Understanding Camshafts

History and design changes

BY **DIMITRI "DEMA" ELGIN**

When talking about camshafts we need to establish the proper definitions about the various parts of the camshaft.

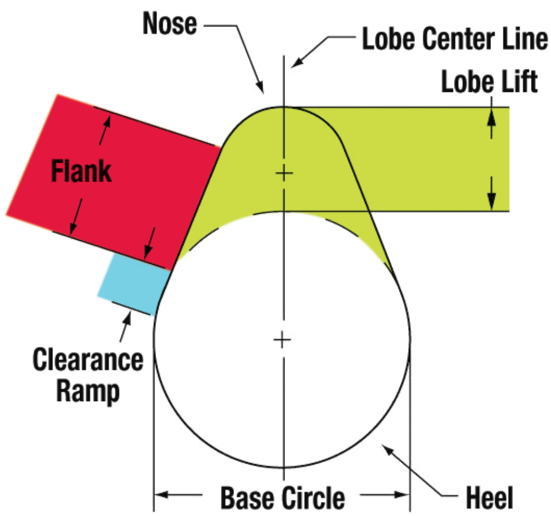
Cam Profile: The actual working surface contour of the cam. We can look at the lobe shape in the end view.

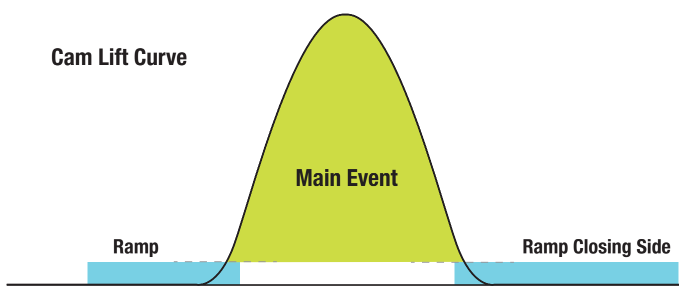
Base Circle: Also called the heel. The base circle can be drawn as a full circle that the rest of the shape is attached to. It must not cause any lifter movement.

Camshaft Lobe "Clearance Ramps": The transition segment of the lobe from its base circle to the opening or closing flanks of the camshaft lobe.

Camshaft Lobe "Flanks": Each lobe has two flanks, opening and closing. The flanks are the business segment of the lobe. The opening flank displaces the lifter away from the base circle and the closing flank brings the lifter back down to the base circle in order to close the valve. Think of this motion as displacement per degree of cam/crank rotation. The closing flank controls the rate, inches per degree that the valve closes. It must join some type of clearance ramp in order not to have the valve bounce when it hits the valve seat.

Camshaft Lobe "Nose": Also called the toe. The top of the cam lobe. It's the radius that joins the two flanks together. The nose center is the point of peak lift.





It is very important to understand when designing a camshaft lobe profile that the valve train is not a rigid system! One must remember that the cam designers calculate the ramps to compensate for the slight bend of the camshaft, the flex in the push rod and rocker arm, the valve stem rock in the valve guide and the growth of the valve stem as well as the engine block and cylinder head.

Clearance ramps are critical to the effective operation of the valve system! They determine how fast the valve leaves its seat and how fast it comes back down onto the valve seat. High seating velocities contribute to valve bounce!

Early cams did not have ramps. At low speeds they were not necessary. The seating velocity for these cams was low. As engine RPM increased, clearance ramps became necessary. Almost all engines by the 1930s had some sort of clearance ramp added to the cam lobe design.

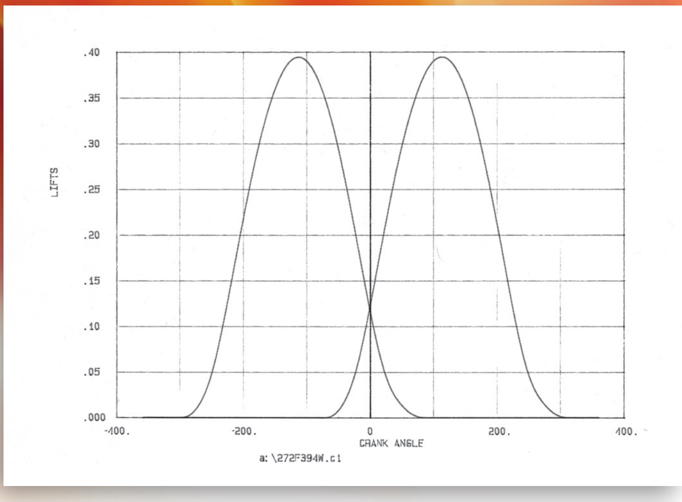
Older roller tappet, radius tappet and flat tappet camshaft engines from the teens up to the 30s set the valve lash close to .003-.005". This worked well at engine RPMs below 2,000 which is 1,000 cam RPM.

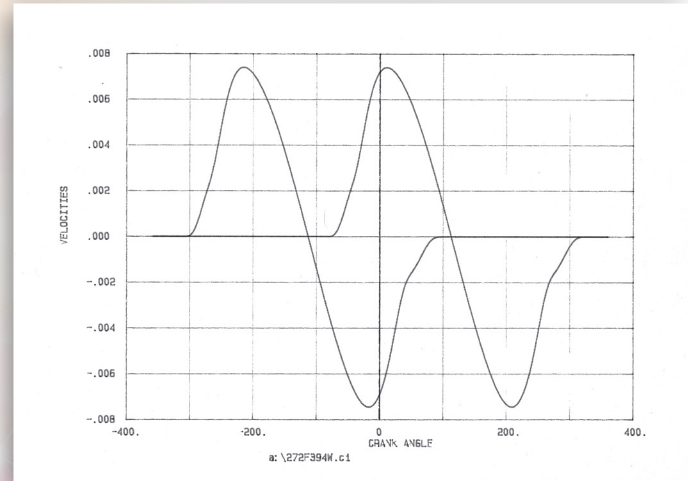
If there were no clearance ramps designed onto the cam lobe, and the valve lash was set loose like .010" or above, the rotation of the camshaft would hit the lifter-tappet hard. That would shock the valve spring and it would vibrate due to the sudden impact. Cam designers learned that a certain amount of PRE-LOAD was required in order to set the valve train into motion without shocking the system. Clearance ramps were then designed in order to soften the blow when they realized that the valve train was not a rigid system. They understood that the valve train was a compliant system and needed to be controlled with clearance ramps and flank speeds along with valve springs that would not vibrate so easily.

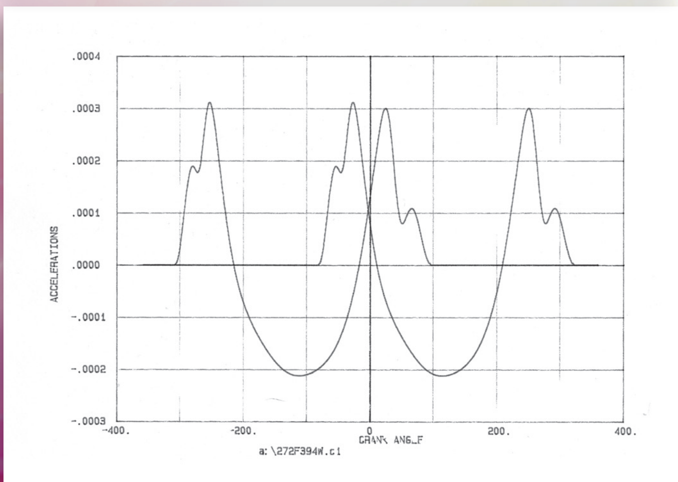
There are a few different styles of clearance ramps. The most popular, that was used for years, is the "constant velocity" ramp. The second style is the "constant acceleration" style and the third is the "constant jerk" that sometimes is blended into the constant radius of curvature or the constant velocity ramp. With the aid of good cam design software different styles of ramp can be blended together for better control of the valve seating velocity. It is important in applying the clearance ramp in such a way that it becomes a CONTINUOUS curve joining the

Assorted Cam Lift Curves

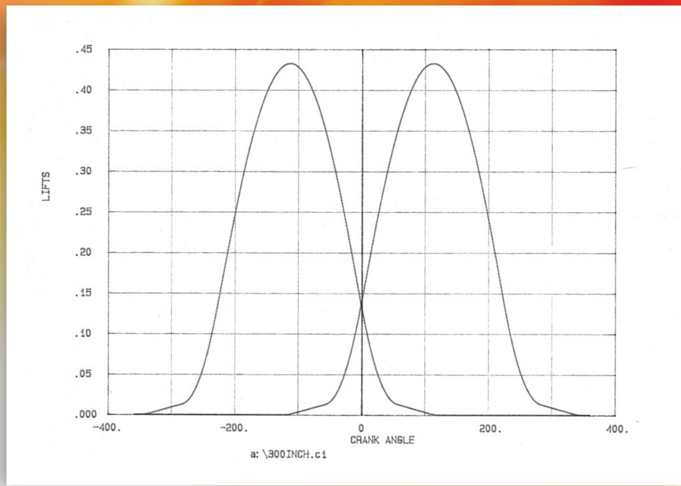
First, Cam Lift Curve; second, the Cam Velocity Curve (first derivative of lift curve); and third, the Cam Acceleration Curve (second derivative of lift curve). Shows the clearance ramps that join into the flank of the cam on both the opening and closing sides.

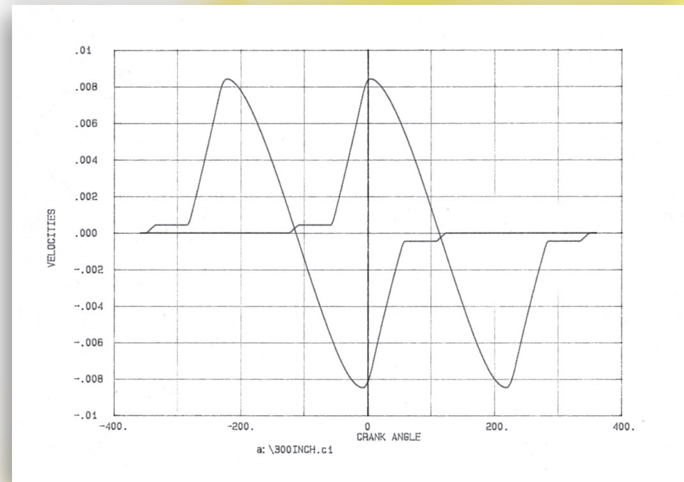


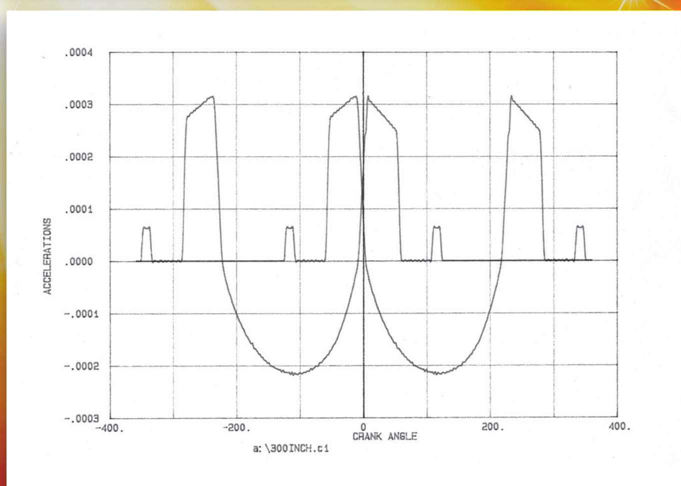




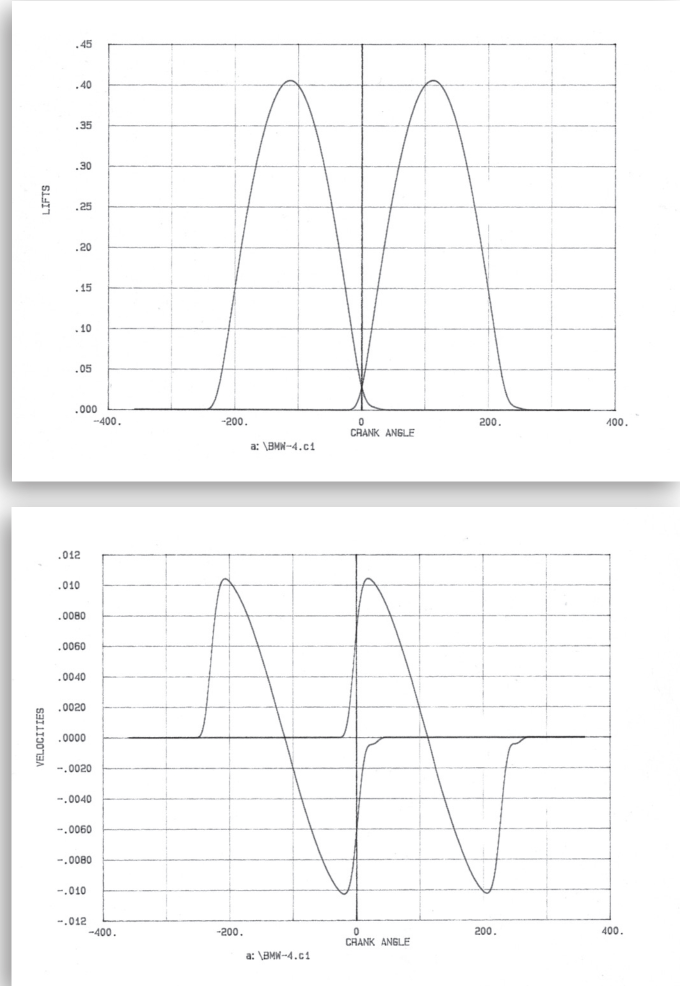
Elgin's Mechanical Lifter
Racing design OHV high RPM
Fast open, slower closing ramps.
Constant acceleration designed ramps.



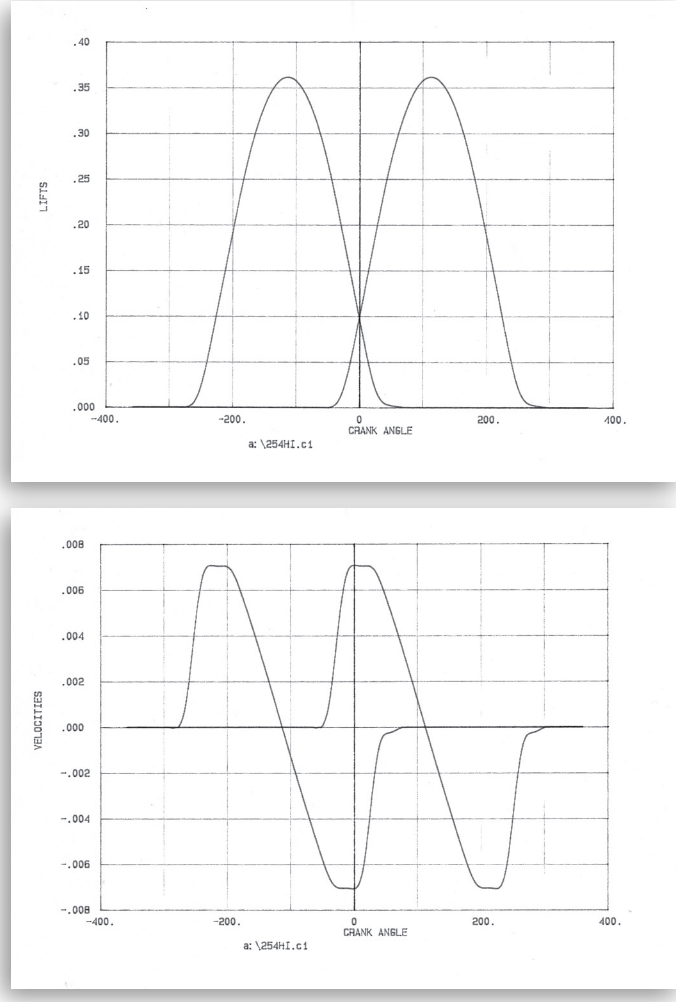




Traditional Constant Velocity Ramps
Older style design like 3 arc
Big changes – sharp angles = higher jerk.
Not so good on the valve springs at the higher RPMs.



Traditional Hydraulic Overhead Cam Design
Fast open; slower, longer closing side.



Elgin Performance Style – Pushrod Hyraulic Tappet Design
Easy start on open ramp; longer, slower closing ramp.

heel diameter at one end and blending into the flank curvature.

Let's discuss the clearance ramp for the over head valve (OHV) engine that is using mechanical lifters, solid or roller style. A certain amount of clearance is required to be able to have the lifter start to pre-load the valve train. The open side of the ramp can be a little shorter and faster than the closing side ramp. However, if it's too fast it can shock the valve spring and the spring will start to surge.

I've found out that if the open side is slow and long on the exhaust valve, the valve head temperature can become excessive. If the closing side is too fast and short there could be a problem with the valve closing too fast at the higher RPMs and the valve will bounce off of its seat therefore losing cylinder pressure. The valve locks can take a beating as well as the valve face and valve seat.

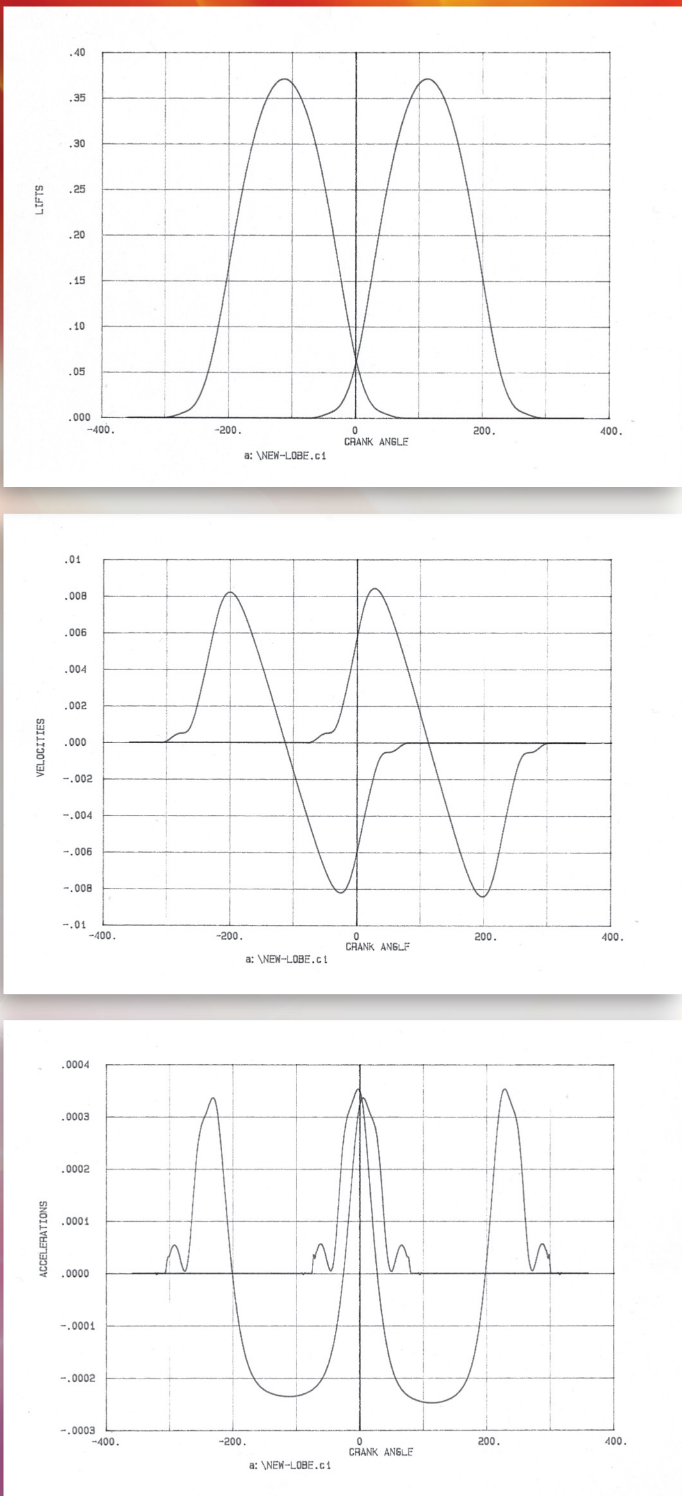
Conversely, if the ramps are too slow and tall, some engine performance will suffer especially if the valve lash is on the tight side. It is important that the valves close fast enough in order to seal tight and to be able to transfer the heat from the valve face into the valve seat and then into the cooling system.

Valve lash is very important when the cylinder head or engine block is aluminum. The coefficient of expansion of the aluminum parts require a tighter lash so that when the parts expand the lash will increase and should be almost at the end of the clearance ramp and then the valve will have the proper timing.

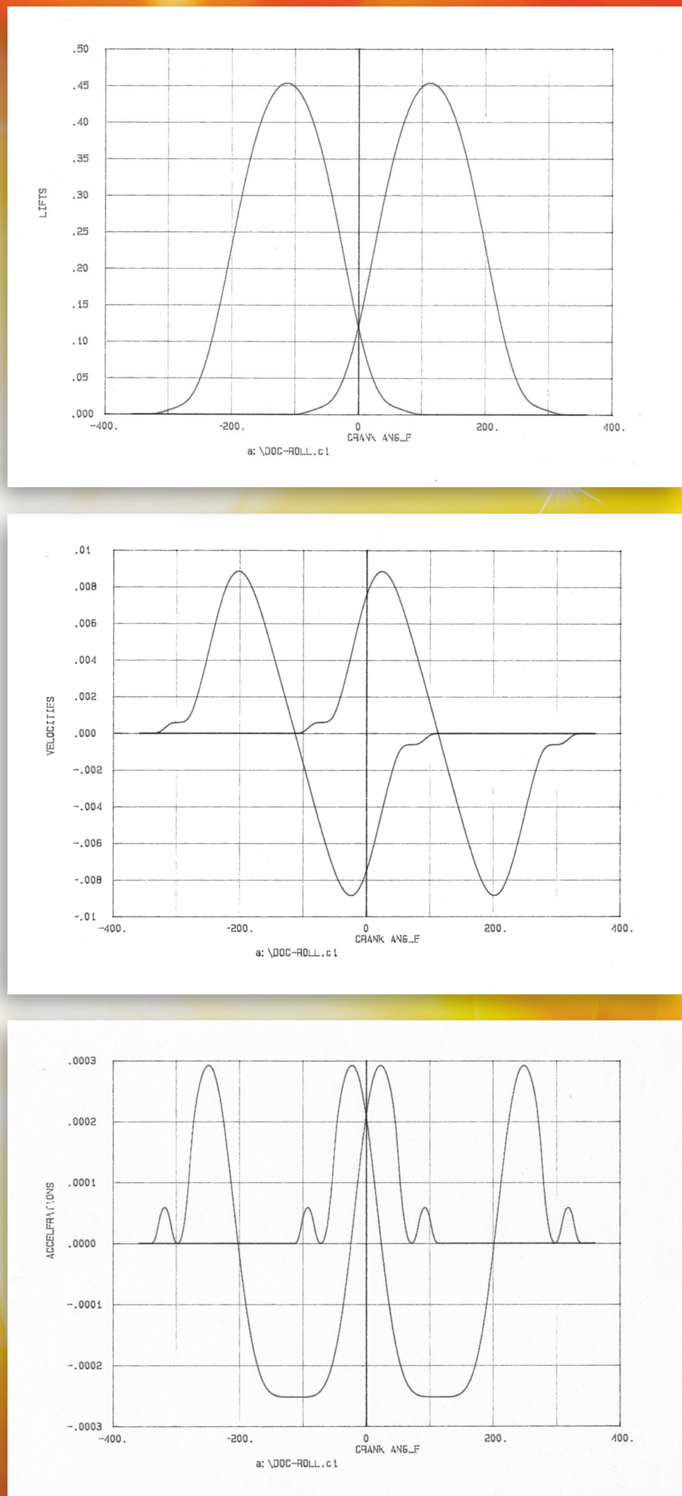
For example, the air cooled Volkswagen engine 1200-1600cc has a ramp height of in the area of .017-.018" tall and consumes a considerable amount of duration. When cold, the lash is set in the .004-.006" range and when the engine is at its operating temperatures the lash is about .012" and (this gives the valve train about .005"of pre-load) is a very compliant valve train. That is a good cushion as to not shock or bang the valve train.

When using an aluminum cylinder head and a cast iron engine block like some Ford and Chevy V8 engines, the cold lash needs to be a little tighter like about .005". Doing so allows the lash to expand (loosen) to the designed lash when the engine reaches operating temperatures. When the cylinder head and block are aluminum then the lash needs to be a lot tighter by about .012"+/- than designed, so that when the parts reach operating temperatures the valve lash will be at the designed settings. Hydraulic lifters solve those types of problems.

The question always comes up, "WHAT VALVE LASH IS REQUIRED FOR MY CAMSHAFT? I cannot find my cam card or the information from the engine builder."



Mechanical Roller – Pushrod OHV Design
Nice clearance ramps; fast flanks for the roller.



Mechanical Roller Tappet Design – OHV Symetrical Design
Easy ramps; good high RPM use.

UNDERSTANDING CAMSHAFTS

BY **DIMITRI "DEMA" ELGIN**

If it's a mechanical style camshaft, and not a hydraulic lifter style cam, you can put a dial indicator on top of the valve spring retainer. Reduce the lash to close to zero and slowly rotate the engine and watch the first .020" of valve movement on the opening side as well as the last .020" closing side. You should notice the .005"-.010" to be slower and it will speed up as it reaches the .020"-.025". Above that point the valve is moving very fast!! Say that you see the indicator change speed around the .015"-.020' area then you should try to adjust the valve lash to .015" +\-.002". If the lifter is noisy then tighten it .002" at a time until the tapping noise goes away.

With the hydraulic lifter style cam you can adjust the valves, try setting the pre-load after you hook up a vacuum gauge to the intake manifold and with the engine running, loosen the rocker until it clicks and the very slowly tighten the adjuster until the clicking goes away. If the pre-load is too tight the vacuum gauge will flutter and will not stabilize. When the pre-load is at the minimum the vacuum will be a little higher than if the pre-load, plunger is way down into the lifter body. If the intake manifold is off and you can see the camshaft, you can get the lifter on the heel of the cam and then tighten the rocker/adjuster so the pushrod will just go down into the pushrod seat and then you can pre-load the plunger about a quarter to a half turn. In some cases longer or shorter push rods may be required in order to obtain the proper pre-load of the plunger in the hydraulic lifter if there is no adjustment left.

CONCLUSION: A SUMMARY OF RAMP DESIGN

Cast iron liquid cooled engines usually have a minimum change in valve gear length between hot and cold. Opening ramps of .009-.012" on the cam with the closing side of .003-.005" higher than the open side work well on the typical automotive engines that use 1.5:1 to 1.75:1 rocker arm ratios. When we speak of seating velocities as a rate, it is a rate of movement before the valve impacts the valve seat. The final millisecond between .0003" per degree and zero movement at 6,000 RPM is equivalent to a crash into a solid wall at about 18MPH! I'm sure that you have heard an engine sounding like a thrashing machine when the car is coming towards you on the street. The valve train has too much clearance or the seating velocity is too high.

Remember that valve float occurs first when the valve is closing and it bounces on the seat and second when the lifter launches over the nose-top of the cam lobe and lands on the closing flank. That is called valve toss and/or loft. Not a good thing to happen!■

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GLOSSARY OF CAMSHAFT TERMS

DURATION: The valve open period in crankshaft degrees. Although not so simple, longer periods open are associated with improved volumetric efficiency.

LIFT: Cam lift or valve lift measured in inches or millimeters. Up to the limits of port flow, greater lift is also associated with improved volumetric efficiency.

OVERLAP: The period at the end of the exhaust stroke when both valves are open. With split overlap, both intake and exhaust valves are open equally at TDC exhaust stroke.

BASE CIRCLE: The portion of the cam lobe concentric to the center of rotation and, when in contact the lifter or follower, the valve is closed, Because valves are on their seats during this period, this is also when valve cooling is most efficient.

RAMPS: Opening ramps serve to take up valve train slack before opening the valve and extend from the base circle to where valve opening actually begins. Closing ramps extend from the ends of the closing flanks to the base circle and serve to reduce shock on valve closing.

FLANKS: The areas on cam lobes where valve opening or closing rates are greatest.

NOSE: The valve slows to a stop on opening and slowly begins closing as It travels across the nose.

LOBE CENTERLINE: The centerline of the lobe frequently used to locate wide-open points in crankshaft degrees.

LOBE CENTERS: The separation between intake and exhaust lobe centerlines in camshaft degrees sometimes referred to as the lobe separation angle increases in the angle reduce overlap and decreases in the angle increase overlap.

LOBE TAPER: The taper ground into some camshaft lobes to promote lifter rotation and reduce camshaft wear.

SYMMETRICAL CAM LOBES: Lobes ground the same on opening and closing sides of lobe centerline.

ASYMMETRICAL CAM LOBES: Opening and closing sides of lobes are ground to different contours.

DUAL PATTERN GRINDS: Intake and exhaust lobes are ground to different duration and/or lift specifications.