Design of Model T Ford Camshafts

By Larry C. Young, May 7, 2001

Background

Several years ago a handful of Model T enthusiasts started a study of Model T camshafts. I will call this study simply *The Cam Project*. The study was motivated by the frequent observation of low mileage, original Model T's outperforming those with engines rebuilt using all the latest technology. The grind of the modern camshafts was the suspected cause of the difference in performance.

The first major step in the study was to gather information on the specifications for over 30 camshafts. These included two stock T cams, one used prior to 1913 and the one used after, four antique high performance cams, various Model A and B cams, and about fifteen of the available reground Model T cams. Currently, no cams are available with a stock grind or any of the antique high performance grinds. Another noticeable difference between these cams is that the stock cams and antique performance cams had an intake valve duration of 225 degrees (seat-to-seat) or less, while the currently available regrinds had an intake valve duration greater than 238 degrees, and more typically about 250 degrees.

Once the camshaft specifications were obtained, an engine simulator was used to calculate the engine performance for each camshaft. The results clearly indicated that the stock and antique performance cams were superior to all of the currently available regrinds.[1] The modern cams tended to produce less low RPM power and torque.

Chassis dynamometer testing supported the simulation study. Tests were run on a car with a modern cam (264 degrees duration) and again after a NOS (new old stock) cam was installed. The stock cam produced 10 to 15% greater power up to about 1300 RPM and essentially no difference in power above 1400 RPM. With stock gear ratios, 1300 RPM is equivalent to about 32 mph, which is a typical cruising speed for a Model T. With only two gear ratios available, this difference in low-end power is significant, since it helps to avoid the dreaded shift into low gear when climbing hills.

It would appear that Model T enthusiasts have become victims of a very common mistake, i.e. overcaming of the engine.[2] The duration and lift of the available cams are too large for an engine, which needs to develop power in the range of 500 to 2000 RPM. In order of importance, the six major parameters in a cam design are:[2] (1) intake closing, (2) intake opening, (3) exhaust opening, (4) exhaust closing, (5) intake lift and (6) exhaust lift. Of utmost importance is the intake valve duration, which is determined by the first two parameters. In order to achieve good performance, the valve duration must be compatible with the RPM range of the engine. A low RPM engine like the Model T, should have a much smaller duration than a modern high speed engine. Unfortunately, most Model T enthusiasts appear to be fixated on cam lift, and pay little attention to the other more important factors in the cam design. In order to achieve high lift, many of the available Model T reground cams use a duration which is far too large. Given the relative importance of the various parameters, this approach is completely illogical. In the present work, we focus on the design of cams with a duration, which is appropriate for a Model T engine.

Although more testing could be done, those working on *The Cam Project* are convinced that the ideal intake duration for a Model T cam is in the neighborhood of 218 to 225 degrees. The ideal exhaust duration is in the range of 218 to 245 degrees. This report studies the design of camshaft lobes with durations in this range and which can be installed in a Model T engine. We start by documenting the design of the original stock Model T camshaft, since to our knowledge this information is not available to the general public. We then describe some of the numerous dimensional constraints imposed on the camshaft designs, and the design method used. Finally, the designs for three camshafts are presented:

1. *Improved Stock Cam* – a design with stock duration and lift, but with a more gentle ramp and designed for a valve lash of 0.010 in.
2. *Laurel-Roof Cam* – a design with the basic specifications of the Laurel-Roof antique performance cam
3. *280 Lift Cam* – a design which is intermediate between the Improved Stock and Laurel-Roof cams

Original Model T Ford Camshaft Design

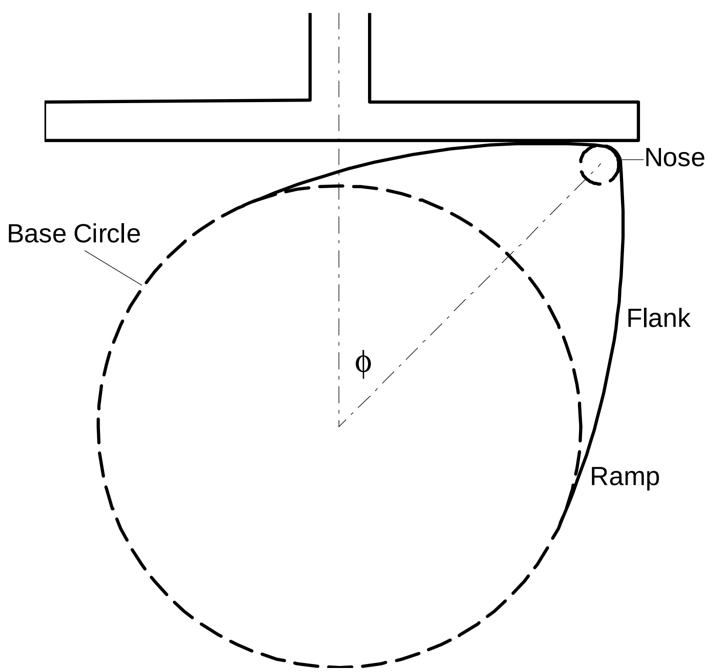

Figure 1. Post-1912 Model T camshaft lobe and lifter, 45 degrees before maximum lift

The specifications for the original post-1912 Model T Ford camshaft are listed in Table 1. This cam is of the three arc or harmonic design. One arc forms the base circle, a small radius arc forms the nose and a large radius arc forms the flank. Designs of this type were common during the Model T era. Unlike later designs, there is no special ramp area modification for this cam. The shapes of the intake and exhaust lobes are identical and symmetric.

Table 1
Original Model T Camshaft Specifications[3]

Intake:	Opening	- 12.67 deg. ATC
	Closing	- 50.82 deg. ABC
	Centerline	- 121.75 deg. ATC
	Duration	- 218.15 deg. (crankshaft)
Exhaust:	Opening	- 37.87 deg. BBC
	Closing	- 0 deg. TC
	Centerline	- 108.94 deg. BTC
	Duration	- 217.87 deg. (crankshaft)
Angle Between Lobes		- 115.35 deg. (camshaft)
Gross Lift		- 0.2502 in
Base Circle Radius		- 0.4060 in
Nose Radius		- 0.0313 in
Flank Radius		- 1.2601 in
Lifter Radius		- 0.5 in
Bearing Outside Radius		- 0.6875 in

Fig.1 is a drawing of a single lobe constructed from the data in Table 1. Equations are available to calculate the lift curves from this information.[4] The lift is:

Opening Flank: $L = 0.8541 [1 – \cos(68.57 + \phi)]$ for $-68.6 < \phi < -40.3$

Nose: $L = 0.2502 – 0.6250 (1 – \cos \phi)$ for $-40.3 < \phi < 40.3$

Closing Flank: $L = 0.8541 [1 – \cos(68.57 - \phi)]$ for $40.3 < \phi < 68.6$

where ϕ is the angle of the camshaft relative to the lobe centerline. As the cam rotates counterclockwise (as viewed from the front of the engine) with no lifter clearance or valve lash, it rides on the base circle until an angle of -68.6 degrees, i.e. 68.6 degrees before the lobe centerline. From this point it rides on the opening flank until -40.3 degrees is reached. It rides on the nose from -40.3 to +40.3 degrees, then on the closing flank and finally on the base circle at +68.6 degrees. Fig. 1 depicts the cam at -45 degrees, i.e. immediately before it leaves the opening flank and begins riding on the nose.

Fig. 2 compares the lift curves calculated from the equations to those measured on a NOS (new old stock) cam. The measurements, taken with a simple degree wheel and dial indicator, agree well with the calculated curves. The measured centerlines for the lobes were 121.1 deg ATC for the intake lobe and 110.4 deg BTC for the exhaust lobe, which agree well with the specifications listed in Table 1.

Fig 3 is an expanded view of half of a lift curve. Since the intake and exhaust have identical symmetrical lobes, the curve in Fig. 3 is representative of the complete curves in Fig. 2. All of the measured data (both opening and closing) from Fig. 2 are plotted on Fig. 3 to illustrate this point.

Model T camshafts are installed with a valve lash or clearance of 0.010 to 0.032 inches. The duration of valve opening for any given lash can easily be determined from Fig. 3. For example, a lift of 0.020 occurs at ±56.1 degrees, so a valve lash of 0.020 would produce a seat-to-seat duration of 2x56.1 camshaft degrees or 224.4 crankshaft degrees. Table 2 shows the duration for various values of lift. By comparing the values in Table 2, it is apparent that valve lash has a significant influence on the seat-to-seat duration. To obtain a duration of 218 degrees as specified in Table 1, the valve lash should be 0.0256 in. for a perfectly ground stock cam. This lash is quite large, even by standards of the Model T era. As a result, the actual valve lift is only 0.225 in.

Table 2
Stock Cam Duration and Velocity vs. Lift

	Duration		
Lift	Cam Deg.	Crank Deg.	Velocity
0.010	119.6	239.2	0.0023
0.015	115.6	231.2	0.0028
0.020	112.2	224.6	0.0032
0.025	109.3	218.7	0.0035
0.0256	109.0	218.0	0.0036
0.030	106.7	213.4	0.0038
0.035	104.2	208.4	0.0042
0.040	101.9	203.8	0.0045
0.050	97.7	195.5	0.0050
0.065	92.1	184.2	0.0057

The lift curve controls the flow of gases in to and out of the combustion chamber. Other important aspects of the design are the valve train velocity and acceleration rates produced by the cam. The velocity is the rate of change of the lift with respect to a change in the camshaft angle and is normally expressed in inches per degree of camshaft

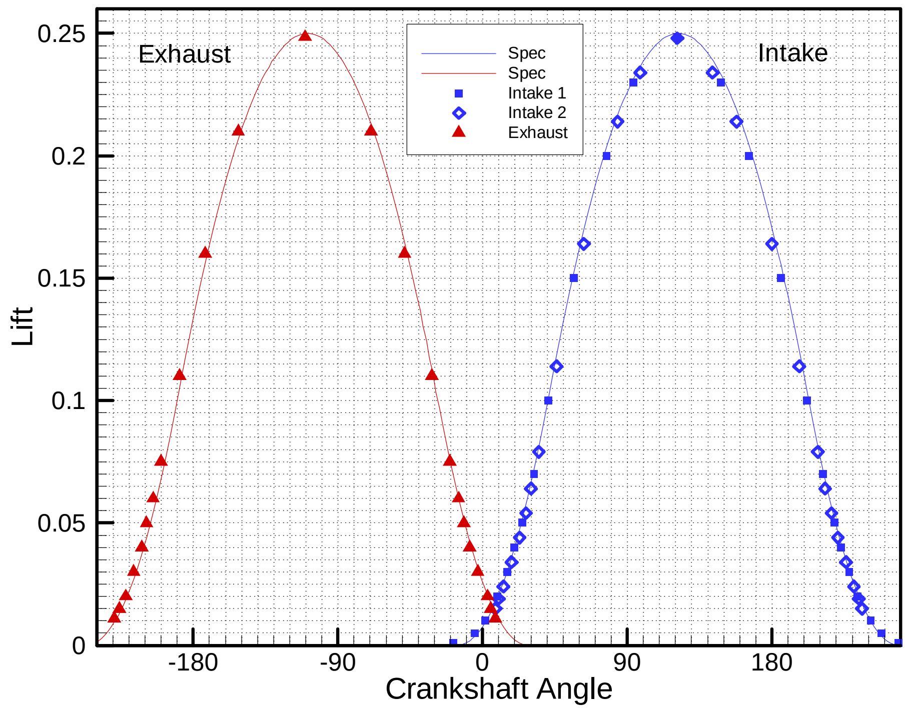

Figure 2. Lift curves for stock cam, measured (symbols) and calculated (lines)

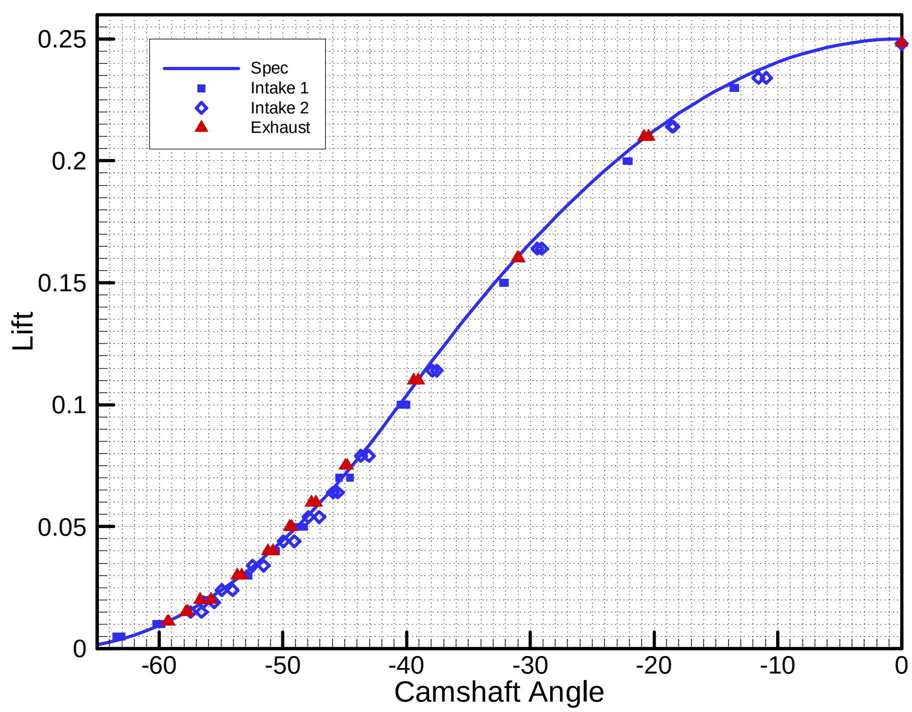

Figure 3. Opening lift curve with measured data showing symmertry

rotation. These values must be multiplied by half the engine speed to obtain an actual velocity, i.e. rate of change of distance with time. A typical Model T engine rarely exceeds 2000 RPM, which would correspond to 50 mph with a stock drive train. However, with an accessory overhead valve conversion, e.g. Frontenac, Roof or Rajo, engine speeds in excess of 4000 RPM are possible.

For the stock Model T camshaft, the opening velocity in units of inches per camshaft degree is:

Flank: $V = (0.01745)(0.8540) \sin(68.57 + \phi)$

Nose: $V = -(0.01745)(0.6250) \sin \phi$

The factor 0.01745 is $\pi/180$. Equations for the acceleration rates are also available.[4] Fig. 4 shows the velocity and acceleration rate together with the lift curve.

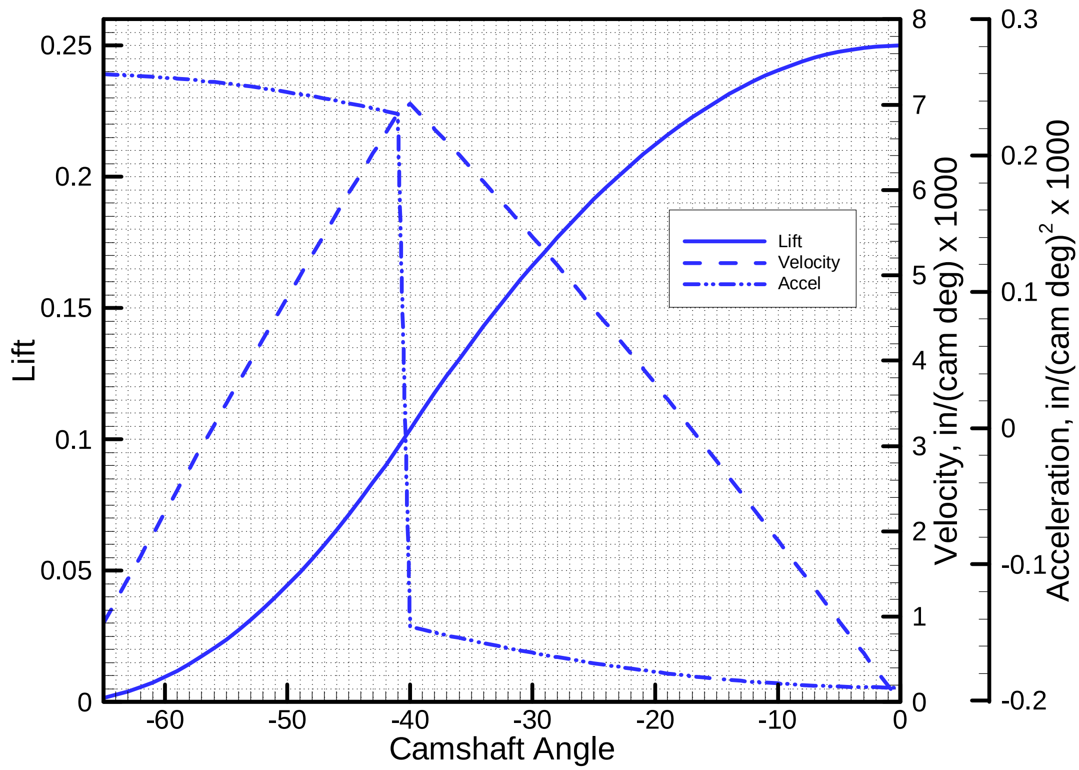

Figure 4. Calculated lift, velocity and acceleration for stock cam

The ramp velocity is important. On opening, the ramp velocity is the velocity at the point of first contact between the cam and lifter, so it determines the impact of the first contact. On closing, it governs the impact as the valve comes into contact with the seat. A large ramp velocity can contribute to noisy operation and high wear. The velocities for various lifts are listed in Table 2. Later methods of cam design incorporated special modifications of the ramp area. Ramp velocities of 0.0005 to 0.0010 were recommended for trucks and low speed engines and 0.0015 to 0.0050 for large diesel and aircraft engines.[4] By comparing these numbers to those in Table 2, the Model T ramp velocity appears to be relatively high.

The rate of acceleration times the valve train mass determines the force caused by valve train motion. During valve opening this force acts together with the force of the valve spring to determine the total force acting on the camshaft. During valve closing this force must be overcome by the valve spring to insure that the lifter remains in contact with the cam lobe. High acceleration rates require a stiffer valve spring and contribute to greater wear. Due to its simplicity, the mass of the model T valve train is low. However, for an accessory overhead valve head, the mass would be much larger due to the addition of push rods and rocker arms. No calculations of valve spring and other valve train requirements have been performed in this study. However, detailed measurement on a reground cam showed maximum acceleration rates of about 0.0006 to 0.0007 in/(cam deg)^2. This reground cam works fine even though the maximum acceleration rate is more than twice that of a stock T cam. Values in this range are used as target maximum acceleration rates in this study.

Another important aspect of the cam design is the location of the point where the lifter contacts the cam lobe. The radial distance of this point from the lifter centerline determines the required lifter diameter. This distance can be calculated by dividing the velocity by 0.01745. From Fig. 4, the maximum velocity is 0.00705 in/deg at -40.3 degrees giving a maximum radius of contact on the lifter of 0.404 inch, which is well within the 0.5 inch radius of a stock Model T lifter. For reference purposes, Fig. 1 is a scaled drawing of the cam and lifter at -45 degrees. At this angle, Fig. 4 shows the velocity is 0.00595, so the contact point in Fig. 1 is at 0.341 inches.

Cam Design

We wish to design three cams for the Model T:

1. *Improved Stock Cam* - a cam with stock duration and lift, but with a lower ramp velocity and a smaller valve lash.
2. *Laurel-Roof Cam* - a cam with the duration and lift of the Laurel – Roof antique high performance cam, i.e. 225 degrees intake duration, 245 degrees exhaust duration and 0.313 lift. This cam will require notches to be cut in the block and larger lifters to be installed.
3. *280 Lift Cam* - a new cam with lift and duration that is intermediate between the stock and Laurel-Roof cams. This cam will run on stock lifters and require no notches in the block, so that it can be installed without disassembling the engine.

In order to produce the higher performance 280 cam and Laurel-Roof cam, the lift must be increased beyond the stock lift, while not exceeding an intake duration of 225 degrees. The Model T has several physical constraints, which makes these designs difficult. First, in order to increase the lift without increasing the duration, the base circle needs to be larger. To gain an understanding of the interrelationship between lift, duration and base circle size, consider a cam with completely flat sides. This shape has the maximum lift for a given base circle size and duration, so it is useful to consider it as a limiting case. The lift for a flat sided cam with base circle radius R_b, nose radius R_n, valve lash δ, and duration of $4\phi_o$ is:

$$L_{max} = [(R_b - R_n)(1 - \cos\phi_o) + \delta]/\cos\phi_o$$

This equation gives an absolute physical limit on the lift. In reality a cam with flat flanks would be too radical in terms of velocity and acceleration. A cam with a suitable shape will need to have a lift, which is at least 0.030 to 0.040 less than this limiting case. For this reason, we have subtracted 0.030 from the equation and plotted the results in Fig. 5 for a nose radius of $\frac{1}{32}$, a valve lash of 0.010 and four values of duration. For example, for a stock duration of 218 and a stock base circle of 0.406, the maximum lift obtainable is about .260. If the duration is increased to 225, the lift could not exceed 0.288. Keep in mind that these are approximate physical limits, a cam with suitable shape may need to have somewhat less lift.

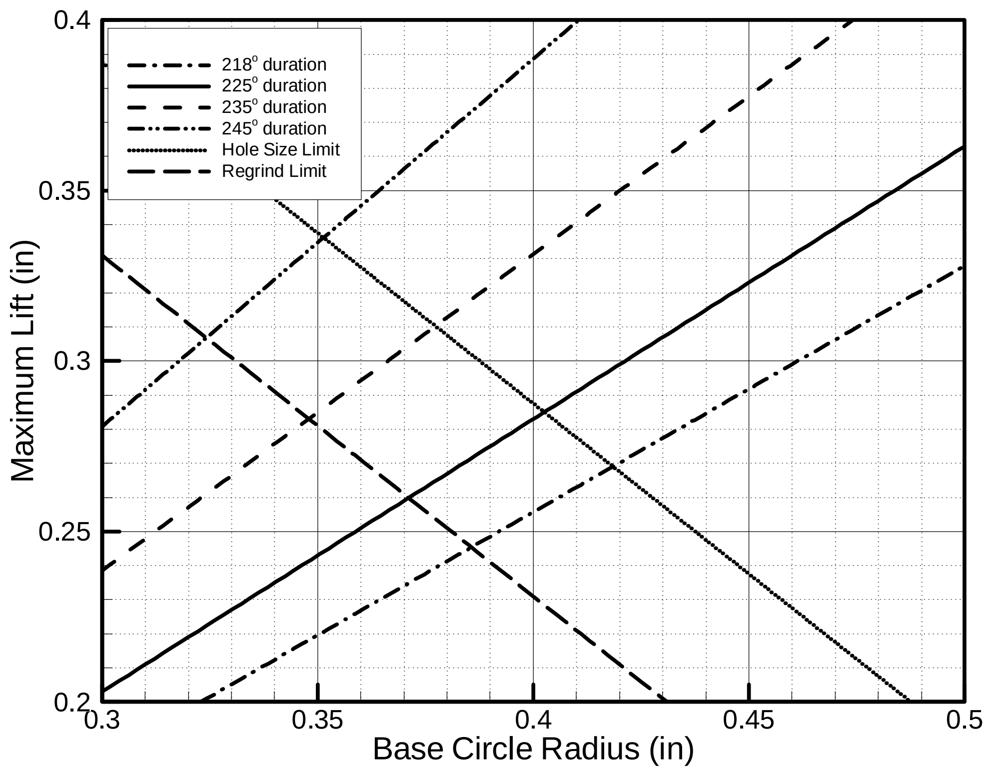

Figure 5. Physical limits on camshaft lift

In order to produce a cam by regrinding a worn cam, the size of the original cam imposes additional constraints on the design, because there is only so much metal in the worn cam. A typical worn Model T cam may have a lift of only 0.225. The maximum lift obtainable on a regrind is then:

$R_b + L_{max} < 0.406 + 0.225 = 0.631$

This relationship is also plotted on Fig. 5. If we combine this constraint together with the previous one, we find that this severely limits the lift, which can be obtained unless the duration is increased considerably beyond stock specifications. For example, with stock duration, the maximum lift would be about 0.245. If a lift of 0.300 is required, the duration would have to be about 243 degrees. When these constraints are taken into consideration, it is not surprising that the currently available reground Model T cams, especially those with high lift, have durations in excess of 235 degrees. Based on the results from *The Cam Project*, it would be better to produce a cam with less lift than the available regrinds, so that the intake duration could be maintained at a value closer to stock.

From the discussion above, it is apparent that a regrind cannot produce the higher performance cams, which are desired. If we consider a new cam, there are still several constraints imposed on the design. First, the improved stock and 280 lift cams must slide through holes in the block which have a radius of 0.6875 in. The distance from the center of the cam to the tip of the exhaust lobes must be less than this value unless the engine is disassembled and notches are cut in the block. This constraint applies to the exhaust lobes of the first and third cylinders, because the camshaft must be centered before these lobes clear the holes for the front and middle bearings. The intake lobes can be considerably larger than this value, since the cam does not have to be centered as the intake lobes pass through the holes. In terms of the cam design parameters, the base circle radius, R_b, plus the maximum lift, L_{max}, must be less than the radius of the holes in the block:

$R_b + L_{max} < 0.6875$

This limit is like the one imposed by a regrind, but it is substantially less restrictive. This limit is also plotted on Fig. 5. Using Fig. 5, we find that a new cam with stock duration could have a lift of about 0.265, while one with a duration of 225 could have a lift of about 0.285. The higher lift of the Laurel-Roof cam, will require that the holes in the block be notched to allow the cam to be installed.

The requirement that the touring cam run on stock lifters imposes still another constraint on the design of the cam. As described previously, the radius of the contact point on the lifter is related to the velocity. Applying a small safety factor, a design lifter radius of 0.485, means that the velocity must be restricted to:

$V_{max} < 0.485(0.01745) = 0.00847$ in/deg

This value is only 20 percent larger than the maximum velocity of a stock T cam. This constraint indirectly restricts the lift and duration of the cam, because the average velocity is given by:

$V_{avg} = L_{max} / \phi_o$

where $4\phi_o$ is the duration in crankshaft degrees. The maximum velocity will tend to increase when the average velocity increases.

Due to the restriction imposed by the lifter radius, we have selected a design method called the *Triple Curve Design*,[4] because this method takes into account the lifter restriction and it is relatively easy to apply. We have modified the method to use a constant acceleration ramp instead of a constant velocity ramp. This method is less sophisticated than modern design methods, but it is more advanced than the three-arc design method used on the original Model T cam. Like the three-arc method, the triple curve design produces continuous velocity profiles, but step changes in the acceleration rates. These designs could be refined using a method which produces smooth acceleration rates.

All three cams are designed for a valve lash of 0.010 inches. The designs use a smaller acceleration for the ramp area and a larger one for the flank. The smaller ramp acceleration is used for the first 0.012 inches of lift. The ramp velocities are all less than the velocity for a stock cam at 0.020 lift. Due to their higher lift and smaller ramp velocity, all of the cams have maximum acceleration rates, which are larger than the maximum acceleration for a stock cam.

Design of Improved Stock Cam

As discussed in the preceding sections, the stock Model T cam has relatively high ramp velocity and requires a valve lash of 0.025 to produce the specified duration of 218 degrees. Consequently, the actual lift is only 0.225. The first cam is designed with stock lift and stock duration, but with a valve lash 0.010 and ramp velocity less than that of a stock T cam. Some pertinent parameters for this design are listed in Table 3. The lift, velocity and acceleration curves are compared to those of a stock cam in Fig. 6, while the lobe shape is presented in Fig. 7. To compensate for the different valve lash between the two cams, 0.015 is subtracted from the lift on the stock cam in Fig. 6. This adjustment is not made in Table 3, so in order to compare the duration at a given actual lift, 0.015 must be subtracted from the lift values in Table 2.

Compare the values for stock and improved stock cams in Fig. 6 and Tables 2 and 3. The ramp velocity for improved stock cam is equivalent to that for a stock cam running with a valve lash of 0.011 and much less than a stock cam running with a standard lash of 0.025. Due to the smaller ramp velocity, the lift initially increases more gradually. To compensate for this difference, the seat-to-seat duration was made slightly larger than stock to minimize the differences between the lift curves for lifts less than 0.050. Note that the improved cam has duration at lifts between 0.013 and 0.042 that is slightly less

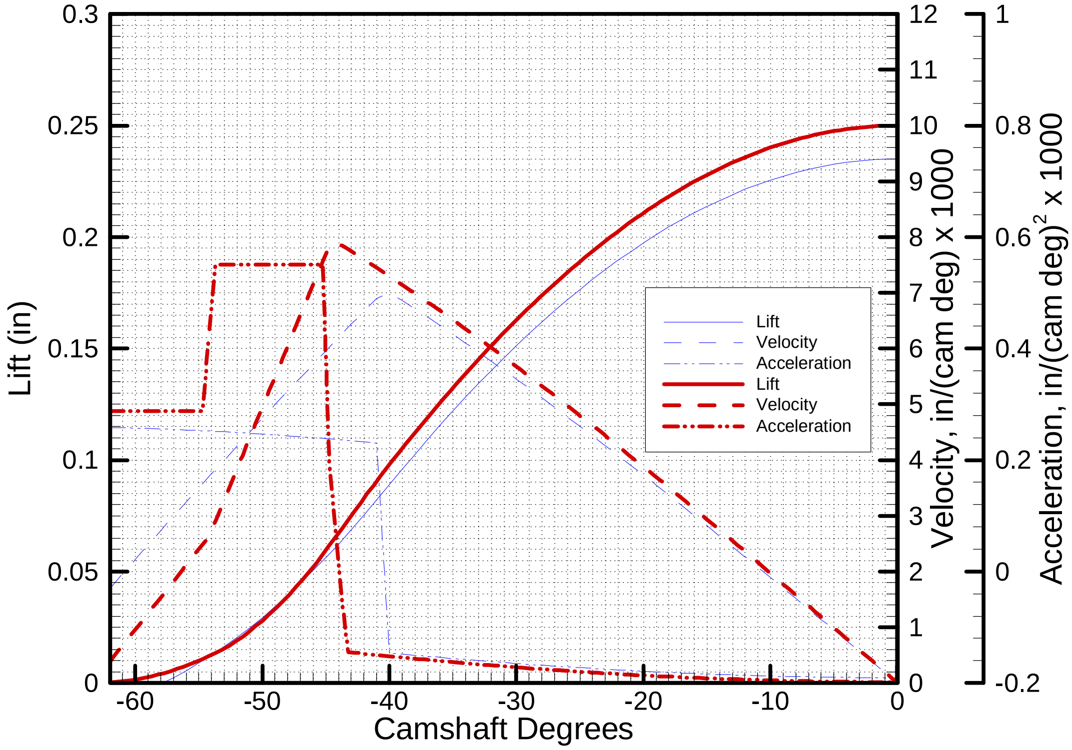

Figure 6. Comparison of improved stock (thick lines) and stock cams

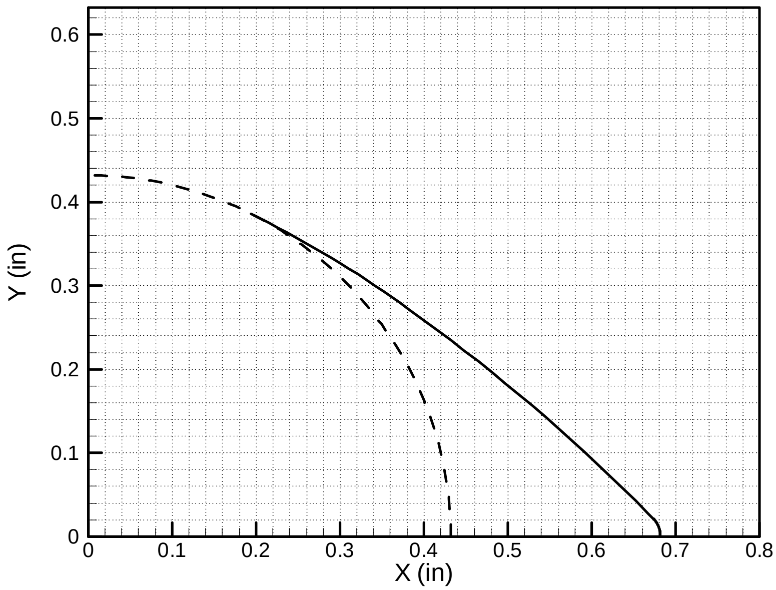

Figure 7. Shape of improved stock camshaft lobe

than stock. Due to the smaller ramp velocity and higher lift, the improved stock cam must have a larger acceleration rate than the stock cam. However, the maximum acceleration rate of 0.00055 should not pose any problem. The value of $R_b + L_{max}$ = 0.682, so this cam should slide easily through the holes in the block. Since the maximum velocity is 0.0079 (lifter contact radius of 0.450 inches), the cam will run on stock lifters. With its low ramp velocity, near stock duration and actual lift slightly greater than stock, this improved stock cam should be very well behaved, have excellent low-end power and torque, and peak power that is slightly higher than stock.

Table 3
Improved Stock Camshaft Specifications

Intake:	Opening	-	12.00 deg. ATC
	Closing	-	52.00 deg. ABC
	Centerline	-	122.00 deg. ATC
Exhaust:	Opening	-	39.00 deg. BBC
	Closing	-	1.00 deg. ATC
	Centerline	-	109.00 deg. BTC
Angle Between Lobes		-	115.50 deg. (camshaft)
Gross Lift		-	0.2500 in
Base Circle Radius		-	0.4320 in
Nose Radius		-	0.0313 in

Lift	Duration Cam Deg.	Duration Crank Deg.	Velocity
0.010	110.0	220.0	0.0024
0.015	106.4	212.7	0.0032
0.020	103.6	207.1	0.0040
0.025	101.2	202.4	0.0046
0.030	99.2	198.4	0.0052
0.035	97.4	194.8	0.0057
0.040	95.6	191.2	0.0061
0.050	92.6	185.2	0.0070

Design of Laurel-Roof Cam

The performance of the Laurel-Roof antique performance cam is legendary. Although examples of this cam probably exist, the only information available to the author is the published lift and opening and closing angles.[5] A design which replicates these parameters is presented in Table 4 and Figs. 8 through 11. In order to achieve the higher lift while maintaining a short duration, the ramp velocity and maximum acceleration rates must be larger than for the improved stock cam. The designed ramp velocity is less than

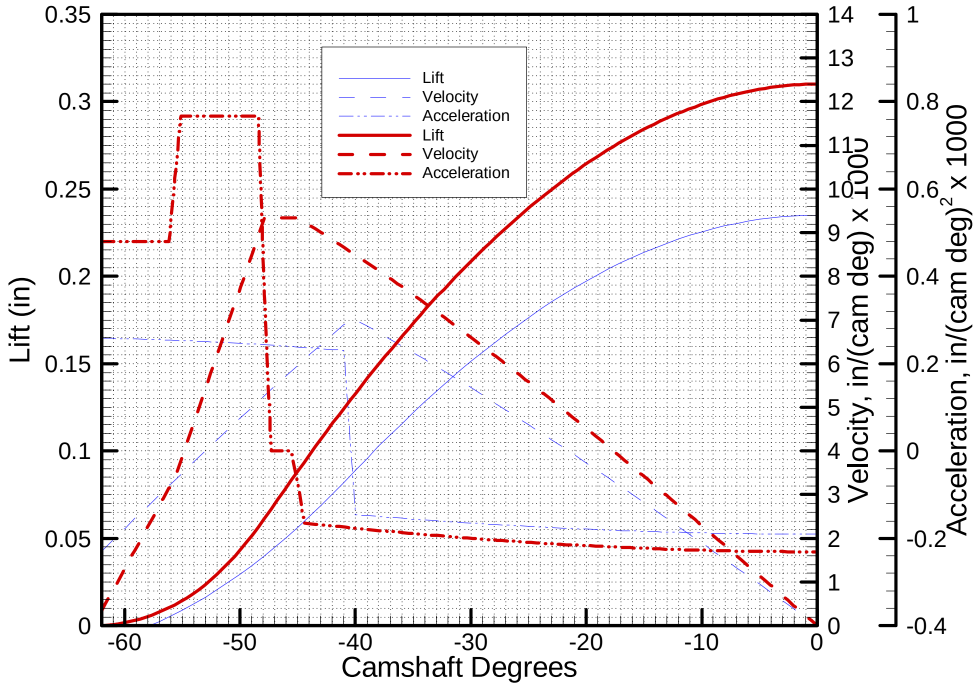

Figure 8. Comparison of Laurel-Roof intake (thick lines) and stock camshafts

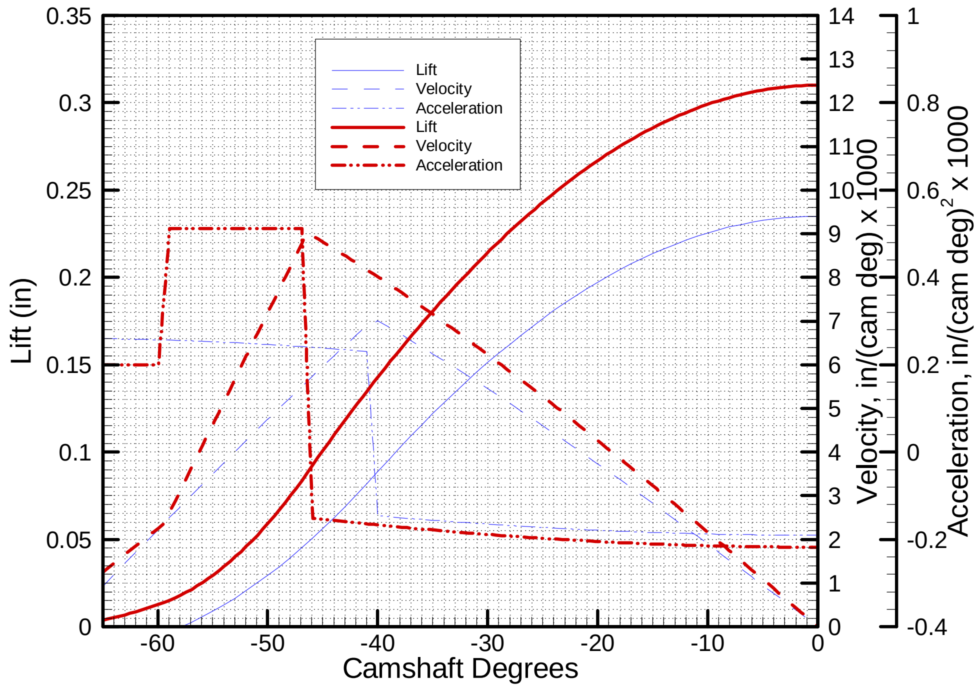

Figure 9. Comparison of Laurel-Roof exhaust (thick lines) and stock camshaft

that for a stock cam running with a valve lash of 0.020. Although the acceleration rate is relatively large, it is difficult to reduce this value for a cam with so much lift and so little duration. There is a tradeoff between the ramp velocity and acceleration rate. Increasing the ramp velocity by 10% would reduce the maximum acceleration by about 15%. Increasing the size of the base circle would also reduce the maximum acceleration, but since this cam is already larger than a Model A cam, making it even larger might not be advisable. For the exhaust lobe, the dimension $R_b + L_{max} = 0.777$ in. is 0.090 inches larger than the holes in the block, so notches of this depth will be required. In this design, the maximum velocity was restricted to 0.0093 in/deg (0.535 lifter radius), so that $1\frac{1}{8}$ inch diameter lifters may be used.

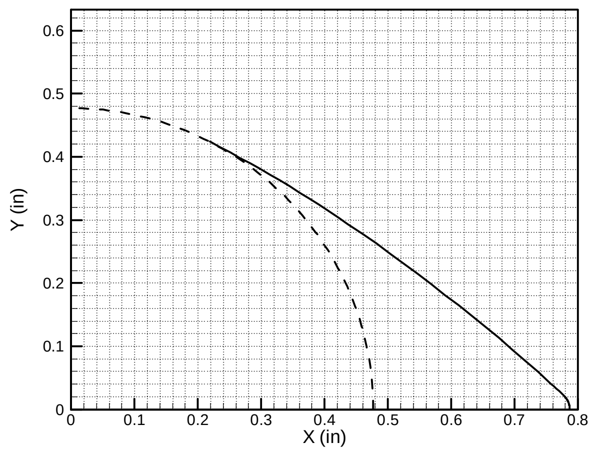

Figure 10. Shape of Laurel-Roof intake lobe

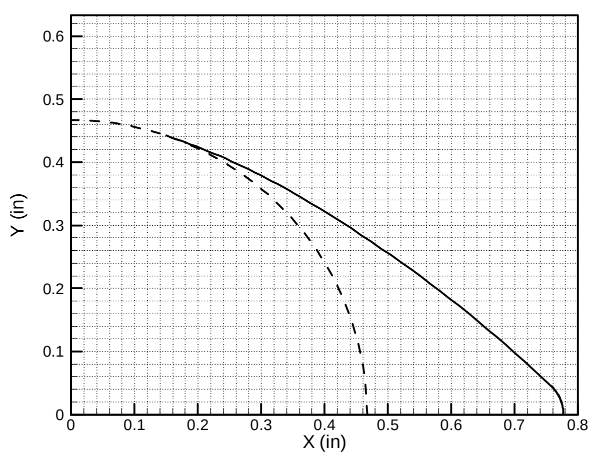

Figure 11. Shape of Laurel-Roof exhaust lobe

Table 4
Laurel-Roof Camshaft Specifications

Intake:	Opening	-	10.0 deg. ATC
	Closing	-	55.0 deg. ABC
	Centerline	-	122.5 deg. ATC
Exhaust:	Opening	-	55.0 deg. BBC
	Closing	-	10.0 deg. ATC
	Centerline	-	112.5 deg. BTC
Angle Between Lobes		-	117.5 deg. (camshaft)
Gross Lift		-	0.310 in
Base Circle Radius		-	0.477 in (intake)
Base Circle Radius		-	0.467 in (exhaust)
Nose Radius		-	0.030 in (intake)
Nose Radius		-	0.063 in (exhaust)
Lifter Radius		-	0.563 in

Intake

	Duration		
Lift	Cam Deg.	Crank Deg.	Velocity
0.010	112.5	225.0	0.0031
0.015	109.7	219.3	0.0040
0.020	107.4	214.8	0.0049
0.030	103.8	207.6	0.0063
0.040	100.9	201.8	0.0074
0.050	98.3	196.7	0.0084

Exhaust

	Duration		
Lift	Cam Deg.	Crank Deg.	Velocity
0.010	122.5	245.0	0.0020
0.015	118.0	236.0	0.0026
0.020	114.7	229.3	0.0034
0.030	109.8	219.6	0.0047
0.040	105.9	211.8	0.0057
0.050	102.6	205.2	0.0065

Design of 280 Lift Cam

The design of the 280 lift cam is presented in Table 5 and Figs. 12 through 15. In all respects, this camshaft is intermediate between the improved stock and Laurel-Roof camshafts. The intake and exhaust centerline angles and the angle between the lobes is the same as a stock cam. The duration of the intake and exhaust valve openings is intermediate between the other two cams. The intake valve opens at the same angle as the Laurel-Roof cam and two degrees before the improved stock cam. The intake closes one degree before the Laurel-Roof cam and two degrees after the improved stock cam. The exhaust valve opens six degrees before the improved stock cam and ten degrees after the Laurel-Roof cam. The exhaust valve closes six degrees after the improved stock cam and three degrees before the Laurel-Roof cam. The ramp velocity is relatively mild, i.e. similar to that for a stock cam at a valve lash of 0.013. The maximum velocity in this design is restricted to 0.0083 in/deg (0.475 lifter radius) to insure that stock Model T lifters can be used. The value of $R_b + L_{max}$ = 0.682 for the exhaust lobe and 0.737 for the intake lobe. The exhaust lobes will pass freely through the holes in the block. The intake lobes are 0.050 inches larger than the holes in the block, but will install without requiring notches. This cam should produce excellent performance for stock and slightly warmed engines.

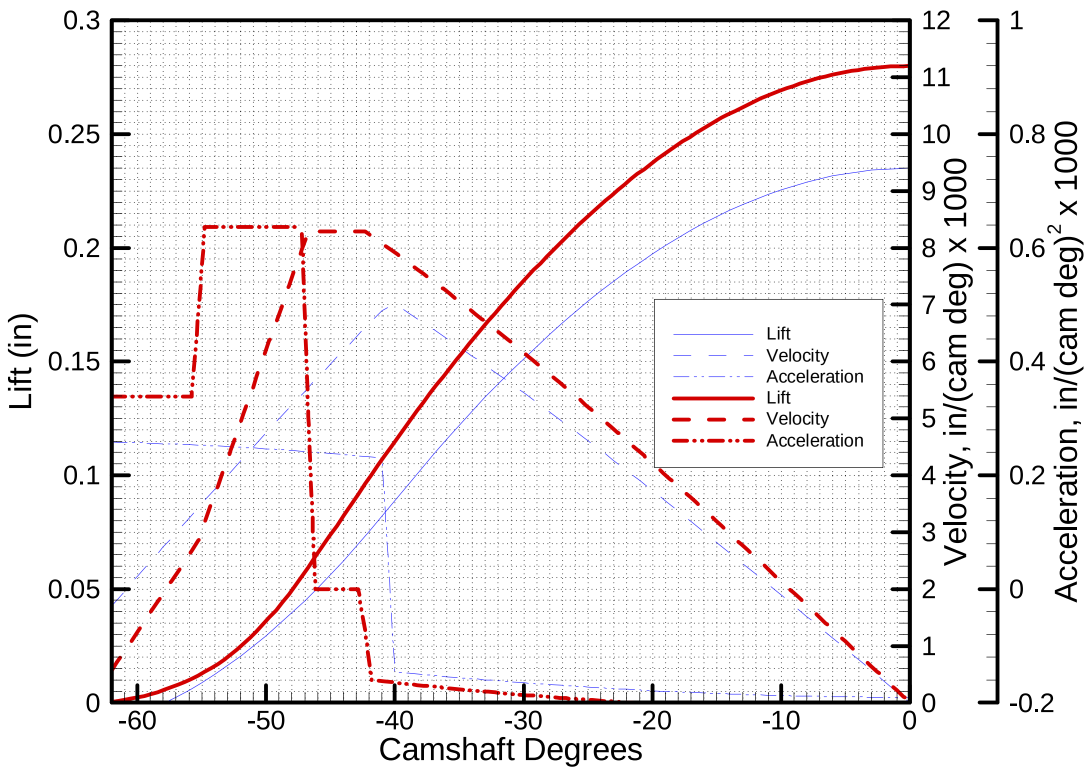

Figure 12. Comparison of 280 cam intake (thick lines) with stock cam

Table 5
280 Lift Camshaft Specifications

Intake:	Opening	-	10.0 deg. ATC
	Closing	-	54.0 deg. ABC
	Centerline	-	122.0 deg. ATC
Exhaust:	Opening	-	45.0 deg. BBC
	Closing	-	7.0 deg. ATC
	Centerline	-	109.0 deg. BTC

Angle Between Lobes	-	115.5 deg. (camshaft)
Gross Lift	-	0.280 in
Base Circle Radius	-	0.457 in (intake)
Base Circle Radius	-	0.402 in (exhaust)
Nose Radius	-	0.031 in (intake)
Nose Radius	-	0.031 in (exhaust)

	Intake Duration		
Lift	Cam Deg.	Crank Deg.	Velocity
0.010	112.0	224.0	0.0026
0.015	108.6	217.2	0.0035
0.020	106.0	212.0	0.0043
0.030	102.0	204.0	0.0056
0.040	98.7	197.4	0.0066
0.050	95.9	191.8	0.0075

	Exhaust Duration		
Lift	Cam Deg.	Crank Deg.	Velocity
0.010	116.0	232.0	0.0026
0.015	112.6	225.3	0.0034
0.020	110.0	220.0	0.0042
0.030	105.9	211.8	0.0055
0.040	102.6	205.2	0.0065
0.050	99.7	199.4	0.0074

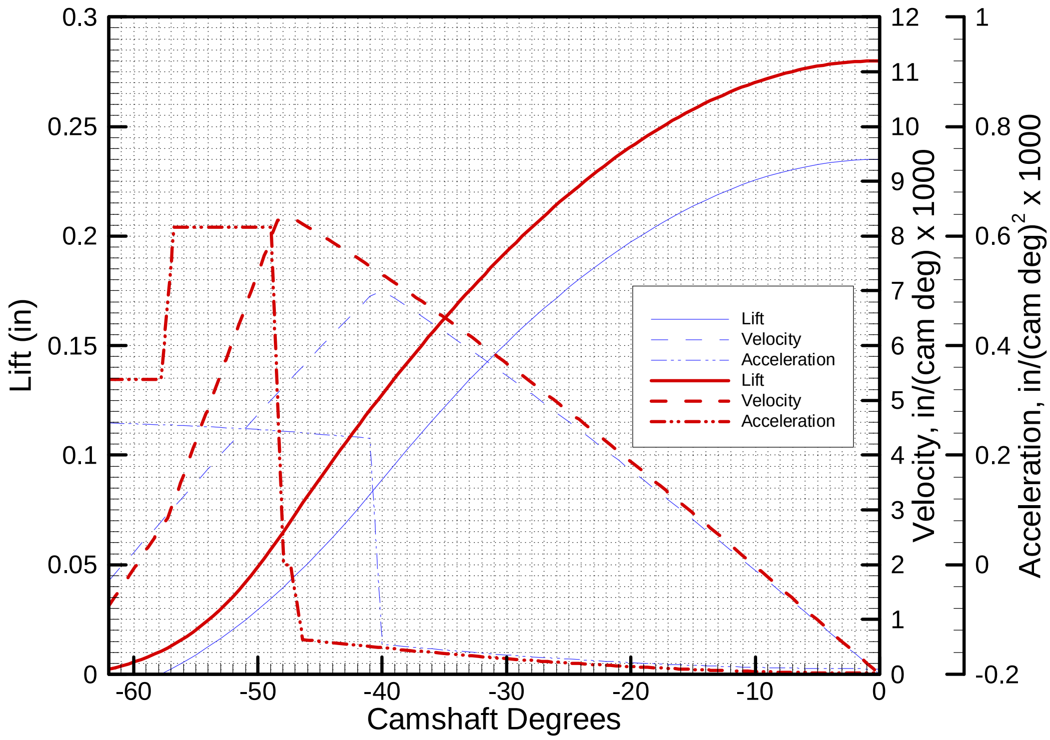

Figure 13. Comparison of 280 cam exhaust (thick lines) with stock cam

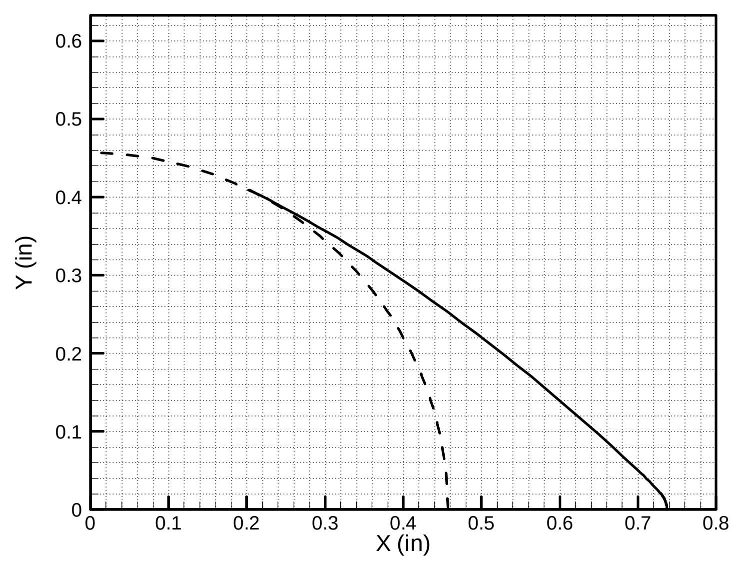

Figure 14. Shape of 280 cam intake lobe

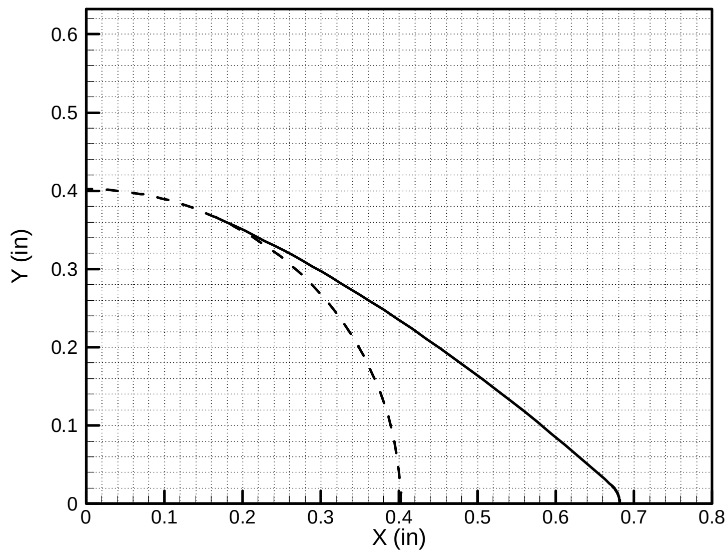

Figure 15. Shape of 280 cam exhaust lobe

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