

Model T Camshaft Design

By
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I first came to this clinic with Fred Houston about 10 years ago to discuss our cam project. At that time, only reground T cams were available. We had confirmed that a cam with near stock characteristics gave better performance than a reground cam, so we knew we needed some new cams. I asked Fred – “Who will we get to design them?” and Fred said “You”. I had no previous experience, so went through a crash course. Steve Coniff was instrumental through discussions and by sending a copy of a very good book (Turkish) to learn from. From that point, I was curious to learn more about cam design and how Ford cam designs evolved throughout the flathead era. George DeAngelis provided the original drawings for the Ford flathead cams from the Ford archives. I also collaborated with Steve Coniff to design a couple of one-off cams for his Montana 500 effort. One of these was in Tom Carnegie’s winning car in 2009. I also got into vintage road racing in a Triumph TR3. That provided the incentive to do my first OHV designs. I’ve sold about 50 of these to other Triumph TR3 and 4 vintage racers.

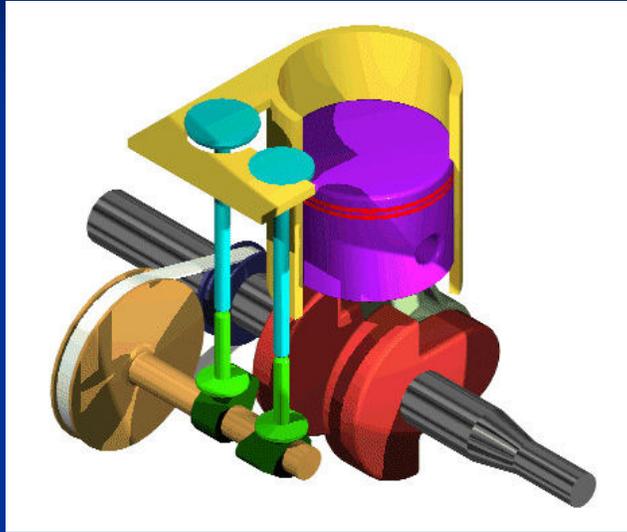
You can find more information about our Model T Cam project at:

clubs.hemmings.com/clubsites/MTFCTulsa/Cams.

Some of my other efforts and a complete history of Ford flathead cam designs can be found at:

www.tildentechnologies.com

4 Stroke Engine

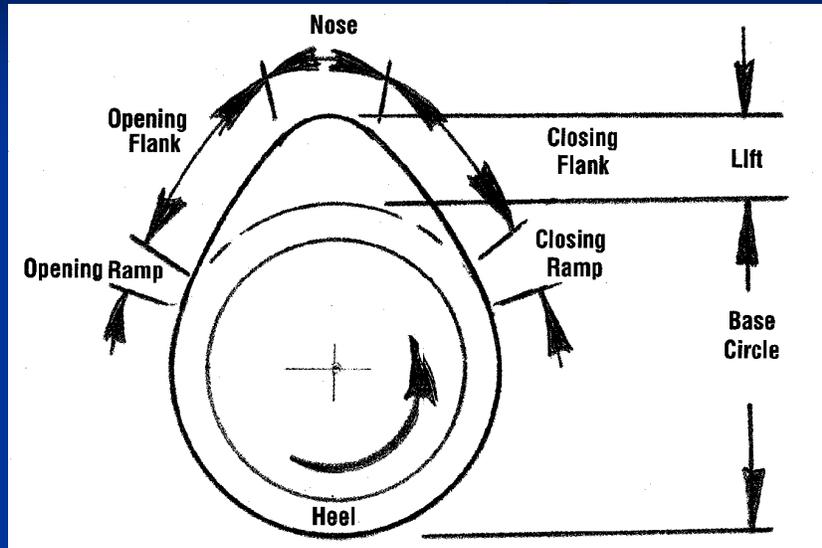


The strokes are – intake, compression, power, exhaust

This could be the intake stroke if the piston is going down or exhaust if it is going up.

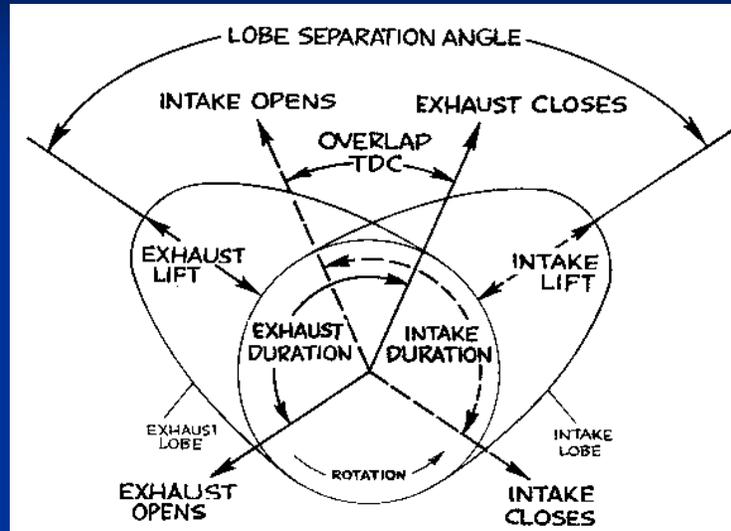
Note 2:1 ratio of crank to cam and focus on the cam lobes, so the crank turns twice for each turn of the cam.

Lobe Terms



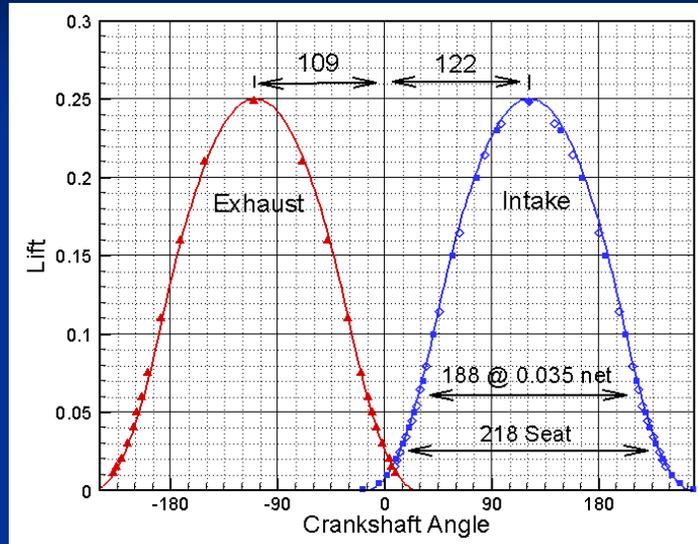
Model T and all Ford flathead cams are gear driven so they turn counterclockwise. The Model T stock cam had no ramp, all other Ford flathead cams had ramps. The new T cams have a small ramp area.

Cam Lobes



Important graph, keep this picture in mind. This is a snapshot of the cam lobes at TDC on the start of the intake stroke. Note open and close of exhaust and intake. The difference is the **Duration**. For most modern engines both valves will be open at TDC. This is called **overlap**. The Model T stock, 250, 280 and L-R have no overlap. Note the **centerlines**. These are typically at about +/- 55 degrees or +/- 110 crank degrees. The angle between the two lobes is the **Lobe Separation Angle**. The angle of a line half way between centerlines is the cam **Advance**. You can think of advance just like in ignition timing. If we increase the advance by rotating the picture counterclockwise, then all the events occur sooner. If the centers are at equal angles, 0 advance, the cam is said to be straight up. For stock Model T and the 250 and 280 cams, the intake is at 122 crank degrees and the exhaust is at -109 crank degrees. This means the cam is retarded, since the angle of the line half way between is $(122 - 109)/2 = 6.5$ degrees to the right. The advance is an important tuning parameter, since it can be changed using a vernier gear or by drilling the dowel pin holes at a nonstandard angle.

Lift Curves



You can look at the lobes, but it is the lift curves that tell the story. These lines were calculated from the original Model T Ford Cam specs. The points were measured by Fred and I on a NOS cam loaned to us by Steve Coniff. To get the Ford spec for duration of 218 degrees and open/close angles, the valve clearance must be set as 0.025. Today, the industry standard quotes timing at 0.050 gross lift. The reason for this is that it measures the duration after the valve is open far enough to start flowing significant air. When comparing cams with different valve clearance, it would be better to use a standard based on net lift. For most Ford cams (Model A thru early 1950's) 0.050 gross lift corresponds to 0.035 net lift, so I will use that here. The stock model T cam had 188 degrees duration at 0.035 net lift. In a moment, I will show how this compares to other Ford cams.

Cam Event Importance

- Intake Close
- Intake Open
- Exhaust Open
- Exhaust Close
- Intake Lift
- Exhaust Lift
- Intake Duration
- Intake Center (Advance)
- Lobe Separation
- Exhaust Duration
- Intake Lift
- Exhaust Lift

Never Sacrifice Duration for Lift!

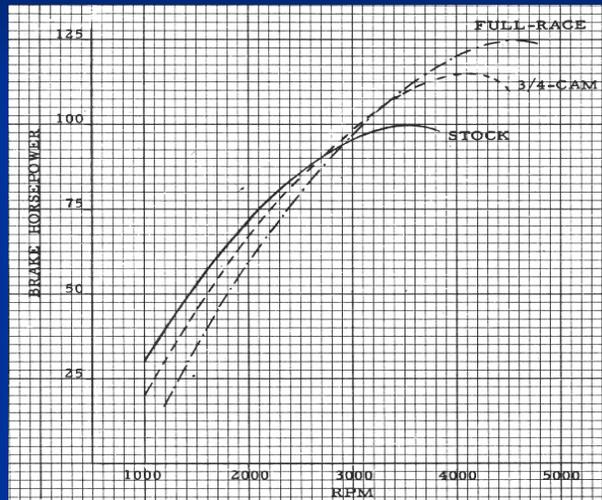
When designing a cam, you should keep the relative importance of the events in mind. On the intake stroke, the A/F mixture is sucked in with only atmospheric pressure as the driving force. The exhaust gases are at much higher pressure, so they flow out more easily. For this reason, the intake timing is far more important than exhaust timing. The most important timing event is the intake close. You can think of the air as a spring, which is being drawn down by the piston. The tail of the spring will lag the head of the spring. To capture as much air as possible, the intake valve should close after BDC. The faster the engine spins, the later it should close. For a slow speed engine the intake should close sooner. The intake opening is less important because the piston is near TDC where there is not a lot of travel for each degree of rotation. However, earlier opening causes more overlap and contributes to poor idle and off idle performance. On the exhaust side, the opening is most important. If it opens too soon, then some of the power will be lost out the exhaust pipe. If it opens too late, power will be lost in what are called pumping losses. The exhaust close is less important again because the piston is near TDC, but a late closing will contribute to increased overlap.

The four timing event are far more important than lift. Unfortunately, lift is what most Model T guys look at. There are cams advertised as stock, when they have stock lift, but completely different timing. This is false and misleading advertising in my opinion.

On the right, I've reorganized the 4 timing events into a different, but equivalent set of four parameters. The duration is the difference between the close and open. The intake center is the average of the open and close. One set of numbers is easily calculated from the other. The other parameter is the lobe separation, the difference between the centers. The reason for selecting these parameters is that 3 of them are built into the cam, but the intake center can be adjusted during installation of the cam, e.g. by using a gear with different dowel pin holes or a vernier gear. For any given cam, we can use the intake center or the advance for tuning.

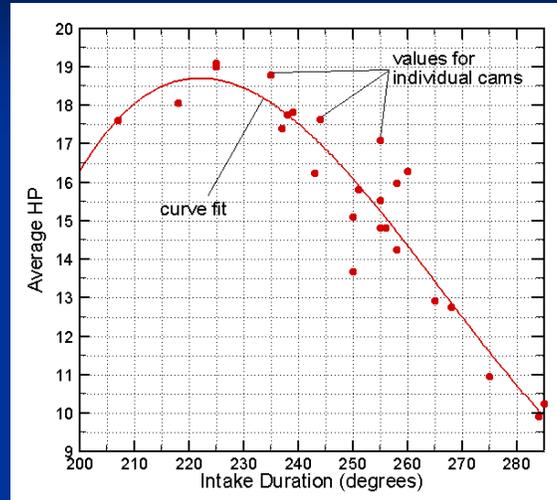
Cam Tradeoffs

from: *How to Hop Up Ford and Mercury V8 Engines*



From this discussion, it is clear there are tradeoffs in cam design. The largest influence is the intake duration and intake closing or intake center. An earlier intake close improves low speed performance, while a later close improves high speed performance. This tradeoff was known even before the Model T was introduced. This graph comes from a neat little book by Roger Huntington in 1951. The stock cam has intake duration of about 200 (at 0.035 net or 0.050 gross) and the $\frac{3}{4}$ race had 20 to 25 degrees more. We can expect the same general behavior for a Model T. Of course, the Model T will not achieve 4000 RPM with a flathead because of its poor flow and low compression.

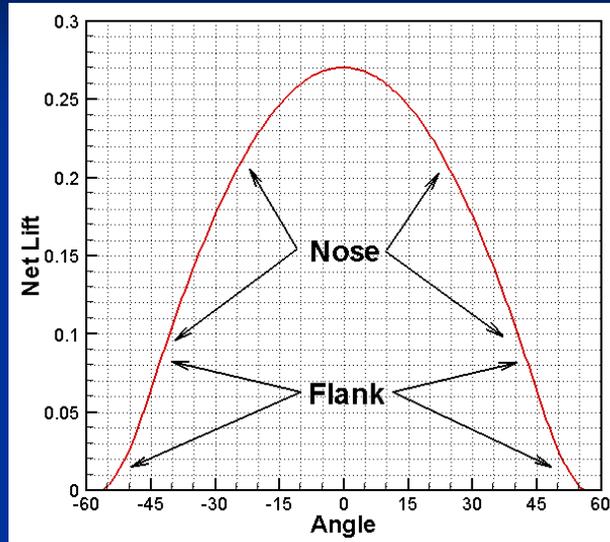
HP vs Duration



data from: *Secrets - The Ford Speed and Sport Magazine (1999)*

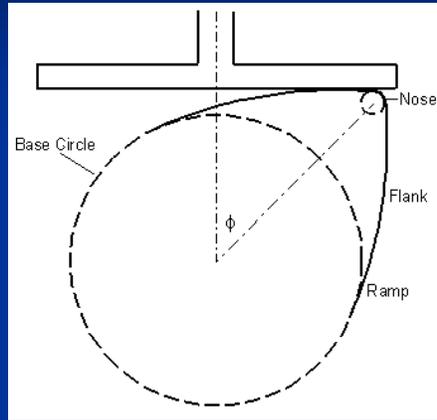
Our cam project was started around 1999, when Larry Sigworth and Fred Houston collected data on a number of different cams and used an engine simulator to predict their performance. At that time, there were no new cams available, only regrinds with intake duration of 235 degrees seat-to-seat or more. I took the data out of their article and created this graph of average horsepower vs intake duration. Each dot is one of the cams they simulated and the line is a simple curve fit to the data. The curve fit suggests that a duration of about 225 degrees would be best. The stock T cam is the point at 218 degrees. At 225 is the Laurel-Roof and some other antique performance cams. Most of the regrinds create the cluster of points around 250 degrees. Based on this data, we decided to design three cams all with a valve lash of 0.010: (1) stock 218 duration and 0.250 lift (2) replica of the Laurel-Roof cam, 225 duration and 0.310 lift and (3) a cam with intermediate duration and 0.280 lift. We used Ford timing specs for the 250 and 280 and the Laurel-Roof timing specs for it. The Laurel-Roof timing was actually copied from a Stutz engine.

280 Cam Lift Curve

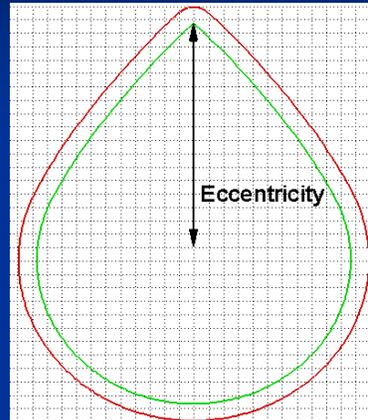


Once the duration has been determined, then the cam should be designed for maximum lift. For the 280 cam the duration at 0.035 is set at 195 degrees. We could get more lift if the slope of the curve were steeper and if the nose part could curve around and match the closing flank. However, there are some limitations as shown on the next slide.

Size Matters



Stock lobe at 45 degrees



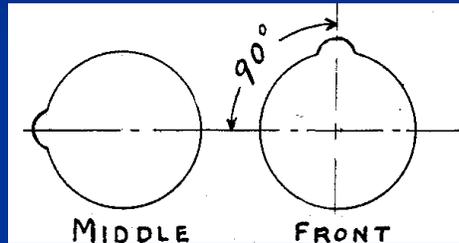
2 sizes of 280 lobe

At the left is a lifter and stock cam lobe at 45 degrees. We have to make sure that the point of contact doesn't occur off the edge of the lifter. It turns out that the point of contact is directly related to the slope of the lift curve (previous slide). The size of the lifter limits the slope of the lift curve.

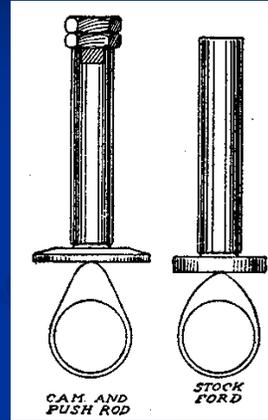
At the right are two lobes that produce the same 280 lift curve. The **eccentricity** determine the curvature of the entire nose portion of the lift curve. More eccentricity gives a tighter curve and more lift. Unfortunately, the cam has to slide through the cam bearing holes, which are 1.375 in diameter. A trick learned from Steve Coniff is that this size limit applies only to the exhaust lobe. The intake lobe can be a bit larger. We used this trick in the design of the 280 cam in order to get more lift. Also, the nose needs to have at least a 1/32 inch radius to reduce wear. The green lobe with a sharp point would not be practical. This also explains why a stock cam with a worn down nose cannot be reground back to a stock profile. If you tried to regrind one, the nose would go to a point like the green lobe. Cam grinders call this "knifing out". Steve Coniff once had a cam which he nicknamed the "Gillette" cam, after the maker of razor blades.

Some Solutions

from: *The Fast Ford Handbook*



Notching the block



Larger lifters

The limitations just described were well known during the Model T era. These diagrams are from Murray Fahnestock. Due to their larger size, antique performance cams like the Laurel-Roof required notches in the block in order to install them. They also required a larger diameter lifter. A replica of the Laurel-Roof cam and larger lifters are available from Bill Stipe.

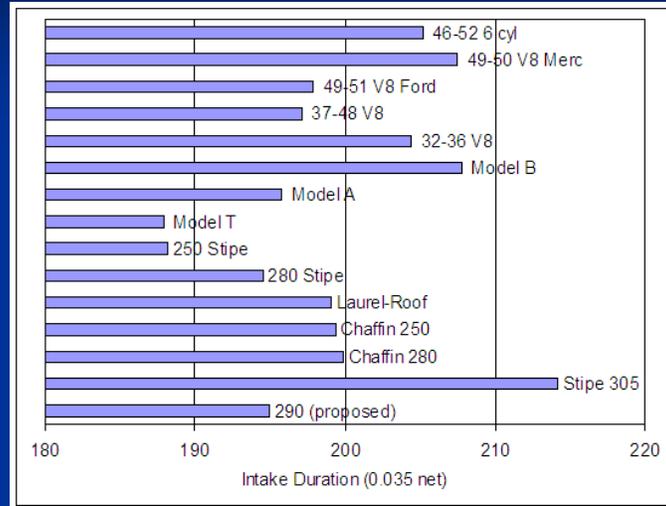
Model T Cams

- 250 Improved Stock (Stipe)
- 280 Super-Power Cam (Stipe)
- Laurel-Roof (replica)
- 250 Chaffin
- 280 Chaffin
- 305 Stipe (prototype)
- 290 (proposed)
- OHV Cam (proposed)

Here are the new Model T cams that are available now and a few that may be available in the near future. The first three were developed in the *Cam Project*. Two other cams are available from the Chaffin Garage. Although the Chaffin cams have the same lift as the two Stipe cams, the valve timing is completely different. The only thing stock about the Chaffin 250 cam is its lift. There is a 305 cam that Bill Stipe has developed and run in his roadster pickup. He also has a performance .335 cam which runs directly in the block. I've also designed a cam with more than 290 lift, but similar duration to the 280 cam. We are planning to have one of these for dyno testing. I believe the current Stipe cams are too aggressive and totally inappropriate for an OHV engine, e.g. Fronty or Rajo, which will turn over 3000 RPM. I've designed a cam strictly for OHV engines. It is less aggressive, but has .320 lift due to a slightly longer duration

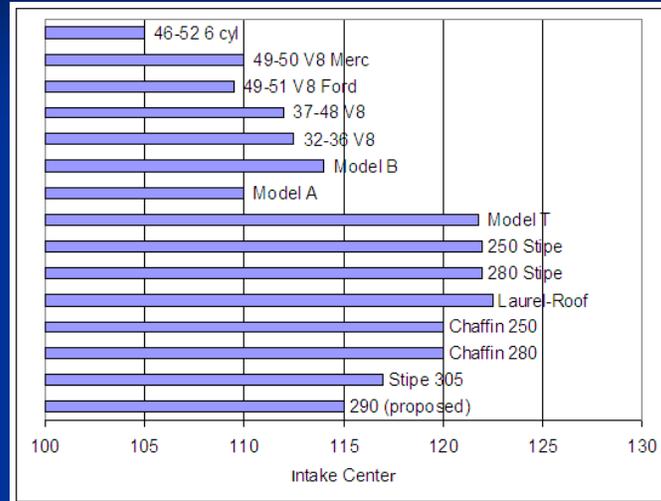
On the next few slides I'll compare these cams to each other and to other Ford cams.

Ford Cams Intake Duration



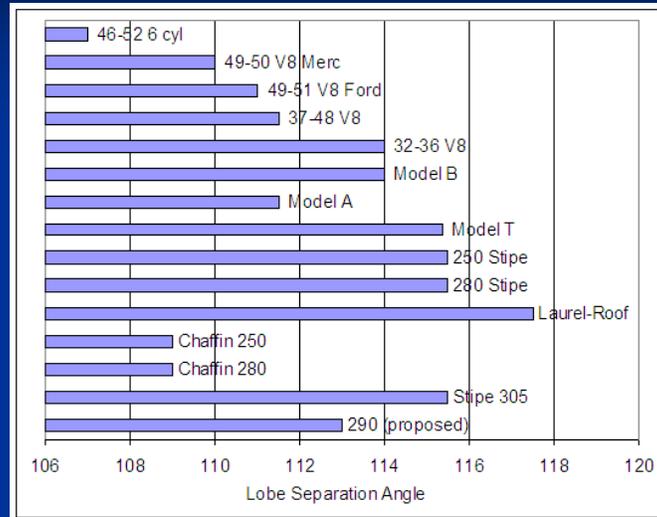
This shows the most important parameter – the intake duration measured at 0.035 net lift. Normally, duration should increase with engine speed, so it is not surprising that the Model T has the smallest duration. However, you will notice that the majority of V8 cams (1937-51) had a duration similar to the Model A and the Model B cam had as much duration as any of the V8 cams. As mentioned, the 250 Stipe cam was designed to have stock duration and the 280 and Laurel-Roof have slightly more. The duration of the Chaffin cams is similar to the Laurel-Roof. The proposed 290 is similar to the current 280.

Ford Cams Intake Center



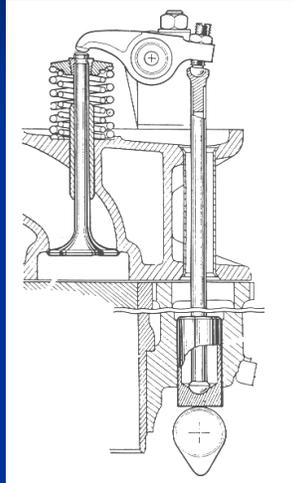
The next most important parameter is the intake center. Here we notice that the intake center for the Model T is greater than the other Ford flathead cams. Some people fervently claim that Model T cams should be advanced 7.5 degrees or half a tooth. This would put the intake center close to that of the Model B at about 115 degrees. During some recent and preliminary dyno work with Mike Bender and Bill Howell, we found that the 280 Stipe cam did benefit if it is advanced 4 degrees, but 8 degrees was worse than no advance. You have to remember the picture of the two lobes. When the cam is advanced, all the events will occur sooner. I believe that 8 degrees is too much for this cam, because it causes the exhaust valve to open too soon.

Ford Cams Lobe Separation



Remember the picture of the two lobes. Once the intake center is established, the lobe separation determines the center of the exhaust lobe. The lobe separation angle is measured in cam degrees, so if the intake center is fixed, increasing the lobe separation by one degree causes the exhaust valve to open and close two degrees earlier. Normally, lobe separation should be somewhat less for a higher revving engine. Nevertheless, the Model T cam has a fairly wide lobe separation. With this wide separation, advancing the cam too much will cause the exhaust valve to open too soon and will not get all the power out of the charge. The new 290 cam will have a smaller lobe separation, so it should work well with the intake center closer to that of a Model A or B. The Chaffin cams have a very small lobe separation, but the intake center is close to the stock position causing the exhaust valve open/close very late, probably too late for the best performance.

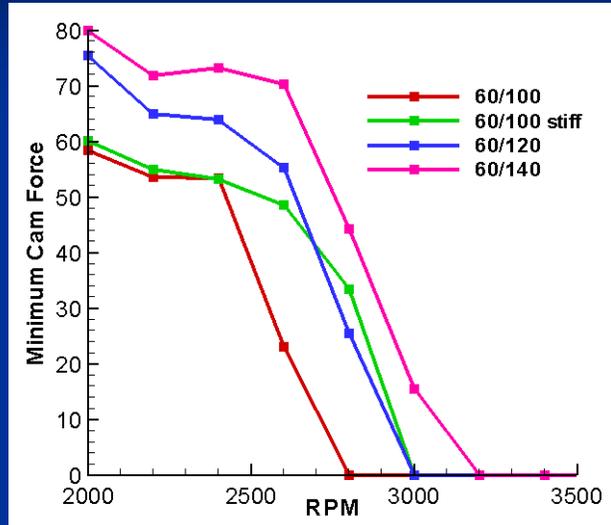
OHV – A Different Animal



- Greater mass or weight
– 1.4 lb vs 0.4 lb
- Not as stiff or less rigid
– approx. 30,000 lb/in
- Stock Rajo or Frontenac springs – 38 seat, 55 open
- Typical early '50s V8 springs – 60 seat, 140 open

To this point, I've only talked about flathead cams. A flathead valve train is very light and very stiff compared to an OHV. For my RAJO head, I pulled up on the end of a rocker with a turnbuckle attached to the ceiling. A fish scale registered the force and a dial indicator measured about 0.001 deflection for every 30 lb of force. It is not unusual to see over 500 lb of force on the pushrod when the engine is running at speed. Due to its flexibility and weight an OHV cam cannot be as aggressive as a flathead cam. I developed a computer model of the valve train for a RAJO or Frontenac head. This model takes into consideration the mass (weight) of all the components in the valve train, the stiffness of the spring(s) and the stiffness of the pushrod. I measured what I believe are stock valve springs for both a RAJO and Frontenac head. They were similar and gave only about 38 lb on the seat and 55 when open to 0.400 lift. This is much less than a typical OHV head from the early '50s.

Rajo or Frontenac 280 Stipe Cam



The model can predict the amount of force between the cam and lifter as the engine is turning at speed. If this force goes to zero, the cam and lifter will separate. Although it doesn't fall completely apart at this speed, this is the beginning of valve float. With the stock springs and a Stipe 280 cam, the engine could not achieve even 2,000 RPM. With stiffer springs (60 closed, 100 open) and engine speed of 2,800 RPM could be achieved. With dual springs (60 closed, 140 open) only 3,200 RPM could be reached. I have designed an OHV cam which is less aggressive and has a bit more duration and about .320 lift. This will give over 0.450 valve lift. It maintains contact with the lifter to beyond 4,000 RPM with springs that are 60 closed and 140 open. With this much spring force, a normal Model T cam of 0.75 inch diameter would flex considerably. In order to have a large diameter, the OHV cam will require notches and will run directly in the block.

Since I know there are many OHV engines that are running the Stipe cams, I will attempt to reconcile these calculations with real life experience. I suspect that most are using 3:1 gears which will give about 90 mph at 3,000 RPM. Does anyone actually run there OHV engines to 3,000 RPM? I know of at least one that runs beyond 3,000, but he doesn't have a Stipe cam. I also wonder what type of valve springs are being run. I will find out more when I run my RAJO with the 280 cam and stock (38 closed, 55 open) springs.