Bay Area Engine Modelers Club
www.baemclub.com

The Crank Calls

July 2023

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NEXT MEETING
Saturday, July 15, 2023, at the
Golden Gate Live Steamers clubhouse site in
Tilden Park, Orinda, CA
Gate opens at 9:00 am
Meeting starts at 10:00 am

Upcoming Events

- Jul 15: BAEM meeting at GGLS
- Aug 19: BAEM meeting at GGLS
- Aug 25-27: Good Guys West Coast Nationals
- Sept 16: BAEM meeting at GGLS

See below for more details regarding events. Watch Crank Calls, BAEM emails and BAEM web page for updates. BAEM meetings are usually 3rd Saturday of the month except December.

MEETING NOTES

Bay Area Engine Modelers met at Golden Gate Live Steamers on June 10, 2023. The meeting was held a week earlier than usual, to permit participation in the Golden Gate Live Steamers weekend.

June 10th was for club members and June 11 was open to the public. Several BAEM members brought engines to show.

President Paul Denham opened the meeting by welcoming attendees and guests. A number of GGLS members attended our meeting.

NEW MEMBERS/VISITORS

BAEM members are reminded that visitors are welcome at our club meetings, and we're always looking for new members.

TREASURER'S REPORT

President Paul Denham reported club finances are "OK" and described some of the club expenses covered by dues.

2023 dues of $25 dollars are due, and checks can be mailed to Deirdre Denham at 1937 Merchant St, Crockett, CA 94525. Make checks payable to "BAEM".

CLUB BADGES

If you are a member in need of a badge, contact Mike Rehmus (mrehmus@byvideo.com) who has offered to produce them.

UPCOMING SHOWS AND EVENTS

-EDGE&TA

Ray Fontaine (rayfontaine2@att.net (925) 784-5411) has coordinated our club's participation in EDGE&TA events. He is recovering from hip surgery, and his participation is limited. The Branch 13 website is here: https://branch13edgeta.com/. Check it out for their full calendar. Upcoming show of interest:

--July 27-30, 2023 **Amador County Fairgrounds**
Robert Facino (916) 417-8732
rtsco@netzero.com

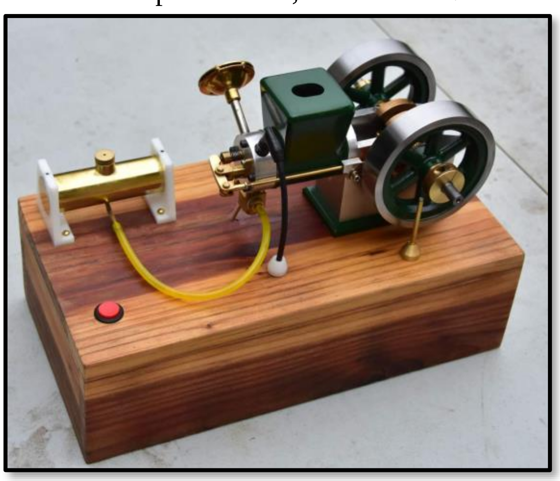
BAEM members interested in participating in this event should contact the person listed, and let Ray know as well.

-Goodguys Show

The Goodguys West Coast Nationals custom car show is scheduled for Friday – Saturday – Sunday, August 25-27 at the Alameda County Fairgrounds in Pleasanton. They have invited us to exhibit our model engines. We need to decide if we are going to participate.

FIRST POPS

Larry Zurbrick had his throttled GEM1 running on the "show the engines" table. It was nicely painted, mounted on a shop made box, and ran well.



Larry's nice and clean GEM1

Dwight Giles admires the design and workmanship of Larry Zurbrick's GEM1

Paul Denham achieved "fists hiss" with his model of a Boulton & Watt 1802 Bell Crank Steam Engine. The early design features made for challenging machining. Apparently six of these engines were built and one survives in a museum. Of interest, the original eccentric had a square shape. The casting kit contained a circular replacement for better timing operability.

Here's a link to a video of Paul's nicely running steam engine: https://youtu.be/p5vWbL5dFRs

Ray Fontaine had his "Open 4" model engine running after some rebuild work. One new feature was a starter that worked with an electric model airplane starter.

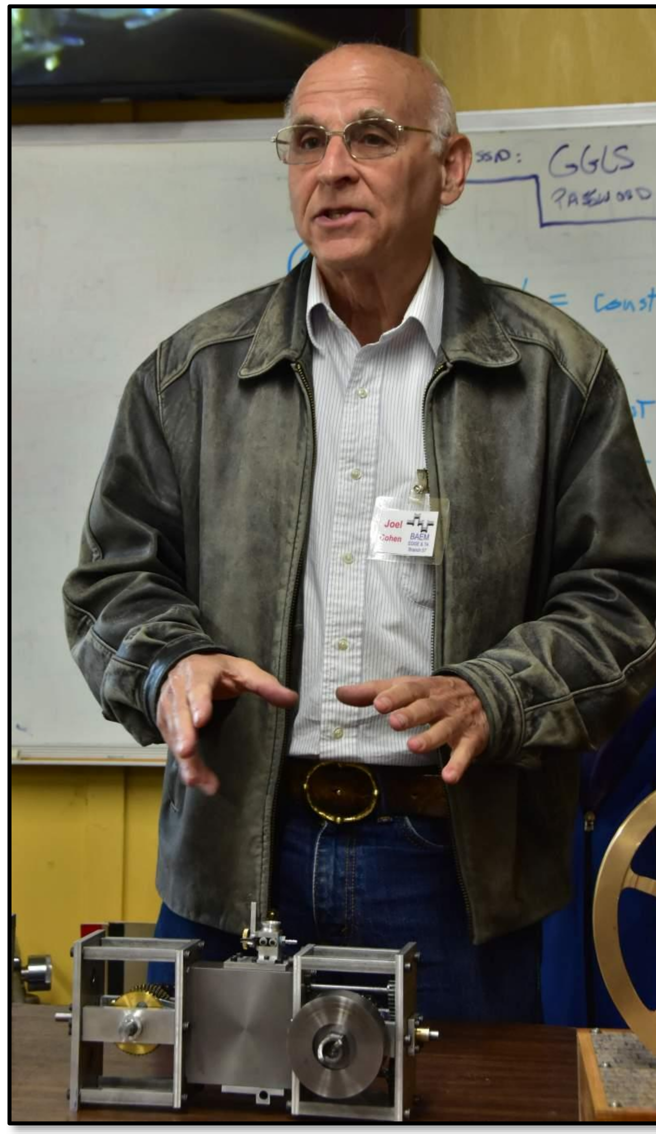
Ray also showed a wood engraving made as a "first cut" with his new Tormach 440 CNC mill. Ray had a trailer full of engines he set up outside on the show tables.

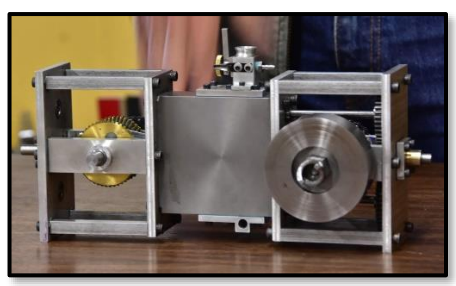
Ray Fontaine showed a wide variety of engines.

BITS AND PIECES

Peter Lawrence reported that his Merlin V12 is running reliably but the low oil pressure issue is still unresolved. He has convinced himself that oil is flowing, and he can run the engine. He also brought his Hansen vertical and two locomotive engines (scaled to fit his display shelf) to show.

Joel Cohen showed an interesting new project. His objective was to build a "balanced" engine with two cylinders with power strokes in opposite directions. He used his rotary valve design and had to move facing machining to his lathe when the part was too big for his mill.





Joel Cohen explains his "balanced" engine design.

Charlie Reiter brought in a Case 65 steam tractor he completed from ten-year-old partially machined castings. Main engine parts were machined, and a commercial boiler was included. He had a "riding trailer" set up as the operator seat and transport for the propane gas tank. The engine got lots of attention from the GGLS members.

Charlie Reiter's Case 65 steam tractor.

Gary Murray was a guest invited by Dwight Giles. Dwight was helping him fabricate seaplane floats for Gary's 1947 Luscombe 8E. Gary was understandably impressed with Peter's Merlin.

During the meeting, someone mentioned the names of two books that were highly recommended reading for BAEM members. Your notetakers remembered the book titles, but failed to note who suggested them. Sorry about that.

The first book suggestion was: *Flame Ignition: A Historical Account of Flame Ignition in the Internal Combustion Engine.* The author is early engine historian Wayne S. Grenning. Here's a link: https://www.gasenginemagazine.com/community/internal-combustion-engine-zbfz1504zhur/

The second book suggestion was: *The Perfectionists: How Precision Engineers Created the Modern World.* Written by historian Simon Winchester. Here's a link for this one:

https://www.amazon.com/Perfectionists-Precision-Engineers-Created-Modern/dp/0062652567/ref=monarch_sidesheet

Long time BAEM member Carl Wilson just completed a technical paper titled "*A New Method for the Design of a Three-Arc Cam Lobe.*" Carl had several cam-related multi-issue articles published in Model Engine Builder, and he has authored cam and grinding tech topic presentations for BAEM club meetings. Carl has uploaded the paper to Home Model Engine Modelers forum and asked Mike Byrne to share the paper for BAEM members that might be interested. Carl is expanding the paper for publication as an upcoming Model Engine Builder article.

You'll find it attached.

RAMBLINGS

After last month's meeting, Paul Denham got to work on his next project: building a Rider-Ericcson Hot Air Pumping Engine model with a single cylinder with a 3" bore (the full sized were 8"). This engine operates on the Stirling cycle, which requires a cylinder bore that is round and true, providing a very precise fit for the piston. So Paul was faced with boring a 7" long, 3" diameter cylinder of steel, without a steady rest. A difficult challenge.

Paul described how he dealt with this. "I tried and tried with many tool bit profiles and sharpening routines. It came out real close but not good enough. I talked to Dwight and I thought about a tool post grinder. He agreed it might be the solution and said I have one I have never used. So he loaned it to me. I needed to true the 2.5" grinding wheel with a diamond. This was done in the mill with the diamond in the quill. This went well. Then back to the lathe and took a ~.001" cut wow that really got out a lot of the junk. Then another .001" cut and a final .0005"cut and a retract cut with no cut depth change. Wowser nice finish. Loud and messy but it was the solution."

"Then I machined the cast iron piston and used it as the tail-stock support to reduce the outside diameter of the cylinder."

"I ended up with a 5-gallon bucket of chips. Really glad this is not a V8."

A tool post grinder was the solution to this challenging boring job, enabling Paul to achieve the high precision needed.

Working on an interesting project? Got a great BAEM story? Share it with us here. Send us pics and project details, and your hard work will be shared with the entire club.

FOR SALE

Mike Rehmus is parting out his machine shop. Contact Mike via Model Engine Builder for a list.

The big item Mike is selling is his Bridgeport mill. Here are details:

Bridgeport 1-1/2 HP variable-speed mill

- 1975 Mill with a newer head
- Accurite 2-axis DRO
- Mitutoyo Z-axis DRO
- Servo Y-Axis table drive
- 6” vise ground within 0.0001” flat and parallel all surfaces.
- 10” circular parallel for tramming head ground within 0.0001” flat and parallel
- R-8 Collet set
- Criterion 3” R-8 boring head
- Albrecht drill chuck
- Horizontal milling attachment
- 3-HP 220 VAC VFD TECO Fluxmaster FM-100
- 8” Rotary table
- Indexing head
- Mist coolant spray head
- Boring bar cutters
- Miscellaneous cutting heads
- Miscellaneous milling cutters
- Manual

Contact Mike Rehmus at (707) 694-7585

Got something you’d like to sell? Your ad is free and will be seen by likely customers.

NEWSLETTER CONTRIBUTIONS

Your contributions to this newsletter are appreciated: workshop reports, tech articles, reviews, historical pieces, whatever. You contribute, we’ll figure out how to post it. Send your contributions to either or both of us. Thanks!

-Mike Byrne at mgbyrne3@comcast.net

-Wes Wagnon at weswag@ix.netcom.cm

BAEM Tech Topic:
A New and Simple Method for the Design of a Three-Arc Cam Lobe

By Carl Wilson

There are many profiles that may be used to design a cam for internal combustion engines. Most of them are defined and designed by the motion of the followers. Two examples are the constant acceleration and the parabolic acceleration profiles. However, the two profiles that model engine builders use are unique in being defined by their shape: the flat flank (Figure 1) and the three-arc cam (Figure 2).

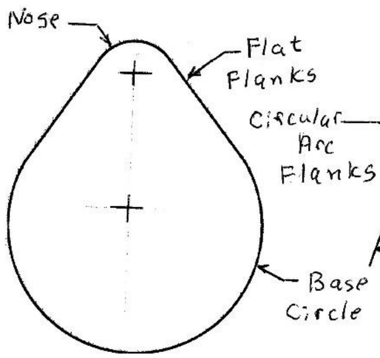


Figure 1

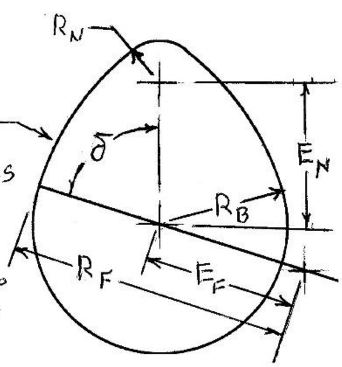


Figure 2

The flat tangent cam is the simplest, consisting of two flat flanks connecting the base circle to the nose arc. It is best used with roller followers but has been used with flat faced lifters. Elmer Wall used it in his engines, probably because it was the easiest profile to machine. This profile will not be discussed further.

The three-arc cam replaces the flat flanks with circular arcs (Figure 2). This makes its design and machining more difficult. It can be designed by calculation of the dimensions of its elements or by drawing, either manually or via CAD.

The Three-Arc Cam

The shape of the three-arc cam is completely defined by its five parameters: lift (L), duration (δ), base circle radius (R_B), nose arc radius (R_N), and flank arc radius (R_F). Two secondary parameters, nose eccentricity (E_N) and flank eccentricity (E_F), locate the center of those two arcs. The center of the nose arc is on the vertical centerline of the lobe, and the center of the flank arc is on an extension of the duration line. The eccentricity of these arcs is the distance of their centers from the center of the base circle. In the Appendix (page 5) there is a scan of a page from a book that is an excellent compendium of the equations for calculating the shape of a three-arc cam. The equations are solely for the design of a cam used with a flat faced follower.

A Problem

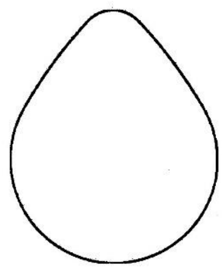
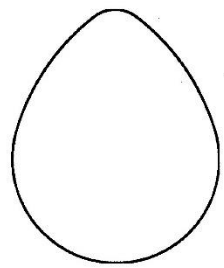



Figure 3 **Figure 4**

Figures 3 & 4 are drawings of two different three-arc cam lobes. One of them is a poor design and the other is good. One has poor gas flow and the other has a much better gas flow. The motion of the follower determines the gas flow of the design.

Motion of the Follower

In the end, the motion of the lifter is the desired result, not the shape of the cam. Designing the shape does not guarantee the desired motion of the lifter. Once the shape of a three-arc cam has been designed, the motion of the lifter should be evaluated for suitability of its use in an engine. The motion of the lifter validates the shape of the cam.

The motion of the lifter may be examined in two different ways. First, the *kinematics* of the cam design and second, the *dynamics* of the entire valve gear train. Dynamics is the study of the motion of the lifter during operation. This includes the rpm of the camshaft, the mass of the parts of the valve gear, the forces imposed by the rotating cam and by the valve spring, and the resulting deformations. Cam dynamics will not be discussed in this article.

Cam kinematics is the theoretical study of the perfect motion of the lifter. There is no consideration of the speeds, mass, forces, and deflection of the valve gear. The lifter is ignored and for convenience we may ascribe the motion of the lifter to the cam, as in "the lift on the flank is …" or "the acceleration on the nose is …."

A new method of creating the three-arc cam profile based upon the motion of the follower is presented below. The method presented here is simpler than the process of designing the shape and then subsequently evaluating the motion of the follower.

Acceleration Ratio

Please look ahead to page 5. You will find a compilation of the conventional equations for designing a cam profile. However, the first eight equations express the motion of the lifter: lift

(L), velocity (V) and acceleration (A) in terms of the eccentricity of either the flank or nose arcs. The eccentricity of the respective arcs may be used as a proxy for the motion of the follower and a new parameter, Acceleration Ratio ("AR") can be defined by the equation:

$$\boldsymbol{AR = E_F/E_N}$$

We will use Acceleration Ratio in a rule of thumb: the Acceleration Ratio of a 'good' cam design should be between 2 and 5. A cam with a lower AR value is slower opening and closing, and imposes less force on the valve gear. It has a relatively low gas flow. A cam with a higher AR value is faster opening and closing, and imposes greater forces on the valve gear. It has a higher gas flow rate. A cam with a lower AR value would be suitable for a low compression, low RPM engine. A high compression, high RPM engine would run better with a cam with a higher AR value.

Φ_M

Φ (phi: rhymes with fly), denotes an angle of rotation of the cam while in contact with a flank. Φ_M is the angle of rotation of the cam lobe during which the acceleration of the lifter reverses from positive to negative – the angle at the reversal point. It is also the total angle of rotation of the cam at which the flank arc contacts the lifter. See the drawings in the Appendix for illustrations of ϕ and ϕ_M.

Φ_M may be used in the evaluation of a cam design. The rule of thumb is that it should be in the range of 15°. A low angle implies a high acceleration on the flank and a fast-opening valve. A high angle implies a low acceleration and a slow opening valve.

The Problem, Again

Returning to the problem depicted in Figures 3 & 4. Figure 3 is the 'good' design. Its acceleration ratio is 3.2 and Φ_M = 13.17°. These values put that design in the middle of the range suggested by the rule of thumb for AR and Φ_M. Figure 4, while it looks good, is a relatively poor design. Its Acceleration Ratio is 1.07, well below the suggested range and Φ_M = 34.85°, way above the suggested value of about 15°. This would be a very slow opening and closing cam with a low gas flow. It is easy to design a good looking but poorly performing cam.

The Defined Acceleration Ratio Design Method

The surest way to avoid having to redesign a cam, is to design it using Acceleration Ratio as one of the input or initial parameters. My design method is to derive the cam lift (L) from the valve head diameter where the lift is ¼ of the valve head diameter. The duration δ (delta) is based upon the service desired from the engine, and the base circle radius R_B is derived from the maximum diameter of the cam: R_B = Dia Max – 2L. The Acceleration Ratio is also derived from the performance desired from the engine. These values of these parameters are the initial parameters of the Defined Acceleration Ratio Design Method.

Equations for Defined Acceleration Ratio Design Method

1. **Initial Parameters:** Lift ≡ L, Duration ≡ δ, Base Circle Radius ≡ R_B,
   Acceleration Ratio ≡ AR

2. $\boldsymbol{Z = \sqrt{(AR^2 + 1 - 2\,AR\cos(180 - \delta))}}$ *Note: Z is an intermediate value used in three of the following equations. The square root on the right side of the equal sign is over the entire expression.*

3. $\boldsymbol{R_N = R_B - \frac{L\,(Z-AR)}{1-Z+AR}}$

4. $\boldsymbol{E_N = R_B + L - R_N}$

5. $\boldsymbol{R_F = R_N + \frac{ZL}{1-Z+AR}}$

6. $\boldsymbol{E_F = R_F - R_B}$

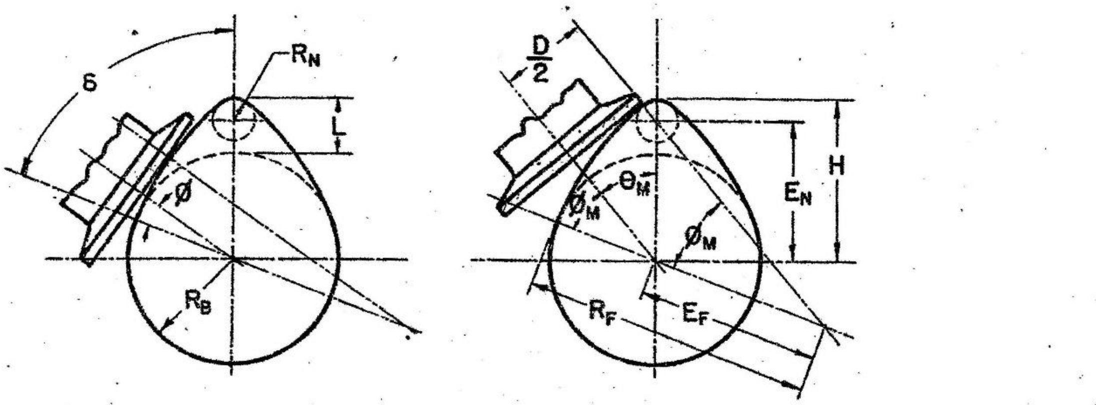
7. $\boldsymbol{\Phi_M = arcsin\,\frac{\sin(180-\delta)}{Z}}$

8. $\boldsymbol{D = 2E_F\,sin\Phi_M}$ *Note: D is the minimum diameter of the lifter or follower assuming the width of the cam lobe is zero inches. For a wider lobe the lifter diameter should be increased so that the contact patch remains within the body of the lifter throughout the rotation of the cam. The lifter bore may be offset from the centerline of the camshaft so that the lifter will rotate in its bore to distribute the wear on its face. An additional allowance A should be made for this, for possible machining errors, and for any chamfer on the face of the lifter.*

9. $\boldsymbol{D_T = \sqrt{D^2 + W^2} + A}$ *Note: D_T is the total diameter of the lifter, W is the width of the lobe, and A is the sum of all other allowances on the diameter.*

All cam design calculations are sensitive to rounding errors. The value of any parameter that is carried over into another calculation or into the other design method should be left at its maximum available number of digits after the decimal point.

Appendix: Equations for the Defined Shape Design Method



$L_F = E_F \cdot \mathrm{VERS}\,Ø$ $\qquad L_N = L - E_N \cdot \mathrm{VERS}\,\Theta = E_N \cdot \cos\Theta - E_N + L$

$V_F = .0174533 \cdot E_F \cdot \sin Ø$ "/DEG. $\qquad V_N = .0174533 \cdot E_N \cdot \sin\Theta$ "/DEG.

$A_F = .30462 \cdot 10^{-3} \cdot E_F \cdot \cos Ø$ "/DEG.^{2} $\qquad A_N = .30462\,(10^{-3})\,E_N \cos\Theta$ in/deg

$A_F = 913.86 \cdot (N \cdot 10^{-3})^2 \cdot E_F \cdot \cos Ø$ FT/SEC.^{2} $\qquad A_N = 913.86\,(N \cdot 10^{-3})^2\,E_N \cos\Theta$ Ft/sec^2

VELOCITY: "/DEG. · .5N = FT/SEC.

ACCELERATION: "/DEG^2 $(3N^2)$ = FT/SEC^2

$$E_F = \frac{3282.77 \cdot A(\text{"/DEG}^2)}{\cos Ø} \qquad Ø_M = \sin^{-1}\left(\frac{E_N \cdot \sin\delta}{R_F - R_N}\right) = \sin^{-1}\left(\frac{E_N \cdot \sin\delta}{E_F + E_N - L}\right)$$

$$D = 2 \cdot E_F \cdot \sin Ø_M = 2 \cdot E_N \cdot \sin\Theta_M = 114.592\ V_M\ (\text{"/DEG.})$$

$$R_N = \frac{2 \cdot E_F \cdot (H \cdot \cos\delta - R_B) + H^2 - R_B^2}{2 \cdot (H - R_B - E_F \cdot \mathrm{VERS}\,\delta)} = \frac{E_F\,(L \cdot \cos\delta - R_B \cdot \mathrm{VERS}\,\delta) + L \cdot (.5 \cdot L + R_B)}{L - E_F \cdot \mathrm{VERS}\,\delta}$$

$$R_B = (R_N - E_F) + \sqrt{E_F^2 + E_N^2 + 2 \cdot E_F \cdot E_N \cdot \cos\delta}$$

$$R_F = \frac{E_N^2 + R_B^2 - R_N^2 - 2 \cdot R_B \cdot E_N \cdot \cos\delta}{2 \cdot (R_B - R_N - E_N \cdot \cos\delta)}$$

$$E_N = -E_F \cdot \cos\delta + \sqrt{E_F \cdot (E_F \cdot \cos^2\delta - 2 \cdot R_N + 2 \cdot R_B) + (R_B - R_N)^2}$$

$$E_F = \frac{E_N^2 - (R_B - R_N)^2}{2 \cdot (R_B - R_N - E_N \cdot \cos\delta)} = \frac{E_N^2 - (E_N - L)^2}{2 \cdot (E_N - L - E_N \cdot \cos\delta)}$$

$$\delta = \cos^{-1}\left(\frac{(2 \cdot E_F + R_B - R_N) \cdot (R_B - R_N) - E_N^2}{2 \cdot E_F \cdot E_N}\right)$$

FIG. 11. HARMONIC TWO CURVE CAM FORMULAE

This set of drawings and equations is reprinted from page 15 of Turkish, Michael, Valve Gear Design, 1946, by permission of the Eaton Corp. The equations are based upon an algebraic analysis of the geometry of the three-arc cam. The primary purpose of reprinting this page is to make it available to model engine builders and cam designers.

The trigonometric function *vers δ* (versine δ) is equal to '1- cos δ.'

About the Author

My name is Carl Wilson. I am a long-term member of Bay Area Engine Modelers and have a much longer-term interest in cam design and grinding. Over the years I have visited three professional cam grinding shops and corresponded with two of the owners. I learned much from these experts in the field. From Bus Schaller of Schaller Cams, I learned how to make a model lobe by the "envelope of flat tangents" method, utilizing a vertical mill. From Jim Dour of Megacycle Cams, I learned why the professionals grind cams from masters, that at one time they ground their masters from a model lobe, but now generate their masters using CNC mills. Dema Elgin of Elgin Cams read some of the article on cam grinding in Model Engine Builder Magazine. He recommended that I find and master the article by Chris Bouvy on the design of the triple curve profile. Digesting that article provided me with the confidence to return to the design of the three-arc profile. I drew about a dozen large-scale designs using manual drafting to gain an understanding of the shape of the three-arc cam. Finally, the page in the Appendix gave me the equations I needed to design a cam by calculating its shape.

My source for the concept of Acceleration Ratio ("AR") was two automotive engineering books published in the 1930's, which I no longer possess. One book suggested a value of 2 to 3 for AR and the other suggested a value of 3 to 4. Those values were probably best suited for the low compression, low speed engines of the time. The concept of AR was not developed further than its definition, equation, and the rules of thumb used to evaluate a cam design. From these I developed the Defined Acceleration Ratio method with its new equations. The new rule of thumb is an AR of 2 to 5, to accommodate higher performance engines.

Today, professional cam designers will not use Acceleration Ratio, particularly for profiles that are not defined by their shape. They use *svaj* graphs/diagrams which display the follower lift (s), velocity (v), acceleration (a), and jerk (j), and are the basis of evaluation of a proposed design. These diagrams require some calculations to prepare and experience to interpret. Acceleration Ratio and Φ_M provide sufficient information about the motion of the lifter to evaluate a design and are much simpler to calculate and interpret. The good ol' way is still good enough for us.

AR was first presented in detail a few years ago in Model Engine Builder Magazine, issue #33. A new article is scheduled for issue #40 and will include this material plus the formulas for Excel spreadsheets for designing a cam under the shape or Acceleration Ratio methods.

My thanks to Mike Byrne, fellow member of Bay Area Engine Modelers for reading the article and making suggestions for its improvement.