has personal experience with Harley-Davidson 1937-73 "45" (VIN letters: "W" or "G") side-valve motors in particular; therefore, no attempt will be made to explain the various technical terms used.

With some interpolation, the information is potentially useful for other similar motors, but I have no experience with them. If you have questions about another engine or installation, please consult another source.

This is not a repair manual, and does not contain instructions on how to tune a stock engine or make repairs. The information presented here is believed to be accurate and reliable, and is honestly offered to assist you in obtaining the best results from your 45 engine.

The level of satisfaction that you will achieve is largely a function of the amount of time and effort that you are willing to devote to this project. However, in the same way that I cannot take credit for your success, I also cannot be held responsible for any failures or unanticipated results.

Despite my best efforts, this book may contain inadvertent typographical errors and inaccurate data. You must use your own good judgment in these matters, keeping in mind that gasoline is highly flammable, and that motorcycles are inherently dangerous to operate.

Any additional information or ideas that you may discover or develop in your own research is always of interest, and will be included (with your permission) in the next revision of this article, with proper credit.

Reference to a diagram in the text will give the Page number on which the illustration appears: "Pg. 8", etc.

Purpose

This is the introduction to getting better performance from your stock 45 motor. The information applies to 1937-73 solo (W & WL), Servi-Car (G), and military (WLA & WLC) models.

I won't go into lengthy technical detail, just tell you what works, and how to do it. I'll assume that you don't want to take your motor completely apart; by completely I mean separating the cases, splitting the flywheels, etc. This discussion will concern itself entirely with what can be done with the engine in the frame, and still substantially assembled.

None of this advice will make your motor refuse to start, idle like a coffee can full of rocks, overheat, or blow up. If you follow this material (and your service manual) carefully, you will have no problems doing all of this yourself (even if this is your first time).

Bad Rumors:

Let's throw out some of the nonsense that has been printed about 45 motors. You can forget what you may have heard about...

» Using UL (80" flathead) cams: they don't fit (too many teeth on the gears).

» Using Sportster cams: they don't work (only .267" lift - less than stock! And have too much timing for our purposes).

» Using WR cams: they're not that good (designed in 1941 - how fast were cars back then?), plus, they require special tappets, blocks, covers, etc. - $$$.

» Putting on UL barrels: they won't fit (much too big).

» Installing a front-drive magneto: lots of trouble (major machine work).

» "Bolting on" Sportster heads & barrels: you can't, it's lots of work (welding, etc.).

» Installing Sportster rods, etc.: it's do-able, but do you really need this? Lots of trouble.

» Using a WR close-ratio transmission: bad acceleration, lousy in traffic.

» "Bolting on" K heads: they don't fit (unless you're using K barrels, which require modifications).

» Keeping the compression stock: all late 45 solos are 6-1, the K is 6.5-1, the KH is 6.8-1, Indian Chief Bonneville is 6.75-1, etc.

» Staying with a small carb: I have successfully used 38^{mm} carburetors on 45" motors.

Before I begin, a warning: if your motor is worn out, or even tired, no amount of speed equipment is going to help. Never, never modify a worn-out motor! A lot of the missing power will suddenly "appear" when your motor is freshened up! A motor that smokes, uses oil, makes lots of noise, etc. is a candidate for a rebuild. After you tighten it up (if you're still not happy), come back and read this.

First: what are we trying to do? When most people say they want more power, what they mean is more torque - especially at low to moderate speeds. This is the power range most riders really want - power that lets you take off from a light, pass in traffic, ride double, and generally have fun, without having to down-shift all the time to keep the motor turning fast. This is what we will concentrate on.

Let's divide up the work into categories based on how far apart you're willing to take the motor; we'll call this the "*limit*".

Stage I

The motor is fully assembled, in the frame. Its mechanical condition is very good to excellent (no known problems or strange noises). Your compression tests out at 90 lbs. or better in both cylinders (test taken with motor warm, both plugs out, throttle wide open). The *limit* is to remove only the external systems, such as the intake, exhaust, ignition, etc. and not touch the engine itself.

Stage II

The motor is still assembled and in the frame, but you feel OK about taking the heads off.

The *limit* is the head gasket surface.

Stage III

The top end is coming off, either for repair (smoke, noises, bad compression, etc.), or just improvement. The *limit* is the cylinder base gasket surface.

Stage IV

The top end is off. You want to install mild cams, with no more lift than stock. This requires removing anything in the way, such as controls, pegs, oil lines, etc. The *limit* is the cam cover gasket surface.

Anything more complicated at this point puts you into the expert class - you should be reading "45 Power II" (following pages)! Now, the actual work.

Clean off the top end of the motor as best you can with solvent, air pressure, etc. This is a good time to check for loose cylinder base nuts, oil leaks, etc. Use Kroil, CLP, WD40 or your choice on all hardware that will be coming off 24 hours before starting work: intake manifold nuts, exhaust clamps, carb bolts, etc.

Exhaust

A small gain can be made by dropping the original 2 into 1 pipe set, & using individual pipes. Mufflers are hard to fit on these (especially on a solo) due to space & ground clearance limitations, so plan carefully. The longest pipes you can fit will work best. Another set-up (for those of you that have a friend at Muffler King) is to use your old rear pipe, a drag-style front pipe (available from Paughco), and a bit of work to put both of them into a larger pan-type Y pipe (Paughco again). See my "45-EX" booklet for more detail. This cuts out the restriction where your front pipe is squashed to pass under the cam cover, increases the pipe diameter where they join by 39%, and allows you to use a 1¾" (big twin size) tail-pipe and muffler. This still looks fairly stock, and has much better ground clearance than dual pipes. Do not use silencers that fit inside the pipes. One of the best mufflers around is the factory "off-road" accessory unit. Another good choice is the Supertrapp, but it doesn't sound good! Don't confuse noise with power - a bad choice of muffler will lose a lot of power; if you're not sure it works well, don't buy it.

Ignition

If you can find a 1964-73 Servi-Car (trike) distributor, take it. This looks much like the older type, but the cap is flat on top, and held in place by a screw on the side. The 1965-69 Sportster unit is almost as good, and looks identical, but the advance curve is too long and should be shortened by 50% (from 30° to 15°). These have an automatic-advance feature (like a car), and both are a drop-in fit. Either one will improve your idle quality, keep your motor cooler in traffic, and give a bit more power at low speeds.

Adjust it so that (when the point plate is held to fully-advanced position) the points just begin to open when the timing mark is centered in the inspection hole, or slightly to the rear of this point. This should be at 30° (.3125" = $^5/_{16}$" BTDC, or Before Top Dead Center, the absolute highest point the piston reaches when the engine is rotated) at full advance.

A magneto is a good way to burn a hole in your wallet, but only helps at very high engine speeds. A used magneto is a dangerous purchase unless you can see it run in a motor - don't buy one at a swap meet, they're expensive to fix. Don't bother unless it's cheap.

Coil

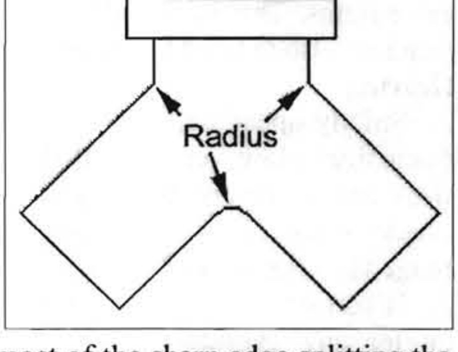
The original coils are terrible by modern standards. Get yourself an Andrews, Action or Accel high-performance unit. This is also a good time to consider going to a 12 volt set-up - more voltage at the plugs, stronger generator output, and makes bulbs easier to find, too.

Spark Plugs

All aluminum heads (and all iron heads up to 1955 or so) use the 18^{mm} (large) spark-plugs. The correct plug not only fits the hole, but has the right heat range for the motor's intended use & power output. There is no single proper plug for your motor - for best results use the right plug for each job. For break-in & traffic, use NGK A6 (equivalent to H-D factory #3). For parkway & high-performance, use NGK A7 (equivalent to H-D factory #4). If they come out black & dry, check your carb; black & wet, you have an oil problem; 2 different colors, you have an air leak in the cylinder with the lighter colored plug - find it & fix it. Do not over-tighten the plugs - 25 ft/lbs is plenty. For full-throttle use (racing), keep a set of A8 (equivalent to H-D factory #5) around; use these when you try out different jets, etc. Gap them at .025" for best power, .030" for traffic use. Magneto only: .020"

Carburetor

If you have a W or G motor with 1" Linkert or small Tillotson (1937-73 M-16, M-18 or DC, etc.), get rid of both the carburetor and the manifold.



What you want is the 1936-52 solo & military manifold - looks the same but bigger, and bolts directly to your cylinders. You can improve it a bit with a little grinding & polishing inside; remove most of the sharp edge splitting the flow between the 2 legs to the cylinders - make a smooth radius instead. A spacer between the carb & manifold helps a bit. This manifold takes the 1¼" Linkert (such as the M-88, M-41, M-51, etc.). Find one with a $1^1/_{16}$" venturi as a minimum (see my "Linkert Book" for a complete list of carb numbers). Most of these carburetors will work well with no modification, and are a big step up from the smaller unit. If you have a 1¼" set-up and want more, get (or make) an adapter to install a 1¼" or 1½" SU (MG Midget, Sprite, Volvo, Herald, etc.); 32 or 34^{mm} Mikuni, Dell'Orto, or Amal; Tillotson, Bendix or Keihin.

Don't try to use a 1¾ or 2" SU, S&S, or Weber. Certain 1½" Linkerts are good, but be very careful about which one you use. Don't run without an air filter (unless you like rebuilding motors!). "K&N" brand is very effective, with no loss of power.

Some of our modifications will require a slight carburetor adjustment, generally richer. On the Linkert, turn the idle and power screws out to do this. If you get a "pop" or flat-spot when the throttle is opened fast, this means you're too lean! Go richer until it stops. Be sure your plugs come out with a color between card-board and chocolate (no color at all is dangerously lean, sooty black is too rich). If you don't take the trouble to get your carb jetting on the money, you're wasting your time.

Temperature

A cooler motor is a faster motor (lasts longer, too). Never polish, paint or chrome aluminum heads - glass-beaded or sand-blasted is best. For iron heads, use heat-proof black (not VHT!). Trikes especially may need an oil cooler - install this in your return line from the bottom of the motor to your oil tank. A cheap cooler can be made from a power-steering cooler from a Cadillac, police car, etc. (junk-yard); if you can find one. Make sure they're clean first, mount them where they won't block air flow to the cylinders, and be sure the hoses can't touch the pipes! I also suggest you add Marvel Mystery Oil to your gas; just follow the can directions. What this does is put some lubricant on your cylinder walls above the pistons, as well as your valve stems. This has a definite effect on engine temperature (also helps it last longer).

Gearing

Strictly speaking, the chassis is not part of our discussion. However, note that ALL motor sprocket sizes are a compromise: speed against power. The smaller sizes (27-29 for a solo) greatly improve acceleration, but reduce cruising speed & top speed, increase engine noise, vibration, & wear, and generally reduce rider comfort. Most of my customers report that they are happiest with the largest size they can find (33 tooth can still be found, 34 is the largest available), unless they never use the machine on the parkway.

The standard method of determining the maximum safe engine rpm is to calculate the point at which the pistons reach some set speed. This is considered to be 2500 feet per minute for cruising, and 4000 f/m for top end. With the stock motor, these points arrive at 3934 rpm (for cruising), and 6295 rpm (for shifting and top speed). If you consult my chart "45-GR", you'll see that a solo needs a 33 tooth sprocket to cruise at 71 mph (which is reached at the 2500 f/m limit, assuming a rear tire of 26" diameter). The theoretical top speed with this sprocket is 113 mph, which is probably not possible due to insufficient power in the case of a mild motor (should take about 40 hp, still within the range of a stock-size motor in a high state of tune (big cams & carb, relieved, big valves, high compression, etc.).

100 mph, however, is possible, with 3 requirements:

» Big sprocket (a 29 tooth will just make it, and will have the best acceleration up to 100, but makes an uncomfortable cruising machine)

» Heavy valve springs to allow enough rpm (radical cam timing is not necessary for this, but is helpful in the next Stage)

» Enough power; about 30 hp will do it

That's about the whole list of what can be done without taking the motor apart - remember that a careful tune-up is always the last step. Next we will work on only the upper end; the motor can remain in the frame, etc.

Stage II: Aluminum Heads

If you don't have them, get them. They're a bolt-on for any cylinder that uses $^{7}/_{16}$" bolts (not ⅜" studs!). If you can find #6 ("6" is stamped on the right side), use them; if they're #5 (stock 1940-45 & military) mill them to #6 specs (take about .120" off the gasket surface). Use copper head gaskets. Check your parts manual for all the hardware you'll need. Remember that the head bolts may bottom out when your heads are milled; measure before installation, you may need a small washer as a shim above the thick protective washer (always used between the bolts and head surface). Torque all the bolts to 20 lbs. First, then do them all to 30, then 40, then 45, and let it sit overnight. Try them all again at 45 lbs.

The next day, and re-torque them after the motor warms up the first time. They take the old-style large (18^{mm}) plugs. Please note: WR, K or KH heads do NOT fit your motor - don't waste your time & money.

Next we will take the cylinders off; the motor can still remain in the frame, etc.

Stage III: Pistons

Even if you use stock pistons, remember that how well the cylinders are prepared will have a big effect on your power. I prefer the last finish to be done with a Flex-Hone (2¾" 180 SC). Use only honing oil (or motor oil) while doing this - never Safety-Kleen fluid, kerosene, gas, or any other thin liquid! When finished, clean the walls thoroughly with detergent, rinse carefully, then blow dry with compressed air.

A white cloth passed down the bore should show no marks! Do not bother to polish the piston dome, as it will have no effect. For best results, put 1000 miles on the motor before using full throttle.

The best pistons are (in this order):

1. K/KH replacements, which are slightly too tall for your cylinders, but will work fine with a thin ($^1/_{16}$" or so) shim of aluminum stock under the cylinders as a spacer. Be sure that the pistons are at least .020" down from the top of the cylinder at their highest travel!
2. Stock late (1955-73) pistons, or repro using late, thin ($^1/_{16}$") compression rings.
3. Stock early & military pistons using thick ($^3/_{32}$") compression rings.

Rings

For best results your ring end gaps should come as close as possible to the minimum specs listed in our data table. Most ring sets will fall on the loose end of factory specs (.020" or so). If you have a loose set (all .015" or more), try to average them out - don't put both the tight compression rings in one cylinder. You may wish to use the next oversize ring set (that is, use a set of .020" oversize rings with your .010" oversize pistons, etc.). This will tighten up the end gap - more than you think! Adding .010" to the ring size will close up the gap by .031" (formula for circumference of a circle: $C = \Pi * D$). In all cases this will require you to carefully file or grind material from the end of each ring in order to obtain the proper minimum end gap.

If you don't have a ring compressor use popsicle sticks or something soft to get the rings in - not a screw-driver! Even small marks on the rings permanently damage them.

Compression

All side-valve designs are limited to fairly low compression by the chamber shape. More compression will help, up to about 6.5-1 (if it can be done without hurting breathing). Besides high-compression heads, another way this can be done is by milling some material right off the top of the cylinders. For some very complicated reasons, this works better than you think.

The amount to remove is just enough to leave .021" between the top of the cylinder and the top of the piston at TDC. This will bring the piston to .040" of the underside of the head when at TDC (assuming a head gasket thickness of .019"; use you own gasket thickness to do the math). If you're going to put in fresh pistons, bore the cylinders now, put in the new pistons, then measure the distance between the piston and the cylinder's top surface at TDC. Subtract .021", and mill off the figure you have left.

For example:

Distance from piston to cylinder top (@ TDC):	.075"
Subtract clearance:	.021"
Remainder to mill off top surface:	.054"

If you prefer not to go through the measurements, I'll cut out the math, and say that in almost all cases it is safe & advisable to cut .030" off the top gasket surface (any big automotive machine shop can do this). This must be done before any valve seat work or relieving!

Big Valves

A larger intake valve is very useful. A WR or K valve is easy to install by cutting the existing seat to about the same size as the valve head (be sure the seat angle is cut correctly - the WR is 30°, the K is 45°, like you have now). You can make a good valve from auto parts (see Page 16). 18071-41V valves (available from KNS Cycle) are lighter than stock, and come with complete instructions and all necessary parts. In some cases, one edge of the new valve will just touch the pocket in the head (directly above it) when the valve is fully open. A little metal can be easily removed from the pocket with a Dremel tool to cure this. Cut your existing seats to the same size as the OD of the new valve head, at the same angle (30°is best for air-flow; if possible, re-cut the valve to 30° 1st). Narrow the seat from the inside @ 70° to .080" width.

If they're in good condition, your old exhaust valves can be improved by narrowing the seat area to about .100" wide (from the inside). Use a shallow angle to remove as much metal as possible without cutting into the radius where the stem joins the head. Use a 20°stone (or the factory relief cutter) to narrow the seats in the cylinders from the outside to 1.58" OD (smaller than the valve OD), and then from the inside with a 70°stone to .080" wide.

Oil

H-D's new bikes all come with 20W50 oil - I like it for all-round use. It makes the motor easier to kick over in cold weather. For hot weather, (over 80°), use H-D 105. If not available, use a good Pennsylvania-type 60 wt. Such as Kendall, Quaker State, Wolf's Head, Valvoline, etc. The best oil is marked "For Service SG" on the can (this is the highest current test standard). For low temperatures, use 40 wt. Change the oil at least every 2000 miles, more often if you have no air cleaner; change the filter (if you have one) every other oil change.

If you want to know what's going on in your pump, don't bother with a 100 lb. gauge screwed directly to the motor - your normal reading will not exceed ⅓ of the scale, the vibration will shorten the life of the gauge, and you won't be able to read it unless you hang half-way off the bike.

The smart thing to do is to replace your oil pressure sending switch (on the back of your cam cover) with a ⅛" NPT close nipple and a female T. Put the sender back in the 2nd leg of the T, and install an electric sender in the 3rd leg. Now you can put a good 60 lb. gauge anywhere you want, without a leaking hose leading to the gauge (just a single wire, easily hidden).Give your feed pump a check-up for dirt, bad springs, etc. Make sure all lines are free of kinks and sharp bends, and do not go within 1" of exhaust pipes or cylinders.

Installing a "Z"-modified rotor will help power and oil consumption, but this is very difficult to do with the motor in the frame.

Stage IV: Cams

The limit is the cam cover gasket surface. No head or cylinder modification is needed, although stronger valve springs are recommended.

If the new cams are on hand, measure each cam across the thrust ends (where it touches the bushing flanges) with a micrometer or dial caliper, and write down the length to .001". Remove the old cams, and measure them. Be careful to record the exact number and position of each shim on the old cams. Use whatever shims you need to get the same end-play on the replacement cams on as the originals. If not sure, use the factory specs.

45 Power II

Purpose

The following material is intended to assist the serious mechanic in obtaining the best performance from his 45 motor. I'll begin by assuming that you are already familiar with the factory service manual, engine assembly procedures, and have at least some acquaintance with hot-rodding.

This is not going to be another one of those guides on how to construct a hot motor by using factory racing parts. Those parts work, and in many cases are very useful, but are rapidly becoming very expensive, as well as difficult to find & identify. When I refer to motor parts in this booklet, we are talking about stock military, solo or trike parts (WLA, WL, or G), unless I say differently.

Using only std. parts does reduce the maximum power potential to some degree, but careful selection, preparation, and modification of these parts can nearly double power output. Since these parts are still available for the right price, you'll have no problem with spares.

The following are useful, but are fairly difficult and/or expensive for the help they offer:

» magneto (even the Morris has no advance mechanism)

» belt drive (severely limits choice of drive ratios and top speed)

» Linkert WR MR-3 or MR-4 carburetor (only about 32^{mm})

Every 45 high-performance motor <u>should</u>:

» be relieved

» have minimum deck clearance

» use aluminum heads

» have the front case baffle removed & skirt oilers installed

» have altered breather timing (see "BT-HP" for details)

» have at least 6-1 compression

» use big intake valves

» use the best possible coil (especially if still 6 volt)

» use an oil filter of some kind

» use new & heavier valve springs every time the motor is apart

» have maximum weight removed from the chassis

» use a larger intake manifold (WLD or UL as a minimum)

Intake Manifold

Even the solo (largest factory) manifold is too small for our purposes. If you insist on using this, use a spacer between the manifold & carb to increase manifold volume, and enlarge the passages. Remove the "V" separating the 2 port legs as much as possible (stop before you break through). JB Weld, Devcon etc. can be added to the exterior to allow more interior enlargement. For best results, locate a UL/WLD (3 bolt) or WR/K/KH (4 bolt) manifold and prepare it in the same way. Both of these require adaptation (not a bolt-on); this is generally done by using a hose between the bare manifold leg and the outside of the intake nipple. Besides the larger size, the 4 bolt manifold allows the use of any pan/knuck carb adapter (same bolt pattern). Try to enlarge the port opening and close up the manifold leg to the same size to make a neatly tapered transition. If dual carbs are desired, new ports can be machined into the cylinders (see "2PORT" for details on this operation).

Carburetor

All Linkerts are too small, even the M-74B (yes, this is even larger than the factory racing model such as MR-3, etc.). If you insist on using a Linkert, try to get a M-53, M-53A, MR-3, MR-4, MR-4A, or M-61 as these are the closest factory models to what you'll need for your motor. Even a stock-size 45 (meaning one with stock stroke and a normal piston oversize) can use a larger carb to good advantage.

A motor with big cams, K manifold, etc. can successfully use a 38mm Mikuni, or factory Bendix, Tillotson, or Keihin. I have also seen 1¾" SUs used (early Jaguar etc.) such as H6, HS6, HD6; also Rivera Eliminator.

Remember that the demand of a 45 motor is nothing like that of an overhead (shovel, Sportster, etc.) even if the maximum power is close. A hot 45 has much less low-speed vacuum, and will need much richer low-speed circuits to operate in traffic. Count on re-jetting any carb that was used last on a bigger motor - just because it works doesn't mean it can't be made to work much better. Accurate jetting is worth more than a few extra millimeters of size! If you' re going to use a Bendix or Keihin, get an adjustable main jet, and the smallest low-speed (also called slow or idle) jet you can find.

Combustion Chamber

The very basis for the construction of the flat-head (or side-valve) motor is the "Ricardo Principle", patented by Sir Harry Ricardo around 1923. The idea was to design a combustion chamber that would permit a reasonable compression ratio which would function with normal low-octane gas (which the previous IOE type would not do, such as the JD & Power Plus).

The problem is that when the plug fires, the burning process should progress from the electrode across the chamber at a predictable rate (like lighting a fuse). However, when the compression ratio reaches a certain number (depending on fuel quality, bore size, material, etc.) several undesirable things occur:

» a pressure increase takes place throughout the entire chamber due to the increased gas temperature

» a shock wave crosses the chamber like a ripple effect

» a heat wave crosses the chamber by radiation and increases the temperature of the gas on the side away from the plug

When these take place, the gas opposite the plug spontaneously ignites, causing a violent jump in pressure BEFORE the piston reaches TDC. This is referred to as knocking or pinging, and quickly results in damage to the head, dome, rings, pin, rollers, etc., and elevated engine temperature. The quick cure is to retard the spark to nearly TDC, which also raises the temperature even higher and kills power completely.

Ricardo reasoned that the problem could be cured by cooling off the far end of the chamber. This is done by placing the 2 surfaces (the top of the piston dome and the underside of the head) in very close proximity (allowing only a safety margin to allow for heat expansion and component flexibility). As the gas becomes excited by the combustion process, these two surfaces approach each other, and the gas loses heat to them very quickly (this is part of the reason why aluminum heads are so helpful). Finally, the distance between them becomes too small for any volume of combustible material to remain (the previous gas volume has been "squished" across the chamber back towards the plug to be burned normally). This turbulence mixes the gas very efficiently, which improves the percentage burned (hemi motors such as the shovelhead and Chrysler are fairly bad at this).

Pistons

Unless the cylinders have been milled, you should be using WR, K, or other high-dome pistons (such as 22255-52A) to improve your compression and combustion efficiency. If your cylinders' head-gasket surface has been milled by at least .050", you may be able to get by with standard-type 45 pistons - check to see that your deck clearance is .060" or less (remember to allow for your base-gasket & head-gasket thicknesses). Try to use pistons with $^1/_{16}$" compression rings, as these provide a better seal at high engine speeds.

There is some advantage to preparing the skirts with Kal-Gard Piston-Kote, (easy to apply, bake it on in your toaster oven). This reduces skirt scuffing & friction somewhat, and reduces motor temperature slightly.

The dome (above the top ring land <u>only</u>) can be glass-beaded for texture (mask off the ring lands with tape first), and given several coats of white VHT paint, then baked to cure it. This also helps motor temperature a bit, and is also worth some free power - it prevents energy from escaping from the chamber by soaking through the aluminum.

Compression ratio vs. Combustion Chamber Volume							
Compression Ratio	5-1	5¼-1	5½-1	5¾-1	6-1	6¼-1	6½-1
std. bore & stroke	5.64"	5.31"	5.01"	4.75"	4.51"	4.30"	4.10"
CC	92cc	87cc	82cc	78cc	74cc	70cc	67cc
+.030" bore	5.76"	5.43"	5.12"	4.85"	4.61"	4.39"	4.19"
CC	94cc	89cc	84cc	80cc	76cc	72cc	69cc

Compression

The chart indicates combustion chamber volume (in ccs & cubic inches) for the std. size motor and ratios. To use this, look up your motor size first, then your desired ratio, and mill your heads to obtain the volume shown.

As an alternate, look for your present volume, and find your actual ratio. Remember that the volume includes:

» deck clearance (minus pop-up dome volume, if present)

» valve seat and relief area

» gasket thickness

head volume (including pop-up relief, if present).

Cams

What we want for a practical motor is the most lift possible (.375" - .425" at the cam) with moderate duration to keep a broad torque range. There is an old saying in motor racing: "Horsepower sells motors, but torque wins motor races!". Still true today.

The roller tappet limits you to what is currently on the market for H-D motors. Most of these grinds are for overheads, and have little or no lift advantage over the stock 45 cams (.312" at the lobe; would produce .468" at the valve in a Sportster due to its rocker arm ratio). These motors also have much more compression than we can use, and generally have more cam duration (especially on the intake closing side) than is practical for a 45. Very long duration produces a shaky idle, "soft" low-speed power, and only offers a power gain at high rpm - about what you'd get if you used stock late 900cc Sportster cams.

Andrews has a cam set for the WLDR but it's quite mild (dates to 1939), and may not offer much help. If you ask nicely, you may get them to make up a special pair of intake cams with a different lobe shape, such as their # 3 (246°, .360" lift), or "M" (264°, .413") at extra charge.

The KK/KHK intake cam is an excellent choice; pay particular attention to the concave flanks (the lobe is a "figure 8"; the sides are slightly hollow-ground).

KR grinds marked "A" on the lobe are also safe (about 288°, .395" lift), but have ball-bearing spindles. You must press the cam & gear (1 piece) off the old spindle, and install the spindle from a standard 45. A slot (½ round) must be ground in the correct place for the ignition ball on the #2 (rear intake) cam - just match the slot in your 45 #2. The KNS Cycle 25506-37V (296°, .375" lift) is slightly milder than either of these 2, but can be made from any 45 cam in excellent condition; this and other 45 regrinds are available from KNS Cycle.

I believe that a flat-faced lifter of the original WR type has advantages over the std. roller tappet. Of course, the cam profile is completely different - flat lifters must never be used on a roller-type cam!

Valve Springs

Any motor with improved breathing will develop power at higher speeds than the stock unit. In order to allow proper valve action at higher rpm, a stiffer spring is needed. The 18201-52 spring set (which is about 30% heavier than the standard spring) offers some help in this area, but even more tension is definitely useful. If you have the larger 1930-38 VL/UL covers, you can use the super-duty springs (Crane, Crower, etc.). For this one you will also need some of the UL spring stack parts. The bigger covers screw right onto your tappet blocks, and are very attractive, but will require clearance grinding on your fins and cylinder base flanges.

Valve spring efficiency is directly affected by the weight of all reciprocating components, including the tappet, adjuster, valve, collar, and locks. The locks are best left "as-is", both for safety's sake, and because very little material can be removed. The remaining components can all be lightened to some degree, and I strongly suggest that this be done in all cases. Since the 45 does not use rocker arms, there is no bending or wiping motion exerted on any component, and therefore they can be lighter than the comparable part in a pushrod motor, without fear of breakage or loss of proper valve action. The size of the hex on both the adjuster & lock nut can be reduced by careful grinding. It is preferable to shorten the valve stems as much as possible first, and then trim the adjuster when the proper length for correct lash is known (the stem is a solid steel bar .312" diameter, the adjuster is only .270"). The diameter of the stem below the guide can be reduced on a lathe (very carefully!); remember to allow for your lift, don't touch the area on the tip end of the lock groove, and polish well as a last step. Part of the threads at the bottom of the adjuster can be cut off (once the length necessary for a proper valve adjustment is known, of course); leave enough to properly anchor the adjuster in the tappet body, of course. A carbide drill could be used to remove a few molecules by hollowing out the center of the adjuster. Metal can be removed from various areas of the tappet body. The collar can have material removed from its edge by drilling to "scallop" away ½ round holes; this is done by positioning the point of the drill immediately adjacent to the outer rim, so that ½ the drill diameter falls inside the rim, causing a semi-circular cut (this may also be carefully done with a die-grinder, etc.). A total of 4 holes is generally used; this still leaves sufficient metal to adequately support the spring without flexing.

A substantial improvement to both weight & flow can be had by sleeving the existing guides down to .316" ID and using custom stainless valves with $^5/_{16}$" stems.

Manley does this sort of work (it may be possible to reduce the stem to .250" for even better results, but this is unknown as of this point).

Flywheel Assembly

A considerable improvement to acceleration & throttle response can be made by removing weight from the flywheels. This does not produce more power, it simply allows the engine to pick up speed more rapidly. The following effects can be expected:

» better acceleration in 1st gear (less noticeable in 2nd, practically no change in 3rd).

» best acceleration improvement in machines using small motor sprockets (more effect from a 27 than a 33, etc.).

» slightly harder to kick through, due to lack of inertia to "carry over" into the compression stroke.

» slight increase in carb idle setting may be necessary to hold the motor at the same idle speed, due to more irregular pulses (most noticeable in motors with high compression).

» slightly higher idle speed may be necessary to prevent motor from stalling, same reason.

» more careful clutch operation will be required for getting away from a dead stop.

» in general, the motor will run slightly rougher at low speeds, and be more prone to lugging.

» slightly improved braking (assuming the clutch remains engaged), as the brakes do less work slowing down the flywheels.

» shifting may be improved (with practice) as the engine will conform more rapidly to the rpm required after a gear-change.

» engine will appear to respond to open throttle faster in neutral; do not assume that it is safe to lean out your carb - this effect will not occur in gear, and in some cases slightly richer mixture will be required.

Connecting Rods

If you wish, the sides of the rod beams can be polished along their length (not across) to remove potential crack-forming surface irregularities. Don't remove a lot of metal, only enough to get a smooth (not perfect) surface. The rods should be shot-peened afterwards if possible.

Additional lubrication for the lower end can be had by cutting (filing or grinding) small notches (.020" deep by .060" wide) across the outside of the big ends of the rods. See the picture in the "Stroking" section.

Bearings

A small improvement can be made to the pinion-side bearing assembly by simply reversing the outer cage, and installing 24 .250" × .270" rollers (in place of the 12 .250" × .550" used prior to 1955). There is no gain in bearing area, but the shorter length of the new rollers permit more mis-alignment of the flywheels without scoring or edge-contact (as may occur during rpm ranges of imbalance, or extreme power). This same idea was used in the big twin beginning in 1954, and continues through today.

Balancing

Due to its relatively light pistons & rods, and the large rod-to-stroke ratio (1.95-1), the 45 does not suffer as badly as larger H-D motors from inaccurate balancing. However, an expert balance job will improve high-speed smoothness, allow freedom from vibration, and more mileage between rebuilds. If you are stroking the motor, or altering the weight of the components to a large degree (Sportster rods, lightened flywheels, short-skirted pistons, etc.) balancing is necessary for best results. Various "balance factors" between 50 & 60% have been used for different purposes; the larger percentages appear to be most useful in cases where the rod angle is the most severe (strokers) or increased piston weight (this is very rare in 45 motors).

Drag Racing

The basic problem is that the motor tune-up specs, and chassis preparation for the drags are not useful for street purposes. The following observations will be of use to anyone anticipating a try-out.

Use the lowest-profile tire & rim you can find (probably easiest to make up a separate wheel for this; a mid-size Jap hub with 16" alloy rim and nylon sprocket is our 1st choice). The idea is not only to change the gearing, but to reduce the gyroscopic effect of the wheel as much as possible for a good "gate".

Stock-weight flywheels are best, as you will want to light the tire for take-off, which will require a strong shock..

Use a small motor sprocket. If you have good high rpm breathing, you should allow the motor to turn 6000 rpm in the traps. The exact tooth count will depend on the expected top speed, and rear tire diameter. For example, if you think (seriously) you might reach 90 mph, and you have a 24" tire, you'll need a 30 tooth motor sprocket (using the stock rear wheel sprocket). This is a better set-up than a 27 tooth sprocket and 26" tire, as it will "launch" harder, even though the over-all gearing comes out very close.

Run the motor as cold as possible. If it starts easily, shut it off while waiting to run.

Run high pressure in both tires. In the front, it reduces rolling resistance. In the rear, it makes it easier to light the tire; this is what keeps your rpm & power up for best acceleration. The more cam timing you have, the faster your motor must turn during take-off.

An auxiliary hand lever for the clutch may make for better control during take-off.

Run the highest octane gas you can find, as protection against detonation (in the event you guess wrong on mixture or spark, etc.).

Rich up your idle & part-throttle settings to allow for best response when you snap the clutch out. You'll also need a bit extra for a cold motor.

The motor will take more spark in low gear than in high. If you have a hand spark control, consider shortening the travel to restrict it to about 5°. This will allow you to run (for example) 35° for take-off, and drop back to 30° when you make the 2-3 shift for better top end (and less chance of damage).

Please note that these figures are probably safe for all motors, but are not best for all motors. Find your own maximum high gear setting by test!

BIG INTAKE VALVES

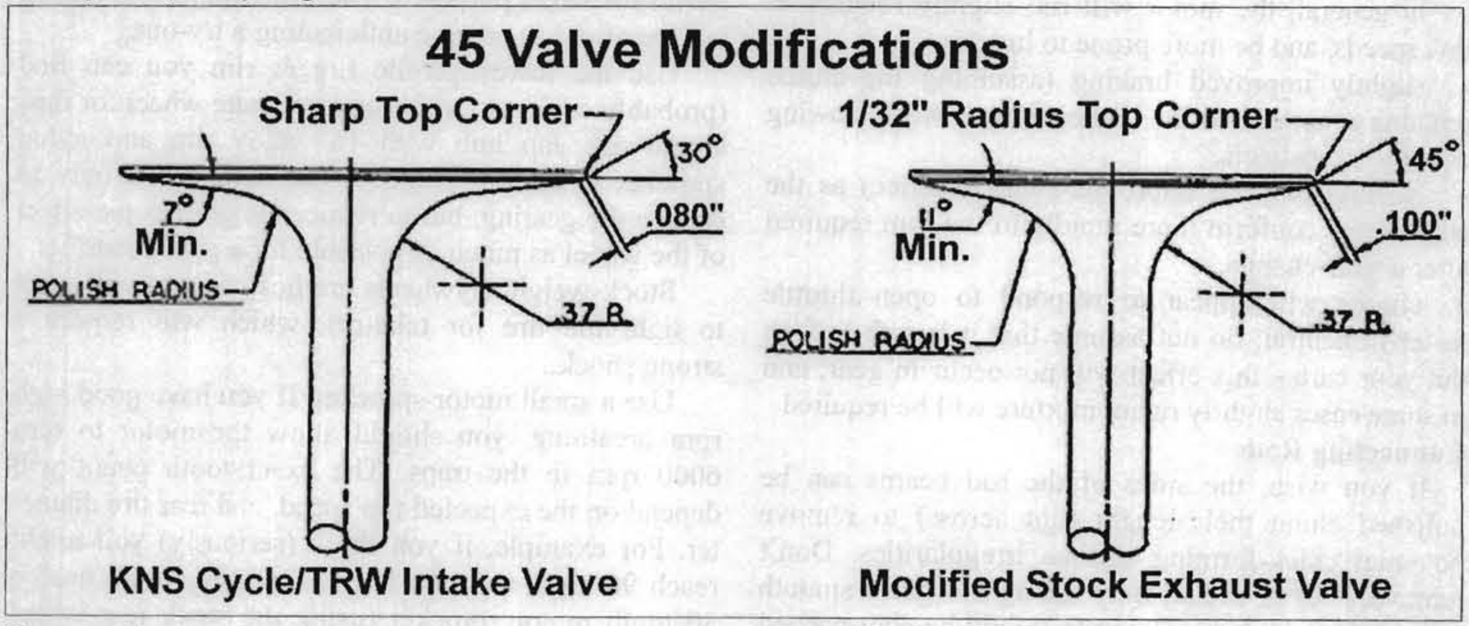
Purpose

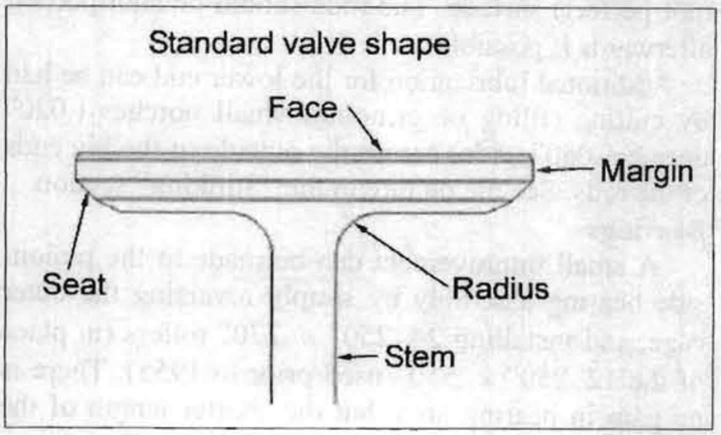
Any 45 motor being re-designed for high-performance should be use larger intake valves.

What can you expect to gain from this work? More power! The motor will pull harder on top end (much like with hotter cams, but without loss of low-speed smoothness or gas mileage).

Rather than search for obsolete factory high-performance parts such as WR or K intake valves, we will use a common auto part. The intake valve from a pre-1963 Chevrolet or GMC 6 cylinder 235" or 261" motor, is an excellent choice.

The head diameter (as supplied) is 1⅞" = 1.875", exactly ¼" (.250") larger than the 45, the material is excellent quality, the stem diameter is about .001" larger than the original (your slightly used guides may be used, rather than replaced), and the shape is far better for air-flow than stock. The lock groove is for the common GM $^{11}/_{32}$" split locks. The new valve spring collar is 1¼" OD, and is available in steel or titanium, and may be found used from many cam & speed equipment manufacturers but no longer in production.The only draw-back is the work involved. This can also be utilized as a method of restoring the breathing capacity of worn, rusted or pitted intake seats, which would ordinarily produce less power. After installation of larger valves, they will perform better than new.





Preparation

All milling on the cylinder's top gasket surface for repair or compression increase must be completed before the new seats can be planned. A slight mill cut (by Bridgeport, etc.) off this surface is strongly recommended as a preliminary step. This increases compression slightly, but (most important) reduces the piston-to-head clearance @ TDC to a smaller figure. Generally, taking between .030" and .050" off here will correct the sloppy original factory tolerances, and put the piston .040-.050" below the head's quench surface @ TDC.

Remember to include the head gasket's compressed thickness in your calculations. This will also elevate the highest side of the existing seat area to flush with the gasket surface. This increases compression very slightly, and reduces the amount of work to relieve this area. The edge of the new seat is also closer to the bore opening, so that the relief is shorter (less work again).

If you examine your aluminum head carefully, you will notice that the intake valve pocket is larger than the valve head, but may not completely clear larger valves "as is", and require minor trimming.

The head diameter can be slightly reduced on a lathe etc. to $1^{13}/_{16}$" = 1.8125" for slightly better torque and a potentially easier installation.

The stem must be shortened from the lock end by ¾" = .750". Be careful: if not enough is removed, the stem is too long to permit valve adjustment. If too much is removed, the stem end will be below the collar surface. If possible, re-harden the end with Kasenite, it or simply heat and quench. Dress the end square, flat and smooth with a file, then garnet paper, etc.

Some additional work can improve the valve a bit – see the following pages for more details.

The lock groove is slightly too far away from the valve head, and will not provide enough spring tension. For a stock or nearly stock cam, add .090" total shim thickness to each spring stack (inside the upper cover, or between the cover and guide flange). For more cam lift, deduct the added lift from .090" to get the shim total: new cam .375", std. cam .312", difference is .063". Subtract .063" from .090" = .027" shims. In any case, the springs must have at least .020" between each of 3 coils when the valve is fully open (total .060" before all coils touch each other). If this is not done, parts <u>will</u> break.

The valve stem clearance in the guide should be .0035".

The new valve spring collar is too large to enter the std. 45 cover. Since the std. 45 valve spring seats on the inner ring, remove the outer ring completely. If using 1¼" special springs, omit this step.

Parts Required

Component	Intake valve	Valve collar	Valve lock	Shim
Specifications	1.875" OD	1.25" OD, $^{11}/_{32}$" stem	$^{11}/_{32}$"	1.25" × .030"
Mfg. & Part Nº	TRW V2275	Crane 99916	GM $^{11}/_{32}$"	TRW 623201

Term	Definition & Description
Face	Top of the valve opposite the stem; this part is inside the combustion chamber
Margin	Small area between the valve seat and the face; it's parallel to the stem
Seat	Angled part of the valve or cylinder that forms the mating & sealing surface The 2 seats align & contact each other when the valve is closed
Bowl	Port area immediately below the seat, roughly parallel to the valve stem
Stem	Rod-shaped part of the valve that rides inside the valve guide
Head	Disc-shaped part of the valve that closes off the port when seated
Stub	End of the port where it joins the intake manifold (intake) or exhaust pipe (exhaust)
Guide	Removable metal (iron, steel, bronze) insert that the valve stem rides in
Boss	Raised area in the port that surrounds & supports the guide
Roof	Upper curved part of the port leading away from the bowl into the port stub, when the cylinder is in normal assembled position

Porting

The breathing capacity of the std. 45 cylinder (casting numbers 120-36 front & 120-361 rear) is chiefly limited by its design, not by the size of the ports. Once relieving has been done, additional flow capacity can be added by improving the efficiency of the ports.

Intake Port

The intake port begins where the intake manifold ends. The manifold is attached to the port with a nut and male-threaded nipple, approximately 1.19" ID. The nipple threads into the port, and secured by a rivet. The rivet protrudes into the ID of the nipple, and disrupts flow a bit.

There is no larger replacement nipple available, but a skilled machinist can re-thread the port, or bore it out to take the next larger (WLD, UL) nipple. The original nipple can be enlarged (die grinder, etc.) to about 1.28" ID. If you enlarge the nipple ID, you will have to trim or remove the "button" or inner head of the rivet. This will compromise its original function (no longer in tension), and reduce it to a mere locating dowel, as well as a potential air leak. If a nut & seal will be used you <u>must</u> leave the rivet body (stem) in place, as this prevents nipple rotation when the manifold nut is tightened.

It is not possible to enlarge the nipple ID to match the port diameter, which is larger. A smooth transition is the best we can do here.

If the port can be made clean enough, Marine-Tex, JB Weld, DevCon, or silver solder, lead, brass, etc. can be added to form a fillet or radius here. This material will come out if not attached to a surgically-clean surface.

In extreme cases, the nipple can be entirely removed, and a new stub or extension (such as an EL, WLD or UL nipple) threaded or inserted into the enlarged opening, or attached to the face of the existing port opening by welding or brazing. This stub should be a match for the leg of the larger manifold being used, such as WLD, UL, etc. I suggest not using the larger UL nuts to attach the manifold, as the alignment is critical; I prefer O-rings or sleeves.

The bowl (or throat), the curved tract leading from the port below the guide up to the valve seat is not well shaped. There are many casting irregularities, etc. that would require major work to remove, reshape, etc. If an oversize valve is fitted, the bowl enlargement will take out a lot of this material; blend the cut into the existing walls, see the chart to calculate bowl size.

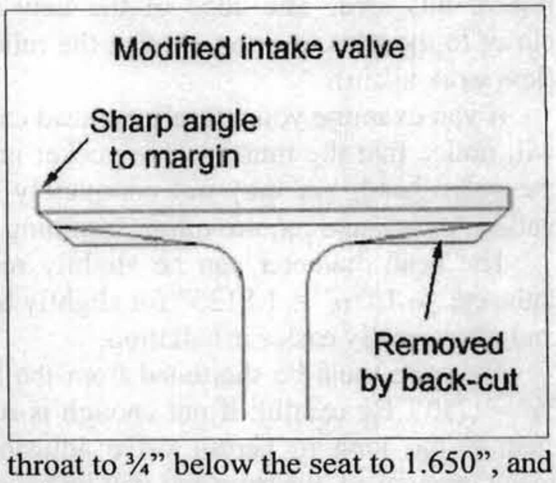
The port immediately before & after the guide can be slightly opened up on both sides to "make up" for the loss of area caused by the presence of the guide & valve stem. This will produce an elliptical shape (from the original roughly round cross-section). The guide is about .565" wide by .300" tall, for an area of about .170 $In.^2$. If applied evenly to the left & right sides, that's about .085 $In.^2$ in area for each side. A depression about .125" deep can be cut or ground in each side of the port wall, centered at the top of the guide, and tapering off to blend in with the existing wall. The port is now elliptical, stretching the sides to increase the area only where the boss intrudes into the flow. Do this very carefully, or not at all.

The short-side curve (roof of the port stub) is too abrupt (bend is very sharp), and should be smoothed out to increase the radius (make the turn more gradual). Do not simply bevel this up to align with the seat, the larger the radius the better.

The port contains some casting roughness, which can be polished out.

Intake Valve

An oversize intake valve should be fitted (see Page 14). If the new valve is larger than 1¾" = 1.75" (such as the KNS 1⅞" = 1.875" oversize, or K-Model), it's possible to cut the new seat at a 30° angle (in preference to the original 45° seat), which improves flow. Enlarge the entire throat to ¾" below the seat to 1.650", and blend the cut into the existing wall curvature.



The valve itself (oversize or std.) can be improved by narrowing the seat face to .080" wide with a back-cut at a very shallow angle (as small as 7°). This cut should just touch the stem-to-head radius, and remove the greatest amount of metal from the back of the valve head. This reduces weight, and improves flow. Try to make the valve look more like a "T" in cross-section. Grind off any raised numbers or marks on top of the valve. The outside edge where the face joins the margin (at the top of the valve) should be left at a sharp 90° angle - no radius or bevel. Polish the top.

Intake Seat

The seat (as fitted for the std. valve) is cut at a 45° angle, the factory recommended width being .125" (⅛"). A somewhat narrower seat is acceptable, with .080" the lowest safe figure.

Narrow the seat from inside with a 60° stone to .080" wide, then from the inside with a 75° stone. For more flow area using the std. valve, the bowl ID can be increased to 1.51", and the bottom of the cut blended into the ledge where the factory seat machining stops.

Intake Guide Boss

There is no "boss" or protrusion in the floor supporting the valve guide. No substantial improvement is practical here.

However, if the bowl is substantially enlarged, the area behind the guide will be partially removed, and the ledge remaining should be narrowed by removing material from both sides only, leaving the length of the ledge intact. Taper it on both sides with the "long" axis aligned with the gas flow (roughly following a line drawn between the guide center and the bore).

Making it "boat-shaped", with the leading (intake port) end rounded and the trailing (bowl) end a smooth point. This has the effect of "streamlining" the guide, directing gas more easily around it with less resistance and flow disturbance, by using the remaining boss to direct gas around the stem & guide.

Intake Guide

Taper the portion of the guide that protrudes into the port itself to only $^{1}/_{16}$" wall thickness at the top. The guide body can be narrowed to $^{3}/_{32}$" wall (minimum) on both sides, making it boat-shaped, with the "long" axis aligned with the gas flow (roughly following a line drawn between the guide center and the #2 head bolt). This "streamlines" it a bit, directing gas more easily around the stem & guide, with less resistance and flow disturbance.

We're looking into the possibility of using another guide: the Manley intake for the thin-stem OHV motors. This is shorter (less guide body in the flow area), and is $^{5}/_{16}$" ID for those who would like to use a thinner valve stem for additional air flow, and some weight savings.

Valve Sizes

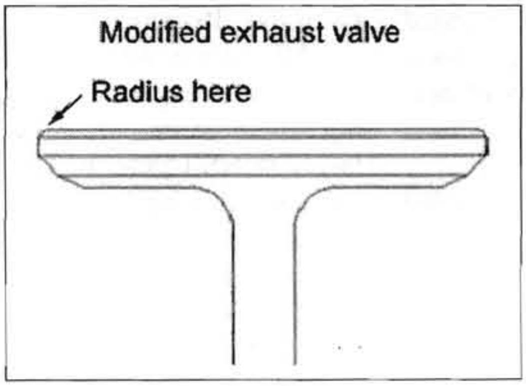
The intake & exhaust valve head diameters are normally the same size as the outside diameters of their seats (unless the seats are deeply worn or sunken, etc.). To calculate the most efficient valve head diameter for a given bowl size (or calculate how large to make the bowl for a given valve head diameter), first decide the seat angle, then the width:

Seat angle	45°	30°
Use	Standard (best life, more accurate seating)	Improved flow (shorter life)
Valve head OD	Seat ID + (width × 1.414)	Seat ID + (width × 1.732)
Seat ID	Valve head OD - (width × 1.414)	Valve head OD - (width × 1.732)

Seat width	Std.	Minimum	Maximum
Intake	.125"	.080"	.100"
Exhaust	.125"	.100"	.125"

Exhaust Valve

The stock size exhaust valve (1⅝" = 1.625") is big enough (WR & KR race motors actually had even smaller valves). The std. valve can be improved by narrowing the seat face to .100" wide with a back-cut at a very shallow angle (as small as 11°), as pictured on Page 16. This cut should just touch the stem-to-head radius, and remove the greatest amount of metal from the back of the valve head. This reduces weight, and improves flow. Try to make the valve look more like a "T" in cross-section.



Grind off any raised numbers or marks on top of the valve to prevent them from becoming hot spots under full load. The outside edge of the face at the corner of the valve (opposite the seat) should be back-cut 25° & radiused a bit ($^{1}/_{16}$" - ⅛") to make a smooth curve from the margin (straight area) to the top of the valve, as indicated in the picture, above. A high polish on the top will slightly reduce heat absorption.

Exhaust Seat

The seat (as fitted) is cut at a 45° angle, the factory recommended width being .125" (⅛"). A somewhat narrower seat is acceptable, with .100" the lowest safe figure, as the valve's cooling is largely through heat transfer to the seat. Narrow the seat inside with a 60° stone to .100" wide, then from the inside with a 75° stone.

For more flow area using the std. valve, the bowl ID can be increased to 1.45", and the bottom of the cut blended into the ledge where the factory seat machining stops.

Exhaust Guide

The guide should be left heavier than the intake, as it carries more heat. The top can be tapered off to $^{1}/_{16}$", as suggested at top of Page 3.

Exhaust Guide Boss

The boss can be narrowed by removing material from both sides only, leaving the length intact. Taper it on both sides with the "long" axis aligned with the gas flow (roughly following a line drawn between the guide center and the #2 head bolt). Making it boat-shaped, with the leading (bowl) end rounded and the trailing (pipe) end a smooth point. This has the effect of "streamlining" the guide, directing gas more easily around it with less resistance and flow disturbance, by using the remaining boss to direct gas around the stem & guide.

Exhaust Port

The bowl of the port directly below the seat can be enlarged slightly to 1.45" ID, with the cut going down into the bowl area about ½". Blend the bottom of the cut into the existing wall. You will find that this increase in diameter helps the "short-side" radius.

This is the curve on the side away from the bore, that passes under the bolt hole and forms the "roof" of the port.

The "long side" is the side closest to the bore, which contains the guide, and forms the "floor".

The short-side curve is too abrupt (bend is very sharp), and should be smoothed out to increase the radius (make the turn more gradual).

The port contains some casting roughness, which can be polished out. Be sure not to remove any metal from the machined 1½" ID pipe receptacle, located at the very end of the port stub. If this is disturbed, the pipe will not fit well, and exhaust gas will leak until it "carbons up".

Do not drill the rear exhaust port to hold the pipe in place. The screw will rust & vibrate loose, and cause the hole to crack and break the casting. Best method is to weld/braze a small tab (chain side plate is excellent) to the back (invisible) side of the pipe. Drill a hole in a thick part of the cylinder above the port. Use a 2-stroke expansion chamber spring to hook the 2 together. Paint the end of the pipe with maple syrup before assembly - this will carbon up immediately.

RELIEVING

Purpose

The goal here is to improve the volumetric and thermal efficiency of the std. "45" combustion chamber in the following models: 1936-73 R, G, W, WL, WLD & WLDR. This will be the limit of my subject matter; other breathing considerations are discussed in other booklets.

What can you expect to gain from this work? More power! The motor will pull harder on top end (much as it would with hotter cams, but without loss of low-speed smoothness or gas mileage). Any 45 motor being re-designed for high-performance should be relieved. Most people also experience a modest drop in engine temperature, caused by increased exhaust efficiency. The only draw-back is the work involved, and a slight loss of compression (which can be compensated for, if you wish - see Page 8). This can also be utilized as a method of restoring the breathing & cooling capacity of worn, rusted or pitted cylinders that would ordinarily produce less power and run hotter. After proper relieving, they will perform better than new.

Definition

"Relieving" is the traditional term used to describe improvement of gas flow between the valves and the cylinder by selective metal removal. Most of this work is done on the head-gasket surface of the cylinder, the balance in the head itself. The basic idea is to form channels to guide & direct gas along the correct paths, so that all the gas entering the port may be drawn into the cylinder (and out again, of course) with minimal restriction, but without removing any more metal than necessary.

To give you a better idea of the shape of the relieved area, picture the gasket surface as a river map, as seen from above. Gas must flow easily from the intake valve seat into the bore opening, then back to the exhaust seat. The deepest part of the intake relief will lead from the deep side of the intake seat to the edge of the bore. The exhaust relief will lead back from the bore to the deep side of the exhaust seat.

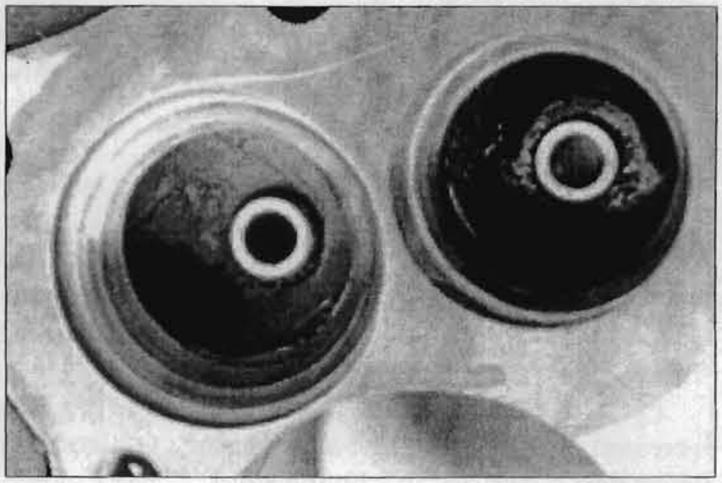
Diagram A (page 4) shows all 8 bolt holes numbered in order of their placement in the cylinder, and references to the bolt locations will be made in the text ("B1" = Head Bolt #1, the top motor mount bolt on both front & rear cylinders) to give you a better idea of where we are. B1-B2-B3 are around the intake seat, B3-B4-B5 are around the exhaust seat, B6-B7-B8 are around the bore. The head-bolt numbering sequence will be counter-clockwise on the front cylinder and clockwise on the rear cylinder, so that the same bolt will refer to the same area on both cylinders.

The preferred tool is a die-grinder, Dremel, etc. equipped with a ¼" carbide or abrasive bit. Once the general shape of the pattern to be followed is understood, anyone with a steady hand and good judgment can do a decent job.

I will deal with the cylinder, head and compression as separate topics.

Cylinder, Preparation

All valve-guide, valve seat and compression milling work must be completed before you begin relieving. In most cases, it is desirable to install slightly larger (KNS Cycle, K-Model, etc.) intake valves. Not only will this improve the breathing by itself, but also elevate the seat area to flush with the gasket surfaces. The new seat is shown in the photo ⇨. This increases compression a bit, and reduces the amount of work to relieve this area.



The edge of the new seat is also closer to the bore opening, so that the relief is shorter (less work again). If you examine your aluminum head carefully, you will notice that the intake valve pocket (B1-B2-B3) is larger than the intake valve head, and will clear most larger valves "as-is", or with only very minor trimming.

The first step is to get the correct tools. An air die-grinder is fastest (also most likely to cause mistakes). An electric die-grinder is fine (Sears Craftsman Industrial model is an excellent buy for the money), just a bit slower. A Dremel is going to take longer due to the smaller motor. The best bits are carbide (don't bother with "high-speed steel", etc. as they will quickly become dull), and are available in a wide variety of shapes. I use a ¼" cylindrical bit for roughing out work. They're expensive, but unless you drop it, it'll last a long time and cut through iron like cheese. For small curves, radii, etc. you may find abrasive bits helpful; I use 1" ball & ½" cone shapes a lot. "Cratex" and abrasive cartridge rolls of various sizes are useful for finishing work (use low speed for these). You will not need finer polishing material than 240 grit, as a satin-smooth finish is quite sufficient.

You must wear eye protection when doing this work, for obvious reasons. Be sure to use ear protection as well (shooting muffs, etc.). Wear a dust mask, abrasive dust is hard on the lungs.

Layout

Begin with an absolutely clean gasket surface. Completely cover the gasket pattern with a single layer of duct tape; use a rolling pin, etc. to make sure it's firmly attached. Feel with your finger-tip for the head-bolt holes, and cut through at least 4 of the holes using an Exacto, utility knife, single-edge razor blade, etc. Take a copper head-gasket (used, in good condition OK), and very carefully position it on top of the cylinder, being certain to line up the bolt holes all around. Now, trace a line following the inside surface of the gasket. Trim off the tape inside the gasket. Carefully peel it back, and discard. Only the exposed surface may be relieved, and the remaining tape will offer good protection against accidents. If you prefer, use Dykem, etc., coating the cylinder top surface as per product directions. Spray paint may be substituted - lightly spray the top surface from directly above. Wait 5 minutes, then remove the gasket. In the case of Dykem, you now have a line separating the area needing work from the area that must not be touched. If paint is used, only the painted area may be cut. You may find it useful to apply masking tape to the head-gasket pattern to protect it from accidents.

The area inside the gasket is the absolute limit to the reliefs in any case, but please note that not all this area will be cut.

The bore outline that is not relieved (B7-B8, etc.) should be chamfered at a 45° angle, $^1/_{16}$" deep by $^1/_{16}$" wide, especially if a "pop-up" piston relief is machined into the head.

Removing additional metal that does not directly affect flow is a negative. Some common layout errors are:

» Shallow side of the relief is cut to the same depth as the deep side (i.e., cuts are parallel depth to gasket surface).

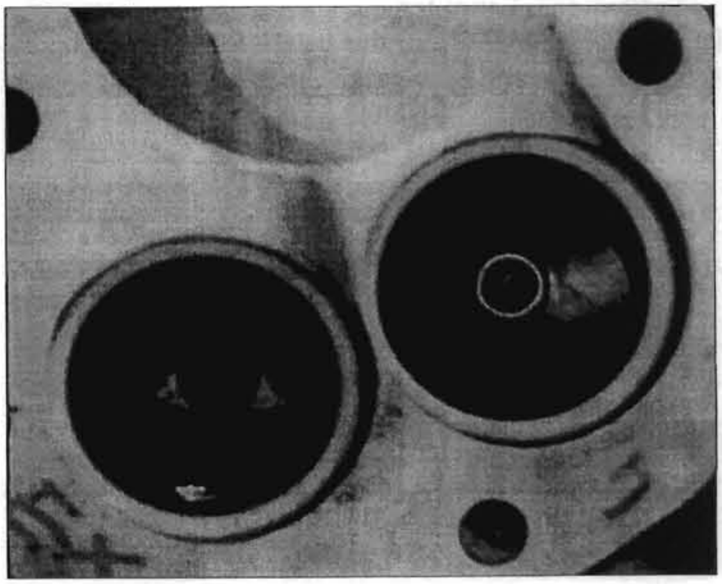
» "Wedge" area (triangle @ B3 at the gasket between the 2 seats) is removed, reduced, etc.

» Deep side of the intake relief is made full-depth all the way to the head-gasket line @ B1.

» Shallow side of the exhaust relief runs all the way to the gasket surface between B5 & 6.

When trying to decide how extensive to make your reliefs, remember that it is easier to remove metal than to put it back!. If not sure, do a mild job as shown in the photo (shown, left; this is a U-Series cylinder for reference only; don't copy this). You can always do it over when the top end is off. The most frequently made mistake is doing the 1st cylinder to the max, and not having the patience to do the 2nd one to match it. Any relief at all is a big improvement, and the first metal you take off has the greatest effect.

As you have noticed, the valve seats are not parallel (flush) to the gasket surface. This is because each cylinder is at a 22½° angle from vertical (45° angle to each other), but all of the valve stems, guides, tappets, tappet blocks, etc. are at an 18° angle. The resultant misalignment is 4½°, which is the "tilt" of the seats in relation to the gasket surface. This is true in all H-D side-valve motors (except WLDR "40A Special", WR, K, KH & KR, which have even more complex alignment).



The deep side of the intake relief will follow the head-gasket pattern most closely where it passes nearest to B1. The absolute deepest part of this relief is located approximately $^{3}/_{16}$” in-board of the gasket at this point and rolls uphill @ 45° to the gasket line on one side, and angles up to the exhaust relief much more gradually (parallel to the valve seat) on the other side.

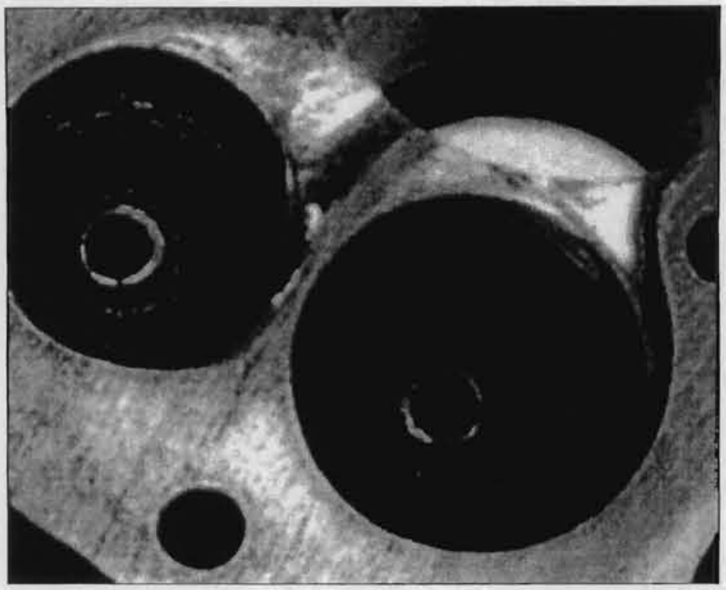
Please note that this will cause an inward curve to the relief (as shown, seen from above). Aside from this specific area, the remainder of the relief is “aimed” at the piston.

When in doubt, go slowly. The front & rear cylinders are mirror images of each other (exactly alike, but reversed), and must have matching reliefs.

Alignment

The alignment of both the intake & exhaust reliefs is intended to direct gas flow between the center of the valve throat opening and the center of the bore. They will follow and be parallel to an imaginary line connecting the center of each valve guide to the center of the piston (use your actual piston by inserting it in the bore at Top Dead Center - most have small machining marks indicating the center still visible).

As mentioned above, the valve seats themselves are not flush with the gasket surface, but are inclined at a 4½° angle - your reliefs must be at the same angle. As seen from the bore, they will form shallow “V”s. The short leg is at approximately a 60° angle toward the gasket side of the intake relief. The long



leg is parallel to the valve seat, and only 4½° (nearly flat) to the gasket surface.

Limits

The relief begins as an outer circle concentric & parallel to the valve seat OD, but ⅛” larger in diameter. This means a flat ring $^{1}/_{16}$” wide all around the valve seat. On the deep side of both reliefs, a 45° cut rises from this ring toward the gasket surface.

Moving outward from the valve, the next step is a non-concentric circle, offset to the deep side of the relief. Outer limits of reliefs around the valve seats are no larger than:

Position	Letter	Intake Seat	Exhaust Seat
Deep	D	¼”	⅛” away from intake relief
Rear	R	$^{3}/_{16}$”	$^{1}/_{16}$”
Shallow	S	⅛” away from exhaust relief	$^{1}/_{16}$” before rising to gasket surface

The outer edge of the relief must not be too far away from the valve seat. The chamber wall straightens and steadies the gas flow, so removing too much metal here (and especially in the head) will hurt both compression and flow.

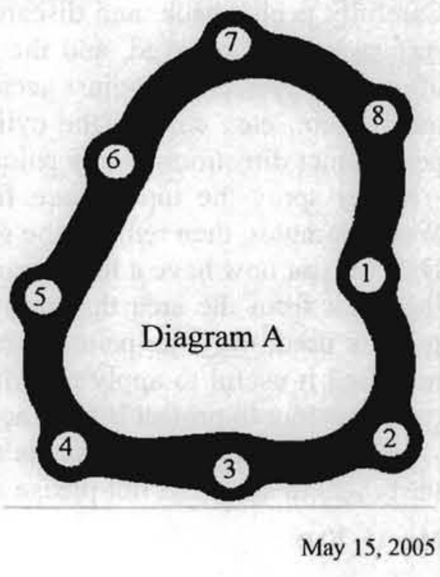
Specifications, Cylinder

Distances given are from the shaft of an installed head-bolt to closest edge of the relief. B3 is at the “Wedge”. B7 & B8 are around far end of bore - no reliefs.

Intake Relief for $1^{7}/_{8}$” KNS valve to:		
B1	⅛”	.125”
B2	$^{11}/_{32}$”	.344”
B3	$^{9}/_{32}$”	.281”

Exhaust Relief for std. valve to:		
B3	$^{9}/_{16}$”	.563”
B4	$^{7}/_{16}$”	.438”
B5	½”	.500”
B6	⅝”	.625”

Maximum width of relief channels between seats and bore:



Valve Type	45 Std.		WR, K, KR Std.		KNS Oversize Valve	
Head OD	1⅝"	(1.625)	$1^{13}/_{16}$"	(1.8125)	1⅞"	(1.875)
Intake (OD +⅜")	2"	(2.000)	$2^{3}/_{16}$"	(2.19)	2¼"	(2.25)
Exhaust (OD + $^{3}/_{16}$)	$1^{13}/_{16}$"	(1.813)	1¾"	(1.75)		

Maximum depth of these reliefs is the lowest part of the valve seat OD (the outer-most part of the seat, which will actually contact the relief where they meet).

To calculate the maximum relief depth, multiply the head diameter by .078459 (this is the sine of the valve inclination angle of 4½°). For fresh, high seats (shallow end flush with the gasket surface), use the following chart:

Valve Head OD	1.625" (1⅝)	1.8125" ($1^{13}/_{16}$)	1.875" (1⅞)
Comment	Std. Intake & Exhaust	K-Model Intake	KNS Cycle Intake
Maximum Relief Depth	.127"	.142"	.147"

Do not remove any metal from the roughly triangular area (B3) between the 2 seats and the gasket surface. This "wedge" is filled by part of the head. If done carefully, the wedge shape can be transferred to the gasket surface, and blended into the reliefs.

The extent of the relieved area depends on a number of factors; among them are:

» Size of the intake valve, as previously discussed

» Valve seat condition (deeply sunk or rusted seats require deep reliefs; new or oversize seats need less)

» Have the cylinders been top-milled? If so, some of the factory relief machine-cut is missing.

» Breathing capacity of the motor (bore & stroke? carb size? manifold volume? cam timing?)

» Final compression ratio desired

The reliefs should join the seat edges smoothly and gradually. For maximum effect, the relief should be this same depth all the way from the seat edge to the bore opening, although in very mild motors this is probably not necessary. Obviously, if the cylinder has had many valve jobs, or is in otherwise poor shape, more metal must be removed to cut the reliefs down to the level of the sunken seats. Although this does reduce compression a bit, the improvement in breathing far outweighs the slight drop in pressure.

When planning relief depths, bear in mind that in no circumstance may the reliefs go below the highest point of ring-travel. If the rings are exposed, they will quickly fail, so try to keep the ring land @ TDC at least .030" below the lowest point of the relief. Remember that K, WR, strokers and other special pistons will not have the same ring land placement as the stock 45 piston - take careful measurements.

The edge of the relief should receive a gentle radius downwards where it joins the bore opening; ($^{1}/_{16}$" is sufficient); this is to prevent the sharp edge from becoming overheated by the flame and causing premature ignition. Generally speaking, removing all sharp edges inside the chamber is good practice.

To avoid losing your "mirror" effect, I suggest working alternately on both castings: mark out each cut on both, do one, then the other before moving on to the next cut. If you cannot remove all grinding marks, remember that those running in the same direction as the gas flow are relatively harmless, but the ones that cut across this line are bad. If you must leave any surface roughness, end with light strokes in the same plane as the gas flow (parallel to it).

Head

Heads are (sometimes) marked outboard of the mating surface with a number to identify the compression ratio. I assume you're using aluminum heads, which are only made in High & Medium ratios. If a 2-digit number is present, this is the chamber volume, in cubic inches: "4.5" (High, 6-1 compression), or "5.5" (Medium, 5-1). Original aluminum heads may also be marked on the right (cam) side with the actual ratio, "5" or "6". Both heads must have the same volume & ratio after all modifications are completed.

Welding

If any welding is to be done to repair plug thread, mating surface, or fin breakage do this first. Milling for compression, mating surface truing, etc. can be reserved for post-relief to balance out chamber volumes, or raise the final compression ratio to the desired level.

For extreme efforts, additional aluminum may be added to the walls to "close up" the chamber, especially around the valve pockets, both to improve gas flow, and increase compression. If you find that the wall of your head is more than $^{1}/_{16}$" away from our planned relief outline, you may wish to do this.

Especially important is the "Wedge" (B3), which should match & cover the triangle of flat (gasket-height) surface of the cylinder bounded by the intake & exhaust reliefs, and the gasket outline. If the existing Wedge is smaller than this area, or the point is irregular, add heli-arc to correct this.

A light surface cut or mill is necessary to correct warpage if welding has been done!

Pop-Up

For motors with pop-up (1948-51 WR, K, KH, and converted 45s), some re-shaping of the last edge of the "transfer" (where it touches the dome relief cut) is helpful. Undercut the wall slightly with a ¼" radius cutter, so that the curve ends pointing down. This is a 1948-51 WR head.

If you wish, a major re-shaping of the transfer will be helpful, but very difficult. If your pop-up relief cut is already done, you will have to clean it up a bit when you're done. If you haven't done it yet, make it the last step. The transfer is the scooped-out curved area (above the piston) that directs gas down into the bore. This cannot be removed, but its size, shape and location (and that of the squish ledge above the piston) can be dramatically altered without loss of effective gas flow area. This is done by adopting the pattern used in the factory pop-up motors, and transferring it to the mating surface. A great deal of heli-arc welding is required here, so a head already damaged by water, ring breakage, etc. is an excellent candidate. Do not attempt this unless expert welding is available. The remaining alteration will be very time-consuming, and is best left to experts with porting tools.

Alignment

To best way to accurately locate each head onto its cylinder is to lightly bolt them together (with the gasket you're using for a template in place), using all bolts. Reach down into the cylinder, and scribe a mark around the bore onto the head with a marker. Disassemble and inspect - is the mark accurately placed? If not, back off on all bolts and try to wiggle the head a bit. When you believe it to be as good as possible, re-assemble, and drill 2 holes $^{1}/_{16}$" in diameter through the head & gasket, and ⅛" into the cylinder deck surface.

Ideal places for these are near B1, and between B5 & B6 The depth will be about ¾ - ⅞" total. Try to get between the fins, and in the center of the gasket width. 2 old (dull, broken) $^{1}/_{16}$" drills or pieces of drill rod are now used as locating dowels to be sure every assembly goes together the same way; it also exactly places your gasket/template on the surface for accurate transfer. These dowels will not be used when assembling the motor - remove them after snugging down the bolts a bit.

An outline should be scribed or marked on the mating surface, using the same head-gasket as a template. Inboard of this, a tracing of the actual relief area is transferred from the cylinder to the head. Remember to use the matching cylinder, front or rear! This is easy to mix up, as the tracing will fit both if flipped over.

Do not remove any metal from the point of the "Wedge" that separates the intake & exhaust pockets. This is necessary to direct flow out of the bowl & seat area as the valve opens. Do not use the head-gasket as a guide here. Leave the actual mating surface of the wedge completely intact, although the walls of the pocket may be straightened. With the mating surface up & absolutely horizontal, cut the chamber wall straight back to match the intake relief on the deep side (cut is 90° to the mating surface).

Do not cut the pocket back to the head-gasket outline. The exhaust relief (shallow side will be closest to the mating surface) will probably fall inside the existing chamber wall, but check to be sure. Again, do not move the wall of the pocket back.

Do not touch the mating surface at all between B5-B6-B7. This area does not need help, and the squish area must remain as large as possible. Cutting the wall back vertically to the existing edge of mating surface (not the head-gasket surface) between B5-B6 may help a bit if you need to "lose" some compression, but don't move the edge back.

The "pocket" or recess for the intake valve must be deep enough for the valve to go to full lift (see your cam specs) + .120". The exhaust valve pocket only needs full lift + .080". These figures are not for safety, but to allow gas to use the area above the valve for added flow. If not deep enough, this can be done with a Bridgeport, etc., or by hand with a large end-cutting bit in a die-grinder.

Blend the new floor(s) into the chamber wall;⅛" radius is fine.

Be sure that the new "floor" (actually the ceiling) is flat, and parallel to the old surface, which is "tilted" 4½° to align with the valve head.

The chamber wall can also be undercut a bit to move part of it away from the valve head. This cut can be up to $^{1}/_{16}$" deep for intake, $^{1}/_{32}$" for exhaust. The cut does not go to the mating surface, and will be invisible from directly above. Remove any sharp edges from the plug thread insert.

Specifications, Head

Distances @ B given are from edge of bolt hole to chamber wall. Pocket depth is minimum.

Valve	Pkt. Depth	B1	B2	B3	B4	B5	B6
Intake	Lift + .120"	⅛"			NA	NA	NA
Exhaust	Lift + .080"	NA	NA				

NA = not applicable. B3 is at the Wedge. B7 & B8 are around far end of bore - no reliefs.

Compression

This is very complex, as best peak power in hot motors comes from compression ratios of 6½-1 or less. As the power potential of the motor falls, the maximum compression ratio rises. A 45" motor in a mild state of tune may use up to 6½-1, but a relieved motor with big cams & K manifold should stick to 6-1. In all cases, the final ratio should be no lower than 5½-1. Stroked motors can use higher figures, ½ point or more.

Any relieving at all will remove metal from the combustion chamber, and reduce compression. It's a trade-off, but you'll will always wind up with more power from less (rated or nominal) pressure with a relieved motor.

However, in most cases you'll want the benefit of both, and will wish to increase the compression ratio to compensate for this drop. If you have high-compression "6" heads, this is probably not necessary, but medium-compression (and military) heads should be milled for best results. This will not, repeat not change your piston-to-head clearance (except in pop-up motors).

Roughly, a mill cut off the gasket (mating) surface of a Medium head removes about .10 $^{In.3}$ for each .010" of depth cut, as shown in the following chart.

Chamber Volume			
Milled Off	Vol. Removed	New Vol.	Remarks
.000" (std.)	.00 $^{Cu.In.}$	5.5 $^{Cu.In.}$	Original casting (nominal)
.010	.10	5.4	
.020	.20	5.3	
.030	.30	5.2	
.040	.40	5.1	
.050	.50	5.0	
.060	.60	4.9	
.070	.70	4.8	
.080	.80	4.7	
.090	.90	4.6	
.100	1.00	4.5	Approx. "High Ratio (6.0-1)" volume
.110	1.10	4.4	
.120	1.20	4.3	
.130	1.30	4.2	Safe limit (mating surface flush with cstg.)

Comp. Ratio	5.5-1	5.75-1	6.0-1	6.25-1	6.5-1
Chamber Vol., C.I.	5.01 $^{Cu.In.}$	4.75 $^{Cu.In.}$	4.51 $^{Cu.In.}$	4.30 $^{Cu.In.}$	4.10 $^{Cu.In.}$
Chamber Vol., C.C.	82 ^{cc}	78 ^{cc}	74 ^{cc}	70 ^{cc}	67 ^{cc}

These volume figures are not suggestions. They will be useful to match the compression ratios after work is completed. For smaller engines the higher ratios will not be practical in any case. Remember to add gasket thickness, piston deck clearance (or subtract pop-up), chamber relief volumes, etc. to head casting measurement. See my booklet "MAGIC" for math details, or write me for calculations (make all volume measurements, give bore & stroke, and I will supply the ratio).

Remember that the only ways a relief can hurt you are:

» Relief work has damaged the valve seat
» Relief extends into the gasket surface
» Lack of symmetry (the front & rear cylinders do not match)

» Combustion chamber volume error results in more than 1/10 point difference in compression between the front & rear cylinders
» Squish area is reduced
» Wedge is removed, reduced, etc.
» Piston ring travel appears in the relief area
» Extreme roughness (waves, lumps, grinding marks, etc.)

After the work has been completed to your satisfaction, it is probably advisable to lap the valves in again, to "heal" any light scratches on the seating surfaces and insure proper sealing.

Of course, the final step is a thorough cleaning before re-assembly.

Note: the comments given here are believed to be accurate and reliable, and based on well-proven, time-tested techniques and are safe & effective for all motors (if careful applied). I feel that modern air-flow research may be able to improve on this, but such developmental work is beyond my financial means. In all likelihood, other patterns & theories are effective (to a greater or lesser degree), but the ideas given here are taken from professionally-prepared motors, as well as interpolations from factory racing department drawings & instructions.

STROKING

Purpose

All Harley-Davidson 45 motors 1929-1973 (except XA) share the same stroke length: $3^{13}/_{16}$" (3.8125"), the same as 1952-1953 K & KK Models, 1953-1969 KR, and all 1957-85 900^{cc} & 1000^{cc} iron, and 1986-* 883^{cc}, 1100^{cc} & 1200^{cc} Evo Sportsters®. The bore-to-stroke ratio of the 45 motor is radically "under-square" (the stroke is greater than the bore) and obsolete by modern standards, but the only effective method of increasing the displacement is to increase the stroke, using "stroker" flywheels. This permits displacement increases of up to 59 $^{In.3}$ or 970^{cc} with std. bore pistons.

This is especially useful in motors equipped with big-port WLDR, WR and K-Model cylinders, as the increased vacuum, compression, and sharper rod angle will greatly reduce the normally "soft" low-speed response of these motors.

My subject here is some of the more basic work involved in planning and installing these parts. I will not cover engine assembly in general; consult your service and parts manuals, as well as "How to Restore Your Harley-Davidson" by Bruce Palmer III. I strongly recommend that the breather timing modified per "BT-HP" instructions, and that the cylinders be relieved.

Please read this entire article thoroughly before purchasing or modifying any components. Large strokes and/or heavier rods will require extreme reliefs to the cylinder mouth areas. *Certain combinations of rod & extreme stroke are not practical due to severe interference with the crank-cases, case fasteners, and cylinder base flange*. For reading convenience, I will refer to 1957-1985 iron-head Sportster® parts as "XL".

Dimensions

Each std. flywheel contains centered ⅞" (.875") tapered holes to receive the sprocket & pinion shafts. Rotation takes place around this shaft axis. The std. 1.00" crank-pin holes are off-set from these shaft holes by 1.90625" (½ of the std. stroke of 3.8125"), so that the crank-pin & rods follow a different path. The amount of off-set determines the stroke length:

Stroke Length = 2 × Off-set Distance

This is the <u>only</u> dimension that affects the stroke. Rod length (although otherwise important) <u>does not change the size of the motor</u>.

In addition to the obvious change in displacement, compression is also increased, and other functions are also affected.

Selection of Components

The <u>total height of the assembled parts:</u> *50% of stroke + rod length between centers + piston compression distance* with the new stroke must equal the <u>total height of the motor:</u> *crank-case deck height + stroker plate (if used) + cylinder height + piston to head clearance*.

Changes in any dimensions must be compensated for in the other components. If the stroke is increased but the motor height remains stock, the rod and/or piston must be shortened to compensate for the stroke increase.

Certain combinations of stroke length, piston, etc. appear to offer the advantage of maximum size, when compared to other choices. It's important to keep in mind that re-designing the motor allows you to make other improvements as well. The most important of these is increasing the efficiency of the combustion chamber.

Positive deck ("pop-up") pistons add power and torque to any size motor, and are well worth the extra trouble to calculate the measurements and do the machine work.

No factory race or high-performance side-valve motor (including Indians) was built without this feature after 1948. Before making your final choices, remember that pop-up is almost certainly worth more power than an extra inch or two of displacement.

If given a choice between stroke alone, and stroke + pop-up, go with pop-up.

Flywheels

Truett & Osborn of Wichita, Kansas produces 45 stroker flywheels which are direct replacements in all respects except stroke length. The material is 80,000 psi ductile steel, far superior to the original factory cast-iron. They are available in $4^7/_{16}$" (4.4375"), 4½" (4.500") and 4⅝" (4.625") stroke, and other sizes are available on request for additional charge. The T&O-45 flywheels accept std. 45 & WR parts, including ⅞" = .875" diameter sprocket & pinion shafts, 1" crank-pin & bearing assembly, and std. 45 rod set. Special pistons are required, either modified std. pistons, or aftermarket sources (Arias, JE, Venolia, Wiseco, &c.). Since T&O has made flywheels for H-D motors for 25 years, to avoid confusion in this article I will specify the new product for the 45 as follows: "T&O-45".

The only other available flywheel that fits the 45 directly is the S&S Cycle Products replacement for the WR, #32-3013 (stamped "KRS" + code # for stroke length on the wheels for identification). The S&S flywheels accept std. 45, WR & KR ⅞" sprocket & pinion shafts, but require a special short 1¼" (XL diameter) crank-pin, which is included with the flywheels. An XL rod set is also required, which is not included with the flywheels, but available from S&S among others. Special pistons are required, which S&S does not supply.

It is also possible to adapt commercially-manufactured stroker flywheels intended for XL-type motors. Sources include S&S, T&O & H-D factory 1954-56 KH ($4^9/_{16}$") flywheels. I will not go into detail here, let's just say it's more trouble than it's worth.

Indian Chief 74 ($4^7/_{16}$") & 80 ($4^{13}/_{16}$") flywheels have been used for a long time, but are not easily available, and require major modifications.

There is also a H-D factory stroker flywheel that has been used in the past, but because of its extreme rarity it's not likely to be available: 1954 KHR (not KH). All early (1939-196?) "R"-type flywheels have .875" shaft tapers, including WLDR, WR, KR & XLR, but only this year has 4.5625" ($4^9/_{16}$") stroke and 1.00" crank-pin tapers, permitting the std. 45 or "stepped" 1939-1954 WR 1¼" pin (23960-39R) to be used. The previous year (KR) is std. stroke, and the next year uses the much larger 1¼" tapered, 1½" journal 23960-55R crank-pin.

Flywheels specifically made for 45 use are available from both T&O and S&S in many stroke lengths, but in my opinion the only practical choices are:

Stroke, fractional	$4^5/_{16}$"	$4^7/_{16}$"	4½"	4⅝"	$4^{13}/_{16}$"	5"
Stroke, decimal	4.3125"	4.4375"	4.5000"	4.6250"	4.8125"	5.000"
Size, std. bore	51.0 $^{In.2}$	52.5 $^{In.2}$	53.3 $^{In.2}$	54.7 $^{In.2}$	57.0 $^{In.2}$	59.2 $^{In.2}$
Size, CC	836^{cc}	861^{cc}	873^{cc}	897^{cc}	933^{cc}	970^{cc}
Added stroke, fractional	½"	⅝"	$^{11}/_{16}$"	$^{13}/_{16}$"	1"	$1^3/_{16}$"
Added stroke, decimal	.5000"	.6250"	.6875"	.8125"	1.000	1.1875"
½ stroke added	.2500"	.3125"	.34375"	.40625"	.500	.59375
Increase, %	13%	16%	18%	21%	26%	31%
S&S code number	#3	#4	#11	#6	#7	#8

Baffle

The "baffle" is part of the crankcase casting, closing off the front cylinder opening (shown right), leaving only a slot for rod movement (as well as half of the rear cylinder opening in pre-war motors). In 45 motors I've measured, it's about ¼" - $^9/_{32}$" thick (.25-.28").

Its purpose is to *increase* (not reduce) the amount of oil on the front cylinder wall, which functions as follows: oil is splashed from the pressure-fed crank-pin bearings, &c. onto the underside of the baffle. As the front piston rises, a vacuum forms in the cylinder between the piston and baffle, causing vapor to rush up from the crankcase, carrying the oil with it and depositing it on the front cylinder wall.

The rear cylinder is more than adequately lubricated by centrifugal splash from the rotating flywheels, as well as oil removed from the flywheel's diameter by the crankcase scrapers. In early motors the rear cylinder half-baffle actually deflects some of this oil to prevent overloading the oil control ring (no longer necessary with more modern oil rings).

The baffle method works fairly well as far as its primary purpose is concerned: lubricating the front piston. However, this makes the front piston perform an extra function as an air-pump, forcing vapor in & out of the rod slot. This reduces power, and increases oil temperature.

If the front baffle is removed (or even reduced), the vacuum effect vanishes.

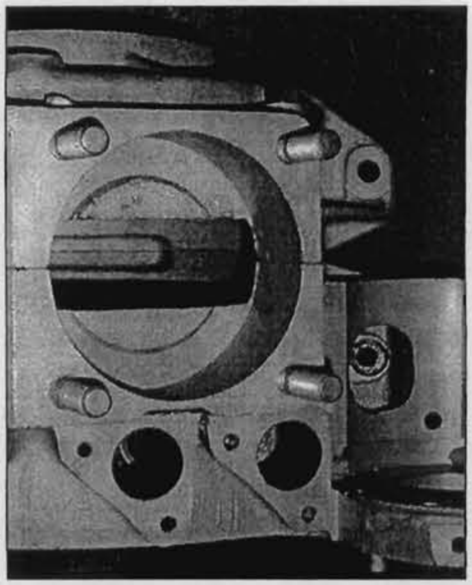
All later motors use some other method of oiling the walls; the panhead, shovelhead, & Sportster® drain the rocker oil back through the cylinder, and on to the piston. The K-Model motor has an oiling port in the cylinder wall, pressure fed from the pump. The conclusion is clear - the baffle was dropped immediately when some other method of oiling the front piston was perfected.

If you wish to modify your oil system to provide a pressure feed to the front cylinder (the rear is helpful but not critical) you will not only increase piston life and reduce cylinder temperature, but you will gain power by removing the (now un-necessary) front baffle. If you remove the baffle and make no other provision for front cylinder lubrication, increased temperature and wear will occur in street use. Motors operated at racing speeds only appear to do well without baffles, probably due to the high oil droplet content of crankcase vapor, which is not present at moderate engine speeds.

At this point you must make a decision. If you wish to leave the motor as close to stock as possible and not remove the baffle from the front (or front & rear) cylinder(s), the motor will produce slightly less power (as described above). The dimensions of the pistons (at least of the piston to be installed in the front cylinder) will be different, in that the skirt must be short enough to safely clear the baffle when the piston is at its lowest point @ BDC. If you intend to, or already have, removed the baffle (compare your motor to the picture), I strongly suggest that you install some form of skirt oiling to the front cylinder. The front stroker plate (if used) is an excellent place to install a skirt oiler. The front piston will now look exactly like the rear piston, in that the skirts must be short enough to safely clear the outside diameter of the flywheel rim when the piston is at its lowest point @ BDC. This allows approximately .25 - .28" longer skirt on the front piston. If in doubt, it's safe to shorten the skirt in any case.

Pistons

The problem is height. The additional stroke length causes the piston to rise farther up towards the top of the cylinder @ TDC by 50% of the stroke increase, and to retreat farther down towards the flywheel's rim @ BDC by the other 50%.



The latter "down" distance can be "fixed" by shortening the skirt of the piston (below the piston pin), reducing the flywheel's diameter, increasing the rod length, or any combination of the three. The former "up" distance cures include taller cylinders, "stroker plates" (spacers under the cylinders), shorter pistons, shorter rods, or any combination of the four.

There are no taller cylinders for the 45 (except 1954-1956 KH, which are very helpful, but are not discussed here), and stroker (spacer) plates would have to be extremely thick to make up this distance, which will interfere with the intake manifold, valve covers, 2-1 exhaust, spark plug access, head steady, valve stem length & alignment, etc.

A shorter piston will have the "up" distance removed (completely or partially, depending on which other components are modified) from the piston's compression distance ("CD"). This is measured between the piston pin centerline and the top of the dome. The new CD should be less by ½ the stroke increase (except as noted). There is presently *no specific stroker piston available* for the 45. For motors with "pop-up" heads (1948-1952 WR, 1952-56 K, KH or modified 45 heads with a dome relief cut in the head), which I strongly recommend, custom pistons can be made to your specifications by JE, Arias, Venolia, Wiseco, etc.

The illustration (Page 32, View 1) shows a "generic" 45 piston at Top Dead Center (TDC).

Please note that the dome is below the cylinder's head-gasket surface, which is true for all 45 motors, except 1948-52 WR. The two dimensions that require examination here are the "compression distance" ("CD"; how tall the dome is above the piston pin, not the cylinder), and the "skirt length" (how long the piston is below the piston pin).

The additional stroke length causes the piston to rise farther up towards the top of the cylinder @ TDC by ½ of the stroke increase, and to retreat farther down towards the flywheel's rim @ Bottom Dead Center (BDC) by the other ½.

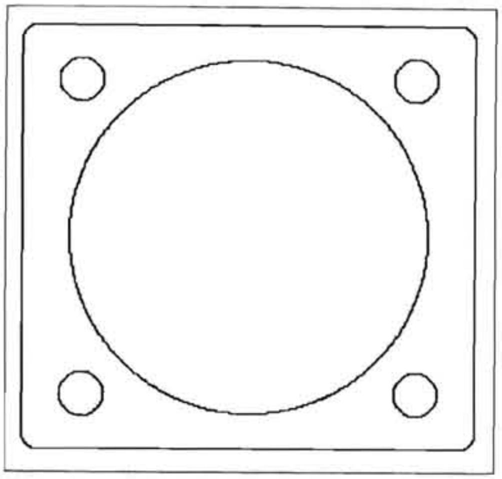
The latter "down" distance can be "fixed" by shortening the bottom of the piston skirt. There are other methods, but they aren't applicable to this installation.

The former "up" distance can be cured by either of 2 methods:

1. Shorter ("stroker") pistons are specially-made (or adapted from another application) with a shorter CD than the stock piston's by approximately ½ the stroke increase.

The skirt is usually shortened by the same amount, so the piston is shorter from top to bottom than the stock piston by the full stroke increase.

2. "Stroker plates" are flat spacers (usually aluminum) that resemble the cylinder base flange, and are installed in between the cylinders and the crankcase to raise the cylinders. This places the top of the piston dome with the new stroke at the same position relative to the cylinder's head gasket surface (deck height) that the stock piston was with the original stroke.



The stroker plate thickness is approximately the same as the CD adjustment on a stroker piston: ½ the stroke increase. Since a base gasket is generally used between the cylinder base and the crankcase, the gasket thickness should be subtracted from the plate thickness for calculations.

The gasket is frequently paper (.002"), and should be measured compressed (after tightening the base nuts) for the actual thickness. Do not use this drawing as a template – not to scale.

In some cases, a combination of a thinner stroker plate and a different stroker piston may be used. The total height adjustment remains the same, it's simply achieved by splitting the adjustment between two components.

Stroker plates will make the entire motor taller, and also separate the front & rear cylinders slightly. This growth will slightly interfere with the intake manifold, 2-1 exhaust, spark plug access, head steady, &c. A washer equal to the plate thickness between the upper valve spring covers and the valve guide flange lengthens the covers. If necessary, use "lash caps" on the valve stems for some extra length.

Modifying Stock 45 Pistons

There are 2 different areas where the std. piston requires modification for use with stroker plates: the length of the piston skirt (below the piston pin), and a point on the bottom of the skirt where the pistons will contact each other @ BDC. I will explore these in order.

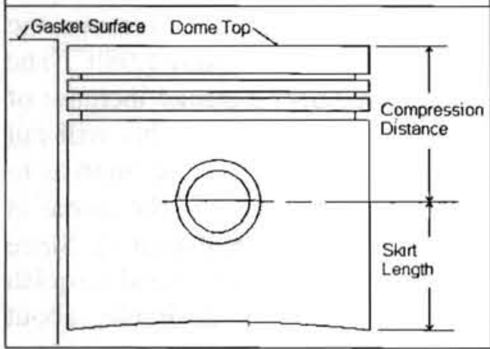
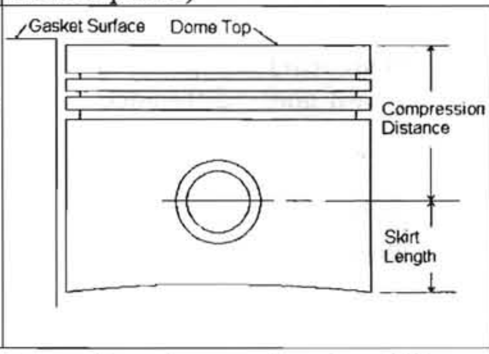
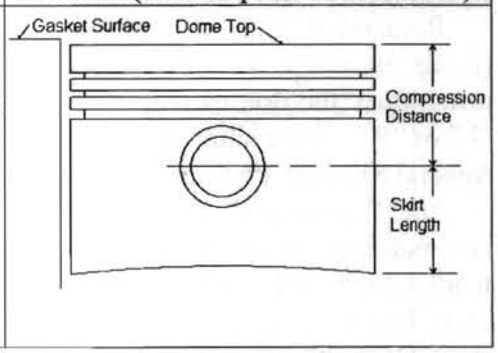
» Skirt clearance to the baffle or flywheel rim:

Ordinarily, compensation for the new, longer stroke must be made by shortening the piston skirt by ½ the stroke increase. However, that's the absolute outer limit – it's not always necessary, since the stock piston has a little "slack" in it. You won't need to take off the whole ½, just remove enough for the bottom of the skirt to clear the baffle or flywheel rim by $^{1}/_{16}$" @ BDC.

Remember that in motors that still have baffles, the front piston must clear the baffle, but the rear piston can be longer – it only needs to clear the flywheel rim.

The illustrations on the following page (not to scale – I have exaggerated the differences to provide more contrast) will provide more detail.

45 Piston Comparison

View 1	View 2	View 3
Std. piston	Std. piston with skirt shortened from the bottom (only for use with stroker plates)	Stroker piston with reduced skirt length and shorter compression distance (stroker plates not needed)
		

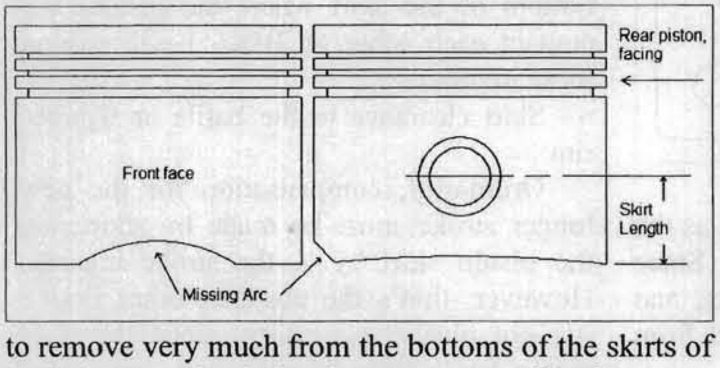
In all three of the illustrations above, the piston dome and cylinder head-gasket surface have been placed at the same deck height for comparison.

Note that the modified std. piston (View 2) has its piston pin at the same height as the stock piston (View 1); the difference is the shorter skirt for flywheel and/or baffle clearance @ BDC. Compare the lengths at the piston's bottoms. This piston must be used with a stroker plate to compensate for the compression distance.

The 3rd piston (View 3) is a custom product (can't be made from a std. piston); note that the skirt length matches the modified piston (View 2), but its CD is shorter than the previous two.

Compare the heights from the piston pins to the piston tops. This piston doesn't require a stroker plate.

For motors without baffles, both front & rear pistons will look alike, and the skirts only need to clear the flywheel rim @ BDC. Since the stock pistons safely clear the baffle now with stock stroke, and the baffle is about .25" - .28" thick, you may not need



to remove very much from the bottoms of the skirts of both pistons. Check the clearance yourself to be sure.

» Skirt clearance between the front & rear pistons @ BDC:

The leading (forward-facing) skirt of the rear piston will strike the trailing (rearward-facing) skirt of the front piston at or near BDC. The trailing skirt is the major thrust surface, and must be left as long as possible. Cut the leading skirt of the rear piston with a die grinder or Dremel, finished with a large, fine, ½-round file. The picture shows the rear piston's front face after the cut has been made. The actual cut will be an inward curve, actually an arc of a circle with a radius of ½ the bore diameter: roughly 1⅜" for the 45, the mirror image of the skirt that will pass by it. Enough metal must be removed to allow a medium paperclip (about $^{1}/_{16}$") to pass between them as the flywheels pass through BDC. Remove any sharp edges.

Remember that the pistons can't be reversed (faced the other way) or interchanged (front to rear) now. Mark the domes with an arrow for forward and "F" or "R" with a china marker.

Special Stroker Pistons

For "zero-deck" (no pop-up) heads, there may commercially-available pistons worth adapting, intended for small cars* and larger Japanese motorcycles. The 45 bore size is 69.72^{mm}, so look for bore sizes from 70-72^{mm}. The domes that I've researched are too short (from the top ring land top the dome's upper surface) to be used as pop-up, and therefore cannot be used in a pop-up (WR, K, KH, &c.) installation. They will be only be useful in motors where size is the sole consideration. The top ring's placement will also limit the maximum depth of the intake relief channel - the ring must not pass into the relief, but should be at least .030" below the deepest part of the relief @ TDC. Do not use a piston with a shorter CD than you need, this is extremely important. The motor will assemble without problems, but will have no power, overheat, and refuse to respond to adjustments.

The KH piston is not a stroker piston, and will not help you.

Truett & Osborn Piston

T&O can supply a piston in std. bore and +.010", +.020", +.030", +.040", +.050", +.060" & .070" oversizes, with the proper compression distance and skirt length to safely accommodate their $4^{7}/_{16}$" & 4½" stroke flywheels. The skirt length will clear the front cylinder baffle, and the deck height will be approximately the same as stock. These pistons can be used with longer (but not shorter) strokes by using small stroker plates, &c.

Ford Festiva Piston*

The 71^{mm} Ford® "Festiva" (1988-94 with Mazda-supplied 1300^{cc}) piston is 45 std. + .050". The piston pin is strong enough, just the wrong diameter at .787", but a new pin bushing with this ID can be made & substituted for the original bushing, or the piston honed to H-D® size.

The piston pin is off-set in the piston, and must be installed with the pin closest to the rear of each cylinder. KB/Silv-O-Lite can supply this in several sizes, as #3126.

The dome contains a shallow depression, which should be removed for best results. It's about .040" deep, and a simple lathe cut will do this. Be careful not to distort the skirt when mounting it, and to make the cut flat to the dome surface. Again, a large, fine flat file may be substituted by the careful craftsman. Remove all sharp edges and lightly radius the dome.

The CD (as supplied) is 1.12", compared to the 45 at about 1.469". After the .040" cut to remove the depression, the remaining height is about 1.080". The difference of about .389" requires a stroke increase of twice this figure, or +.778" to 4.5905". This will put the new piston very close to the original position as to deck height @ TDC (the distance that the dome is below the head-gasket surface of the cylinder). Since this is generally not close enough to the head's squish surface, some additional height is desirable, about .040-.050" in most motors.

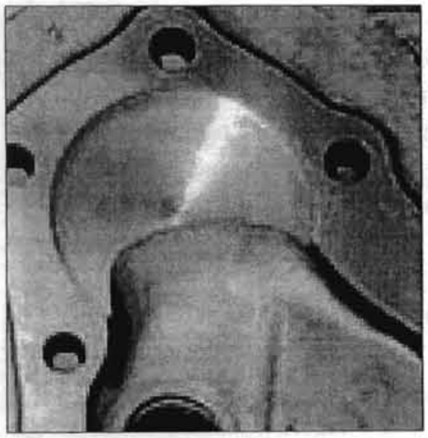
With this figure added to the height, the new stroke length is 4.67 - 4.69", or roughly $4^{11}/_{16}$". Unless some other adjustment has been made, use the next larger stroke ($4^{13}/_{16}$"), and add a plate or shim (about .060") to compensate.

If you prefer, a special (shorter) stroker piston can be made to your specifications by JE, Arias, Venolia, Wiseco, &c., in either normal negative-deck (piston dome is below the cylinder's head-gasket surface @ TDC), or positive-deck ("pop-up", where the dome is above the gasket surface @ TDC, as used in 1948-1952 WR, 1952-56 K, KH). Shown on Page 34 is a 1952-56 K & KH model piston (22251-52A); the WR is very similar but dome is lower.

A special piston will have the "up" distance removed from the piston's compression distance (completely or partially, depending on whether or not you are also using stroker plates), which is not practical to do to a std. piston.

The new CD should be smaller than the stock piston by the same adjustment calculated for stroker plate thickness, above. The skirt will also be short enough to clear the flywheel or baffle. To my knowledge, no manufacturer carries such a product, nor do they have the dimensions of the std. piston on hand. The custom piston you receive will be no better than the information and instructions you can provide to the manufacturer.

Remember, your choice of whether or not to retain the baffle affects your choice of skirt length, and whether the two pistons are alike.



You have a choice between old (wide) rings, or late (narrow) rings – narrow is preferred, if you can't send them a sample piston using late rings I think the data is available to them.

You can also specify two slightly different bore sizes if your cylinder are slightly off – no, it won't affect the balance, don't worry about it. Don't limit your choice to "normal" oversizes – they can make any size at all. I suggest an in-between size slightly smaller than the next oversize, such as .045" (rather than .050"), so that the .050" rings will be tighter, allowing you to set the final end gap by hand.

If you go through the "deck height" steps, you'll have a precise figure to include with your sample piston, so the instructions to the manufacturer will be something like:

"I need 2 pistons for a Harley-Davidson Model W air-cooled side-valve 750cc 45" V-twin exactly like the enclosed sample, except for the following changes:

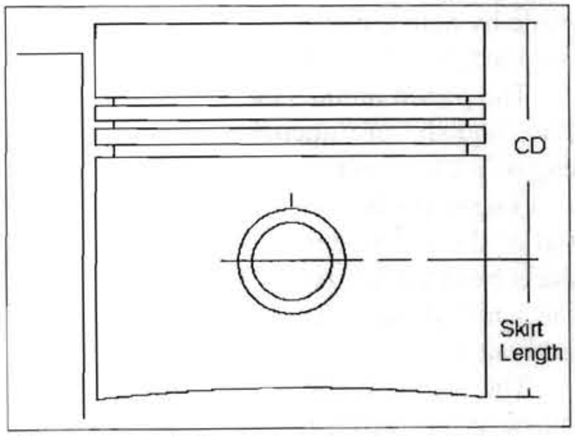
1. reduce the compression distance by .XXX".
2. shorten the skirts by .YYY".
3. the final bore size is sample +.045" (or exactly 2.800", &c.)."

Positive-Deck Pistons

It's important to keep in mind that re-designing the motor allows you to make other improvements as well. The most important of these to increase the efficiency of the combustion chamber.

Positive-deck pistons (which I strongly recommend) can be used by modifying 45 heads with a dome relief cut in the head. This adds power and torque to any size motor, and is well worth the extra trouble to calculate the measurements and do the machine work. No factory race or high-performance side-valve motor (including the Indian 45 Sport Scout, 74 Bonneville & 80 Blackhawk Chiefs) was built without this feature after 1948. If given a choice between stroke alone, and stroke + pop-up, go with pop-up. The only available H-D factory positive-deck piston is the K piston (shown, above left), which is similar to the 45 piston except that the dome ends above the head-gasket surface, and the skirt length is shorter to clear the flywheel rim with $4^{9}/_{16}$" (KH) stroke.

A K piston can easily be substituted for a 45 piston; they're reproduced, have the same bore size and use the same piston pin



diameter and ring set as the late 45 piston.

The picture (shown left), shows a 45 aluminum head with a relief cut for a K-type piston dome made with a Bridgeport mill. The depth calculations appear on Page 35.

Stroker Plates

If you're going to use modified std. 45 pistons, you'll have to make the stroker plates (see the diagram on Page 4). Unfortunately, aluminum plate is not easily available in precise sizes for this purpose, generally only ⅛" increments (¼", ⅜", &c.), so you have a choice: use ¼" and add shims, or ⅜" &c. and machine it down to the correct thickness (as described on Page 6). Steel plate may be available in $^{5}/_{16}$" thickness, but it's harder to work with, and this thickness may still not be completely accurate as you will see from the calculations.

If using ¼" plates, height can be added with aluminum or brass shim stock, easily available in hobby & craft stores as model airplane stock ("K-D" brand). This can be cut to size with a razor saw or even shears.

2 pieces about 3½" wide by 4¼" long is enough for both plates. Commercial-quality plate is sufficiently parallel that surfacing shouldn't be required, but check to be sure. Note that the ⅜" cylinder base stud hole pattern is not square but rectangular. The spigot (center) hole must be large enough not to contact the cylinder mouth; 3.00" is fine. I suggest that the fit & placement of the stud holes can be slightly "tighter" than found in the cylinder flange for a snug fit.

Setting the Deck Clearance

Regardless of whether you have chosen to use modified std. 45 pistons with stroker plates, stroker pistons, or a combination of both, proper positioning of the pistons @ TDC cannot be done by mathematical prediction alone. The final "adjustment" should be made by actual measurement of the components to be installed, before final assembly.

The piston dome's distance from the head @ TDC (the "squish" or "quench" distance) is critical to the engine's life, power and efficiency. The "deck height" in a **negative-deck** (non-pop-up) motor is how far the top of the piston dome is below the top of the cylinder's head-gasket surface @ TDC. The remainder of the squish distance is the head-gasket thickness, which is about .019" with copper gaskets.

The deck height in a **positive-deck** (pop-up) motor is the depth of the piston dome recess in the cylinder head (plus the head gasket thickness as above), minus the distance the top of the piston dome is above the top of the cylinder's head-gasket surface @ TDC. Please note that WLD, WLDR, WR, K & KH motors used silver paint was as a sealer instead of head gaskets.

Deck height measurements must be very accurate, and allow for gasket compression. If this distance is less than .016" (negative deck motors), thin shim stock (or thicker spacer, gasket, &c.) must be installed under the cylinders to get a minimum of .035" between piston and head.

It is extremely important that the piston miss the head @ TDC by a very small margin. *The absolute smallest safe distance is .035"*. Distances larger than .050" greatly reduce the motor's efficiency and make it more knock-sensitive.

If the distance is more than .050" (the piston is below deck by .031" or more), consider reducing the stroker plate thickness (if used) and/or a light mill cut off one of the following surfaces (if stroker pistons are used), in order of practicality:

» cylinder head-gasket surface
» cylinder base-gasket surface
» crankcase deck surface
» *please note that milling a non pop-up head is not included – it does not work*

To install std. 45 pistons with modified skirts or K pistons, a stroker plate of ½ the stroke increase is predicted, but since the 45 motor's factory deck clearance is very "loose", some of the predicted stroker plate thickness is not necessary – we can simply allow some of the stroke increase to move the piston upward to a more favorable position @ TDC.

In 45 motors I've measured, the amount of excess deck clearance is about .030-.060"*, meaning that this amount can be safely added to the "up" distance by removing it from the predicted stroker plate thickness.

Crank-pin

The following flywheel choices make use of specific crank-pins mandatory:

» S&S 45 flywheels: the supplied special short XL-type 1¼" crank-pin must be used.

» T&O-45, Chief or 1954 KHR flywheels: the original 1.00" crank-pin (23960-29) is used with the original rods, or the "stepped" 1939-1954 WR 1¼" pin (23960-39R) with WR rods.

Crank-pin bearing assembly

Use a bearing assembly consistent with the crank-pin choice:

Crank-Pin	Flywheels	Roller Bearing & Cage Assembly
S&S 1¼" Special	S&S Special	1952-* XL $^3/_{16}$"
Std. 1.00"	T&O-45, Chief or 1954 KHR	original ¼"
WR 1¼"	T&O-45, Chief or 1954 KHR	1939-1954 WLDR/WR (parts are obsolete)

Connecting rods

S&S: use some version of the XL rod set. These are available used, repro, heavy-duty, super-duty, and Carrillo (in order of price). Various lengths are available: 6.926", 7.113", 7.4375" and 8.00" (not in all types). The Carrillo's extreme beam width will not fit with the longer stroke lengths.

T&O-45 Chief or 1954 KHR flywheels: try to find a good 1939-1954 WLDR/WR/KR complete rod assembly. This has the small stepped crank-pin (1" tapers, 1¼" journal), and a heavier rod beam than the 45, but still interchanges with the std. 45 rod set as to width and length.

Motor	Rod Length	Comment
All 45, K, KH, XL 900/1000^{cc} 1932-85	7.4375"	includes WR
1983-84 XR1000, Evo XL 1986-*	6.926"	883, 1100, 1200^{cc}
S&S #7900 for Evo XL stroker (up to $4\frac{5}{16}$")	7.113"	adds clearance for stock frames

Rod Pair	Crank-Pin	Flywheel Use	Length	Width
Std. 45	Std. 1"	std. 45, T&O-45, '54 KHR, Chief	7.4375"	1.38"
WR	WR 1¼"			
XL std.	1¼" S&S Special	S&S Special	7.4375"	1.50"
S&S 7900 Special			7.113"	
Evo & XR1000			6.926"	
Carrillo			8.00"	

Preparation, Flywheels

Check the 2 oil holes in the right wheel to verify alignment of oil transfer between the pinion shaft and crank-pin holes - elongate the wheel holes and radius as required. S&S informs us that alignment of this oil passage is critical in 4⅝" & larger flywheels.

If you wish, mark the left wheel for TDC (a dot is the usual mark). The formula for determining the movement of the flywheel in inches for each degree of rotation is $OD * \Pi \div 360$.

At the rim, the wheels are 7⅞" (7.875") OD, giving a circumference of 24.74".

This makes each degree of crank rotation .0687" of movement. To find TDC (from a 30° timing mark slot), measure .206" back with a tape along the rim (against engine rotation).

The effective size of the inspection hole in the left case is .53", which allows a movement of about 4° in either direction to be observed. A second dot (or 2 small dots, 1 above the other, &c.) at 10° BTDC may be useful. This should be between the TDC and 30° marks.

Crankcases

The cases must be a matched pair. If the bottom numbers do not match, machine the deck surface, main bearing bore, motor mounts, &c.

Bore the case mouth(s) straight through to remove the baffle(s) completely. The mouths should be radiused at the bottom, with the curve ending at the exact placement of the cylinder spigot. This will improve cylinder oiling, and reduce pumping losses. The scrapers should clear the flywheel OD by no more than .005-010" if possible.

Remove & discard the original base studs (soak them in Kroil, Rustbuster, &c. for 24 hours first). Lightly ($^1/_{32}$") countersink the stud holes before installing the new longer studs.

Very carefully draw a large, flat, fine file over the deck surface of the mated cases to be sure that the deck has not pulled up around the studs. If so, carefully reduce this area flush with the deck. Perform the same operation on the cam cover gasket surface & case mating faces - <u>only</u> to remove high spots.

Install S&S XL, or H-D factory 16830-54 (1954-1971 KH & 900^{cc} XL) or 16830-72 (1972-1985 1000^{cc} XL) cylinder base studs (also use flat washers & high-quality base nuts).

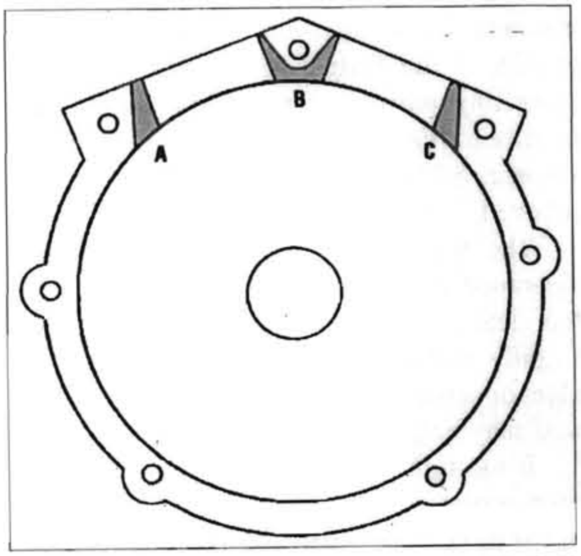
For best results, a "½-assembly" is used to determine the points of interference between components caused by the longer stroke, and piston and rod paths.

This is usually the right case only, tilted to angle the pinion shaft about 30° down. The assembled flywheels are in place, with pinion rollers & cages, right end-play collar, pistons with no rings, and both cylinders snugged down (no base gaskets) on 2 studs each.

Now the motor can be rotated (forward or clockwise - the normal direction), and the points of contact can be checked & measured. *All components must miss each other during rotation by a minimum of $^1/_{16}$"* (a large paper clip as a feeler gauge is slightly too small, but useful). Many components will touch or pass each other too closely, and must be relieved.

The case mouths must have the existing clearance notches deepened a bit.

Aluminum must be removed from the shaded areas (front and rear of each opening, a total of 4 cuts in each case half, as shown, left), and also widened for the extra beam size, if heavier WR or XL rods are used.



More room is necessary in the right case, where the crank-pin nut will touch the cam bearing ledge, main bearing boss, &c.

The best available information suggests that $4^{13}/_{16}$" flywheels will require much aluminum to be removed from the cases in the areas shown, but will successfully clear the case center stud at "B" (24812-37) and through-bolts at "A" & "C" (4080).

With even longer strokes, or heavier and/or longer rods, modification to these fasteners may be needed.

In some extreme cases, the original bolt or stud holes are closed with aluminum stock and/or heli-arc, and new holes are drilled located farther away from the rod path to allow deeper reliefs. If the new fastener is NAS quality (ARP, &c.) a slightly smaller diameter will work OK (7 mm instead of $^{5}/_{16}$"), as long as its installed torque meets or exceeds the original.

Small radiused channels can be cut into the inside case walls in the shape of a "V" to direct drain oil down into the main races.

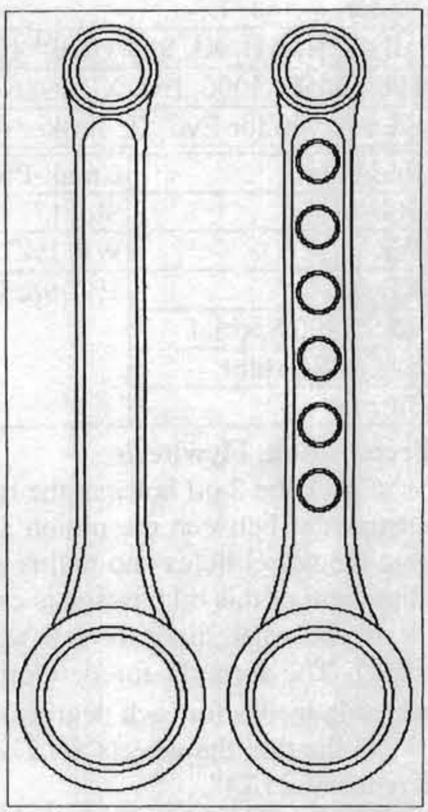
Remove any obvious flashing, casting roughness, &c. and clean very carefully to remove debris. Glass beading is not preferred here, as the beads cannot be completely removed, and will eventually wind up in the oil system. Use walnut shells, plastic media, &c.

Connecting Rods

The female rod must be relieved in the area where the male rod shoulder seats (when the rods are held together, as shown, Page 40). Using crayon, &c. on the male rod beam will show the area to be trimmed. A ⅛" carbide cutter in a die-grinder is the fastest method. *Do not remove any more material than necessary; be sure to blend in the cut to the remaining surface*. S&S & Carrillo rods are already relieved, but check to be sure.

The female rod needs .020-.025" side clearance between the flywheel halves. If the clearance is excessive (beyond .030"), slightly thicker thrust washers are available, or some added torque to the crank-pin nuts may help.

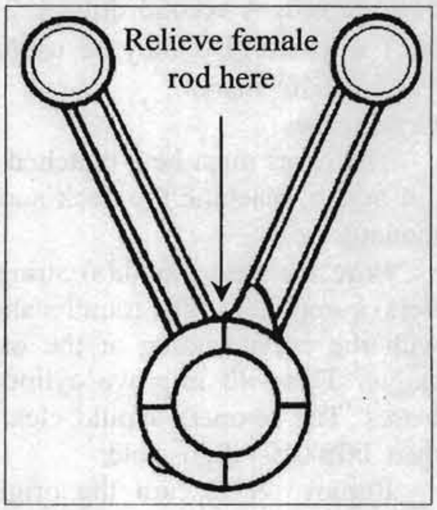
If too tight, the washers can be thinned on a surface grinder, or the thrust surfaces of the rod can be narrowed very carefully.



The wider Sportster rod beam can be slightly narrowed to improve clearance if necessary by removing up to .030" from the shoulder at the point of interference, and blending the cut into the remaining body of the rod over a distance of at least several inches, very carefully.

Restore the curvature of the area as much as possible, and polish the surface, then shot-peen if possible. If done properly, the modification should be nearly invisible. Do this as a last resort only, if all other clearances are at maximum and there is still interference.

If using XL-type rods (which are substantially heavier than std. 45), a small increase in engine smoothness can be obtained by lightening the rod beams as on WR & JD motors (before balancing, of course). Lay out a pattern of holes, about $^{3}/_{16}$" smaller in diameter than the width of the rod web (the depressed area in the center of the beam). Keep equal spacing between the holes. Once the holes are drilled to size, countersink the holes lightly, then carefully radius the holes on both sides to *completely remove all sharp edges*. This reduces the reciprocating weight a bit, but must be done very carefully. The remaining beam structure will be much more than enough to support the RPM, piston weight, and power levels your motor will experience. The picture is not a template, but only a general guide; the size, placement & number of holes is up to you.



Cylinders

The cylinder spigots (extending down from the flange bottom into the cases, seen here, inverted for detail) must be notched for rod clearance. Please note that the rods will need more room in the front & rear only - be careful to identify which side of the cylinder needs work. 45 cylinders have the casting number (as shown, left) in between the cylinders: rear of the front cylinder & front of the rear cylinder.

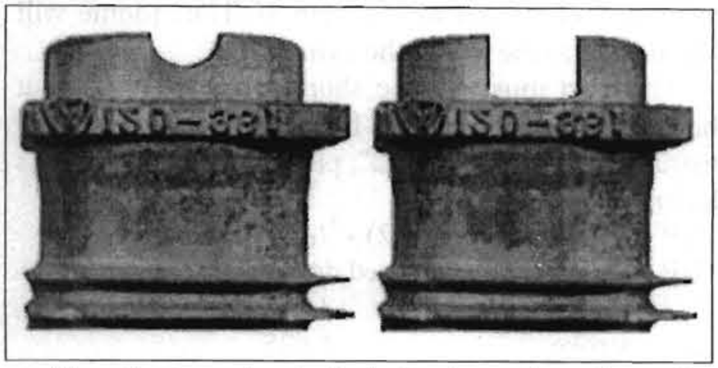
The top (deepest part) of the notch should not be a square cut - use a big radius with no sharp edges, and smooth the cut with a file, &c.

Allow at least 1/16" around each rod at all points. For example, if the rod width is ½", add ⅛" (1/16" each side), for a total of ⅝" notch width. The corners at the bottom of the cut should be a small radius (not square).

In the picture below, the left image is how most stock cylinder flanges are clearanced in at least 1 place for rod movement now.

The right image (notch size exaggerated for illustration) is a typical K or Sportster relief - wider for the thicker beam, and deeper (nearly up to the flange gasket) for a wider rod.

If the notch shown, right, was cut deeper still (*up above the bottom or lower gasket surface of the cylinder flange*) it would approach reliefs as found in KH motors. This is OK if necessary, but be conservative - remove no more metal than needed.



The absolute depth limit is the point where the notch passes through most of the flange and approaches the top or upper cylinder flange surface (where the base nuts seat). *If the relief notch traverses the flange completely, the flange will crack.*

A potential cure for this is to use stroker plates to raise the cylinders (rather than shorter custom stroker pistons), so the cuts in the flanges will be slightly less severe. This allows a less radical cut to achieve the same level of safety (but will not affect the case reliefs).

Be sure to clearance the plates as above, and mark them for installation (which cylinder, top or bottom, facing front or rear, &c.).

Pistons

Once the cylinders have been bored, the pistons cannot be interchanged (between cylinders), or reversed (faced the other way) - be sure what you're doing.

In most cases, the piston skirts too long. The leading skirt of the rear piston will strike the trailing skirt of the front piston. The trailing skirt is the major thrust surface, and must be left as long as possible. Cut the leading skirt of the rear piston with a large, fine, ½-round file. The actual cut will be an inward curve, actually an arc of a circle with a radius of ½ the bore diameter: roughly 1⅜" for the 45, the mirror image of the skirt that will pass by it.

Ordinarily, compensation must be made by making the piston shorter by 50% of the stroke increase. The piston must have its skirt below the pin shortened to clear the flywheels @ BDC. You may not need to take off the whole 50%, just remove enough for the bottom of the skirt to clear the wheels by 1/16". The maximum skirt length of the piston (measured directly under the pin hole) can be calculated using the formula in "MAGIC". S&S recommends clearance to the std. flywheel rim of 1/16".

The piston's distance from the head @ TDC (the "squish" or "quench" distance) is critical to the engine's life, power and efficiency. The "deck height" is how far the top of the piston is @ TDC below the top of the cylinder (the remainder of the distance is the gasket thickness).

Deck height measurements must be very accurate, and allow for gasket compression. If this distance is less than .015", thin shim stock must be installed under the cylinders to get a minimum of .035" between piston and head; this assumes use of copper gaskets about .020" thick.

It is extremely important that the piston miss the head @ TDC by a very small margin. *The absolute smallest safe distance is .035"*. Distances larger than .050" greatly reduce the motor's efficiency and make it more knock-sensitive.

If the distance is more than .050", consider a light mill cut off one of the following surfaces, in order of practicality (*please note that milling a non pop-up head is not included*):

» cylinder head-gasket surface
» cylinder base-gasket surface
» crank-case deck surface

Balancing

The wheels must be balanced; use whatever procedure your balancer feel comfortable with. This must be done accurately, however, due to the rod/stroke ratio.

The balance weight (large eccentric area opposite the crank-pin hole) may not be sufficiently heavy, so some weight may have to be removed from the area near (not at) the crank-pin hole.

The alternative is to drill holes in the balance area, and fill them with "Mallory metal" (a tungsten alloy, even heavier than lead). The difference between the steel removed and the Mallory metal installed adds weight, but costs $$$.

A less efficient alternative is to drill the wheels for the largest safe pipe tap pilot size, thread the hole, fill with lead, and close with an allen-head pipe plug.

Vent the plug with a $^1/_{16}$" drill to allow air to escape as the plug is tightened. The plug should be flush or slightly recessed, and peened over to prevent loosening. The following chart shows common pipe thread sizes:

Hole Diameter	.339"	.4375"	.5781"	.7031"	.9219"
Pipe Thread	⅛-27 NPT	¼-18 NPT	⅜-18 NPT	½-14 NPT	¾-14 NPT
Pilot Drill	Letter "R"	$^7/_{16}$"	$^{37}/_{64}$"	$^{45}/_{64}$"	$^{59}/_{64}$"

"Short-Rod" Flywheel Assembly

A different method can be used to install 4⅝" flywheels. The additional stroke length ($^{13}/_{16}$", or .8125") raises the piston farther up towards the top of the cylinder @ TDC by 50% of the stroke increase (.40625"), and farther down @ BDC by the other 50%, as discussed previously.

The usual method of coping with this is a shorter piston. The method I will explore here is to remove most of this height from the assembly by using a shorter connecting rod set. Please note that this is <u>only</u> a method of avoiding use of an expensive specially-made custom piston, and is most effective when used with WR, WLDR or K-Model cylinders, due to their large intake ports. A motor with std. cylinders will last longer and breath better with std. length rods.

The S&S Special stroker flywheel set uses a special crank-pin, but will accept <u>any</u> XL rod pair. The std. XL rods are the same length (center of race to center of pin bushing) as all 45, WR, K or KH. However, there are other lengths available, see Table on the top of Page 5.

The S&S 7.113" long rod pair is the one I will explore. It is available from S&S as #34-7901 & 7902 (bare male & female rods). These rods are super-strong, but must still be checked for this stroke length (relieve the female rod mouth as shown in the previous diagram).

This crank-pin is unique to the S&S 45 wheels, a rod <u>set</u> is not directly available. However, these rods can be fitted by S&S to the correct crank-pin on request. The rod length is .3245" (just under $^{11}/_{32}$") shorter than the original 45 (or std. XL) rod, and "uses up" (compensates for) a great deal of that .40625" "up distance" we needed to lose. The remainder is .08175".

Since the std. 45 piston does not reach close enough to the cylinder top @ TDC in the std. motor, we only need about a $^1/_{32}$" (.03125") shim under each cylinder to put the piston right where we want it: .035" away from the squish surface of the head @ TDC, or .015" below the cylinder's gasket surface (this assumes use of copper gaskets about .020" thick). Measurements must be done as described above.

The K piston (used <u>only</u> with K heads, 1948-52 WR heads, or other heads modified for pop-up) also does not come close enough to the squish ledge, and can be brought closer, with the math & adjustments being about the same. Remember that the K does not normally use head gaskets, and that the .035" clearance will now occur <u>inside</u> the head, and that the dome will come out of the bore @ TDC (dome will protrude from the top of the cylinder).

The skirt must still be shortened, by enough that the lower edge clears the flywheel OD. Taking our instructions from "MAGIC", page 2, the skirt length is determined:

$NP = L - (S \div 2) - (D \div 2) - {}^1/_{16}"$, where

NP	skirt length measured down from the pin	
L	rod length	7.113"
S	stroke	4.625
D	flywheel diameter	7.875
$^1/_{16}$"	safety margin	

Solving, we get NP = .801" from the pin center to the skirt bottom, or .405" from the pin's lower edge (pin diameter is .791").

The skirt along the thrust face can and should be slightly longer, due to the curvature of the flywheel. To determine this length, we refer to "MAGIC" again:

$NT = NP + (D \div 2) - (R^2 - B2^2)^{.5}$, where

NT	skirt length measured down the thrust axis	
NP	skirt length (above) on pin axis	.801"
R	piston diameter ÷ 2	1.3725"
NT	1.048"	

Note: I cannot supply any of the parts or services listed in this article (except as noted: *). Parts listed above as being available from KNS Cycle <u>must be ordered from them</u>.

The comments given above are not suggestions, but observations, and are not practical in all instances. It is your own responsibility to make all measurements and decisions.

Component	Part No	Source
Flywheel set, 4$^{7}/_{16}$" for std. 45 lower end	23903-02R	Victory
Flywheel set, choice of stroke	see text	Victory, T&O, S&S
XL special 1¼" crank-pin	NPN	S&S
XL std. 1¼" crank-pin	23960-54	KNS Cycle, S&S
Crank-pin nuts, locks		KNS Cycle, S&S
Special short S&S XL rod set	34-7902 & 7902	S&S
Std. repro XL rod pair or set		KNS Cycle
Stroker pistons, 4$^{7}/_{16}$ & 4½"		T&O
Special pistons (your dimensions)	NPN	Arias, JE, Venolia, Wiseco
Ford Fiesta pistons	3126	Silv-O-Lite (see Summit or Jeg's)
Std. 45 pistons	22216-29, &c.	KNS Cycle
K pistons	22216-52A, &c.	KNS Cycle
Sportster pinion cage, new & used	24718-54*	Victory
$^{3}/_{16}$" Sportster roller bearings	see text	KNS Cycle
Aluminum 6061 stock for custom plates	NPN*	Victory
Long base studs	16830-54 or 72	KNS Cycle
$^{5}/_{16}$" longer base studs		S&S
Special length base studs	NPN	ARP (see Summit or Jeg's)

FACTORY HOT PARTS

If you own a stock 45 solo, Servi-Car or military model, you can increase your horsepower and durability by adding or adapting parts from one of the factory high-performance motors. The standard models have serial letters (VINs) as follows:

1932-36 R, RL
1937-1952 W, WL, WLA, WLC
1937-1973 G, GE, GA

The high-performance motors have VINs as follows:

1932-36 RLDR
1939 WLDD
1939-1946 WLD
1937-1941 WLDR
1941-1952 WR
1952-1953 K, KK
1953-1969 KR, KRM, KRTT
1954-1956 KH, KHK, KHR, KHRM, KRHTT
1957-* XLR

A great deal of confusion exists as to the identification of these parts, and much inaccurate data is passed off as factual. To clarify the history and construction of these motors, I have assigned all similar and/or interchangeable parts to the same group, which I will refer to as a "**Type**". I will use these Type numbers (shown in the 1st Column) to indicate a specific and related state of tune. Generally, similar parts with the same Type number or number group are interchangeable (except as noted). The degree of similarity can be deduced by a comparison of the Type numbers; i.e., 2.00 and 2.01 are very close, whereas 2.00 and 3.00 are quite different (perform the same function, but cannot be directly interchanged). Wherever practical, the same Type number will be used to indicate parts in the same stage of development, that were originally used in combination. For example, a WR head and cylinder are both listed as Type 3, &c. In some cases, this is (obviously) impossible, as with manifolds, &c.

The type of part number used by H-D® has varied over the years. Always present is the "characteristic", a number sequence indicating the function of the part; all modern crank-pins have similar numbers, as in "239XX". After this characteristic, a hyphen ("-") appears, then the 1st. year of use. This may not be the earliest year the part can be used – retro-fitting is sometimes possible, see the specific listings for details.

I have used the type of H-D® part number consistent with the age of the part wherever practical to make searching lists for these pieces easier.

In the 1930s, a 5-digit number was used, with the 1st digit being "8" (indicating a racing part), then the identifying characteristic, then the hyphen, and ending with the year. For example: a WR intake manifold is 81107-40. The next type began in mid-1940s, with a 5-digit number beginning with "R" in place of the "8", otherwise identical: R1107-40. The last type is modern (1950-*), in which a different characteristic reference is used, then the hyphen & year, with the letter "R" as a suffix, as: 27020-40R.

When 2 part numbers are listed in Column 2, the 1st is the left, front, or upper, the 2nd is the right, rear, or lower of a pair.

A 2nd pair is the later or alternate number for the same part.

A letter "X" in the part number or year means "exact number unknown". The phrase "as 1.00" means substantially identical to the Type quoted, except for the differences specified.

I will list parts in H-D® rough part-number order, beginning at the top of the motor:

Cylinders (Note: std. bore of all 45, K, KH & KR cylinders is 2.745" or 69.72mm)

Type	Part Nº	Model	Description & notes
1.00	16460-36 16461-36; 2-36, 3-36	1937-73, all with $^{3}/_{8}$" studs	Base cs^{tg} #120-36 (front), 120-361 (rear), can use only Type 1.00 iron heads; both valves 1.625" (1⅝") OD, have 45° seat ∠; 1½" pipe fits <u>into</u> exhaust port
1.01	80002-37 80003-37	1937-38 WLDR	As 1.00, except relieved, and intake port enlarged to 1$^{5}/_{16}$" ID and U-sized nipple inserted
1.20	16460-40 16461-40	1940-73, all with $^{7}/_{16}$" bolts	As 1.00, except can use any Type 1.2X-1.4X heads with $^{7}/_{16}$" holes (iron or aluminum)
1.21	16460-4X 16461-4X	1946-4* WL	As 1.20, except full-width gasket surface, uses 1.30 type aluminum head
1.30	80002-39 80003-39	1939 WLDD early 1939 WLD	Cs^{tg} #120-39 (front), 120-391 (rear), similar to 1.20, but slightly thicker base flange, has 2" manifold nut, 1$^{7}/_{16}$" ID intake port, full-width gasket surface, std. Valves
1.31	80002-39A 80003-39A	1939 WLDR, late 1939-46 WLD	Similar to 1.30, but heavier casting with thicker base flange, bigger fins, std. Valves
1.40	80002-40 80003-40	1940-41 WLDR	As 1.31, except 2⅛" nut, 1$^{9}/_{16}$" ID port, std. Valves
2.00	80002-40A 80003-40A	1940A WLDR (Special)	As 1.40, except valves closer to bore, guides are "tipped" towards bore: intake 1°2'∠, exhaust 3°32'∠
3.00	80002-41 80003-41; R0002-41 R0003-41	1941-52 WR	Similar to 2.00, but has 1.81" intake seat, 1$^{9}/_{16}$" exhaust seat, 30° valve seat ∠, intake slightly closer to bore opening, exhaust much closer to bore, guides are "tipped" towards bore: intake 1°2'∠, exhaust 3°32'∠;
4.00	16471-52 16473-52	1952-53 K, KK	Resembles 3.00 (different casting), but for 2 base studs (under exhaust ports), 1¾" pipe fits <u>over</u> exhaust port stub, guides are "tipped" towards bore, different head-bolt pattern, 45° seat ∠
4.01	16471-54R 16473-54R	1953-69 KR KRM, KRTT	As 4.00, except ported & relieved, 30° valve seat ∠ (many other part numbers during 1950s & 1960s)
5.00	16471-69R 16473-69R	1969 KR Low-Boy	As 4.01, except shorter (head gasket to base gasket distance), exact distance unknown
6.00	16471-54 16473-54	1954-56 KH, KHK	As 4.00, except .375" taller
6.10	16475-54R 16476-54R	1954-56 KHR, KHRM, KHRTT	As 6.00, except ported & relieved, 30° valve seat ∠

Valves, Exhaust

Type	Part Nº	Model	Description & Notes
1.00	18080-32	1937-73 G, WL, WLD, WLDR	Exhaust 1.625" (1⅝") diameter head, 45° seat ∠, $^{11}/_{32}$" stem diameter, 5.59" long
2.00	1808X-52	1952-53 K	As 1.00 except 1.56" (1$^{9}/_{16}$") diameter head
2.10	80164-41	1941-52 WR; 1953-54 KR	As 2.00 except 30° seat ∠
2.20	18080-55R	1955-68 KR	As 2.10 except $^{5}/_{16}$" stem
3.00	1808X-54	1954-56 KH	As 2.00 except 5.875" long stem

Type	Part №	Model	Description & notes
1.00	9-36B 10-36B	1936 RL 1937-39 WL	6-1 compression, iron, fastened by 3/8" studs & nuts to cylinder, 18^{mm} plug thread, marked "4.5"
1.01	80009-36 80010-36	1936 RLDR 1937-38 WLDR	As 1.00, except polished chamber
1.20	16692-40 16695-40	1940-46 WL, WLA, WLC	5-1 compression, aluminum, 7/16" bolts, stamped "5", military, casting # 119-39/119-391
1.21	16681-39 16683-39	1947-52 WL	As 1.20, except 6-1 compression, stamped "6"
1.30	80009-39 80010-39	1939 WLDD; 1940-46 WLD; 1940-41 WLDR	6-1, aluminum, 7/16" bolts, wide gasket surface (no indents between bolt holes, 1939-41 WLDR does not use head gasket)
2.00	80009-40 80010-40	1940A WLDR (Special)	As 1.30, except valve reliefs close to bore opening, similar to 3.00 except smaller intake valve relief
3.00	80009-41 80010-41	1941-47 WR	Aluminum, 7/16" bolts, wide gasket surface Valve reliefs close to bore opening
3.10	R0009-48 R0010-48	1948-52 WR	Aluminum, 7/16" bolts, wide gasket, valve reliefs close to bore, .090" deep relief above bore for piston dome
4.00	166XX-5X	1952-67 K, KK, KR; 1954-56 KH KHK, KHR	6.5-1 (K) or 6.8-1 (KH), aluminum, different bolt pattern than 45, different casting with "deck" connecting fins together, 14^{mm} plug thread, .150" deep relief above bore for piston dome; many different part numbers and variations
4.10	166XX-6XR	1967-68 KR	As 4.00, except different squish ledge shape
5.00	166XX-6XR	1968-69 KR	As 4.00, except different pop-up relief for radiused dome on piston

Valves, Intake

Type	Part №	Model	Description & Notes
1.00	18070-32	1937-73 G, W, WL, WLD, WLDR	Intake 1.625" (1⅝") diameter head, 45° seat ∠, 11/32" stem diameter, 5.53" long
1.10	1807X-52	1952-53 K	As 1.00 except 1.8125" (1 13/16") diameter head
2.00	1807X-54	1954-56 KH	As 1.10 except 5.875" long stem
1.20	80163-41	1941-52 WR; 1953-54 KR	As 1.10 except 30° seat ∠
1.21	18071-41V	all 45 & K 1937-73	As 1.20, by KNS Cycle, 1.875" (1⅞") diameter head, thinner head with small special stem-to-head radius ("T"-shape)
1.30	18070-55R	1955-68 KR	As 1.20 except 5/16" stem, fits all 45 if correct guide or sleeve is used

Tappets

Type	Part №	Model	Description & Notes
1.00	18490-29	1929-73 all std. motors	Roller tappet design, steel body, interchangeable in 1.0X tappet blocks (also used on VL/UL), 2 large holes through the body for weight saving
1.10	18508-52R	1952-* KK, KHK, KR, KHR	As 1.00, except 3 holes through the body, Larger internal id for lighter weight
2.00	80200-40	1940A WLDR (Special)	As 1.00, except special for this model only, rollers are on an angle to the body, intakes & exhausts are different
3.00	80200-41	1941-52 WR	Flat & wider contact surface on an angle to the body: intake 1°2'∠, exhaust 3°32'∠, resembles an ice-skate, use only 3.XX cams, all 4 tappets are different
4.00	18490-53R	1953-55 KRM, KHRM	Similar to 3.00 (flat), except contact surface is .375" wide (same as roller tappet), and at 90° to the body axis (not tipped), intended for use in std. K blocks with special cams for this desert-racer motor

Tappet Blocks

Type	Part Nº	Model	Description & Notes
1.00	18605-30	1930-54 all std. motors, incl. 1939-41 WLDR	2 bolt flange, front & rear are different, accepts all tappet Types, uses any screw-on spring covers (including VL & UL 1930-38), roller slot is approx. $^3/_8$" wide
1.01	186XX-55	1955-73 all std. motors	As 1.00, except has a small hole in rear of tappet bore for oil drain
2.00	80235-40X	1940 WLDR (Special)	Same flange as 1.00; seals to special push-on covers with O-rings, all 4 blocks are different, tappet bores are off-set & angled: intake 1°2'∠, exhaust 3°32'∠, use only 2.00 (roller) tappets
3.00	80234-41 (set)	1941-52 WR	Similar to 2.00, use only 3.00 (flat) tappets, all 4 blocks are different, intake & exhaust are offset & angled: intake 1°2'∠, exhaust 3°32'∠, tappet contact surface slot is much wider than roller types (1.0X, 2.00)

Valve Spring Covers

Type	Part Nº	Model	Description & Notes
1.00	182XX-41	1941-68 all std. motors	2 piece, flat rubber band for seal between halves, threaded lower matches 1.00 blocks
1.01	182XX-69	1969-73 all motors	As 1.00, except has O-ring seal between halves
1.10	182XX-30	1930-38 VL & UL	3 piece, O-ring seal, large diameter, threads on the lowest section match 1.00 blocks
2.00	80173-40 80174-40	1940 WLDR (Special), 1941-52 WR	2 piece, O-ring seal to block, only fits 2.00 & 3.00 blocks

Crank-Pins

Type	Part Nº	Model	Description & Notes
1.00	23960-29A	1937-73 all std. motors	1.00" OD; 1.00" diameter @ larger end of tapered holes; roller bearing journal area is 1.40" long, pinion side is drilled for oil
1.10	23960-39R	1939-51 WLDR, WR; 1953-54 KR, KHR	1.25" OD; 1.00" tapers ("stepped" like a miniature UL or EL pin); 1.40" long; requires 1.1X cages, rollers & rods, fits all stock 45 flywheels 1937-73
2.00	23960-54	1954-56 KH; 1957-81 XL	1.25" OD; 1.25" tapers; 1.50" long; like shorter straight FLH pin
2.10	23960-81	1981-* XL	As 2.00 except for "commonized" tapers on shaft holes
2.20	S&S 513	45 special	As 2.00 except shorter for use <u>only</u> with S&S 3012/3 std. Or stroker flywheels for 45
3.00	23960-55R	1955-69 KR; 1955-56 KHR; 1957-* XLR; 1970-71 XR	1.50" OD; 1.25" tapers ("stepped" like a giant UL or EL pin); 1.50" long; requires 3.00 rods, &c.

Flywheels Note: all flywheels are 7.875" (7⅞") diameter

Type	Part Nº	Model	Description & Notes
1.00	239XX-32/37	1937-73 all std. motors	3.8125" ($3^{13}/_{16}$") stroke, 1.00" crank pin holes; .875" (⅞") shaft holes @ larger end of tapers; Pinion side drilled for oil (all flywheels)
1.01	80338-39 80339-39	1939-54 WLDR, WR, KR	As above, but lighter, casting #150-406, 150-408
1.10	239XX-54R	1954 KHR	As 1.00 except 4.5625" ($4^9/_{16}$") stroke
2.00	239XX-55R	1955-69 KR, XLR	3.8125" stroke, 1.25" crank pin holes; .875" sprocket + pinion shaft holes
2.10	239XY-55R	1955-56 KHR	As 2.00 except 4.5625" stroke
3.00	239XX-54	1954-56 KH	4.5625" stroke, 1.25" crank pin holes; 1.00" shaft holes
3.10	239XX-57	1957-81 XL	As 3.00 except 3.8125" stroke
3.11	239XX-81	1981-85 XL	As 3.10 except for "commonized" tapers on shaft holes

Type	Part Nº	Model	Description & Notes
1.00	24370-29	1937-73 all std. motors	¼" rollers (36) in 4 identical steel cages; 12 .550" long in 2 facing cages for Male rod, 12 .270" in each side of Female rod; cages are 12 slot, 1.00" ID, 1.44" OD
1.10	R0309-39	1939-41 WLDR, 1941-48 WR	$^{3}/_{16}$" rollers (54) in 4 identical steel cages; 18 .518" (M), 36 .256" (F); cages are 18 slot, 1.25" ID, 1.56" OD, .340" wide
1.11	R0309-49	1949-52 WR 1953 KR, KHR	$^{3}/_{16}$" rollers (54) in 4 identical steel cages; 18 .480" (M), 36 .238" (F); cages similar to 1.10, but slots are shallower
1.12	24370-54R	1954 KR, KHR	As above, different cages?
2.00	24370-54	1954-56 K, KH, 1957-* XL	$^{3}/_{16}$" rollers (51); 17 (M) in 1 closed aluminum cage, 34 (F) in 2 closed aluminum cages
3.00	24370-55R	1955-* KR, XLR, XR	$^{5}/_{16}$" rollers (51); 17 (M) in 1 closed aluminum cage, 34 (F) in 2 closed aluminum cages

Connecting Rods

Type	Part Nº	Model	Description & Notes
1.00	24275-32	1937-73 all std. motors	7.4375" ($7^{7}/_{16}$") center-to-center Length; female big end 1.37" Wide; 1.500" ID races; marked "UA" on beam
1.10	24275-39R	1939-41 WLDR, 1941-52 WR	Same L&W as 1.00; 1.625" (1⅝") ID races; Heavier beam area, drilled for lightness; Requires 1.10 crank-pin assembly
1.11	24275-52R	1953-54 KR, KHR	As 1.10, except rods not drilled for weight removal
2.00	24275-52	1952-85 K, KH, XL	Same L as 1.00; 1.49" W; 1.625" ID races; solid beam marked "2429X-52"
2.01	S&S 7500, 7600, 7700	1952-85 K, KH, XL special	As 2.00, "S&S" on beam (different models), generally heavier construction
2.10	24275-83	1983-84 XR1000, 1986-* XL V2	As 2.00, except 6.926" L
2.11	S&S 7800	XL V2 special	As 2.10, heavier
2.20	S&S 7900	XL V2 stroker	As 2.11, except 7.113" L special, also 45 stroker
2.30	24275-04?	Buell XB9	As 2.00, except 7.27" L
3.00	24275-55R	1955-68 KR; 1955-56 KHR; 1957-* XLR	Same L&W as 2.00; 2.125" (2⅛") ID races; super-heavy construction; requires 3.00 crank-pin assembly
3.10	24275-69R	1969 KR "Low-Boy", 1971-72 XR	As 3.00, except 6.44" ($6^{7}/_{16}$") L
4.00	NPN	Carrillo special	As 2.00 except very heavy "H" beam cross-section, 7.8" or 8.0" L for extreme strokes

Cams

Cam Nº	Cylinder	Valve	Gear Rows	Teeth	Notes
Pinion	N/A	N/A	1	18	4 flutes, asymmetrical
1	rear	exhaust	1	28	2 tangs for oil pump drive (45 only)
2	rear	intake	2 + spiral	28 & 36	Spiral gear for ignition drive (except ①)
3	front	intake	1	28	Plain
4	front	exhaust	2	28 & 36	Plain, may have 2nd timing mark for mag

Cam Covers

With 1 exception (marked *), all 45 cam covers are identical in appearance from outside, and are based on the same casting (131-372, which appears inside the cover in most cases). There are a wide variety of models used, of which the most common types appear below:

Type	Part Nº	Model	Description & Notes
1.00	25201-37	1937-57, all models	Plain brass bushings in all positions, 12⅝" long, fins run the full length of the cover. $^1/_4$" generator screw holes. #2 bushing boss is $^5/_{16}$" tall. Must use early #2 cam. Cs^tg # 131-372
1.01	25201-58	1958 G	As 1.00, except $^5/_{16}$" generator screw holes
1.02	25200-59	1959-73 G, GE, GA	As 1.01, except #2 bushing boss is $^5/_{32}$" tall. Must use late #2 cam. Cs^tg # 25202-37
1.10	80584-39	1939-41 WLDD, WLDR	As 1.00, except dual-position (figure "8") idler boss for front-drive magneto or generator
2.00	80584-41	1941-46 WR	Ball brg. in #2, 3 & 4 positions; no ignition drive on #2; breaker boss has drive hole cover plate; Idler boss for front-drive magneto
2.01	R0584-47	1947 WR	Same as 2.00, except breaker mounting area is deleted from cover casting
2.10	R0584-48	1948-49 WR	Ball brg. in #3 & 4 positions; idler boss for front-drive magneto; breaker hole has removable cover plate
2.20*	25201-50R	1950-52 WR	Ball brg. in #3 & 4; different casting & fin pattern; idler boss for front-drive magneto; removable access plate (25720-50r) on face of cam cover for magneto drive

Type	Part Nº	Model	Description & Notes
.90	80610-32 80611-32	1932-36 RLDR	Intake only, used with std. exhaust cams, asymmetrical lobe shape, no specs
1.00	2550X-37	1937-58 all std. motors	240° duration, .312" ($^5/_{16}$") lift, large-diameter journals for plain brass bushings
1.01	2550X-59	1959-73 G, GE, GA	#1, 3 & 4 identical to Type 1.00 above; #2 has less undercut on cover side of gear
1.02	80610-39 80611-39	1937-41 WLDR	Intake only, used with std. exhaust cams, asymmetrical lobe shape?, no specs
1.10	R0600-39	1939-41 WLDR; 1940A WLDR (Special)	As 1.00, except 270°, .320" lift
1.11	25505-02R	45 special	As 1.10, supplied by KNS Cycle as a regrind
2.00	R0600-41	1941-47 WR①	Duration 300°⁺, .344" lift, ball brgs. on #2, 3, & 4 in cam cover, lobe peaks are nearly flat on top, for use with flat tappets only
2.10	R0600-48	1948-52 WR	As 3.00, except ignition spiral drive on #2, ball brgs. on #3 & 4 in cam cover, flat tappets only
3.00	255XX-53	1952-56 K, KH	Similar to 1.10, but .344" lift, #2 cam gear wider than 45, all lobes are tapered (intake 1°2'∠, exhaust 3°32'∠?)
3.10	255XX-56R	1952-56 KK, KHK	As 2.00, except very broad lobe, concave (hollow) flanks, .375" lift, all lobes are tapered
4.00	255XX-53R	1953-55 KRM, KHRM①	Similar to 3.00 but has plain journals, for flat tappets only, all lobes are tapered
5.00	25499-53R	1953-69 KR, KHR①, &c.	As 3.10, except 295-315°, .395-.440" lift (various grinds, see following tables*), very broad lobes, ball brgs. on #1, 3 & 4 in cover, all lobes are tapered

Note: all 3.XX - 5.XX cams above have tapered lobes, exhausts are tapered more than intake.

Note: all cams listed above are suitable for roller tappets only, except as noted.

*** KR "C" (25499-61R)**

Duration, Front Intake Duration, Rear Intake	324° @ .010" 319° @ .010"	Duration, Exhaust	282° @ .010"
Intake Lobe C-Line, F Intake Lobe C-Line, R	82° ATDC 84.5° ATDC	Exhaust Lobe C-Line	99° BTDC
Lobe Separation, F Lobe Separation, R	90.5° 91.75°	Overlap, Front Overlap, Rear	122° 117°
Front Intake Opens Rear Intake Opens	80° BTDC 75° BTDC	Exhaust Opens	60° BBDC
Intake Closes	64° ABDC	Exhaust Closes	42° ATDC
Intake Lift	.395"?	Exhaust Lift	.375"?

KR "E" (25499-62R)

Duration, Intake	316° @ .010"	Duration, Exhaust	278° @ .010"
Intake Lobe C-Line	88° ATDC	Exhaust Lobe C-Line	97° BTDC
Lobe Separation	92.5°	Overlap	112°
Intake Opens	70° BTDC	Exhaust Opens	56° BBDC
Intake Closes	66° ABDC	Exhaust Closes	42° ATDC
Intake Lift	.395"?	Exhaust Lift	.375"?

KR "F"

Duration, Intake	312° @ .010"	Duration, Exhaust	278° @ .010"
Intake Lobe C-Line	90° ATDC	Exhaust Lobe C-Line	97° BTDC
Lobe Separation	93.5°	Overlap	108°
Intake Opens	66° BTDC	Exhaust Opens	56° BBDC
Intake Closes	66° ABDC	Exhaust Closes	42° ATDC
Intake Lift	.395"?	Exhaust Lift	.375"?

KR "H"

Duration, Intake	312° @ .010"	Duration, Exhaust	280° @ .010"
Intake Lobe C-Line	90° ATDC	Exhaust Lobe C-Line	98° BTDC
Lobe Separation	94°	Overlap	108°
Intake Opens	66° BTDC	Exhaust Opens	58° BBDC
Intake Closes	66° ABDC	Exhaust Closes	42° ATDC
Intake Lift	.410"	Exhaust Lift	.405"

KR "J" & "K" (25499-69R)

Duration, Intake	312° @ .010"	Duration, Exhaust	280° @ .010"
Intake Lobe C-Line	90° ATDC	Exhaust Lobe C-Line	98° BTDC
Lobe Separation	94°	Overlap	108°
Intake Opens	66° BTDC	Exhaust Opens	58° BBDC
Intake Closes	66° ABDC	Exhaust Closes	42° ATDC
Intake Lift	.395"	Exhaust Lift	.395"

KR "J" & "L" (25498-69R)

Duration, Intake	312° @ .010"	Duration, Exhaust	285° @ .010"
Intake Lobe C-Line	90° ATDC	Exhaust Lobe C-Line	102.5° BTDC
Lobe Separation	96.25°	Overlap	106°
Intake Opens	66° BTDC	Exhaust Opens	65° BBDC
Intake Closes	66° ABDC	Exhaust Closes	40° ATDC
Intake Lift	.395"	Exhaust Lift	.395"

Intake Manifolds

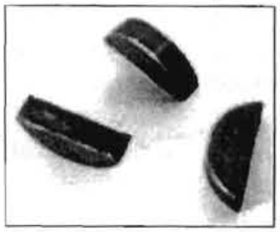
Type	Part №	Model	Description & Notes
1.00	27011-36	1936 RL, RLD, RLDR; 1937-52 WL, WLA, WLC	1⅞" nut, 3-bolt pattern, $1^3/_{16}$" ID port, takes 1¼" Linkert (M-41, 88, &c.) (there are several slightly different models)
1.01	81107-37	1937-38 WLDR	As 1.00, except enlarged internally to $1^5/_{16}$" ID, for use with 1.01 cylinders
2.00	81107-39	1939 WLDD, WLDR; 1939-46 WLD	2" nut, 3-bolt, $1^7/_{16}$" port, bolt pattern as 1.00, H: $2^1/_{16}$"
2.01	27012-33	1933 VLD, 1934-36 VL, 1937-38 UL	Very similar to 2.00, H: 2⅛"
2.02	27012-39	1939-48 UL	Very similar to 2.01, but ⅝" longer carburetor leg, H: 2¾"
3.00	81107-40 (27011-52)	1940-41 WLDR, 1941-52 WR, 1952-53 K, 1954-56 KH, 1953-68 KR	2⅛" nut, 4-bolt, $1^9/_{16}$" port, takes 1½" Linkert (M-25, 35, 36, 45, 74, 75, MR-3/4, &c.)
3.10	27045-69R	1969 KR	As 3.00, but for dual Tillotson, requires O-ring conversion of nipples, may have been converted to Mikunis

Height is listed as "H"; measured with manifold flange facing down, to top of leg vertically:
45 manifolds (1.00, 1.01, 2.00, 3.00) are $3^7/_{64}$" (3.11") wide across the legs.
V & U-Series manifolds (2.01, 2.02) are $3^7/_{32}$" (3.22") wide across the legs.

Carburetors

Type	Part №	Model	Description & Notes
1.00	2712X-37	1937-52 WL 1937-48 UL	1¼" Linkert (M-41, 51, 52) with $1^1/_{16}$" venturi (not M-88, 90)
1.01	2712X-37	1937-46 WLD 1937-48 ULH	As 1.00, except with 1⅛" venturi (M-41L, 51L, &c.)
2.00	2712X-40	1940-48 EL, FL	1½" Linkert with 1⅛" venturi (M-25, 35, 36, &c.)
2.01	2712X-40	1940-48 EL, FL	As 2.00, except with $1^5/_{16}$" venturi (M-45, 75, &c.)
3.00	27146-52	1952-53 K, KK	1½" Linkert with "bombsight" venturi(M-53)
3.01	27146-52A	1954-56 KH, KHK	As 3.00, except with $1^5/_{16}$" venturi (M-53A, A1)
3.10	271XX-50	1950-64	1½" Linkert with $1^5/_{16}$" venturi (M-74B), modern air-bleed design, similar to M-53
4.00	27148-46R	1940-65 WLDR, WR, KR, KHR	1½" Linkert MR-4 with "bombsight" (dual) venturi (MR-3 & MR-3A earlier, MR-4A later)

The exact timing of the cams can be modified somewhat. When an engine is rebuilt or assembled from parts, the rotational position of the pinion shaft and stack may not "time in" to the H-D factory specifications. The cams and/or breather assembly may be out of time due to "stacked" production tolerances.



There is no easy method of dealing with this, as the cam shaft and gear are one piece. However, the following idea may prove useful. The pinion shaft key aligns the oil feed passage in the pinion shaft with the transfer hole in the right flywheel, which supplies oil pressure to the crankpin.

By a happy coincidence, the key's dimensions are very similar to one used in automotive applications: the Chrysler "LA" (small block) V8 camshaft drive. Keys are available for this application with various degrees of offset, where the top is shifted slightly laterally (sideways) from the bottom, causing a partial misalignment. These keys may be easily modified to fit the H-D installation. This allows fine tuning of the cams without regrinding.

The offset will cause the entire cam gear train to be rotated forward or back (depending on which way the offset is installed) at the same point of flywheel rotation. This is not easy to do, as it requires disassembly of almost the entire engine, but no expense or modification to the cams themselves.

Closing the intake valve sooner increases cylinder pressure and torque by trapping more compression, but loses some peak power; closing it later has the opposite effect. A change of 4° or more should be noticeable; less than this may not be of much use. More coarse adjustment may be made by "jumping" the cam gear one tooth forward or back on the pinion gear, and fine-tuning this effect with the key offset.

The most important cam event (the intake valve closing point, as described above) may not match on the two intake cams (#2 & 3); either one, or both, may be "off"; the lobe centers may not be separated by the correct 315°/405° interval. However, the key offset can be used to "average out" the #2 and 3 to the <u>same</u> intake closing point, even if it's not what the specification calls for.

The thickness (the width of both the key & slot, in both the pinion shaft and right flywheel half) of both the 45 and Chrysler keys is identical at $^3/_{16}$" (.1875") [4.8^{mm}].

The length of the Chrysler key is greater at .730" [18.5^{mm}] vs. .460" [11.7^{mm}] for the 45. However, the slots are longer than the key: .750" [19.1^{mm}] in the flywheel, and .650" [16.5^{mm}] in the pinion shaft.

The total depth (height) of the Chrysler key is also greater at .300" [7.6^{mm}] vs. .173" [4.4^{mm}] for the 45.

The "top" (flat section, fits the flywheel slot) is about the same depth in both keys: .100" [2.5^{mm}]. The "bottom" (curved section, fits the pinion shaft slot) is much larger in the Chrysler key. The non-matching dimensions (length & bottom depth) can be trimmed with a grinder to fit.

Table 2: Harley-Davidson vs. Chrysler key dimensions

Source	Part N°	Thickness		Length		Total depth		Shaft depth		Flywheel depth	
H-D	23985-12	.1875"	4.8^{mm}	.460"	11.7^{mm}	.173"	4.4^{mm}	.073"	1.9^{mm}	.100"	2.5^{mm}
Chrysler	P4286500			.730"	19.1^{mm}	.300"	7.6^{mm}	.200"	5.1^{mm}		

The Chrysler key is available in offsets of 1°, 2°, 3°, 4° & 5° as a set, under the above part number

Table 3: Chrysler key: degrees vs. offset

Key Color	Natural		Red		Blue		Gold		White	
Offset, Degrees	1°		2°		3°		4°		5°	
Offset, inches & MM	.010"	.25^{mm}	.020"	.51^{mm}	.030"	.76^{mm}	.040"	1.02^{mm}	.050"	1.27^{mm}

In calculating the amount of rotational change, do not use the Chrysler degree figures. The offset in inches will not change, but the Chrysler camshaft is larger in diameter than the 45 pinion shaft, so the same amount of offset will have a greater effect in the 45 engine.

The effect of a known amount of offset can be calculated based on the distance as a function of the circumference of a circle. The diameter of the circle is the diameter of the pinion shaft at the point of offset.

The smaller end of the 45 taper is about .750" [19.1^{mm}]. The same formulae apply: each degree of rotation needs about .00655" [.00017^{mm}] of offset.

Do not use the figures on this table directly; it has been provided for illustration only.

For best results, you must measure the actual components yourself. Any dimensional changes will require new calculations.

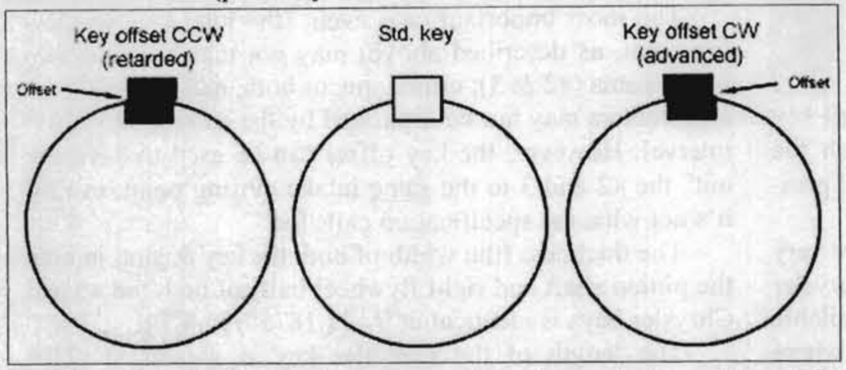
Table 4: Approximate effect of Chrysler offset in 45 applications

Key Color	Natural		Red		Blue		Gold		White	
Offset, In. & MM	.010"	.25^{mm}	.020"	.51^{mm}	.030"	.76^{mm}	.040"	1.02^{mm}	.050"	1.27^{mm}
Offset, Degrees	1.5°		3.0°		4.5°		6°		7.5°	

<u>Do not</u> remove metal from the sides (width) of the key, or the offset area (top). The most important revision is the depth: the new key must seat completely in both slots, or the pinion shaft will not be properly secured to the flywheel. Material must be removed only from the bottom (curved) part of the Chrysler key, as the top is already approximately correct. The length should be reduced by removing material evenly from both ends to retain the curvature.

The bottom of the curve must be centered in the length.

When properly modified, the key will seat completely up to the offset step in the pinion shaft slot. Remove the key; it should seat completely up to the offset step in the flywheel as well. Clean & dry all three parts thoroughly, and assemble. Lightly tap the pinion shaft with a block of wood, etc. to seat the taper. The shaft must not wiggle or click. If it rocks at all, the key is not fully seated, and more metal must be removed (probably from the bottom curved section).



The oil hole alignment between the pinion shaft and the right flywheel must be modified to allow full transfer of oil. I suggest the flywheel be modified, as the material is softer, and the shorter passage is easier to clean. Elongating the hole with a Dremel, die grinder, etc. in the direction of the offset by the same amount should be sufficient. Use Brake-Kleen etc. and then compressed air to be sure to get the debris completely out.

A trial assembly does not have to include the upper end parts, if your flywheel degree mark is accurate. The flywheels must be assembled & trued, cases should be closed, the cam chest assembled, tappets & blocks in place, etc. but the following steps should <u>not be necessary</u>:

» set flywheel end-play
» set cam end play
» install breather (unless relevant)
» install idler & generator gear
» install breaker

A complete rotation of the engine (720°, two full turns) should tell you whether the problem is fixed. A degree wheel on the sprocket shaft, and a dial indicator on the front intake tappet is the usual method. Be sure to rotate the engine forward only (counter-clockwise, as seen from the left side) to remove gear back-lash.

If the position is worse, you have the key offset facing the wrong way. If the position is improved, but not enough, use a key with more offset.

If the position is now incorrect in the other direction, the offset is correctly positioned, but too large. Several trials may be necessary for best results. Be sure to make written notes on every change.

Select & install the final key and assemble the engine. Turn it over slowly by hand two full revolutions to check for piston to valve clearance (not required in side-valve engines). Remember that breather and breaker installations reference TDC and the flywheel timing mark, not pinion shaft position, so they will be accurate if installed "by the book". However, the physical position of the rotor and breaker will change slightly to achieve this.

Flywheel weight

All engines have flywheels that balance out compression and power strokes, maintain idle, aid starting and reduce component wear. If the flywheel is too light the motorcycle requires more effort to start, idles badly, and is prone to stalling. Weight is not the important factor here, but inertia, which is stored energy.

Flywheel inertia is stored when you rev the engine slightly before letting the clutch out - this small amount of extra power helps in getting the motorcycle underway with minimal effort. By "borrowing" power for a few seconds, the engine has to develop less to move from a standing start. Once the clutch is completely engaged, inertia can no longer be borrowed - the motorcycle can only use what it produces in "real time". Regardless of engine speed, or change in speed, power is used to accelerate the reciprocating weight from dead stopped @ TDC & BDC. This power is completely lost (as heat) twice in every 720° cycle.

Any power the engine develops must accelerate the flywheels before leaving the sprocket shaft, and any used in bringing the flywheel up to speed is not available at the rear wheel.

This will not show up on a steady-state or rear wheel dyno or simple desk-top dyno program, but is detectable in a transient dyno that accelerates the engine at a specific rate (300 or 600 RPM per second are common).

In any event, <u>all flywheel weight reduces acceleration</u>, except for when the clutch is slipped. There is no engine speed or other condition where extra flywheel weight increases acceleration.

However, let me clarify something that is frequently mis-stated and/or mis-understood. The power a engine develops is not related to flywheel weight. Heavy flywheels do not "make more torque", this is completely fictional. The power is merely stored by the flywheels, and they only have what is diverted from the primary drive.

Under steady-state conditions (no speed change) more inertia is more comfortable and allows the engine to operate at a lower speed without lugging, chain snatch &c.

There is also a problem where the engine speed is not "regular" (the speed of rotation is not constant throughout the 720° cycle). A single cylinder, or an engine with very high compression, or a light flywheel will almost stop @ TDC and BDC, be very slow after 90° ABDC on compression, and be fastest around 45°-90° ATDC on the power stroke. This is not only uncomfortable, and breaks parts in new ways (load reversals on cam gears, oil pumps, rollers), but adds new time factors to the cam lobe vs. tappet equation. This condition persists into the high RPM ranges - only recently discovered through SpinTron use.

As the number of cylinders rises the cyclic variation drops immediately, with results decaying as the number of cylinders increases with almost no detectible difference between 12 and 16 cylinders. A V12 with a heavy flywheel and 7:1 compression will have almost none of these effects.

Cast-iron doesn't damp vibration very well, but more of it is certainly going to help, and more flywheel (where most of the weight differences are) will have a very slight effect against flywheels flexing due to gyroscopic stability - the spinning flywheels can be moved vertically, horizontally, or laterally without effort (except the actual static mass), but a gyroscope strongly resists out-of-plane force. Unfortunately, that also includes banking and turning the motorcycle.

Road racing, where DNF is always a possible, is a venue where flywheels weight has less value. The power lost to accelerating the flywheels varies as the square of the gear ratio, so tall (high top speed) close ratio gearing has less effect than street or drag use, and most time is spent in the upper gears in any case.

Obviously, there's a certain minimum amount of flywheel inertial that should be present for several reasons:

- » idle stability
- » tolerance of high compression, cam overlap, large ports, &c.
- » better clutch operation for low speed and traffic operation
- » fewer load reversals on the driveline during low speed
- » better traction
- » the carburetor's accelerator pump and off-idle circuit settings are closer to "real world"
- » damps vibration out some
- » oil pressure is more consistent

But, other than as needed for driver preference &c. the lowest inertia you can stand the better:

Reduced inertia

For extreme performance, flywheel weight can be radically reduced. Flywheel inertia is not directly proportional to flywheel weight; it's possible to have a light flywheel with much more inertia than a heavier flywheel. A lighter flywheel assembly substantially increases acceleration, but roughly proportionate to the square of the overall gear ratio (individual gear ratio × primary drive × final drive). 1st gear is always the biggest difference, and it's greatest with a strong (high number) 1st gear such as the wide-ratio (trials, sidecar, &c) and high numerical overall gearing. A low numerical (viz., close ratio) 1st gear receives much less benefit from this, not to mention the lower torque from reduced gear multiplication. Machines with tall gearing don't get much, and no one sees a big change in high gear.

However: it's worth a couple of HP in 1st gear - very noticeable. It doesn't add any RPM (but it does reach high RPM faster in neutral) or develop more power from the engine - it wastes less power accelerating the flywheel assembly.

Removing weight from the sides on an angle directs oil picked up from the case outward by centrifugal force to the rim where the scraper can catch it, without changing the scraper position.

It also reduces inertial momentum much more than it appears.

The math to predict the effect is very complex because the weight "acts" only at its mean center of mass, it's very difficult to locate, and changes when weight is removed, but I would hazard that removing 4 lbs. is worth at least 1 HP.

Inertia varies with two major inputs: speed and diameter (let's leave material as a constant).

Inertia varies proportionate to the square of the RPM and also proportionate to the 4th power of the radius. This is why light-weight cam pinions &c. are nearly useless - too small and turning too slowly.

Higher reciprocating weight always reduces power, but won't show up on a steady-state dyno.

When comparing two flywheels or flywheel designs for the same engine the single most important consideration is the outside diameter. If the flywheel were a simple solid disc the inertia would vary in proportion to the 4th power (^4) of the diameter.

In theory the heavy flywheels may be more comfortable because the larger mass of iron damps vibration better.

This is also a mod that should be approached with extreme caution. A 45 with light flywheels and tall gearing will have to be ridden like a 2-stroke.

The lighter flywheel:

- » is harder to kick through when starting
- » requires slightly higher idle speed screw setting for stable idle
- » is more likely to stall when cold/out of tune
- » is easier to shift
- » has better braking (unless you disconnect the engine by pulling the clutch in while braking)
- » requires more delicate touch with the clutch in traffic
- » harder on the primary chain
- » less tolerant of "walking speed" in gear
- » improves acceleration
- » improves braking
- » reduced overall weight
- » best acceleration improvement in machines using small engine sprockets (more effect from a 20 than a 24, &c.)
- » slightly harder to kick through, due to lack of inertia to "carry over" into the compression stroke
- » slight increase in carb idle setting may be necessary to hold the engine at the same idle speed, due to more irregular pulses (most noticeable in engines with high compression)
- » slightly higher idle speed may be necessary to prevent engine from stalling, same reason
- » more careful clutch operation will be required for getting away from a dead stop
- » in general, the engine will run slightly rougher at low speeds, and be more prone to lugging
- » slightly improved braking (assuming the clutch remains engaged), as the brakes do less work slowing down the flywheels

Shifting may be improved (with practice) as the engine will conform more rapidly to the rpm required after a gearchange

The engine will appear to respond to open throttle faster in neutral; do not assume that it is safe to lean out your carb - this effect will not occur in gear, and in some cases slightly richer mixture will be required.

However: it's worth a couple of HP in 1st gear - very noticeable. It doesn't add any RPM (but it does RPM faster in neutral) or develop more power from the engine - it wastes less accelerating the flywheel.

Weight removed from the flywheel OD is more important than knife-edging, hole drilling &c. because it's farther away from the center of rotation.

4 lbs. off the rim - the bike might not idle below 1,200 RPM, and the tach needle will go off-scale when you touch the throttle. Sounds great, faster, but very annoying to ride especially in traffic.

Stock flywheel weight

These factors suggest stock weight flywheels:

» hot cams, especially late intake closing and/or high overlap
» big carburetor
» big engine and/or transmission sprockets ("highway" gearing)
» high compression
» open exhaust
» heavy chassis or rider, frequent passenger, sidecar, &c.

For most casual use the heavier flywheels is preferred - it's just slower. What would I do? Ask around for comments on known mods rather than pick an arbitrary dimension. If you're not sure, too heavy is a far safer choice than too light.

This Table applies to all standard model 45" Harley-Davidson models 1937-73

Female rod end-play between wheels	.015 - .020"
Flywheel end-play in cases	.015 - .018"
Main roller clearances	.0012 - .0015"
Crank-pin roller clearance	.0015"
Skirt clearance	.003" minimum
Piston ring end gaps: top compression ring 2^{nd} compression ring oil ring	 .016" minimum .012" .012"
Cam end play	.005 - .007"
Spark advance	30° for a start up to 34° by test only
Plugs	NGK A6 break-in & traffic A7 for parkway A8 for racing
Plug gap	.025" (battery & coil) .020" (magneto)
Deck clearance	.035" (minimum) .060" (maximum)
Valve lash	add .002" to std. to be safe

Lubricate both chains thoroughly; check for tight links. Raise tire pressure by 2-4 lbs. Add Marvel Mystery Oil to the gas per can directions. Be sure the battery is fully charged. Check cylinder base nuts for tightness.

45 Bore & Stroke

This Table applies to all 45 & 55" Harley-Davidson® models D, R, W, G, K & KH, 1929-73

Bore, Relative	Bore,[1] Absolute	$3\,^{13}/_{16}$"[5] (3.8125")	$4\,^{7}/_{16}$"[6] (4.4375")	$4\,^{9}/_{16}$"[7] (4.5625")	$4\,^{5}/_{8}$" (4.625")	$4\,^{13}/_{16}$"[8] (4.8125")
Std.	2.745"	45.12"	52.52"	54.00"	54.74"	56.96"
+.010	2.755	45.45	52.91	54.4	55.14	57.38
.020	2.765	45.78	53.29	54.79	55.54	57.79
.030	2.775	46.12	53.68	55.19	55.94	58.21
.040	2.785	46.45	54.06	55.59	56.35	58.63
.050	2.795	46.78	54.45	55.99	56.75	59.05
.060	2.805	47.12	54.84	56.39	57.16	59.48
.070	2.815	47.46	55.24	56.79	57.57	59.90
.080	2.825	47.79	55.63	57.20	57.98	60.63
.090	2.835	48.13	56.02	57.60	58.39	60.76
.100[2]	2.845	48.47	56.42	58.01	58.80	61.19
.130[3]	2.875	49.50	57.61	59.24	60.05	62.48
.140	2.885	49.84	58.02	59.65	60.47	62.92
.150[4]	2.895	50.19	58.42	60.06	60.89	63.36

Size, MM	Std.		S1		S2		S3		S4	
70	+.010"	2.755"	+.020"	2.765"	+.030"	2.775"	+.040"	2.785"	+.050"	2.795"
71	+.050"	2.795"	+.060"	2.805"	+.070"	2.815"	+.080"	2825"	+.090"	2.835"
72	+.090"	2.835"	+.100"	2.845"	+.110"	2.855"	+.120"	2.865"	+.130"	2.875"

Notes:
① All 1929-73 D, R, W, G, K & KH 45 & 54" motors are the same bore size
② Largest commercially-available 45 piston oversize
③ Norton 750^{cc} Atlas (73^{mm}) or Indian Scout 45 ($2^{7}/_{8}$") piston
④ Absolute upper bore limit of all 45 std. type cylinders, not recommended
⑤ Std. stroke, all 1929-02 D, R, W, G, K & XL flywheels (except 1954-56 KH, & XR750)
⑥ Indian Chief 74" flywheels
⑦ 1954-56 KH flywheels
⑧ Indian Chief 80" flywheels

Gear Ratios

This Table applies to Harley-Davidson® solos & Servi-Cars® 1941-73, equipped with the original 59 tooth clutch drum, 17 tooth transmission sprocket, and 37 tooth (Servi-Car) or 41 tooth (solo) rear sprocket. Rear tire diameter is premised at 26", which is normal for 5.00-16, 4.00-18, etc. Other tire diameters will affect figures proportionate to the ratio of diameters.

Solo:

Motor Sprocket	Note	Primary Chain	Final Drive Ratio	MPH @ 5K RPM	RPM @ 60 MPH
27	original side-car	100 link (solo)	5.27-1	73	4090
28	no factory sprocket	100 link	NA	NA	NA
29		100 link	4.91	79	3810
30	common solo	100 link	4.74	82	3680
31	common solo	100 link	4.59	84	3560
32		100 link	4.47	87	3470
33		100 link	4.31	90	3340
34	largest factory	100 link	4.19	92	3250

Servi-Car:

Motor Sprocket	Note	Primary Chain	Final Drive Ratio	MPH @ 5K RPM	RPM @ 60 MPH
22	original Servi-Car	96 link (Servi-Car)	5.84-1	66	4530
25		* either?	5.14	75	3990
26		* either?	4.94	78	3830
27	original side-car	100 link (solo)	4.76	81	3690
28	no factory sprocket	NA	NA	NA	NA
29		100 link	4.43	87	3440
30	common solo	100 link	4.28	90	3320
31	common solo	100 link	4.14	93	3210

* 25 & 26 tooth sprockets may need the larger (100 link) solo primary chain.

Motor Data

Bore	2.7445" - 2.7455" (just under 2¾")
Stroke	3.8125" ($3^{13}/_{16}$", same as K & Sportster)
Displacement	45.12 cu.", 739 ^{cc}
Piston skirt clearance (measured at bottom of skirt)	.001" - .002" @ 90° to pin axis
Ring end gap	.010" - .020"
Crank-pin OD	.999"
Rod race ID	1.500"
Rod length, on centers	7.4375"
Piston pin bushing ID	.7925"
Shaft OD (sprocket & pinion)	.875"
Pinion shaft (bushing end)	.62425"

Main race ID (sprocket & pinion)	1.376”
Valve head diameter, intake & exhaust	1.625” (not interchangeable)
Valve stem diameter, intake & exhaust	.3395”
Valve length, intake & exhaust	5.502”
Valve seat angle, intake & exhaust	45°
Valve guide OD, intake & exhaust	.5645”
Valve guide ID, intake & exhaust	.3424”
Valve stem-to-guide clearance	.0035” (.0055” is listed as acceptable)
Valve spring (free length)	$2^{19}/_{32}$”
Valve spring tension, closed	50 - 60 lbs. (seated @ $2^{3}/_{16}$” assembled ht.)
Valve spring tension, open	90 - 100 lbs. (to std. lift of .312”)
Cam end play	just free - .005”
Cam gear tooth count, all	28
Rear intake & front exhaust 2nd row	36
Cam journal size; crank-case, all 4 cams	.68675”
Cam journal size; cam cover, # 1 cam (pump drive)	.68675”
Cam journal size; cam cover, # 2 cam (ignition)	1.12425”
Cam journal size; cam cover, # 3 & 4 cams	.7805”
Feed pump pressure regulating spring (free length)	$2^{1}/_{16}$” (1941-73), $1^{5}/_{8}$” (1937-40)
Vane spring (free length)	$1^{5}/_{32}$”
Check valve spring (free length)	$1^{9}/_{32}$”
Head bolt torque	60 lbs.
Spark plug torque (18 ^{mm})	18 - 25 lbs.

Transmission Ratios

Harley-Davidson transmission’s intermediate gear ratios (1st & 2nd) are the result of the transmission of power through two pair of mating gears, one of which is the main drive gear being turned by the countershaft high gear (on the cluster). The numerical gear ratio is determined by multiplying the two pair’s ratios together.

Since the high gear ratio is the product of the tooth counts: 22 for the clutch gear and 14 for the countershaft gear, the 1st number is always 1.571429. The other number is the product of the pair of gears (mainshaft + countershaft) for that ratio.

In 3rd gear the clutch gear is locked to the mainshaft, so no power is transmitted through the gears, and the ratio is 1.000 (1-1). Although the intermediate gears still turn, they're only idling. Below are some useful tables of common ratios and their effects on performance.

Std. Ratio Calculation				
Components	Teeth M/S	Teeth C/S	22/14 ×	Ratio
1st gear	22	14	22/14	2.469388-1
2nd gear	18	18	28/18	1.571429-1
3rd gear (clutch gear)	26	(none)	(locked)	1.000000-1

Std. Gear Tooth Counts		
Cluster Gear	Countershaft Gear	Mainshaft Mating Gear
1st gear	14	22
2nd gear	18	18
3rd gear	22	14
Reverse gear	14	19

Std. RPM Loss on Shift					
Ratio	1st	RPM Drop to 2nd	2nd	RPM Drop to 3rd	3rd
Std.	2.47	36.4%	1.57	36.4%	1.00000

WR Ratio Calculation				
Components	Teeth M/S	Teeth C/S	20/16 ×	Ratio
1st gear	22	14	22/14	1.964286-1
2nd gear	18	18	18/18	1.250000-1
3rd gear (clutch gear)	20	(none)	(locked)	1.000000-1

WR Gear Tooth Counts		
Cluster Gear	Countershaft Gear	Mainshaft Mating Gear
1st gear	14	22
2nd gear	18	18
3rd gear	20	16

WR RPM Loss on Shift					
Ratio	1st	RPM Drop to 2nd	2nd	RPM Drop to 3rd	3rd
WR	1.96429	36.4%	1.25	20%	1.00000

1940 Std. Ratio Calculation				
Components	Teeth M/S	Teeth C/S	21/13 ×	Ratio
1st gear	21	13	21/13	2.609467-1
2nd gear	17	17	17/17	1.615385-1
3rd gear (clutch gear)	13	21	(locked)	1.000000-1

1940 Std. Ratio Gear Tooth Counts		
Cluster Gear	Countershaft Gear	Mainshaft Mating Gear
1st gear	13	21
2nd gear	17	17
3rd gear	21	13

1940 Std. Ratio RPM Loss on Shift					
Ratio	1st	RPM Drop to 2nd	2nd	RPM Drop to 3rd	3rd
WR	2.609467	38.1%	1.615385	38.1%	1.00000

1940 Special Ratio Calculation				
Components	Teeth M/S	Teeth C/S	19/15 ×	Ratio
1st gear	21	13	21/13	2.046154-1
2nd gear	17	17	17/17	1.266667-1
3rd gear (clutch gear)	15	19	(locked)	1.000000-1

1940 Special Ratio Gear Tooth Counts		
Cluster Gear	Countershaft Gear	Mainshaft Mating Gear
1st gear	13	21
2nd gear	17	17
3rd gear	19	15

1940 Special Ratio RPM Loss on Shift					
Ratio	1st	RPM Drop to 2nd	2nd	RPM Drop to 3rd	3rd
WR	2.046154	38.1%	1.266667	21.1%	1.00000

Service Tips

Electrical

» Motor misfiring only under load, but will rev OK under light throttle: problem is probably electrical (rather than mixture); check for bad ground, condenser, coil, plug wires, closed points, etc.

» Easy spark timing check:
1. Open the points with a clean screwdriver blade, knife, etc.
2. Put a piece of cellophane (cigarette pack, etc.) between the points
3. Put slight tension on the cellophane as you slowly rotate the motor
4. The cellophane will pull free as the points open – this should happen when the timing mark has just arrived in the correct position in the timing hole.

» Generator-equipped bikes without magnetos must have a battery, a capacitor is not enough.

» To install a late generator (65A, 58, etc. with 5/16" screws) in an early motor (¼" screw holes):
Drill the cam cover & right case half to 5/16", or
Use ¼-24 heli-coils in the existing generator screw holes to use the ¼-24NS screws, and
Use the correct drive gear; 31075-58B for all 45 & U-Series has the oil slinger

» When adding shims to adjust your generator position: if the generator body has a drain hole, make a matching hole in each shim, or they will block the drain. Beer cans make good shim material.

» To set generator gear lash, put 3 shims (.004" each) under the generator body, or until the gear turns freely. Run a sheet of newspaper through the gears to get a cut where the gear teeth mesh. Examine the paper closely:
If the paper locks up the gears, the generator is too close (tight), add a shim and test again
If the paper isn't cut, the generator is too far away (loose): remove a shim and test again
If the marks from the teeth run across the paper on an angle, the generator body may be on an angle check for alignment
The paper should only have a cut or mark at mid-gear tooth face, not at the bottom flat or valley of gear teeth, or your gear is worn out

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Intake

» A Bernzomatic propane torch can be used to detect an intake system leak. Start the motor, and just barely crack the torch valve (don't light it). Hold the nozzle tip near any suspected leaks - if the motor speeds up or smoothes out, you've found your leak.

» Ragged idle and no response to idle mixture adjustments generally means an air leak; if the 2 spark plugs are different colors, the pale one is the cylinder with the leak; this will also be the warmer cylinder, head, and exhaust pipe.

» Bad throttle response from a big carburetor – go richer.

» Good valve head color as a mixture indicator: tan to brown intake, red exhaust (white exhaust is hot, lean, or both).

» To tighten early intake manifold nuts (45, K & big twin 1930-54), leave the cylinder base nuts loose so that the cylinders can be slightly rotated into alignment until the thread on the 2nd nut engages. Remember to re-tighten the base nuts securely after installing the manifold.

» Excellent non-factory base nut wrench: automotive starter wrench (Craftsman, Snap-On, Mac, etc.)

Wrench sizes for manifold nuts, measured across the flats	
2⅛"	1940-68 WLDR, WR, K, KH, KR; 1940-54 OHV big twins (4 bolt manifolds)
2"	1930-48 V & U-Series; 1936-39 OHV; 1939-* WLD
1⅞"	1932-73 45 std. models

Crankcases

» When assembling the cases in any roller-bearing type motor (pre-Timken: big twin OHV & side-valve 1917-54, all 45 & singles; no K-Models or Sportsters), you may have to use end-play collars of 2 completely different sizes, rather than splitting the total end-play between 2 washers. Try to get the beam of the male rod centered between the case halves within .015".

Connecting Rods

» To check for a cracked or broken female connecting rod, suspend it from the small (piston pin) end with a piece of thread, and strike the big end sharply with a metal object. A good rod will ring like a bell, a bad rod will make a "clunk" sound. If bad, try 1 more test. Press out the rod races and try again - it may pass this time. A loose or cracked race will cause the same symptom as a bad rod.

» To straighten a big twin rod, don't bend it in the motor – the factory now deprecates this method, as it ruins rollers, etc. Use an old 'Glide fork leg cut down a few .001".

Rod Data (lengths measured center of main race to center of pin bushing)			
Application	Year	ID cast into rod beam	Length
45 (except 1939-52 WLDR, WR)	1932-1973	UA	7.4375"
K, KH, Sportster (except XR1000)	1957-1985	-52	
XR1000	1983-1984	-83	6.926"
Evo Sportster	1986-*		
V-Series	1930-1936	SA	7.6875"
U-Series	1937-1948	ZA	7.90625"
OHV big twin	1936-1972	XA	7.46875"
OHV big twin	1973-1983		7.4375"

Oil System

» After an oil change or long storage, be sure your oil feed pump is not air-locked (air bubble obscuring a passage). Remove the oil pressure sending switch and kick the engine over until a steady stream of oil comes out – this bleeds the pump.

» To remove a bad flutter valve (25350-37) from a 45 or UL cam cover:
If the triangle plate is gone, the hole behind it is a good fit for a 4-40 tap. Tap it thru, then I have a nice socket head 4-40 cap screw that I put thru the backside of a counter bored do-hickey (counterbored slightly larger and deeper then the valve assembly being pulled. Turn the screw till the valve lifts out. File the stake marks out of the cover first with a curved file to help (courtesy of Steve Lemay, Resurrection Cycle Works).

Temperature

» Use Marvel Mystery Oil in the gas (4 oz. per 10 gal., about 1 oz. in a 3½ gal. tank is OK). This reduces engine temperature slightly, and also provides additional lubrication to valves and guides, especially in flathead motors.

Transmission & Clutch

» Hard shifting may be due to:
- Loose chains
- Low transmission oil level
- Bent shift forks
- Loose transmission bolts
- Loose rear axle or adjusters
- Dragging clutch

» Big twin mainshaft end-play is controlled by the ball bearing (H-D # 9020). Try pulling in the clutch with the motor running; see if the pushrod adjusting end moves in and out. If you have more than a few thousandths your bearing is toast.

Miscellaneous

» Vibration may be caused by:
- Loose axles
- Low transmission oil level
- Bent shift forks
- Loose transmission bolts
- Loose rear axle or adjusters
- Dragging clutch

» Always use a flat washer plus a lock under every bolt and nut (std. aircraft practice).

» Bolt and stud threads must be long enough to show 1½ threads minimum after nut is tight.

» Always use Nevr-Seize or equivalent product on any steel part going into aluminum, or you may not get it out.

» To disassemble a VL wheel hub use a 4x4 hub lug wrench. Cut down the lugs with a Dremel tool to fit the VL hub nut, 3913-30. The wrench fits a ½" drive ratchet and allows removal of a stubborn and rusty hub nut. To buy the correct wrench, just measure the hub nut OD and measure the ones at the Auto store until you get a close fit and then modify to fit nut (My wrench is marked K-D 2467 and I bought it at NAPA.). This wrench eliminates using chisels and punches, which do more harm than good. (tip courtesy of Greg Fittro, AMCA)

Thread sizes

» Heads bolts:	
Knucklehead, flathead 74 & 80, 45 1940-73	7/16-16 NS (Nat'l. Special)
Head nut, 45 1929-39 + some later Servi-Cars	⅜-16 NC (Nat'l. Coarse or USS)
Panhead, shovelhead	7/16-20 NF (Nat'l. Fine or SAE)
K & KH model	7/16-14 NC
» Star hub brake-drum lug	3/8-20 NS
» Cam cover, oil pump, tappet block screws 1930-76	¼-24 NS
» Fork stem:	
Big twin 1930-36	1⅛-24 NS
Big twin 1936-*	1-24 NS
Single, 45, K, early Sportster	⅞-24 NS
Later Sportster	15/16-24 NS
» Handlebar end threads:	
1931-35 big twin, 1931-39 45	13/16-24 NS
1936-48 big twin, 1940-57 45	⅞-24 NS
» Zerk fitting, 1924-*	5/16-32 NEF (Nat'l. Extra Fine)
» 45 clutch lever, 1941-73	7/16-28 NEF
» Gas tank top screw, 1918-35 all, 1937-73 45	7/32-32 NS
» Cylinder base studs	
Big twin, 1930-83, to case*	7/16-14 NC
Big twin, 1930-83, to nut	7/16-20 NF
45, K, Sportster 1929-85, to case	⅜-16 NC
45, K, Sportster 1929-85, to nut	⅜-24 NF
* Note: same cylinder base stud pattern is used on all big twins 1926-83	
» Gas tank petcock, 1940-65	¾-18 NS

Are Harleys That Bad?

The myth is that Harley-Davidson® motorcycles are fun, patriotic, valuable, but inefficient and obsolete. They appear to produce much less horsepower than an equivalent J****ese bike, and are therefore inferior.

This is not true. A fair evaluation cannot be made solely on the basis of displacement (1000cc, for example, regardless of motor type). Dr. F. W. Lanchester, one of the earliest true geniuses of the internal combustion engine, analyzed this problem 90 years ago, and correctly decided that comparing motors on the basis of size only gave an unfair advantage to motors with more cylinders, and favored those with larger bores and shorter strokes. He devised a formula to allow motors with different numbers of cylinders, and different proportions to compete on a fair and equal basis, with the superior product to be determined by the execution of its individual design & construction, regardless of bore and stroke. His original formula needed only slight modification to be accurate today:

$$\mathbf{HP = B^{1.65} \times S^{.5} \times N \times C}$$

In plain English, the horsepower of a motor is equal to the Bore taken to the 1.65 power, times the Stroke taken to the .5 power, times the Number of cylinders, times a Constant representing the quality of material available, type of fuel, barometric pressure, temperature, etc. I've arbitrarily chosen to value "C" at 4 for a race motor, and 60% of that, or 2.4 for a street motor, to return a realistic number.

For those of you who've forgotten their math, I've used superscript to indicate powers.

"B^2" is "B squared", or multiplied by itself; "$B^{.5}$" is "square root of B". Today's pocket calculators make easy work of this.

Using this formula, an Evo 80 ($81.7^{cu.in.}$) motor has its theoretical power calculated as follows:

B = 3.498", S = 4.25", N = 2, C = 4

HP = 130 (race), 78 (street)

For comparison, take a "technically superior" Kawasaki motor, the 4-cylinder, double-overhead-camshaft, 4-carburetor, big-bore, short-stroke KZ1000 ($62^{cu.in.}$):

B = 70^{mm}, S = 66^{mm}, N = 4, C = 4 (same as H-D)

HP = 137 (race), 82 (street)

Doesn't look that good now, does it? They should both produce about the same power. But doesn't that make the Kawasaki better? It does the same work, with less displacement? No, it's supposed to!! The Harley-Davidson® does not have the advantage of size.

The Kawasaki's power is the result of physics, not better quality, as the formula shows!!

By the way, side-valve motors, such as the 45, K, and U-Series have also been given another allowance to make up for their restricted breathing and low compression. AMA Class "C" racing permitted 50% more displacement for a side-valve when competing against an OHV or OHC motor. This means that the correction factor for theoretical power for a 45 is not 4, but 2/3 of 4, or 2.67 (2.67 + 50% = 4). The math for a 45:

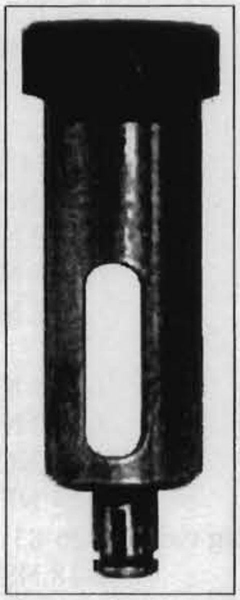
B = 2.745", S = 3.8125", N = 2, C = 2.67

HP = 55 (race), 33 (street)

The KR motor easily beats that - over 60hp in 1969, using regular gas. A K-Model is rated 32 hp. So, even Harley-Davidson's® oldest types are better than you thought…

Stop apologizing, and be proud of what you ride!

Z Rotor



The original 45 oil return (lower) pump & breather assembly (shown) works acceptably in std. form. It can be installed and timed on the original marks as per the service manual if you wish. However, breather timing is always a compromise; the most effective settings for a specific engine size and speed is not best for others. Some additional power can be had by increasing the breather timing.

To avoid incomplete oil return from the crankcase (which can occur when breather timing is too extreme for the engine size and speed) we can open & close the breather at the proper times (insuring that the pressure begins to blow down when it should, etc.), but restrict the breather area during the beginning & end of this cycle, so that vapor speed is kept high enough to keep the oil droplets in suspension and return them to the cam chest as intended.

The modifications given here are based on an average of std. timing figures taken from 45 motors using the factory timing mark:

A total duration of about 221° works well (similar to 1972-76 1000^{cc} Sportsters). The following suggestion will produce good results in most motors, but the exact position must be "timed in". The final positions should be determined with a degree wheel, etc.

Rather than take a full-height parallel cut off each side of the two slots, reduce the slot area during this extended segment of the timing. This will be done by making a cut extending only part of the height of the existing slot on both sides. The cuts will not be made to only one side, or symmetrically to both sides, since this will affect timing and prevent use of the original mark. Instead, amounts proportionate to the added duration will be removed from the opening and closing sides (as shown here).

The opening side of the rotor is found by holding the rotor in the normally-installed position (drive gear on top, and the slot directly in front of you). The opening edge is on your right. The cut must widen the slot .115" more to the right, making it open earlier. The bottom of the new cut will be flush with that of the existing slot, but only extend upwards by .250". This insures that any residual oil from the last cycle remaining inside the rotor will be quickly forced upwards into the cam chest, and then to the return pump.

The closing side of the rotor is on your left. We will make another cut here, going .084" to the left this time, but with the top of the cut flush with that of the existing slot, and extending down .250".

This is to allow additional time for clean air to flow back into the crankcase After Bottom Dead Center, to prevent a strong vacuum from forming as the pistons speed upward. Keeping the new slot extension as high as possible means it will tend to bypass any residual oil lying in the bottom of the rotor, rather than drawing it back into the crankcase. When these cuts are completed, remember to turn the rotor 180°, and do the other slot exactly the same way.

Std. Vs. Modified Breather Duration				
Function	Std. Duration	Modified Duration	Added Duration	Added Width
Total duration	169°	221°	52°	.199"
Breather opens	55° ATDC	25° ATDC	30°	.115"
Breather closes	44° ABDC	66° ABDC	22°	.084"

Good Numbers?

Purpose

The following information is a guide to help you find, match, evaluate, buy and rebuild Harley-Davidson® 2-cylinder motors ("twins") manufactured from 1930-69. The 1970-* numbers are considerably different, both in location and appearance, and are beyond the scope of this booklet. Specific topics are separated for reference.

Methods of Identifying the Engine Crankcases

There are four basic "**Data Items**" that form the framework of physical and legal identification of Harley-Davidson motors for the model years 1930 through 1969 (inclusive). As all four of these may not be accessible to casual inspection, the ones which can be verified take on even greater importance. All four of these items must agree (with known exceptions as noted®). I will explore them in chronological order of production:

Item 1	Case Casting N^{os}	Formed in the molten aluminum, as the crankcases are cast at the foundry
Item 2	Physical Characteristics	Partially determined by machining variations on the casting
Item 3	Case Bottom N^{os}	Factory-stamped after the left & right crankcase casting halves have been matched for use as a "mated pair", and machining has been completed
Item 4	Serial N^{o}	Stamped in place on the boss after the bottom numbers, and only if the motor is fully assembled

Item 1: Engine Crankcase Casting Number

Many engine components carry a cast-in (not individually stamped) number coded for the 1st year of use (the "model year" begins with 1st production on September 1st of the previous year), not the year of manufacture or sale. This is especially true in early models, as many components are used for long time periods, and motors may contain many parts made either earlier than the model year (due to carry-over of design from previous types) or later (by inclusion by an owner or mechanic of improved components).

The exception to this rule is the cast-in number in the left crankcase half itself, which must always be the same or earlier than the Vehicle Identification Number or "VIN" ("VIN number" is, of course, redundant). Even this has exceptions (in the case of authorized dealer replacement of crankcases, and military or police contracts), in which a later crankcase set may be substituted provided that all laws are obeyed.

Item 2: Physical Characteristics of the Engine

It is a frequent practice to incorporate components from other model motors to improve appearance or performance. Some of these are bolt-on modifications, others require machining, still more complex are those requiring welding, and still others are impractical to the point of approaching impossible.

Tables A & B show the most common crankcase casting numbers, and the model year group for which they are legal as original equipment.

Item 3: Engine Crankcase Bottom ("Hidden") Numbers

These are found on the lower exterior curved surface of the crankcase halves, below the front motor mounts. If the two halves were originally machined and assembled at the factory as a mated pair, the numbers will be identical to each other, but will not match the VIN.

In 1930-47 motors the bottom numbers will appear as follows:

Last 2 Digits of Year	(Hyphen)	Production Sequence (beginning with 1000)

For example: 37-1634 is a 1937 motor, the 634th produced that year (may not be the 634th vehicle, or even assembled motor). The same bottom number will appear on both crankcase halves (if they are still a factory-matched pair).

It is common practice for the motor (or crankcase halves) to be manufactured up to 5 months prior to the model year, since new vehicle production began on September 1st, and will be stamped for the actual year of production in the bottom number set (a crankcase set made & bottom-stamped in November of 1938 will be VIN-stamped for the 1939 model year). The purpose of these numbers is the factory production code sequence - the crankcases are only numbered after the left & right halves have been finish-machined as a mated pair. Following this, in most instances, the motor will be completely assembled, and assigned and stamped with a VIN. Once this has been done, the motor will be sold as a complete engine (with a bill of sale indicating the VIN), or installed in a chassis and sold as a vehicle (with a title to the VIN). The vehicle is legally the year shown as the 1st 2 characters in the VIN. However, the crankcases may also be sold to a dealer for service replacement purposes (in which the intent was for the dealer to repair a damaged motor with the new crankcases).

After 1948, a slightly different code is used; the bottom numbers will appear as follows:

Prefix Code + Last 2 Digits of Year	(Hyphen)	Production Sequence (beginning with 1000)

A numerical prefix appears before the year as an engine type reference. Remember that engine type does not invariably indicate displacement, VIN letter type, or external appearance.

Crankcase Bottom Number Prefixes			
Prefix	VIN Primary Character	Motor Description	Type
1	F	Single-cam big twin OHV 74"	III·
2	E	Single-cam big twin OHV 61"	III·
3	G, W	Servi-Car, 45 solo or military	I·
4	U	74 & 80" sidevalve	II·
7	X	Sportster 883 & 1000cc	I·

For example, a 1963 Sportster may be numbered 763-3128 (7 for Sportster, 63 for 1963, and the 2127th motor pair produced that year).

I do not know if production numbers begin at 1000 for each engine type, or if the 1st set of each year is 1000, and the sequence continues regardless of motor type. The production numbers will always exceed the total number of vehicles or motors produced that year, due to discards from errors, crankcase sets sold as replacements, etc. so the VIN will always be a lower number than the production number (except, possibly, for the very 1st motor made each year).

Non-matching left & right crankcase halves are common, indicating that (if done legally) a replacement right crankcase half has been acquired and installed to replace a damaged (or obsolete) original. The left (VIN-bearing) crankcase half must always have a bottom number consistent with the VIN, with the remarks above applying. Removal of these numbers (generally by grinding) does not technically fall within the scope of prosecution under the "altered VIN" statutes, but certainly it is useful as physical evidence of intent to defraud, either by destruction of evidence contradicting the (improper) VIN, or by falsifying evidence (with the presence of a re-stamped bottom number).

Item 4: Serial Number

The serial number (also referred to as the "VIN") contains three **Data Items**:

Last 2 digits of Year	Primary & Modifying Characters	Title Sequence (starts @ 1000)

They will appear as a stamped (recessed below the surface) impression, 3/16" high, in the exact order shown. No Items will be absent.

I believe that VINs begin at 1001 for <u>each engine type</u>, not in a continuous sequence throughout the production year. There may be **40U1257** <u>and</u> **40E1257** (each the 257th motor of its Primary Character sold that year), but <u>not</u> **59XLH1483** and **59XLCH1483** (both the same Primary Character: Sportsters® of Type I).

The numbers used 1930-68 will all have appearance as shown in Diagrams.

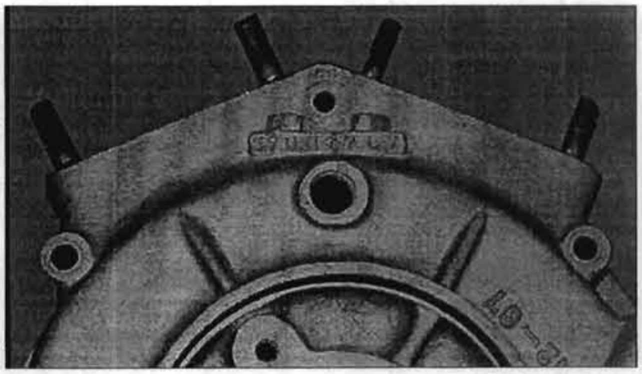
The serial number has several purposes:

- Proof of ownership: this is the sole identification number appearing anywhere on almost all H-D motorcycles through 1964 (there is no frame number until the 1970 model year, with the possible exception of vehicles intended for export sale, military, police, etc.)
- Year of sale: this may not be the year of actual manufacture of all of the components, but is always the model year for which the vehicle was sold (see Item 3)
- Engine displacement: the Primary Character (s) appearing after the year is a code indicating the engine displacement range (more than 1 choice) (see Table B)
- State of tune: the letter(s) after the Primary Character also indicate the horsepower level and/or intended use of the engine. Generally, more letters means more power or more specialization.
- Anti-theft coding: the numbers and letters used by H-D are not common machine types, but are of a specific size, shape, and style to make re-numbering more difficult to accomplish, and simpler to detect.
- From 1960 on another feature is used, in which the year and the first digit of the title sequence must agree, odd or even. In other words, a 1963 motor will appear: 63FL1004, or a 1966: 66GA4778. The 1st number sold will be 1001 (odd years) or 2001 (even years). To get the approximate production volume, subtract 1000 (odd years) or 2000 (even years). 64FLH2448 is not the 1448th motor sold of this type (2448 – 1000 = 1448), but the 448th (2448 – 2000 = 448).

Location

On all motors during this time period, the number is found on the left crankcase half, directly above the sprocket shaft, below the center crankcase through-stud, and centered between the front & rear cylinders, as shown, left (1937UH). In this area a rectangular boss is cast into the crankcase metal, slightly raised above the surface, approximately 2 5/16" long by ⅜" high. It is always visible above the primary cover (chain case).

Appearance of the Boss



The surface of the boss is "as cast", and should show no polishing, grinding, filing, or machining marks. The grain structure and "coarseness" should match the aluminum of the parent crankcase casting surrounding the boss. The edges of the boss are not sharp, but slightly rounded to blend into the parent crankcase metal. The boss protrudes approximately 1/16" from the crankcase surface. The characters are all of uniform 3/16" height, and are accurately placed vertically (parallel), but may not be on the same horizontal line (in other words, the tops & bottoms may not exactly line up). Since the length of the boss is fixed, the characters will be more crowded when more of them appear, but the stamped characters will be centered, and the length of blank space appearing before & after the characters will be the same on either side of the boss; the numbers are never placed at one end of the boss with blank space at the other. In some VIN types such as K, Servi-Car (G) and Sportster (XL) there may be a blank space where the center stud nut clearance cut is tangent to the number boss separating the year & primary VIN character from the title sequence; see Dgm 16.

In some motor types (such as the W & G) the boss will show a connection with the nut for the stud (mentioned above) in its upper center.

In late 1936-39 E type and all U type motors two ears or lugs appear above the boss, approximately 1" apart. In the U type they align the carburetor support bracket, and may no longer be necessary; however if they are missing or ground down, the boss may have been altered; see Dgm 16.

Examining the Boss for Alterations

When examining an assembled motor, in some crankcases only part of the exterior of the left crankcase is open to scrutiny (the casting number is either inside the crankcase, or inside the area covered by the primary cover). This is unfortunately true in the most valuable (and frequently stolen) motors: the 1936-69 E & F types.

Fraud

This does not even begin to explore the frauds involving non-existent numbers, how to detect fake based on case castings, how high could a number be per year, which left and right combinations are possible, bad stamps, welding. Anyone who objects to making a rubbing or pic of the VIN is a liar.

There are no records of what numbers were actually made before 1960, only the total volume is known.

About 1/3 to 1/2 of the stuff I see for sale has bad number stamps, and of the ones that appear genny some are good (but illegal) re-stamps, some may have liens, stolen 30 years ago in another state, etc.

"Running the number through the computer" does nothing but do it anyway.

My favorite un-detectable fraud: each VIN is only used once (duh), but a number series is continuous for each motor type (big twin, Sportster, 45). This means that if 51FL3230 exists (and you can find out by watching eBay etc.) 51EL3230 DOES NOT EXIST (nor 51F3230, 51E3230), and is therefore "safe" to use as a fake number - can't be in use, can't be stolen.

Probable Cause

Even if the VIN itself appears genuine, the physical appearance of the left crankcase <u>absolutely</u> <u>must</u> agree with the year & motor type consistent with this number.

The cylinders, heads, carburetor, etc. may all have been modified, interchanged, etc. without affecting the legality of the vehicle itself (assuming the parts were acquired legally).

Table A: Left (Drive or Sprocket Side) Crankcase Half

Type	Cstg Nº	VIN Prim. Character	Motor Size	Years Used	Bearing; Seal	Notes on Physical Appearance
I·	112-29	D	45"	1929-31	Roller; Cast-in	Main race ID: 1⅜". Vertical generator on left, parallel to front cylinder, crankcase drain lever
	112-32	R		1932-36		Front horizontal generator mount, crank-case drain lever
	112-37	W, G		1937-38		More fins than 112-32, no crankcase drain
	112-392	W, G		1939-73	Roller; Snap-ring	As –37, but snap-ring seal
		WR		1941-52	Ball; Snap-ring	Main race ID: 2". Similar to 112-392 but ball bearings
	24534-52	K	45"	1952-53	Timken; None	Unit construction; transmission service requires crankcase disassembly
		KR		1953-54	Ball; Snap-ring	Main race ID: 2". Very similar to 1952-53 K but ball bearing
	24534-54	54KH1001-54KH2620	54"	early 1954	Timken; None	Very similar to 1952-53 K
		KR KHR	45" 54"	late 1954-69 late 1954-56	Ball; Snap-ring	Main race ID: 2". Unit construction; trans-mission is serviced through access ("trap") door
	245XX-54	54KH2621-56KH****	54"	late 1954-56	Timken; None	Very similar to 1954-69 KR
	245XX-57	X, XL, XLH	54"	1957-66		Sportster, all
		XLCH		1967-69		Sportster, kick-start only
		XLR		1958-69	Ball; Snap-ring	Main race ID: 2". Very similar to 245XX-57 but ball bear
	245XX-67	XLH		1967-69	Timken; None	Sportster, electric-start (large solenoid bulge on top of transmission case)
II·	112-30	V	74, 80"	1930-36	Roller; Cast-in	Main race ID: 1½". Case drain lever
	112-37	U	74, 80"	1937-39		Similar to 112-30, but no crankcase drain
	112-402	U	74, 80"	1940-48	Roller; Snap-ring	As –37, but snap-ring seal

Type	Cs^tg^ Nº	VIN Prim. Character	Motor Size	Years Used	Bearing; Seal	Notes on Physical Appearance
III·	112-35	E	61"	1936-39	Roller; Cast-in	Main race ID: 1½"
	112-406	E F	61" 74"	1940-47 1941-47	Roller; Snap-ring	As –35, but snap-ring seal
	112-48	E F	61 74"	1948-52	Roller; Snap-ring	Main race ID: 1½". Wider top deck surface than 112-406, with oil drain channels
	245XX-53	F	74"	1953-54		No oil drain in decks
	24547-55	F	74"	1955-64	Timken; Threaded	Heavier than earlier
	245XX-65	F	74"	1965-68	Timken; Threaded	Large flat bearing boss
	245XX-65	F	74"	1969	Timken; None	As above, but no seal

TABLE B: Right (Pinion or Timing Side) Crankcase Half

Type	Cs^tg^ Nº	VIN Char.	Motor Size	Years Used	# Cams; Brg. Type	Bearing; Seal	Notes on Physical Appearance
I·	112-29	D	45"	1929-31	4; Brass	Brass; None	Main race: ⅞" ID. No generator drive
	112-32	R		1932-36 1933-36			Horizontal generator drive on right side
	112-37	W, G		1937-38		Roller; Cast-in	Main race ID: 1⅜" Return pump cavity
	112-39	W G		1939-52 1939-57?		Roller; Snap-ring	As -37, but snap-ring seal
	24558-58	G		1958?-73			As –39, with drains from tappet block holes to crankcase interior
		WR	45"	1941-52	4; Ball	Ball; Snap-ring	Main race ID: 2". Similar to above, but ball bearings
	245XX-52	K	45"	1952-53	4; Brass	Roller; Snap-ring	Main race ID: 1⅜". Unit construction, cylinder oil feed holes in top deck surfaces
		KR	45"	1953-69	4; Ball	Ball; Snap-ring	Main race ID: 2". As above, but ball bearing
	245XX-54	KH	54"	1954-56	4; Brass	Roller; Snap-ring	Very similar to K
	245XX-57	X	54"	1957			Main race ID: 1⅜". 2 rocker oil feeds from ⅛-27 NPT threaded holes near tappet blocks (no oil holes in deck)
	245XX-57	X	54"	1958-69	4; Needle		As above except cam bearings
		XLR	54"	1958-69	4; Ball	Ball; Snap-ring	Main race ID: 2". As above, but ball bearing
II·	112-30	V	74 80"	1930-36 1935-36	4; Brass	Brass; None	Main race ID: 1". Horizontal generator drive on right side
	112-37	U	74 80"	1937-39		Roller; Cast-in	Main race ID: 1½". Return pump cavity
	112-40	U	74 80"	1940-48 1940-41		Roller; Snap-ring	As –37, but snap-ring seal

Type	Cs^{tg} N^{o}	VIN Char.	Motor Size	Years Used	# Cams; Brg. Type	Bearing; Seal	Notes on Physical Appearance
III·	112-352	E	61"	1936-39	1; Brass	Roller; Cast-in	Main race ID: 1½". Horizontal generator drive on right side
	112-40	E	61"	1940		Roller; Snap-ring	As –35, but snap-ring seal
	112-40	E F	61" 74"	1941-47			
	112-48	E F	61 74"	1948-52			Oil feed holes in top deck surfaces; drain channel at extreme rear deck
	245XX-53	F	74"	1953-54			Lifter screen near rear tappet block
	24563-55	F	74"	1955-57			similar to -53
	24563-58	F	74"	1958-early 1963	1; Needle		Main race ID: 1¾"
	245XX-63	F	74"	late 1963 -1964			No deck oil feed; single fitting (90° ⅛-27 NPT) between tappet blocks
	2456X-65	F	74"	1965			Oil fed from cam cover
	245XX-66	F	74"	1966-69			As above

Appearance of the Stamped Numbers

Several types of number stamps were used in the period 1930-1958. Here are some samples of VIN stamps believed to be authentic, along with the year & model:

VIN Stamps

1929 D 45"

1934 RLD 45"

1934 VLD 74"

1936 RLD 45"

1936 VLD 74"

1937 W 45"

1937 UH 80"

1938 U 74"

1939 WLDD 45"

1942 WLA 45"

1942 WLA 45"

1946 UL 74"

1951 FL 74"

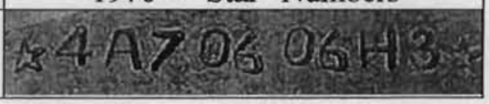
1953 K 45"

1953 KK 45"

1954 G 45"

1939 U Bottom Numbers

1970-* "Star" Numbers



The "Family Rule"

Generally, very few components can be interchanged between the 3 major Types or "families" of engines. Each Type began as a separate engineering design, not a modification of an existing type. Both Type II· & III· are commonly referred to as "big twins", although this also refers to earlier 61 & 74" twins (1914-29), which are yet another design.

Type I· is the oldest (began production in September 1928), and includes both side-valve and overhead valve versions, and both separate transmission and "unit" (integral transmission in the crankcases) construction. The only version currently in production is the Evo Sportster.

Type II· is a "scaled-up" version of Type I· and very similar in appearance, but with very few interchangeable parts (except for the oil system and ignition). This was built as a side-valve only, with the same separate transmission as the Type III·. Type II· production ceased in 1948; therefore it's the only "extinct" "family".

Type III· is completely different from both, but has certain dimensions and components in common with Type II· as to crankcase, flywheel and cylinder base flange sizes, among others. This was built as an overhead valve only, with separate transmission. All modern big twins are Type III·, including Evo motors (except Twin-Cam 88).

Engine Family Types						
Type	Design	VIN, 1st Letter	Common Name(s)	Years	Displacement, in: Inches	CC
I·	Small 4-Cam	D	45 solo, "3 cylinder", flathead	1929-31	45	750
		R	45 solo, trike, flathead, Servi-Car	1932-36	45	750
		G	45 trike, flathead, Servi-Car	1937-73	45	750
		W	45 solo, army bike, flathead	1937-52	45	750
		K	K model, flathead Sportster	1952-53	45	750
			KH model, flathead Sportster	1954-56	54	885
		X	ironhead Sportster, 55", 883, 900	1957-71	54	883
			ironhead Sportster, 61", 1000	1972-85	61	1000
II·	Large 4-Cam	V	big flathead, V, VL, VLD, 74 (called 80 in error) big flathead, VH, VHS, VLH, 80	1930-36 1935-36	74 80	1200 1300
		U	big flathead, U, UL, 74 (called 80 in error) big flathead, UH, ULH, 80	1937-48 1937-41	74 80	1200 1300
III·	Single Cam	E	knucklehead, EL, 61	1936-47	61	1000
			panhead, EL, 61	1948-52	61	1000
		F	knucklehead, FL, 74	1941-47	74	1200
			panhead, FL, FLH, Hydra-Glide, Duo-Glide, Electra-Glide, 74	1948-65	74	1200
			generator shovelhead, FLH, Electra-Glide, 74	1966-69	74	1200

Note: only Types II· & III· are referred to as "big twins", although some parts interchange with Type I·.

Some Type I· motors (Evo Sportster 1100 & 1200) are larger in displacement than some Type III· motors (61" EL).

Legal Adaptations & Conversions

It is possible to use not only non-matching left & right crankcase halves (i.e., numbers don't match, but crankcases are from the same motor type), but to install a right half from the same motor type but manufactured considerably earlier or later. A clever builder can potentially use a right half from a <u>different</u> motor type. How much work is required is determined by the degree of similarity between the motors, but generally the "Family Rule" (Data Item 2, above) applies.

Table C: Possible Adaptations			
VIN Characters	Years	Motor Size	Notes & Adaptations
D, DL, DLD	1929-31	45"	Simple adapt: K-type cylinders & heads, etc. Possible adapt: X-type cylinders & heads by extensive heli-arc on right crankcase half & machining
R, RL, RLD, RLDR	1932-36		
W, WL, WLA, WLC, WLD, WLDR, WR	1937-52		
G, GA, GE	1937-73		
K, KK, KR, KRTT, KRM	1952-53 1952-69	45"	Simple adapt: KH-type cylinders & heads bolt on. Possible adapt: X-type cylinders & heads by extensive heli-arc on right crankcase half & machining
KH, KHK, KHR, KHRTT, KHRM	1954-56	54"	
V, VC, VR, VL, VLD, VLH, VHS	1930-36 1935-36	74, 80"	Simple adapt: U-type cylinders & heads bolt-on. Simple adapt: E or F cylinders & heads.

U, UL, US, UA, UM, UMG, UH, ULH	1937-48 1937-41	74, 80"	
E, EL, F, FL	1936-47 1941-47	61, 74"	Simple adapt: F-type cylinders & heads 1948-84, but cylinder flange will over-hang left crankcase deck. Possible complex adapt: Evo (1984-*).
E, EL, F, FL, FLE, FLP, FLH	1948-52 1948-69	61, 74"	Simple adapt: F-type cylinders & heads 1936-47, 1966-84. Possible complex adapt: Evo (1984-*).
Alternator & Evo (cone) FLH, FX etc. 1200, 1340	1970-* 1978-*	74, 82"	Cases accept almost any barrel up to 3.8125" without welding, studs must be moved.
XL, XLH, XLCH	1957-71	55"	Possible adapt: most 1952-56 K-type parts. Possible adapt: most X-type parts 1972-85. Possible complex adapt: 1936-85 F-type cylinders & heads. Possible complex adapt: Evo (1984-*), major welding.
XLH, XLCH, XLX, XLCR, XR1000	1972-85	61"	Possible adapt: most 1952-56 K-type parts. Possible adapt: most X-type parts 1957-71. Possible complex adapt: 1936-85 F-type cylinders & heads. Possible complex adapt: Evo (1984-*), major welding.
Evo XLH etc. 883, 1100, 1200	1986-*	54, 67, 74"	Cases accept almost any barrel up to 3.8125" without welding, studs must be moved.