COMPUTER METHOD OF DETERMINING CAM PROFILES

by

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INTRODUCTION

Problem solving in Kinematics, on the most part, has long been of empirical and graphical nature. Until recently, the existing tools have not generally allowed handling the problems analytically. The appearance and use of high-speed computing machines have brought the possibilities of obtaining satisfactory analytical solutions into the picture.

By means of computers, changing the design approach and extended theoretical investigations; explicit solutions of practically unsolvable equations have become economically possible. Design simulation has been improved by the possibility of changing the parameters of computer programs. Greater access to the storage of knowledge has been realized. Better control over the problem is established because of the step-by-step approach required in the computer program. Computers have also proven to be significant in the area of design optimization, where iterative aspects of design require analyzing several combinations of likely components and parameters to lead to the most feasible combination.

Computer plotting, as part of high-speed machine facilities, has found an application in the construction of cam profiles. Graphical techniques of drawing cam profiles are time-consuming and approximate. For quick and more accurate cam contour construction, it is sufficient to specify cam parameters for the computer-plotter program. The program can be said to design the cam in terms of kinematic requirements, and approaches more closely to the theoretically exact one.

This thesis presents computer programs for aid in the design of four different cam mechanisms. The output consists of a computer print-out of the coordinates of the cam profile, a plotter drawing of the cam profile and a displacement diagram. The subroutines were modified to make them operable on the KSU IBM 360/50 System, to increase the type of displacements handled and to standardize the input and output. The subroutines are:

1. ROSCAM, to develop the profile of a cam having an oscillating roller follower.
2. FOSCAM, to produce a profile of a cam mechanism with an oscillatory flat-faced follower.
3. CAMROL, to develop the profile of a cam mechanism having a translating roller follower.
4. CAMFLT, to determine the profile of a cam with a flat-faced, translating follower.

In order to make the subroutines operable and to increase the types of displacements handled, it was necessary to develop the cam theory used. The analytical approach to determine the cam profile had to be developed. Among the contents are the descriptions of subroutines and of the auxiliary subprograms contained in them. Some numerical applications to illustrate the use and effect of the subprograms are included in the appendix. Also, given in the appendix are the format specifications concerned and samples of programs run in the computer.

CAM THEORY

A cam is an irregular-shaped, driving mechanical element for transmitting a prescribed motion to a driven link called the follower by direct contact. Kinematically, a cam mechanism formed by the cam, follower and the frame can be identified as a 4-bar, the simplest mechanism. The driving link of the 4-bar is the one that joins a point on the cam normal at contact of follower and cam to the center of cam rotation. The connecting link is any segment of the cam normal containing the joint with the driving link. The driven link is an element between the other end point of the segment of cam normal and the pivot of cam follower.

Cam mechanisms can be classified in several ways. They can be classified according to the follower as:

a) Translating, oscillating (type of movement).

b) Roller, flat-faced and knife-edge (construction of follower surface in contact).

c) Radial, offset (or eccentric) (location of line of movement).

Alternately, classification can be based on the type of cam as:

a) Disk or radial (rotary motion).

b) Wedge (translatory motion).

c) Cylindrical (combined translation and rotation).

Definitions

Displacement diagram - a rectangular layout of the coordinates of the follower motion for one cycle of cam operation.

Cam profile - the actual working surface contour of the cam. (Fig. 1).

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Base circle - the smallest circle drawn to the cam profile from the cam center.

Trace point - the point on the follower located at the roller center, knife-edge or face-center.

Pitch curve - the path of the trace point.

Pressure angle - the angle between the normal to the pitch curve at the point of contact and the instantaneous direction of follower motion.

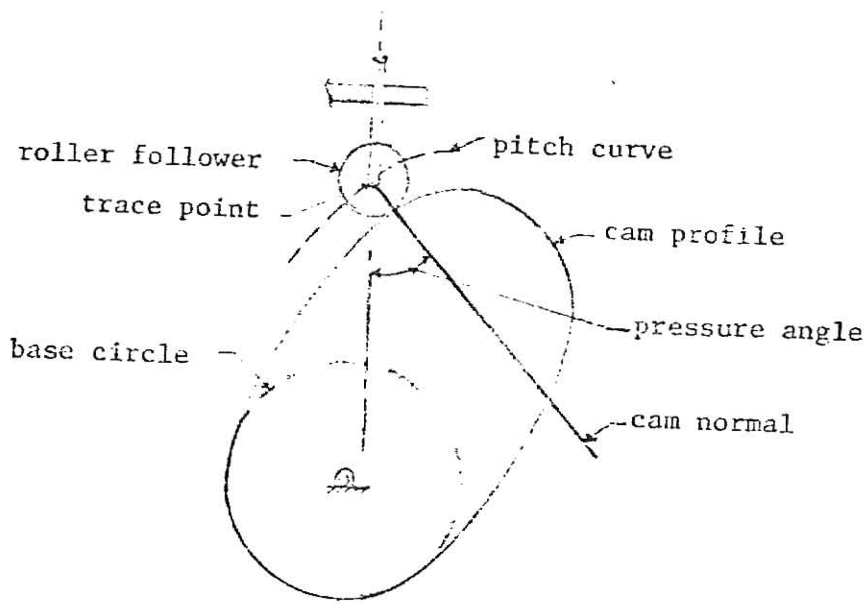

Figure 1. Cam nomenclature.

Basic Follower Motions

1) Parabolic or constant acceleration motion

The displacement, $h(\theta)$, is represented by a curve of a second degree polynomial which has constant positive or negative acceleration.

The form of the equation is,

$$h(\theta) = c_1 + c_2\theta + c_3\theta^2 \text{ in terms of cam angle } \theta. \tag{1}$$

There are two intervals of interest: The speeding-up period starting from rest and the slowing-down region ending the follower travel. The conditions are for acceleration:

$$h = 0 \qquad \text{at } \theta = 0 \tag{2}$$

$$\frac{dh}{dt} = 0 \qquad \text{at } \theta = 0 \tag{3}$$

$$h = \frac{h_o}{2} \qquad \text{at } \theta = \beta/2 \tag{4}$$

Here h_o is the total rise of the follower in β angle of cam rotation. By application of (2), (3), (4) to (1),

$$c_1 = 0, \quad c_2 = 0, \quad c_3 = 2h_o/\beta^2$$

Then,

$$h(\theta) = 2h_o\,(\theta/\beta)^2 \qquad \text{for } 0 \leq \theta \leq \beta/2 \tag{5}$$

$$\text{Velocity:} \quad \frac{dh}{dt} = \frac{4h_o\omega}{\beta^2}\,\theta, \qquad \omega = \dot{\theta} \tag{6}$$

For deceleration period, $h = \frac{h_o}{2}$ at $\theta = \beta/2$ (7)

$$h = h_o \quad \text{at } \theta = \beta \tag{8}$$

$$\frac{dh}{dt} = \frac{2h_o}{\beta}\,\omega \quad \text{at } \theta = \beta/2 \tag{9}$$

Using these conditions, c_1, c_2, c_3 are determined for the second interval, giving

$$h(\theta) = - h_o + \frac{4h_o}{\beta}\,\theta - \frac{2h_o}{\beta^2}\,\theta^2 = h_o\,[1 - 2(1 - \frac{\theta}{\beta})^2] \quad \text{for } \beta/2 \leq \theta \leq \beta, \tag{10}$$

Velocity: $$\frac{dh}{dt} = \frac{4h_o\omega}{\beta}\,(1 - \frac{\theta}{\beta}), \qquad \omega = \dot{\theta} \tag{11}$$

2) Simple harmonic motion

This motion is obtained by projecting the motion of a point moving on a circle with constant velocity onto the diameter of the circle.

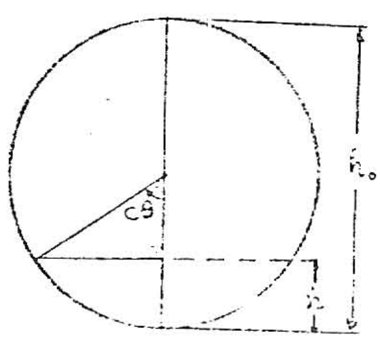

Figure 2. Simple harmonic motion generator.

If the diameter of the circle is h_o, then

$$h = \frac{h_o}{2} - \frac{h_o}{2} \cos c\theta \qquad (13)$$

If $h = h_o$ at $\theta = \beta$ is chosen as a boundary condition for the cam, where h_o is the displacement of the follower in terms of β the cam angle of rotation, then,

$$h(\theta) = \frac{h_o}{2} \left(1 - \cos \frac{\Pi}{\beta} \theta\right) \qquad (14)$$

$$\text{Velocity:} \quad \frac{dh}{dt} = \frac{\Pi h_o \omega}{2\beta} \sin \frac{\Pi}{\beta} \theta \ , \quad \omega = \dot{\theta} \qquad (14)$$

3) Cycloid motion

This motion is generated from a cycloid, which is the locus of a point on a circle rolling on a straight line.

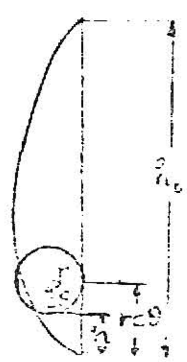

Figure 3. Cycloid generation

The radius of the cycloid-generating circle, r, in relation to cam is:

$$2\pi r = h_o \quad \text{(development of circle circumference = rise)}$$

$$r = \frac{h_o}{2\pi}$$

The equation of a cycloid is of the form:

$$h = \frac{h_o}{2\pi}(c\theta) - \frac{h_o}{2\pi}\sin(c\theta) \tag{15}$$

At $\theta = \beta$, $h = h_o$, hence $c = \frac{2\pi}{\beta}$

Then,

$$h(\theta) = \frac{h_o}{2\pi}\left(\frac{2\pi}{\beta}\theta - \sin\frac{2\pi}{\beta}\theta\right) \tag{16}$$

$$\text{Velocity:} \quad \frac{dh}{dt} = \frac{h_o\omega}{\beta}\left(1 - \cos\frac{2\pi}{\beta}\theta\right) \tag{17}$$

Pressure Angle Formulation

The pressure angle can be expressed mathematically, by making use of the 4-bar linkage (OPRQ, in Fig. 4), which is equivalent to the cam mechanism and has the property that

$$\frac{d(RP)}{dt} = V_{RP} = 0$$

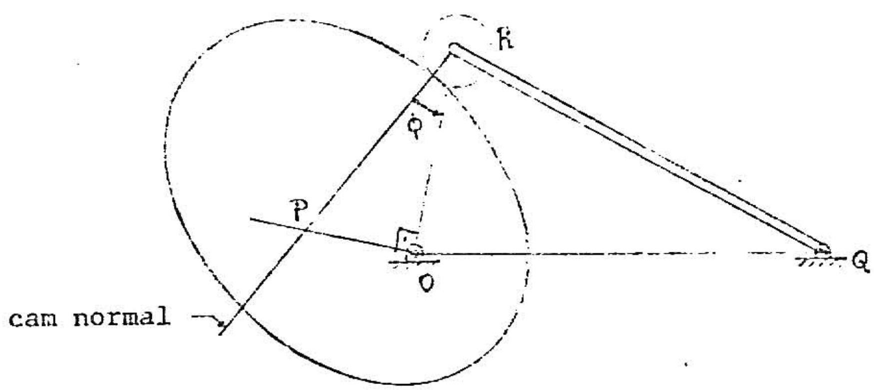

Figure 4. Pressure angle.

$$V_R = V_P + V_{RP} = V_P$$

where

$V_R = \frac{dh}{dt}$, follower velocity

$V_P = \omega\ (OP)$, the velocity of point (P) on the cam

Considering ΔOPR[1], $OP = (OR) \tan \phi$

OR is the distance between cam and roller centers, ϕ is the pressure angle. If b is the smallest value of OR, then at some cam angle θ,

$$OR = b + h(\theta)$$

[1] ΔOPR indicates triangle OPR

Hence, with proper substitutions,

$$\frac{dh}{dt} = \omega[b + h(\theta)] \tan \phi$$

or

$$\tan \phi = \frac{1}{\omega} \cdot \frac{dh}{dt} \cdot \frac{1}{[b+h(\theta)]}$$ [1]

[1] This is the form used in the computer programs for determining the maximum pressure angle for a cam with a roller follower.

GRAPHICAL METHOD OF DRAWING CAM PROFILE

Kinematic inversion[1] is used in this process. Clockwise cam rotation is assumed.

One rotation of cam is divided into equal intervals (6, in Fig. 5). Displacements of the follower for the beginning and end of intervals are determined from the displacement diagram. These displacements (0-1', 0-2', etc. in displacement diagram of Fig. 5) are added to the least value of roller-cam center distance on a radial line (e.g. OR_o in Fig. 5) through cam center, giving points 1", 2", etc.

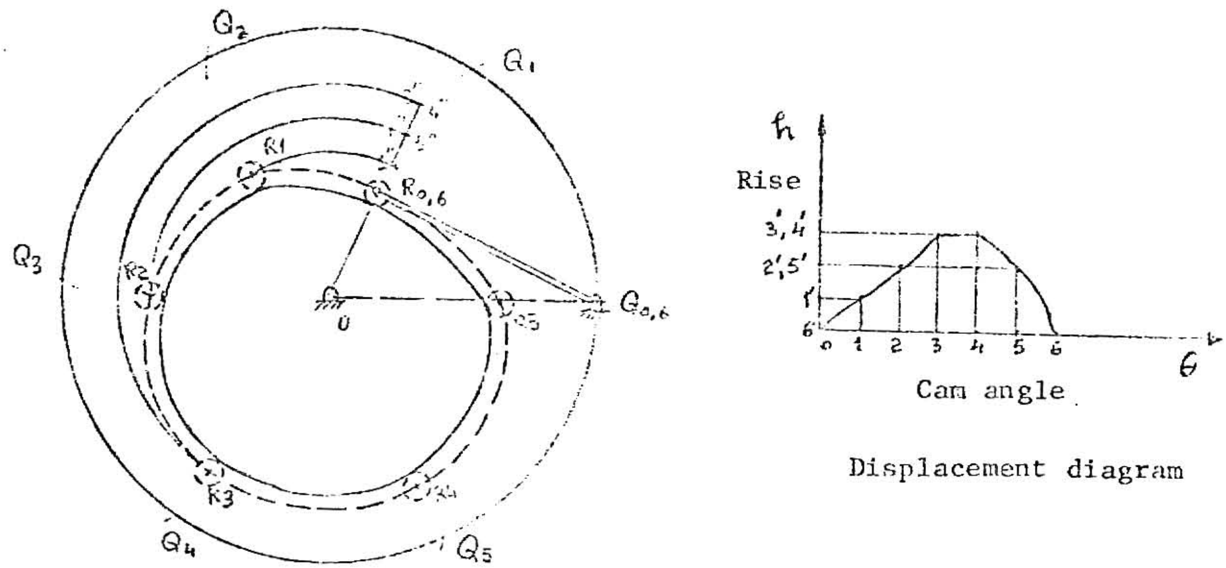

Figure 5. Graphical cam profile layout.

[1]Kinematic inversion is the process of holding a link other than the originally fixed member of a mechanism (frame) fixed and moving other link(s) of interest with respect to the one held stationary.

The circle with radius equal to the length of the distance between cam center and follower pivot (OQ_o) and having its center at the cam axis (O) is drawn. Follower pivot (Q) is located on the circumference of this circle by dividing the circumference into 6 equal parts the same as the divisions of cam angle.

Circular arcs with radii equal to the follower arm length (Q_oR_o) are drawn from the located follower pivot points (Q_1, Q_2 etc.). These arcs are intersected with another set of circular arcs drawn from the cam center and having radii equal to the previously established radial distances (01", 02", etc.). The intersections (called R1, etc. in Fig. 5) are joined to obtain the pitch curve. The roller follower is positioned at each of the intersections. Then a smooth curve is drawn tangent to the various positions of the follower to yield the cam contour. For reasonable accuracy many more than 6 positions need to be used in the development.

ANALYTIC EXPRESSIONS FOR CAM PROFILES

a) ROSCAM Subroutine

The subroutine has a structure resulting from two ideas, one of which is the principle of kinematic inversion. The other is, by means of kinematic inversion, to establish well-ordered program variables dependent solely upon the previously defined variables. This leads to the identification of the configuration of the cam-follower system with respect to a fixed reference frame.

The following sketch consists of the initial and a displaced configuration of the inverted cam mechanism in a fixed x-y co-ordinate system. O,F,R are the cam axis, initial location of pivot of the follower arm and initial roller center, respectively. For clockwise cam rotation, by inversion, the follower pivot will have its new configuration as rotated by α angle of cam rotation in the opposite sense (i.e. counterclockwise).

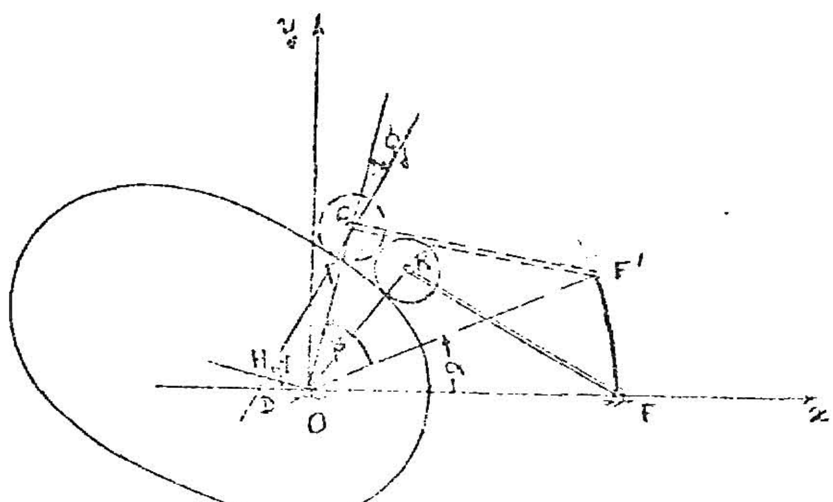

Figure 6. Cam-roller oscillating follower.

The follower pivot will be at F'. The roller center and contact point between roller and cam surface are shown as C and P, respectively. Initially, the radial line OR and the normal to cam surface at contact point of roller are coincident. This is based on the assumption that cam motion starts from the position, for which the radial distance between cam center and contact point has its smallest value, or more generally from the initial dwell (follower has constant distance to the cam center). At the new configuration, there will be an angle ϕ_j between the radial line and normal to the cam surface, which is, by definition, the pressure angle. H and D are the points of intersection of the cam normal with the perpendicular to radial line (OC) at O and the initial frame axis (OF), respectively.

Angles and lengths are defined with respect to the sketch as follows:

<FOF'[1] = α , Cam angle of rotation.

<F'OC = β , Angle between rotated frame (OF') and radial line (OC).

<ODC = γ , Inclination of cam normal with reference to initial frame (OF).

OF = OF' = f , Distance between cam axis (O) and follower arm pivot (F).

PC = r , Roller radius.

F'C = FR = a , Follower arm length.

OR = b , Initial distance between cam and roller centers.

---

[1]<FOF' denotes angle FOF'.

$OC = h_j$, Radial distance from roller center to cam axis.

$OH = \ell_j$, Distance between cam center and the point H.

'j' is an index.

The relations leading to the co-ordinates of the roller center, C and contact point, P at the jth degree of cam rotation can be determined.

$$h_j = b + h(\alpha) \tag{1}$$

Let

$$\ell_j = \frac{dh_j}{d\alpha} \tag{2}$$

From ΔOHC, $\tan \phi_j = \frac{OH}{OC} = \frac{\ell_j}{h_j}$, or $\phi_j = \tan^{-1} \frac{\ell_j}{h_j}$ (3)

Cosine Law applied to $\Delta OF'C$ to get;

$$(F'C)^2 = (OF')^2 + (OC)^2 - 2(OF') \times (OC) \times \cos \beta \tag{4}$$

with proper substitutions, $\cos \beta = \frac{h_j^2 + f^2 - a^2}{2h_j f}$ (4a)

$$\sin \beta = (1 - \cos^2 \beta)^{1/2} \tag{5}$$

$$\beta = \tan^{-1} \frac{\sin \beta}{\cos \beta} \tag{6}$$

From ΔDCO, $\angle FOC = \angle ODC + \angle DCO$ (7)

or, $\gamma = \alpha + \beta - \phi_j$ (7a)

Co-ordinates of roller center, C:

$$x_{cj} = h_j \cos (\alpha+\beta) \qquad \text{from figure 6} \tag{8}$$

$$y_{cj} = h_j \sin (\alpha+\beta) \tag{9}$$

Co-ordinates of contact point, P:

$$x_{pj} = x_{cj} - r \cos \gamma \tag{10}$$

$$y_{pj} = y_{cj} - r \sin \gamma \tag{11}$$

By these formulations, it is possible to locate points on the cam surface and on the pitch curve so that joining of the successive points with straight lines will produce the cam profile and the pitch curve.

b) FOSCAM Subroutine

FOSCAM subroutine formulates the co-ordinates of the points on the cam profile for each degree of cam rotation.

Shown, in Fig. 7, are two positions of the cam, namely at the start of motion and at some angle of cam rotation, α_j.

C is a point on the follower at a distance (R) from the pivot (O') of follower and is used to measure displacement from the center of cam rotation (O). For convenience, it is chosen coincident with the contact point (P) in the starting configuration. The normal to the flat-faced follower at C passes through O. O'N is the perpendicular from O' to

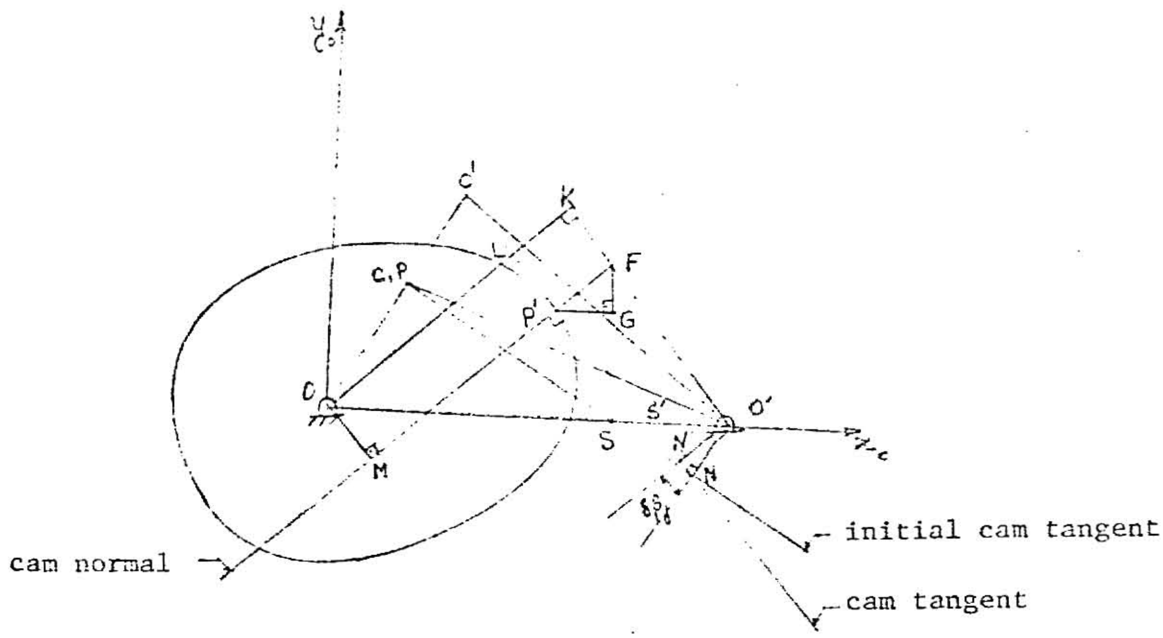

Figure 7. Cam-flat-faced oscillating follower.

the initial position of the face of the follower. The extension of the follower face, initially intersects the frame (OO') at point S. At the jth angle of rotation (α_j), points C,P,N,S will be at C',P',N',S'. The cam center will have projections on the cam normal and cam surface tangent at points M and L, respectively. The intersections of a line parallel to cam tangent, through (O') with lines parallel to cam normal through (O) and (M) will be called K and F, respectively. G is the point of intersection of a line through (P') parallel to frame and a line perpendicular to frame through F.

With the points identified, lengths and angles will define and signify the following:

$O'C = O'C' = R$, Follower arm length.

$O'N = O'N' = e$, Offset of initial cam tangent from follower pivot.

$P'N' = c_j$, Distance between contact point (P') and projection of follower pivot on line tangent to cam.

$OC = OP = b$, Radius of base circle of cam.

$OC' = h_j$, Distance between the follower point (C') and cam center (O).

$OO' = f$, Distance from follower pivot to center of cam rotation, frame length.

$\angle C'S'O' = \beta_j$, Inclination of flat-face of follower relative to frame.

$\angle CO'C' = \angle NO'N' = \delta\beta_j$, Oscillation angle of follower.

$\angle C'OO' = \tau_j$, Angle between frame and line joining cam center to point C' of follower.

$\angle OC'O' = \psi_j$, Angle between lines joining C' of follower to O and O'.

$\angle NPO' = \angle N'C'O' = \phi$, Angle arm (O'C') makes with the tangent to cam profile.

$\angle OS'C' = \delta_j$, Supplement of the angle, C'S'O', between tangent of cam and frame.

Relations resulting in determination of cam profile can be established.

Cosine Law applied to $\Delta OC'O'$,

$$(C'O')^2 = (OO')^2 + (OC')^2 - 2(OO') \times (OC') \cos \angle C'OO' \tag{1}$$

and

$$(OO')^2 = (OC')^2 + (O'C')^2 - 2(OC')(O'C') \cos \angle OC'O' \tag{2}$$

Substitution and rearrangement yield:

$$\cos \tau_j = \frac{h_j^2 + f^2 - R^2}{2h_j f} \tag{1a}$$

$$\cos \psi_j = \frac{h_j^2 - (f^2 - R^2)}{2h_j R} \tag{2a}$$

where $h_j = b + h(\alpha_j)$, $h(\alpha_j)$ is displacement of follower.
Letting $f^2 - R^2 = g$, (1a), (2a) become,

$$\cos \tau_j = \frac{h_j^2 + g}{2h_j f} \tag{1b}$$

$$\cos \psi_j = \frac{h_j^2 - g}{2h_j R} \tag{2b}$$

$$\sin \tau_j = (1 - \cos^2 \tau_j)^{1/2}, \qquad \sin \psi_j = (1 - \cos^2 \psi_j)^{1/2} \tag{3}$$

$$\tau_j = \tan^{-1} \frac{\sin \tau_j}{\cos \tau_j}, \qquad \psi_j = \tan^{-1} \frac{\sin \psi_j}{\cos \psi_j} \tag{4}$$

By APO'N, $\tan\phi = \frac{e}{c_1}$ or $\phi = \tan^{-1}\frac{e}{c_1}$, (5)

where c_1 is the initial value of c_j (i.e., PN = c_1, in figure 7)
Defining a new angle ψ_j' such that

$$\psi_j' = \psi_j - \phi \tag{6}$$

From $\Delta OC'S'$, $\delta_j = \Pi - \tau_j - \psi_j'$ (7)

Supplementary angle relation, $\angle OS'C' + \angle C'S'O' = \Pi$ (8)

or $\beta_j = \Pi - \delta_j = \tau_j + \psi_j'$ (8a)

Combining equations (1b), (2b), (3), (4) results in,

$$\tau_j = \tan^{-1}\frac{[4h_j^2f^2 - (h_j^2 + g)^2]^{1/2}}{h_j^2 + g} \tag{9}$$

and

$$\psi_j = \tan^{-1}\frac{[4h_j^2R^2 - (h_j^2 - g)^2]^{1/2}}{h_j^2 - g} \tag{10}$$

If

$$v = \frac{[4h_j^2f^2 - (h_j^2 + g)^2]^{1/2}}{h_j^2 + g} \tag{11}$$

and

$$u = \frac{[4h_j^2R^2 - (h_j^2 - g)^2]^{1/2}}{h_j^2 - g} \tag{12}$$

then,

$$\tau_j = \tan^{-1} v \qquad \text{or} \qquad v = \tan \tau_j \tag{13}$$

$$\psi_j = \tan^{-1} u \qquad \text{or} \qquad u = \tan \psi_j \tag{14}$$

Differentiation yields

$$\delta v = (1 + \tan^2 \tau_j)\ \delta\tau_j$$

or

$$\delta\tau_j = \frac{1}{1 + v^2}\ \delta v \tag{15}$$

$$\delta u = (1 + \tan^2 \psi_j)\ \delta\psi_j$$

or

$$\delta\psi_j = \frac{1}{1 + u^2}\ \delta u \tag{16}$$

where

$$\delta v = \frac{2h_j\ \delta h_j}{(h_j^2 + g)^2} \left\{\left[4h_j^2f^2 - (h_j^2+g)^2\right]^{-1/2}(2f^2-h_j^2-g)(h_j^2+g)-\left[4h_j^2f^2-(h_j^2+g)^2\right]^{1/2}\right\} \tag{17}$$

$$\delta u = \frac{2h_j\ \delta h_j}{(h_j^2-g)^2} \left\{\left[4h_j^2R^2 - (h_j^2-g)^2\right]^{-1/2}(2R^2-h_j^2+g)(h_j^2-g)-\left[4h_j^2R^2-(h_j^2-g)^2\right]^{1/2}\right\} \tag{18}$$

and where

$$\delta h_j = \frac{\partial h_j}{\partial \alpha_j}\,\delta\alpha_j; \qquad \text{Denoting} \quad \frac{\partial h_j}{\partial \alpha_j} = \ell_j \qquad \text{and}$$

taking the incremental change in angle as unity (i.e. 1^o), $\delta\alpha_j = 1$ (19)

(17), (18) become:

$$\delta v = \frac{2h_j\ell_j}{(h_j^2+g)^2}\left\{\left(4h_j^2f^2-(h_j^2+g)^2\right)^{-1/2}(2f^2-h_j^2-g)(h_j^2+g)-\left(4h_j^2f^2-(h_j^2+g)^2\right)^{1/2}\right\} \tag{17a}$$

$$\delta u = \frac{2h_j\ell_j}{(h_j^2-g)^2}\left\{\left(4h_j^2R^2-(\ell_j^2-g)^2\right)^{-1/2}(2R^2-h_j^2+g)(h_j^2-g)-\left(4h_j^2R^2-(h_j^2-g)^2\right)^{1/2}\right\} \tag{18a}$$

Differentiation of equation (8a) gives: $\delta\beta_j = \delta\tau_j + \delta\psi_j'$ (20)

Noting that ϕ is constant, $\delta\psi_j' = \delta\psi_j$ from (6).

Hence, $\delta\beta_j = \delta\tau_j + \delta\psi_j$ (20a)

To relate the angle of oscillation of follower ($\delta\beta_j$) to the angular velocity of cam, velocities at contact point (P') are considered.

From Fig. 8, $V_{P'c} = V_M + V_{P'M}$, velocity of (P') on cam (21)

$V_{P'f} = V_{N'} + V_{P'N'}$, velocity of (P') on follower (22)

where

$$V_M = (OM)\cdot\omega, \qquad V_{P'M} = (P'M)\cdot\omega \tag{23}$$

$$V_{N'} = (O'N')\,\frac{\delta\beta_j}{\delta t}, \quad V_{P'N} = (P'N')\,\frac{\delta\beta_j}{\delta t} \tag{24}$$

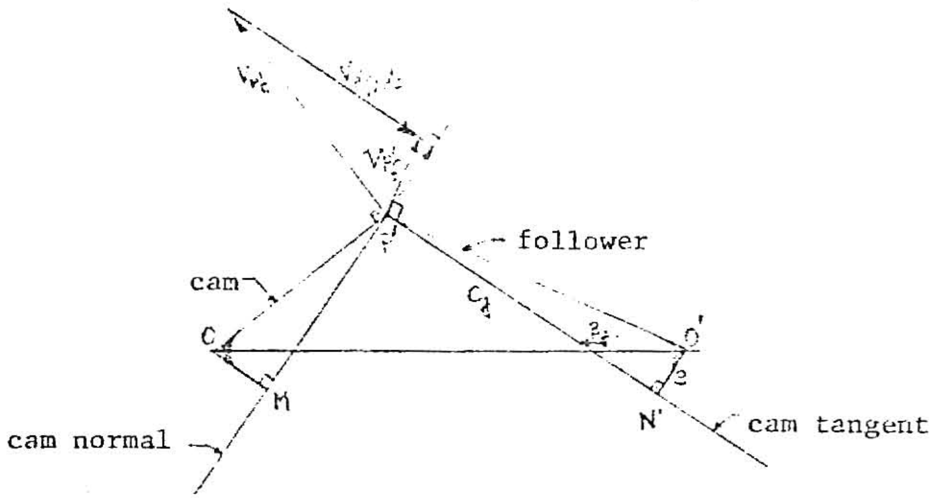

Figure 8. Velocity diagram.

ω is the angular velocity of cam, δt is the time elapsed during oscillation of follower ($\delta\beta_j$).

$$V_{P'f} = V_{P'c} + V_{P'f/P'c} \tag{25}$$

where $V_{P'f/P'c}$ is the relative velocity between cam and follower and is tangent to the cam surface at the point of contact.

Since velocity in the direction of cam normal is identical for cam and follower, it can be written that,

$$(P'M \perp P'N'), \qquad V_M = V_{P'N'} \qquad \text{or } (\omega)(OM) = c_j \frac{\delta\beta_j}{\delta t} \tag{26}$$

or

$$OM = c_j \; \delta\beta_j \; (\frac{1}{\omega\delta t}) \tag{26a}$$

$\omega\delta t = \delta\alpha_j$, increment of angle of cam rotation during (δt) was assumed to be unity, from relation (19).

Hence, $$OM = c_j \, \delta\beta_j \qquad (26b)$$

From $\Delta O'KO$, $$KO' = (OO') \cos(\Pi - \beta_j) \quad \text{(Fig. 7)} \qquad (27)$$

$$KO' = LN', \qquad LN' = -f \cos \beta_j \qquad (27a)$$

$$OM = LP', \qquad LN' = LP' + P'N' \quad \text{from Fig. 7} \qquad (28)$$

By (27a), (26b) and (28),

$$-f \cos \beta_j = c_j \, \delta\beta_j + c_j \qquad (28a)$$

from where

$$c_j = \frac{-f \cos \beta_j}{1 + \delta\beta_j} \qquad (28b)$$

Defining a reference frame $x_o y_o$ rotating with cam angular velocity ω, co-ordinates of the point (P') can be expressed in terms of the previous quantities.

By Fig. 7, $$\angle P'FG = \Pi - \beta_j = \angle FO'x_o$$

$$x_{Poj} = f - [e \sin(\Pi - \beta_j) + c_j \cos(\Pi - \beta_j)] \qquad (29)$$

or

$$x_{Poj} = f - e \sin \beta_j + c_j \cos \beta_j \qquad (29a)$$

$$y_{Poj} = c_j \sin(\Pi - \beta_j) - e \cos(\Pi - \beta_j) \qquad (30)$$

or

$$y_{Poj} = c_j \sin \beta_j + e \cos \beta_j \qquad (30a)$$

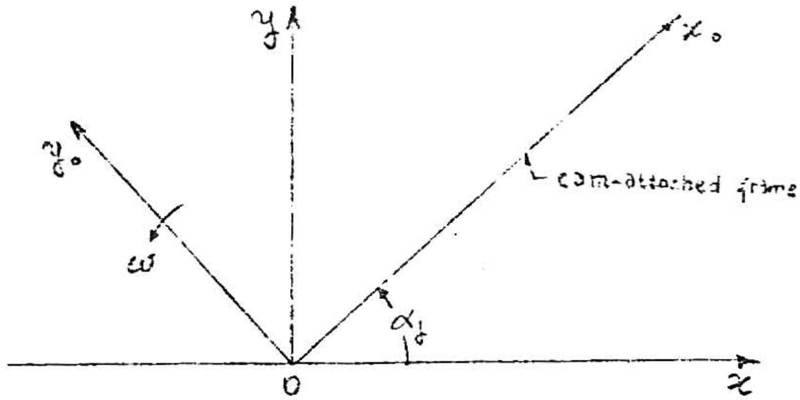

Figure 9. Coordinate transformation

Co-ordinates of, (P'), contact point with respect to a stationary reference frame (xy) can be obtained with the following transformation, as Fig. 9 indicates.

$$x_{Pj} = x_{Poj} \cos \alpha_j - y_{Poj} \sin \alpha_j \tag{31}$$

$$y_{Pj} = x_{Poj} \sin \alpha_j + y_{Poj} \cos \alpha_j \tag{32}$$

c) CAMROL Subroutine

Plotting of the cam profile requires determination of the co-ordinates of points on the cam curve. It will be assumed to be a polygon of finitely many sides formed by the connection of successive points. Increments of angle of cam rotation determine the spacing of successive points.

For clockwise rotation of cam, the geometry of the inverted cam mechanism considered is as shown in Fig. 10.

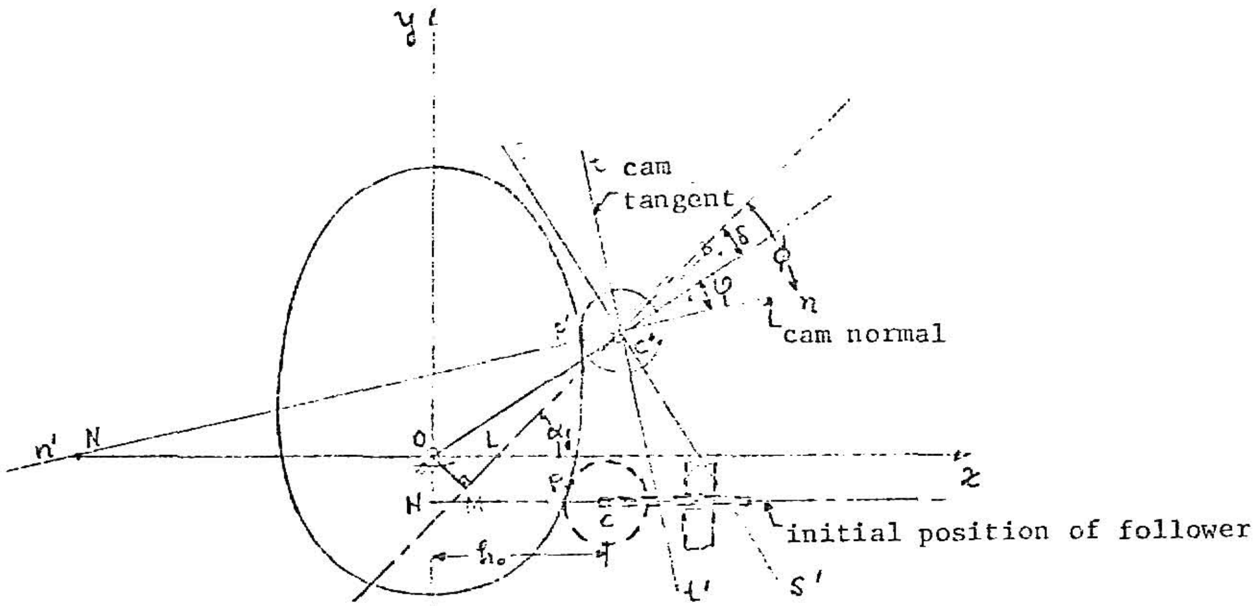

Figure 10. Cam-translating-roller follower.

Contact point, roller and cam centers are designated by P', C' and O, respectively, at some angle of cam rotation (α_j). Initially, P' and C' are P and C. OM is the perpendicular distance from the center of cam rotation to the line of follower motion. M is at H for zero angle of cam rotation. L is the point of intersection of line of follower motion with the line parallel to centerline of follower in the starting configuration and through cam center. nn' and tt' are normal and parallel at C' to cam surface tangent at P'. ss' is drawn perpendicular to radial line (OC') at roller center. Normal to cam cuts x-axis at point N. The origin of the xy co-ordinate system is at center of cam rotation with x-axis parallel to the initial centerline of follower.

The following parameters can be defined, in relation to Fig. 10.

$C'P' = CP = r$, Roller radius

$OH = OM = e$, Amount of offset of centerline of follower from cam center (O).

$HC = h_o$, Shortest distance between roller and cam centers in the direction of follower motion.

$MC' = h_j$, Measurement of roller center (C) from cam center on the centerline of follower.

$OC' = r_j$, Radial distance from a point on pitch curve (C') to center of rotation.

$<C'Lx = \alpha_j$, Cam rotation angle.

$<OC'M = \delta$, Angle radial line (OC') makes with line of follower motion.

$<n'C'O = <s'C't' = \psi$, Angle between cam normal (nn') and radial line (OC').

$<NC'M = \phi$, Inclination of cam normal with respect to direction of follower motion, cam pressure angle.

$<C'Ox = \beta$, Angle radial line makes with positive x-axis.

The lengths and angles are related to each other to get analytical forms of the cam and pitch curves.

Distance from follower roller center to point M in terms of follower displacement is, $h_j = h_o + h(\alpha_j)$ (1)

where $h(\alpha_j)$ is the specified displacement of follower at α_j.

From $\Delta OC'M$ (Fig. 10), $\qquad \tan \delta = \frac{e}{h_j} \quad$ or $\quad \delta = \tan^{-1} \frac{e}{h_j}$ (2)

By $\Delta OC'L$, $\qquad <C'Lx = <LOC' + <OC'L$ (3)

or $\qquad \beta = \alpha_j - \delta$ (3a)

In $\Delta OC'M$, $\qquad <OM'C = 90^o$, $\qquad$ and $\quad r_j = (e^2 + h_j^2)^{1/2}$ (4)

Co-ordinates of roller center (C'):

From Fig. 10.,

$$\left. \begin{aligned} x_{Cj} &= r_j \cos \beta_j \\ y_{Cj} &= r_j \sin \beta_j \end{aligned} \right\} \qquad (5)$$

To obtain a relation between the direction of tangent of cam curve and the radial distance (r_j) with respect to the rotation of cam, Fig. 11, in which R,S are points on cam curve, T is a point such that $OT = r_j$, is drawn.

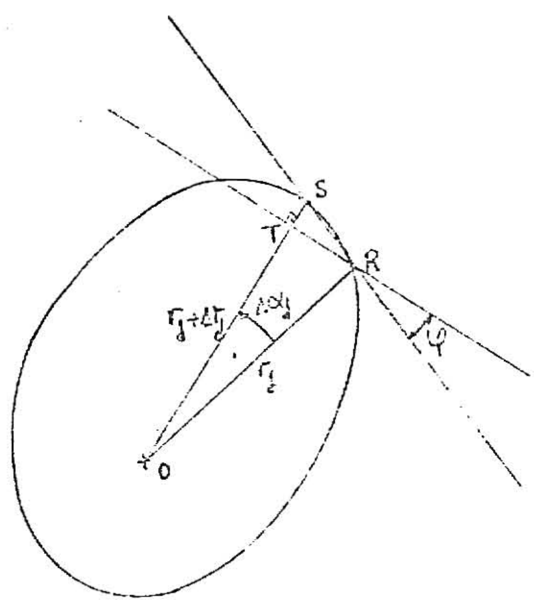

Figure 11. Cam tangent.

In figure, $OR = OT = r_j$, $<ROS = \Delta\alpha_j$, change in angle to arrive at S from R on curve. $OS = r_j + \Delta r_j$, hence $TS = \Delta r_j$, change in radial distance from R to S.

$RT = r_j \Delta\alpha_j$, arc length between T and R.

From ΔRTS, $\tan <SRT \cong \frac{TS}{RT}$ or $\tan\psi \cong \frac{\Delta r_j}{r_j \Delta\alpha_j}$ (6)

where $<RTS \cong 90^o$,

As $\Delta\alpha_j \to 0$, $<RTS \to 90^o$,

Hence,

$$\lim_{\Delta\alpha_j \to 0} \tan\psi = \lim_{\Delta\alpha_j \to 0} \frac{\Delta r_j}{r_j \Delta\alpha_j}$$

$$\text{or} \quad \tan\psi = \frac{1}{r_j} \times \frac{dr_j}{d\alpha_j} \tag{6a}$$

Differentiating equation (4) with respect to α_j gives:

$$\frac{dr_j}{d\alpha_j} = \frac{1}{2}\, 2h_j \frac{dh_j}{d\alpha_j} (e^2 + h_j^2)^{-1/2} \tag{7}$$

Letting $\frac{dh_j}{d\alpha_j} = \ell_j$, (7) becomes:

$$\frac{dr_j}{d\alpha_j} = \frac{h_j \ell_j}{r_j} \tag{7a}$$

Substituting into (6a) yields, $\tan\psi = \frac{h_j \ell_j}{r_j^2}$ (8)

By definition, ϕ is pressure angle and is expressed by:

$$\phi = \delta + \psi \tag{9}$$

By $\Delta NC'L$, $<C'Lx = <LC'N + <C'NL$ (10)

or $<C'NL = \alpha_j - \phi$ (10a)

Hence, the difference between the co-ordinates of roller center (C') and contact point (P') will be,

$$\left.\begin{aligned} d_x &= x_{Cj} - x_{Pj} = r\cos(\alpha_j - \phi) \\ d_y &= y_{Cj} - y_{Pj} = r\sin(\alpha_j - \phi) \end{aligned}\right\} \tag{11}$$

Co-ordinates of the cam profile point (P'):

$$\left.\begin{aligned} x_{Pj} &= x_{Cj} - d_x \\ y_{Pj} &= y_{Cj} - d_y \end{aligned}\right\} \tag{12}$$

d) CAMFLT Subroutine

This subroutine, based on a kinematic inversion, formulates the co-ordinates on the cam profile and on the follower necessary to identify the mechanism.

Geometry of the inverted mechanism at some angle of rotation of cam (α_j) is shown in Figure 12. Cam rotation is assumed to be clockwise, in this configuration.

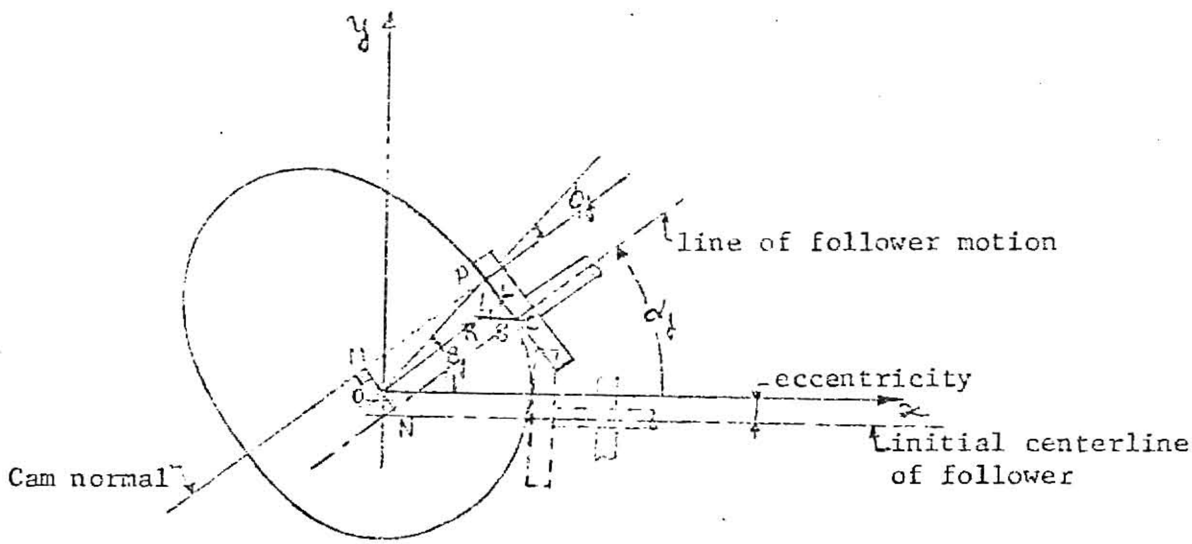

Figure 12. Cam-flat-faced translating follower.

On the figure, O,P,C are cam pivot, contact point between follower and cam surface and center of flat-faced follower, respectively. N is the point where the line of movement is tangent to the circle with radius equal to the eccentricity. The intersection of a line normal to cam surface at P with a line through cam center, perpendicular to the line of movement of follower defines point M. A line parallel to the direction of motion passing through cam pivot cuts the flat-face at L. Projections of L and P on the line through center of follower (C) and parallel to the initial centerline of follower are called S and R, respectively.

Identification of angles and lengths in the figure are:

$OL = MP = h_j$, Distance from flat-face of follower to cam center.

$OM = \ell_j$, Distance between cam center (O) and the point of intersection of cam surface normal with a line through O perpendicular to the line of follower motion.

$OP = d_j$, Radial distance between contact point and center of rotation.

$PC = a_j$, Length between contact point (P) and flat-face center.

$ON = LC = e$, Offset of centerline of follower from the center of cam.

$\angle LOx = \alpha_j$, Angle of cam rotation

$\angle MPO = \phi_j$, Angle between radial line (OP) and cam surface normal.

$\angle POx = \beta_j$, Angle between centerline of follower in the starting position and radial line (OP).

A x-y co-ordinate system with origin at the center of cam and x-axis parallel to initial line of action of follower is assumed.

Noting that $\ell_j = \dfrac{dh_j}{d\alpha_j}$,

From ΔOMP, $\tan \phi_j = \dfrac{OM}{PM} = \dfrac{\ell_j}{h_j}$ or $\phi_j = \tan^{-1} \dfrac{\ell_j}{h_j}$ (1)

$$<POX = <POL + <LOx \qquad (2)$$

or $$\beta_j = \alpha_j + \phi_j \qquad (2a)$$

In ΔPMO, $<PMO = 90^o$ and $OP^2 = PM^2 + MO^2$

or $$d_j = (\ell_j^2 + h_j^2)^{1/2} \qquad (3)$$

Co-ordinates of contact point, P:

From figure $$x_{Pj} = d_j \cos \beta_j \qquad (4)$$

$$y_{Pj} = d_j \sin \beta_j \qquad (5)$$

$<SLC = \alpha_j$, from ΔSLC, $<SCL = 90 - \alpha_j$

Co-ordinates of flat-face center, C:

$$x_{Cj} = h_j \cos \beta_j + e \cos \left(\frac{\Pi}{2} - \alpha_j\right)$$

or $$x_{Cj} = h_j \cos \beta_j + e \cos \left(\alpha_j - \frac{\Pi}{2}\right) \qquad (6)$$

$$y_{Cj} = h_j \sin \beta_j - e \sin \left(\frac{\Pi}{2} - \alpha_j\right)$$

or $$y_{Cj} = h_j \sin \beta_j + e \sin \left(\alpha_j - \frac{\Pi}{2}\right) \qquad (7)$$

By ΔPRC, $PC^2 = PR^2 + RC^2$

or $$a_j = [(x_{Pj} - x_{Cj})^2 + (y_{Pj} - y_{Cj})^2]^{1/2} \qquad (8)$$

Equations (4), (5) define points, which when joined successively, will produce an approximate cam profile.

The significance of the quantity a_j can be seen in drawing the follower.

Fig. 13 shows the inverted configuration of the cam mechanism at α_k angle of cam rotation, where it is assumed that contact point (P) is at its farthest position from the center of the follower.

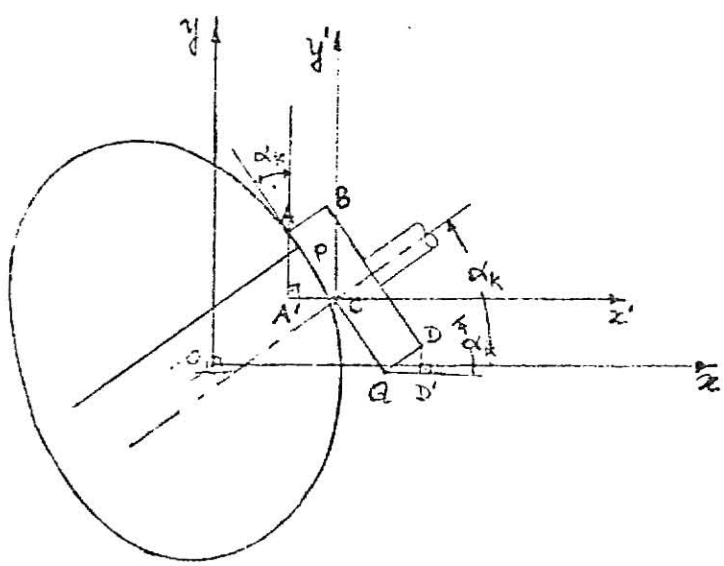

Figure 13. Follower drawing.

Define a x'-y' co-ordinate system with origin at the center of flat-face, whose position is known by equations (6), (7). Co-ordinates of A, B, D and Q can be set up, where these points are assumed to be located according to PA = AB = QD = 0.25 and AC = CQ.

Letting $\angle A'AC = \angle D'QD = \alpha_k$, $PC = a_k$

$QD' = d_x$, $DD' = d_y$

and $AA' = a_y$, $A'C = a_x$

From Fig. 13,

$$\left.\begin{aligned} d_x &= 0.25 \cos \alpha_k \\ d_y &= 0.25 \sin \alpha_k \end{aligned}\right\} \quad (9)$$

and

$$\left.\begin{aligned} a_x &= (a_k + 0.25) \sin \alpha_k \\ a_y &= (a_k + 0.25) \cos \alpha_k \end{aligned}\right\} \quad (10)$$

Then,

$$\left.\begin{aligned} x'_A &= -a_x \\ y'_A &= a_y \end{aligned}\right\} \quad (11)$$

$$\left.\begin{aligned} x'_B &= -a_x + d_x \\ y'_B &= a_y + d_y \end{aligned}\right\} \quad (12)$$

$$\left.\begin{aligned} x'_D &= a_x + d_x \\ y'_D &= -a_y + d_y \end{aligned}\right\} \quad (13)$$

$$\left.\begin{aligned} x'_Q &= a_x \\ y'_Q &= -a_y \end{aligned}\right\}$$

With co-ordinates determined, joining of successive points will form the rectangular shape representing the follower.

PRINCIPLES OF CIRCLE SUBROUTINE

The idea involved in this subroutine is to set up the equations necessary to find as many points as possible on the circular arc, which will be assumed to be made up of finite segments of straight lines. The beginning and end of the straight lines are separated by an incremental angle $\Delta\theta$. $\Delta\theta$ should be chosen such that the straight lines are to be short enough to make the curve almost smooth.

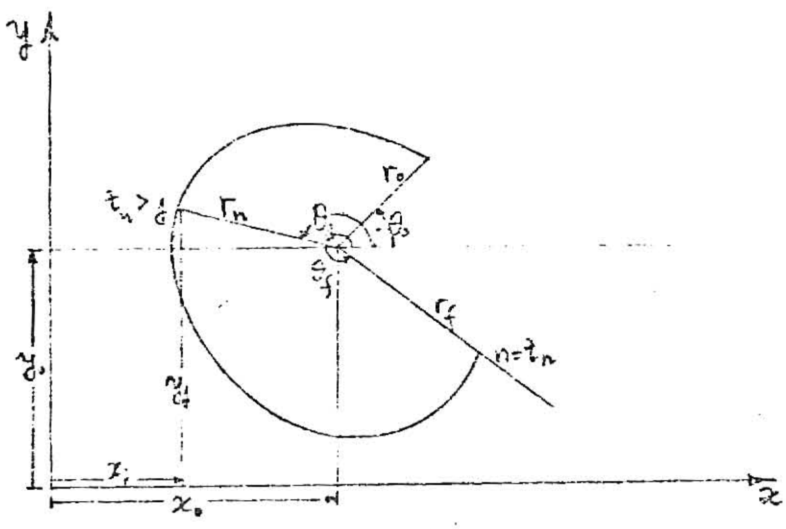

Figure 14. Curve arc.

On the assumption of a circumferential arc of 0.075 inch length, it can be written that

$$\frac{\Delta\theta(r_o + r_f)}{2} = 0.075 \quad \text{or,} \quad \Delta\theta = \frac{0.15}{r_o + r_f} \tag{1}$$

where r_o and r_f are the initial and final radii.

If the number of straight-line segments is t_n, starting angle is θ_o, and final angle is θ_f, then

$$t_n = \frac{\theta_f - \theta_o}{\Delta\theta} \tag{2}$$

Co-ordinates of starting point on the arc;

$$x_1 = x_o + r_o \cos \theta_o \tag{3}$$

$$y_1 = y_o + r_o \sin \theta_o \tag{4}$$

where co-ordinates of the center of curvature of the arc x_o, y_o are defined with respect to a x-y system.

Angle relation between successive points; $\theta_j = \theta_{j-1} + \Delta\theta$ (5)

Assuming linear variation of the radius of curve over the number of increments of angle (n), the radius at $(n\cdot\Delta\theta)$ angle measured from the starting angle (θ_o), denoted by r_n will be (Figure 15):

$$r_n = r_o + \frac{r_f - r_o}{t_n} \times n \qquad \text{for } 1 \leq n \leq t_n \tag{6}$$

Then, the co-ordinates of the point at the jth angle (θ_j) are written:

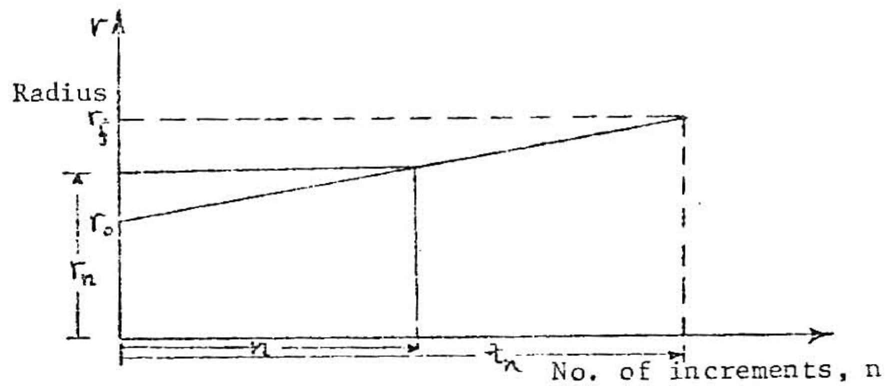

Figure 15. Variation of radius with no. of angles changes.

$$x_j = x_o + r_n \cos \theta_j \tag{7}$$

$$\theta_o \leq \theta_j \leq \theta_f$$

$$y_j = y_o + r_n \sin \theta_j \tag{8}$$

To draw the curve in dashed-line form, a two-way logical branch can be devised mathematically. If the spacing between two successive dashes corresponds to two increments of the angle (i.e. $2\Delta\theta$), then:

$$d_i = -(-1)^i \; d_{i-1} \tag{9}$$

$$e_i = e_o + d_i$$

where e,d are some numbers that are restrained to take only two values for all i = 1, ..., n, n being the number of increments of angle.

i.e. $d = -d_o$ and $d = + d_o$

$e = e_o - d_o$ and $e = e_o + d_o$,

assuming e_o and d_o are specified numbers.

If $\left.\begin{aligned} d &= -d_o \\ e &= e_o - d_o \end{aligned}\right\}$ is accepted to represent blank space at the

jth angle (θ_j), $\left.\begin{aligned} d &= +d_o \\ e &= e_o + d_o \end{aligned}\right\}$ will indicate the dashes

at the (j+2)nd angle ($\theta_j + 2\Delta\theta$).

FUNCTIONS OF SUBROUTINES[1]

a) CIRCLE subroutine

It is used to draw circular arc with differing radii.

CALL CIRCLE (C, B, THO, THF, RO, RF, DI, LC)

C, B   x and y coordinates of the center of curvature of arc, in decimal inches.

THO   Starting angle, in decimal degrees.

THF   Final angle, in decimal degrees.

RO   Initial radius of arc, in decimal inches.

RF   Final radius of arc, in decimal inches.

DI   Type of line

0.0 Solid line representation

0.5 Dashed line representation

LC   Center line indication

2   With centerline

3   Without centerline

b) PLOT subroutine

i) PLOT entry

It is used primarily to move the pen in a straight-line to a new position.

CALL PLOT (XPAGE, YPAGE, ± IPEN)

XPAGE, YPAGE   x,y coordinates, in inches, from the current reference point (origin), to the point to which the pen is to be moved.

---

[1]See Appendix C for Application

± IPEN Signed integer, which controls pen up/down status.

2 Pen down during movement, thus drawing a visible line.

3 Pen up during movement.

-2 Definition of new origin at the end of pen movement, with down status.

-3 New origin definition at the terminal of pen movement, with up status.

999 Last plotting call in the program, used once to close the output device.

ii) PLOTS entry

It is used once to initialize the PLOT Subroutine

CALL PLOTS (IBUF, NLOC)

IBUF Area of storage assigned to accumulate the plotter commands. Defined by a DIMENSION statement.

NLOC Number of locations reserved for IBUF. Integer value, identical with specification in DIMENSION.

iii) WHERE entry

It sets the three variables designated in the calling sequence to the pen's current position coordinates and the plot-sizing factor in the PLOT Subroutine.

CALL WHERE (RXPAGE, RYPAGE, RFACT)

RXPAGE, RYPAGE Variables that will be set to the pen's current position coordinates resulting from the previous call to PLOT subroutine.

RFACT Variable to be set to current plot-sizing factor.

c) SYMBOL Subroutine

It is used to draw titles, text with "standard call" and to draw special symbols with "special call". Hence:

i) "Standard call".

CALL SYMBOL (XPAGE, YPAGE, HEIGHT, IBCD, ANGLE, +NCHAR)

XPAGE, YPAGE	x,y co-ordinates, in inches, of the lower left-hand corner of the first character to be produced.
999.	Continuation in x and/or y co-ordinate of the previous symbol.
HEIGHT	Height, in inches, of character to be plotted.
IBCD	Text, title to be plotted, in H-field.
ANGLE	Angle, in degrees, from the x-axis at which symbol is to be plotted.
+NCHAR	Number of characters to be plotted from IBCD.

ii) "Special call"

CALL SYMBOL (XPAGE, YPAGE, HEIGHT, INTEQ, ANGLE, -ICODE)

XPAGE, YPAGE	x,y co-ordinates, in inches, of the geometric center of the figure to be plotted.
ANGLE	Angle in degrees, from the x axis at which figure is to be plotted.
HEIGHT	Height and width, in inches, of the centered symbol to be drawn.
INTEQ	Integer representing the specified symbol from the following sequence.

0 1 2 3 4 5 6 7 8 9 10 11 12 13

-ICODE (Negative) Pen's up/down status during the move to XPAGE, YPAGE

- -1 Pen up during movement
- -2 Pen down during movement

d) NUMBER Subroutine

It is used to plot a specified number in decimals.

CALL NUMBER (XPAGE, YPAGE, HEIGHT, FPN, ± NDEC)

XPAGE, YPAGE	x,y co-ordinates of the lower left-hand corner of the first character to be plotted.
HEIGHT	Height and width, in inches, of the characters in number.
FPN	Floating-point number, decimal (F-format)
ANGLE	Angle, in degrees, from the x-axis, at which number is to be plotted.
± NDEC	Precision of the number to be plotted.
0 < NDEC < 9	Number of digits to the right of the decimal point.
0	Integer portion of the number and decimal point to be plotted.
-1	Number's integer portion without decimal point to be plotted.
-1 > NDEC > -9	NDEC - 1 digits to be truncated from the integer portion of the number to be plotted.

e) AXIS Subroutine

It is used to draw axes in an indicated area.

CALL AXIS (XPAGE, YPAGE, IBCD, ±NCHAR, AXLEN, ANGLE, FIRSTV, DELTAV)

XPAGE, YPAGE x,y co-ordinates, in inches, of the axis line's starting point.

IBCD Title, which is centered and placed parallel to the axis, H-field.

±NCHAR Number of characters in the axis title.

+NCHAR for x-axis.

-NCHAR for y-axis.

AXLEN Length of the axis line, inches.

ANGLE Angle, in degrees, at which the axis is to be drawn.

0.0 for x-axis.

90.0 for y-axis.

FIRSTV Starting value, which will appear at the first tick mark on the axis.

DELTAV Number of data units per inch of axis.

f) ROSCAM Subroutine

It is used to draw pitch and cam curves of the cam mechanism with oscillating roller follower and the displacement diagram.

SUBROUTINE ROSCAM (FRAME, ARM, HH, ROLD)

FRAME Distance between cam center and follower pivot, decimal inches.

ARM The length of follower link from pivot to the roller center, decimal inches.

HH	The smallest radial distance between cam and roller centers, decimal inches.
ROLD	The radius of roller, decimal inches.

g) FOSCAM Subroutine

The subprogram produces a plot of the cam mechanism with oscillating flat-face follower and the displacement diagram.

SUBROUTINE FOSCAM (FRAME, ARM, BC)

FRAME	Distance between the pivot of follower and cam center, decimal inches.
ARM	The length of follower arm at initial position of cam, decimal inches.
BC	The radius of base circle of cam to be drawn, decimal inches.

h) CAMROL Subroutine

The function of this subprogram is to draw the profile of a radial cam with a translating roller follower.

SUBROUTINE CAMROL (HH, ROLD)

HH	Shortest distance measured along the center-line of follower between cam and roller centers, decimal inches.
ROLD	Radius of roller, decimal inches.

i) CAMFLT Subroutine

This subroutine is used to draw cam surface and the displacement diagram for cam-translating-flat-faced-follower system.

SUBROUTINE CAMFLT (AH)

AH Shortest distance between the flat-faced follower and the center of cam rotation, decimal inches.

USE OF CAM SUBROUTINES

In order to use the subroutines properly, the basic, common assumptions involved in writing them need to be known and input requirements[1] should be met accordingly.

Follower displacement versus cam angle diagram has been assumed to be of the general form shown in Fig. 16.

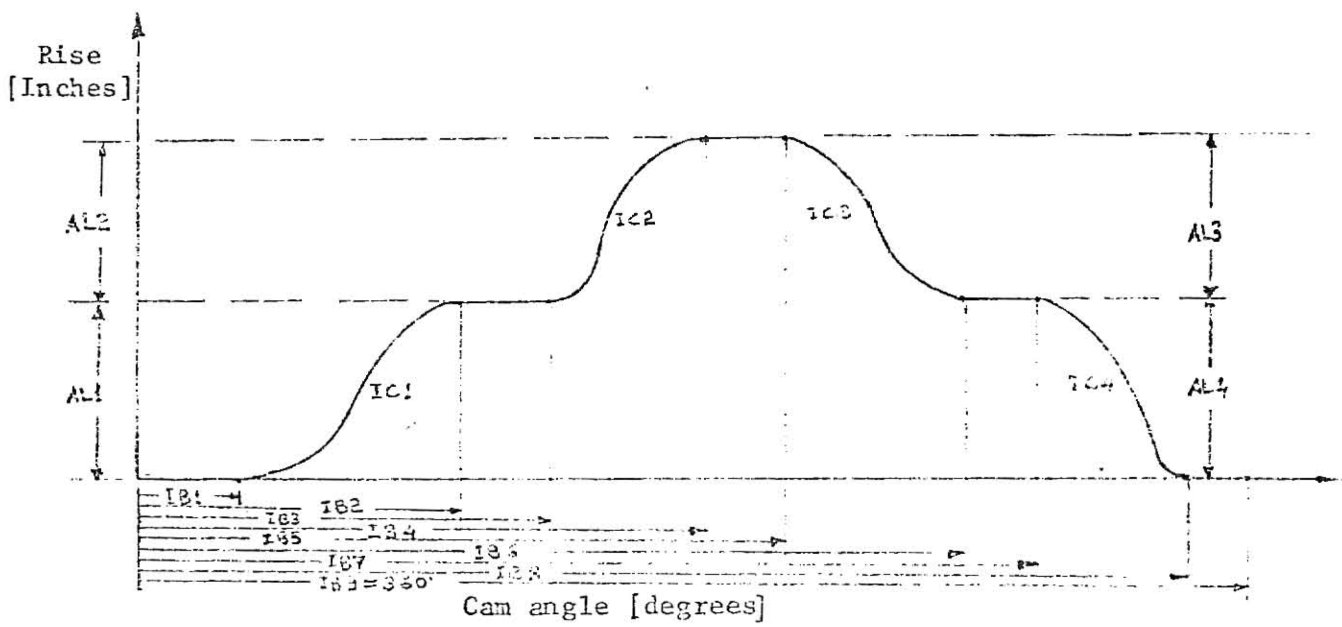

Figure 16. Displacement diagram.

AL1, AL2, AL3, AL4 show the respective rise and fall distances, in decimal inches.

IC1, IC2, IC3, IC4 represent the type of follower motion during the first and second rises, and first and second falls, respectively, as integral numbers.

---
[1] Examples are given in Appendix B.

1, Parabolic Motion

2, Cycloidal Motion

3, Simple Harmonic Motion

IB1, IB2, IB3, IB4, IB5, IB6, IB7, IB8, IB9 define, in degrees, the beginning and end of intervals of cam angle for changes in the state of follower displacement, as integers.

a) ROSCAM Subroutine[1]

1) Roscam subroutine should be accompanied by a main program[2] in order to initialize and to close the operation of plotting. The numerical assignment to the variables shown in the calling sequence of the subroutine are to be made through the main program, also.

2) Data cards needed for ROSCAM Subroutine and the related main program have, in turn:

i) FRAME, ARM, HH, ROLD, format 8F10.2[3]

ii) AL1, AL2, AL3, AL4, format 4F10.2

iii) ICL, IC2, IC3, IC4, format 4I10

iv) IB1, IB2, IB3, IB4, IB5, IB6, IB7, IB8, IB9, IPLOT, format 10I5, first 9 elements in degrees, last entry, either 11 or 30, designating the size of the plotting paper

For FRAME, ARM, HH, ROLD, Fig. 17 is referred to.

1,2) Print-outs are given in Appendix D.

3) Formats are discussed in Appendix A.

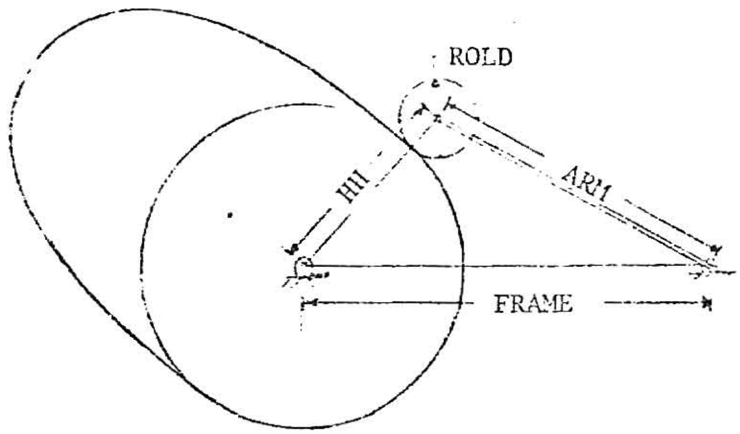

Figure 17. ROSCAM input variables.

b) FOSCAM Subroutine[1]

1) It is necessary to call the subroutine through a main program[2], which actuates and stops plotting.

2) Number of data cards required is one for the main program and four for the subroutine. They are, in order, as follows:

i) BC, EXC, ECT, format 4F10.2

ii) AL1, AL2, AL3, AL4, format 4F10.2

iii) IC1, IC2, IC3, IC4, format 4I10

iv) IB1, IB2, IB3, IB4, IB5, IB6, IB7, IB8, IB9, format 9I5

v) IPLOT, MCW, EC, ECC, format 2I10, 2F10.0

IPLOT, 11 or 30, standard plotting paper size.

[1,2]Print-outs are given in Appendix D.

MCW, 1 or 2, indicating clockwise or counterclockwise cam rotation.

For BC, EXC, ECT, EC, ECC refer to Fig. 18.

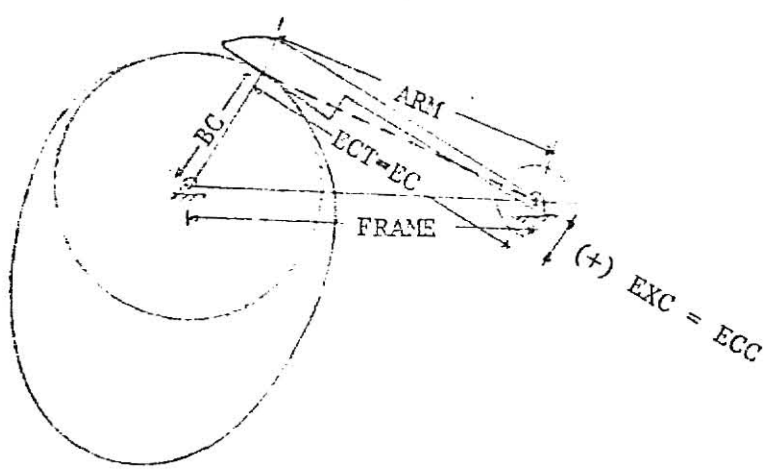

Figure 18. FOSCAM input variables.

c) CAMROL Subroutine[1]

1) The effect of CAMROL Subroutine is obtained by means of a main program[2], where variables in the calling sequence of the subroutine are to be assigned values.

[1,2]Print-outs appear in Appendix D.

2) 4 data cards are needed for CAMROL Subroutine, with the following order:

i) AL1, AL2, AL3, AL4, format 4F10.2

ii) IC1, IC2, IC3, IC4, format 4I10

iii) IB1, IB2, IB3, IB4, IB5, IB6, IB7, IB8, IB9, format 9I5

iv) IPLOT, MCW, ECC, format 2I10, F10.2

IPLOT, 11 or 30 depending on the plot-paper to be used.

MCW, 1 or 2 as to whether cam rotation is clockwise or counterclockwise.

ECC, can be assigned positive, zero and negative values.

Fig. 19 explains HH, ROLD, ECC, HH, ROLD appear on cards in main program.

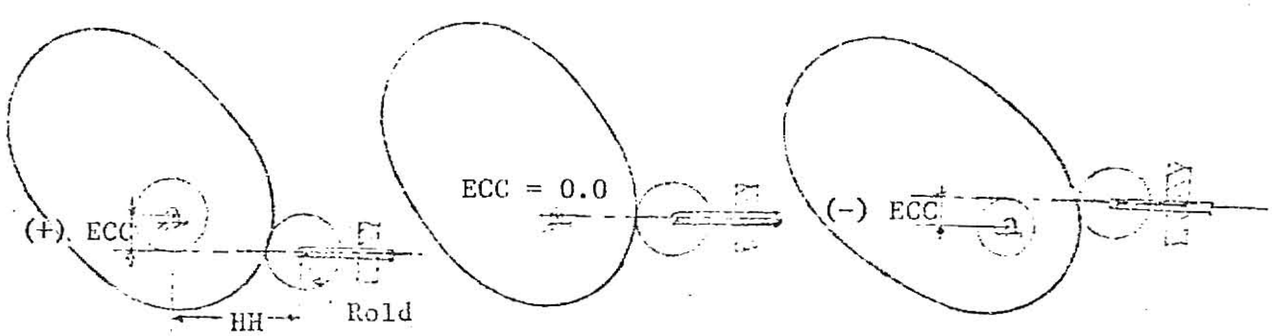

Figure 19. Sign of eccentricity (CAMROL).

d) CAMFLT Subroutine[1]

1) Subroutine CAMFLT should be used together with a main program[2] to get an output.

2) Four data card are required for CAMFLT Subroutine, in the following order.

i) AL1, AL2, AL3, AL4, format 4F10.2

ii) IC1, IC2, IC3, IC4, format 4I10

iii) IB1, IB2, IB3, IB4, IB5, IB6, IB7, IB8, IB9, format 9I5

iv) IPLOT, MCW, ECC, format 2I10, F10.2

IPLOT, Standard plotting paper size, 11 or 30.

MCW, direction of cam rotation; 1 for clockwise, 2 for counterclockwise.

Fig. 20 shows meanings of ECC and AH. ECC is a signed variable. AH is on a card in the main program.

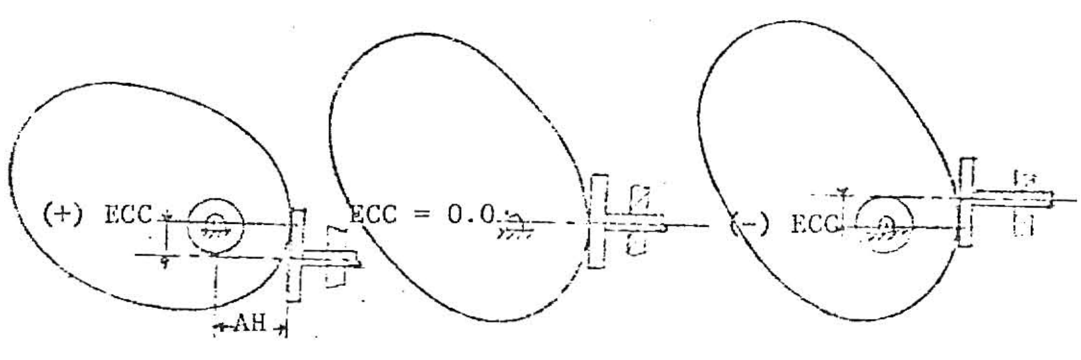

Figure 20. Sign of eccentricity (CAMFLT).

[1,2]Print-outs appear in Appendix D.

DATA AND RESULTS

A) ROSCAM Subroutine

1) 3 programs with different follower motion inputs have been run to produce the cam profiles sought.

Common data in the programs:

3.0, 6.0, 7.5, 0.5; 1st. data card.

0.0, 0.75, 0.75, 0.0; 2nd. data card.

0, 0, 0, 150, 250, 330, 360, 360, 360, 11; 4th. data card.

Differing inputs:

Cycloidal rise, simple harmonic fall

2, 2, 3, 3; 3rd. data card of the 1st program.

Parabolic rise, simple harmonic fall

1, 1, 3, 3; 3rd. data card of the 2nd program.

Parbolic rise and fall

1, 1, 1, 1; 3rd. data card of the 3rd program.

2) The following have been output[1]:

Follower displacement versus cam angle diagram and the corresponding cam profiles have been drawn.

Input parameters with calculated rise, fall and dwell intervals have been recorded. Direction of cam rotation has been indicated.

Co-ordinates of roller center and of roller-cam contact point have been tabulated for each degree of cam rotation.

The location and magnitude of maximum pressure angle have been shown.

---

[1]Print-outs are given in Appendix D.

B) FOSCAM Subroutine

1) The data;

2.0, 0.5, 4.0; 1st. card.

0.0, 0.75, 0.75, 0.0; 2nd. card.

2, 2, 3, 3; 3rd. card.

0, 0, 0, 150, 250, 330, 360, 360, 360; 4th. card.

11, 1, 4.0, 0.5; 5th. card.

2) The result[1] is the plot of the cam mechanism having cam and oscillating flat-faced follower, and also involves the print-out of the input parameters such as calculated rise, fall, dwell intervals, direction of cam rotation and the output parameters as tabulation of co-ordinates of points on cam profile and the minimum required length of follower.

C) CAMROL Subroutine

1) The data;

0.0, 0.75, 0.75, 0.0; 1st. data card.

2, 2, 3, 3; 2nd. data card.

0, 0, 0, 150, 250, 330, 360, 360, 360; 3rd. data card.

11, 2, 1; 4th. data card.

2) Outputs[2] of the program:

A plot of the cam mechanism having roller follower and the displacement diagram.

Input parameters and dwell, rise, fall intervals in degrees of cam rotation.

Sense of cam rotation.

[1,2] Print-outs appear in Appendix D.

Output parameters, co-ordinates of the contact point and those of the roller center at each degree of cam rotation, location and magnitude of maximum pressure angle.

D) CAMFLT Subroutine

1) Two programs have been run with the following input data:

Common data,

0,0, 0.75, 0.75, 0.0; 1st. card.

0, 0, 0, 150, 250, 330, 360, 360, 360; 3rd. card.

11, 2, +1.0; 4th. card.

Differing data,

2, 2, 3, 4; 2nd. data card of the 1st. program.

1, 1, 1, 1; 2nd. data card of the 2nd. program.

2) Results[1] obtained are:

Cam profile with follower at two positions, one in the starting configuration, the other at the position for which the distance between contact point and flat-face center is maximum, together with the displacement diagram, have been drawn.

Data have been recorded with additional rise, dwell and fall periods as calculated. Direction of cam rotation has been indicated.

Coordinates of the face center and of the contact point have been tabulated for each degree of cam rotation.

The maximum face length (diameter) and the angle of rotation at which it is needed have been determined.

---

[1]Print-outs appear in Appendix D.

MODIFICATIONS DONE ON THE ORIGINAL FORMS OF THE SUBROUTINES

There were three objectives in modifying the original forms of the subroutines:

1. To make the subroutines operable.

2. To increase the displacement and velocity characteristics of the cam follower involved in the subroutines.

3. To standardize the output.

In realizing the first objective, it was necessary to observe that mainly the CIRCLE Subroutine contributed to the cause of not being operable. The main subroutines depend on CIRCLE Subroutine. Thus, the theory of it had to be reviewed to provide necessary corrections for operation.

The second objective has been subject to cam theory. The study has led to the preparation of explicit equations for handling constant acceleration motion of the follower.

The third objective was a change of output instructions.

Specifically, changes made on each of the subroutines can be set down as follows:

CIRCLE Subroutine

Expression DI = ABS(DI) has been inserted to secure positive value to the loop of subroutine.

Card with statement,

DTH = 0.03/(RO+RF)/FCTR * 10000.0, has been replaced by the one with

DTH = 0.15/(RO+RF)/FCTR

to decrease the value of 'DTH' so as to provide more points on curve.

KNT = 7 has been changed to KNT = 2 to produce dashes and blanks on the curve for every two angle changes.

<u>ROSCAM Subroutine</u>

Statements for parabolic motion have been added.

Dwell, rise and fall periods have been rewritten to correct calculations.

<u>FOSCAM Subroutine</u>

The sequence of cards,

CALL NUMBER (0., -.3, .1, AEL, 0., 2)

CALL SYMBOL (.5, -.3, .1, 6HINCHES, 0., 6)

have been reversed to correct printing.

Parabolic motion expressions have been added.

To compensate the difference between FOSCAM and other subroutines, statements to cause the printing of data and calculated rise, fall and dwell periods, the output parameters, the co-ordinates of contact point as tabulated for each degree of cam rotation, minimum face length and its angle of occurance have been inserted.

<u>CAMROL Subroutine</u>

Parabolic motion has been introduced into the subroutine.

<u>CAMFLT Subroutine</u>

A card has been replaced to correct printings of cam rotation.

Card inserted: IF (MCW. NE .1) GO TO 510

Card deleted: IF (MCW. EQ. 1) GO TO 510

A second card was replaced to take care of incorrect output message with H-notation.

Inserted card: 507 FORMAT (1H 13HECCENTRICITY = ,F5.2/1X, 63HTHE SIZE OF THE PLOT PAPER IS SELECTED BY IDENTIFYING 'IPLOT' = ,I4)

Discarded one: 507 FORMAT (1H 13HECCENTRICITY = ,F5.2/62HTHE SIZE OF THE PLOT PAPER IS SELECTED BY IDENTIFYING 'IPLOT' = ,I4)

Statements involving parabolic motion have been introduced to the program.

Correct expressions of dwell, rise and fall periods have been placed in subroutine.

DISCUSSION

In this work, use of the CAL-comp plotter was illustrated by means of subroutine programs called ROSCAM, FOSCAM, CAMROL and CAMFLT. Efforts to understand the principles upon which the subroutines are based and hence the use of them lead to some observations of computer plotting.

Computer plotting may be considered important from the standpoint of both theory and application. Studying the effect of parameters forming the coefficients of equations that have no explicit form and that have higher orders, by curve construction on the computer plotter, can result in understanding and control over the physical phenomenon, which the involved equation formulates. As in ROSCAM, FOSCAM, CAMROL, CAMFLT outputs, the plots can carry design value, especially for applications that require a high degree of accuracy.

Practical importance of computer plotting can be specifically explained by comparing the two methods of drawing cam profile. Since the limiting speed of operation of many machines is set by cam design, accuracy is important, especially in high speed cam applications, where a small error in profile can cause variations of large accelerations. This degree of accuracy cannot be practically obtained by graphical layouts. Therefore, computer plotting for the profile becomes a must in such cases. However, when a high degree of accuracy is not required, the graphical method is quite satisfactory. The computer method is time-saving and more reliable, but may be more costly.

Some observations regarding the structures of subroutines, can be made. They have essentially three parts. In the first part, the type of follower motion is selected. In the second part, the coordinates of the cam curve are calculated. The last part contains format specifications necessary to identify the characteristics of the plot. This arrangement of programs gives the subroutines the flexibility to accept additions and changes in their structures. As a matter of fact, parabolic motion has been added because of this property. Similarly, other types of motion such as uniform, trapezoidal or polynomial motions can be added, conforming to the pattern and sequence of the programs. For applications, where jerk, maximum acceleration, or maximum velocity are of importance to design considerations, cam contours to meet these requirements can be constructed. To do this, the explicit expressions relating these quantities to other variables previously defined in the program need to be provided to the subroutines.

REFERENCES

1) H. Rothbart. "CAMS". John Wiley and Sons Inc., New York. 1956 pp. 21-45, 92-133.

2) "PROGRAMMING CALCOMP PEN PLOTTERS". California Products Inc. September 1969.

3) Fredric Stuart. "FORTRAN PROGRAMMING". New York. John Wiley & Sons Inc. 1969.

APPENDIX A

DESCRIPTION OF FORMATS.

a) F-notation: This is used to represent real numbers in computer units. The general form of a specification in F-format appears as: nFw.d,

where n denotes the number of repetitions of the same F-notation corresponding to each of the ordered variables in the input or output statements, w is the width of the field in which the number will be located, d is the number of digits to the right of the decimal point. When n doesn't appear in F specification, it is assumed to be 1.

e.g. If X1 = 6.25, X2=7.02, X3=12.35,

```
      READ(5, 100)   X1, X2, X3
or    WRITE(6, 100)  X1, X2, X3
100   FORMAT(F10.2, 2F10.4)
```

The relative locations of numbers can be shown as:

bbbbbb6.25bbbb7.02bbbbb12.35bb, where b's denote blanks,

5, 6 in READ, WRITE are the number of the computer units for a specific compiler.

b) I-notation: This is used to control the appearance of the integers in the input or output. Its general form is, nIw, where n shows the number of times the same format is used, w is the width of the field reserved for each number. Number is right adjusted in the field.

e.g. If I=1, J=15, K=7

```
     READ(5, 200) I, J, K or WRITE(6, 200) I, J, K
 200 FORMAT(2I5, I6)
```

Input or output would look: bbbb1bbb15bbbbb7.

Here, I, J, K(L, M, N included, as well) are used to represent integer quantities.

c) H-notation: This notation is used to transfer the characters from within the format statement to the output medium. It is of the general form,

nH

where n shows the number of characters (including blanks) to appear on the output, n is to be supplied necessarily, even if n = 1.

e.g. 13HINTEGERbVALUE

Special functions of H-notation:

1Hb, nH indicates that characters stated within the format will be on the same line as of the previously transferred characters. This is usually followed by 'nX' notation, which shows the number of blanks (n) to be passed before the message is printed.

1H0, nH forwards the printing paper one line before the characters are output.

APPENDIX B

EXAMPLES FOR DISPLACEMENT DIAGRAMS IN RELATION TO DATA:

1)

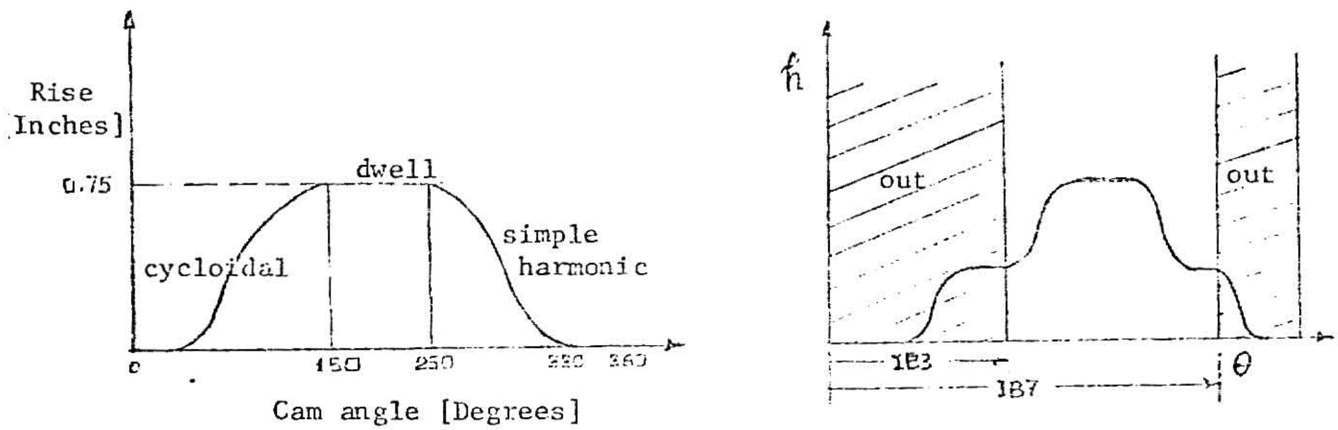

Figure 21. Displacement diagrams (1).

Comparison of the displacement diagram of the cam mechanism to be drawn with that inherent to the subroutines yields the data:

AL1 = 0.0	IC1 = 2	IB1 = IB2 = IB3 = 0
AL2 = 0.75	IC2 = 2	IB4 = 150
AL3 = 0.75	IC3 = 3	IB5 = 250
AL4 = 0.0	IC4 = 3	IB6 = 330
		IB7 = IB8 = IB9 = 360

Data cards would be:

1st card:	0.0	0.75	0.75	0.0	; Format 4F10.2
2nd card:	2	2	3	3	; Format 4I10

3rd card: 0 0 0 150 250 330 360 360 360; Format 9I5

2)

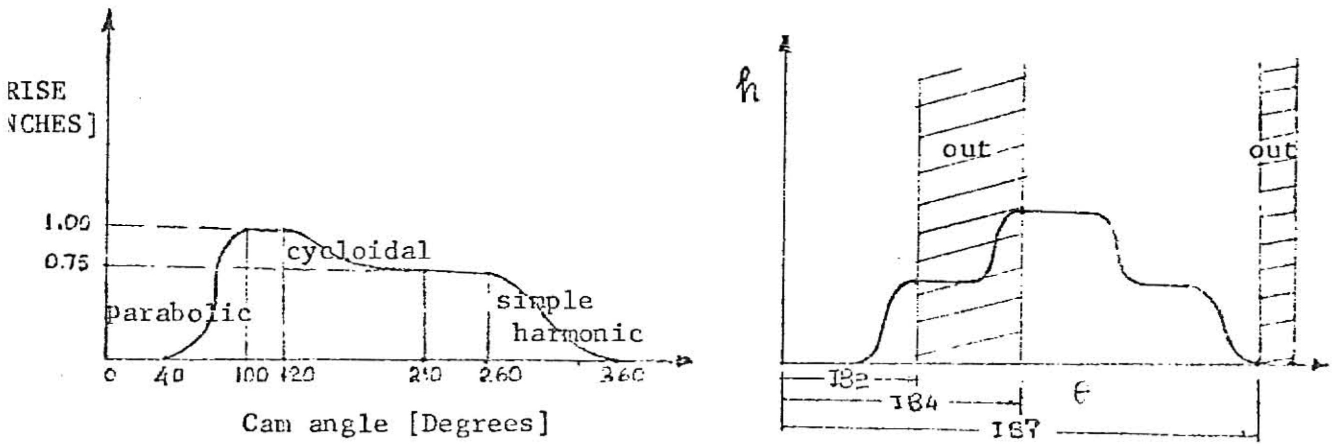

Figure 22. Displacement diagrams (2)

Comparison shows that data are to be:

AL1 = 1.0	IC1 = 1	IB1 = 40
AL2 = 0.0	IC2 = 1	IB2 = IB3 = IB4 = 100
AL3 = 0.25	IC3 = 2	IB5 = 120
AL4 = 0.75	IC4 = 3	IB6 = 210
		IB7 = 260
		IB8 = IB9 = 360

Then, data cards would read:

1st card:	1.0	0.0		0.25		0.75				; Format 4F10.2
2nd card:	1	1		2		3				; Format 4I10
3rd card:	40	100	100	100	120	210	260	360	360	; Format 9I5

APPENDIX C

NUMERICAL APPLICATIONS OF SUBROUTINE ENTRIES

a) CIRCLE Subroutine

CALL CIRCLE (0., 0., 0., 360., 1., 1., 0.0, 2)

The numbers in the calling sequence would indicate the drawing of a complete circle (in solid line) with center at the previously defined origin, radius equal to 1 inch and centerlines drawn.

b) PLOT SUBROUTINE

i) PLOT ENTRY

10 CALL PLOT (0.25, 0.5, 2)

11 CALL PLOT (0.5, 0.25, -2)

12 CALL PLOT (-0.25, -0.25, 3)

If: (0,0) = Origin, · = Terminal point of pen

— = Movement of pen with down-status.

---- = Movement of pen with up-status.

Results of calls:

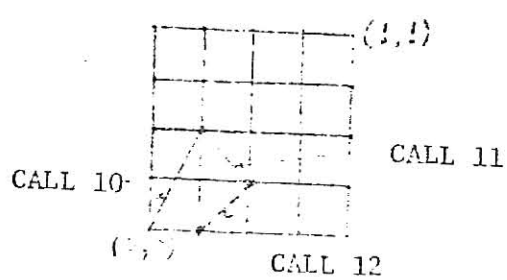

Figure 23. Effect of PLOT subroutine.

As shown, by CALL 10 pen is brought from (0, 0) to (0.25, 0.5) drawing a solid line; CALL 11 draws a solid line to and establishes a new origin at (0.5, 0.25) and pen is returned to a point on X-axis, (0.25, 0) with pen up-status by CALL 12.

ii) PLOTS Entry

```
DIMENSION WR(500)
CALL PLOTS (WR, 500)
```

Plot Subroutine is initialized and the plotting area with 500 locations is given the name WR.

iii) WHERE Entry

```
CALL PLOT (1., 0., -3)
```

New origin is defined at (1., 0.)

```
CALL WHERE (X, Y, FCTR)
```

X, Y are set to 1.0 and 0.0 respectively. If factor does not have an assigned value, it is assumed to be 1. If assigned, FCTR would then be set equal to the assigned value.

c) SYMBOL Subroutine

i) "Standard call"

```
CALL SYMBOL (0., 0., .1, 11HREAL NUMBER, 0., 11)
```

Result:

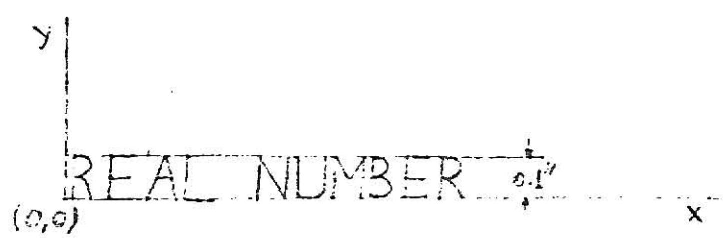

Figure 24. Effect of SYMBOL subroutine (1).

ii) "Special call"

CALL SYMBOL (1., 1., .2, 2, 0., -2)

Result:

Figure 25. Effect of SYMBOL Subroutine (2)

d) NUMBER Subroutine

CALL NUMBER (0., 0., .14, XN, 0)

If XN = 25.20, effect:

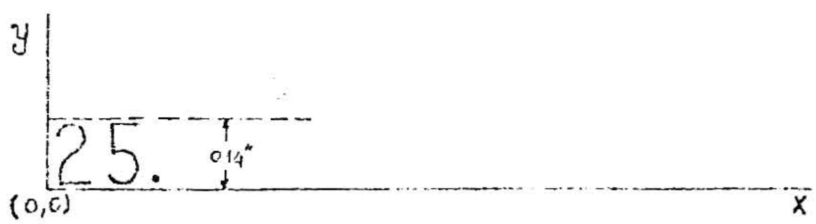

Figure 26. Effect of NUMBER Subroutine

e) AXIS Subroutine

CALL AXIS (0., 0., 8HTIME SEC, -8, 10., 0., 0., 2.)

CALL AXIS (0., 0., 7HRISE IN, 7, 4., 90., 0., 1.)

Result:

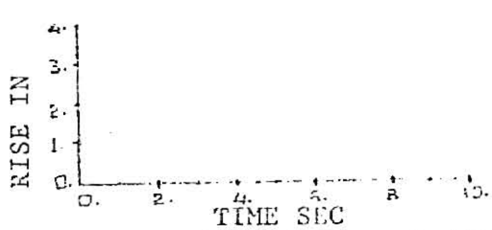

Figure 27. Effect of AXIS Subroutine

APPENDIX D

```
FORTRAN IV G LEVEL  21                MAIN                DATE = 74035          11/49/09            PAGE 0001

                 DIMENSION WP(2500)
                 CALL PLOTS (WP,2500)
                 READ(5,10)HH,ARM,FRAME,ROLD
              10 FORMAT(8F10.2)
                 CALL ROSCAM ( FRAME, ARM, HH, ROLD)
                 CALL PLOT (0., 0., 999)
                 STOP
                 END
```

```
FORTRAN IV G LEVEL  21                ROSCAM              DATE = 74035          11/49/09            PAGE 0001

                 SUBROUTINE ROSCAM(FRAME,ARM,HH,ROLD)
                 DIMENSION IRJ(361)
                 DIMENSION PATH(361),ANGLE(361),AL(361),PRANGL(361),XC(361),YC(361)
                 DIMENSION XP(361),YP(361),H(361),CX(361),CY(361)
                 READ(5,40) AL1,AL2,AL3,AL4
                 READ(5,41) IC1,IC2,IC3,IC4
                 READ(5,42) IB1,IB2,IB3,IB4,IB5,IB6,IB7,IB8,IB9,IPLOT
              40 FORMAT(4F10.2)
              41 FORMAT(4I10)
              42 FORMAT(10I5)
                 RAMAX=0.0
                 K=1
                 DO 110 J=1,361
                 I=J-1
                 A=I
                 AA=A*.01745
                 AB1=IB1
                 AB2=IB2
                 AB3=IB3
                 AB4=IB4
                 AB5=IB5
                 AB6=IB6
                 AB7=IB7
                 AB8=IB8
                 AB9=IB9
                 B1=AB1*.01745
                 B2=AB2*.01745
                 B3=AB3*.01745
                 B4=AB4*.01745
                 B5=AB5*.01745
                 B6=AB6*.01745
                 B7=AB7*.01745
                 B8=AB8*.01745
                 B9=AB9*.01745
                 IF(IB1-I) 1,1,2
               1 IF(IB2-I) 3,3,4
               3 IF(IB3-I) 6,6,7
               6 IF(IB4-I) 8,9,9
               8 IF(IB5-I) 11,11,12
              11 IF(IB6-I) 13,13,14
              13 IF(IB7-I) 16,16,17
              16 IF(IB8-I) 18,18,19
              18 GO TO 22
               2 RISE=0.0
                 AL(J)=0.0
                 GO TO 25
               4 IF(IC1.EQ.2) GO TO 5
                 IF (IC1.EQ.1) GO TO 50
                 RISE=AL1/2.*(1.-COS(3.1416*(AA-B1)/(B2-B1)))
                 AL(J)=AL1/2.*(3.1416/(B2-B1)*SIN(3.1416*(AA-B1)/(B2-B1)))
```

```
      C      HARMONIC UP
             GO TO 25
           5 RISE=AL1*((AA-B1)/(B2-B1)-1./6.2832*SIN(6.2832*(AA-B1)/(B2-B1)))
             AL(J)=AL1*(1./(B2-B1)-1./(B2-B1)*COS(6.2832*(AA-B1)/(B2-B1)))
             GO TO 25
          50 IF((IB2+IB1)/2-I) 51,51,52
          52 RISE=2.*AL1*((AA-B1)/(B2-B1))**2
             AL(J)=4.*AL1*(AA-B1)/((B2-B1)**2)
```

FORTRAN IV G LEVEL 21 RDSCAM DATE = 74035 11/49/09 PAGE 0002

```
      C      IST PARABOLIC UP
             GO TO 25
          51 RISE=AL1*(1.-2.*(1.-(AA-B1)/(B2-B1))**2)
             AL(J)=4.*AL1*(1./(B2-B1)-(AA-B1)/((B2-B1)**2))
      C      IIND PARABOLIC UP
             GO TO 25
           7 RISE=AL1
             AL(J)=0.0
             GO TO 25
           9 IF(IC2.EQ.2) GO TO 10
             IF (IC2.EQ.1) GO TO 53
             RISE=AL1+AL2/2.*(1.-COS(3.1416*(AA-B3)/(B4-B3)))
             AL(J)=AL2/2.*(3.1462/(B4-B3)*SIN(3.1416*(AA-B3)/(B4-B3)))
      C      HARMONIC UP
             GO TO 25
          10 RISE=AL1+AL2*((AA-B3)/(B4-B3)-1./6.2832*SIN(6.2832*(AA-B3)/(B4-B3)
            1))
             AL(J)=AL2*(1./(B4-B3)-1./(B4-B3)*COS(6.2832*(AA-B3)/(B4-B3)))
      C      CYCLOIDAL UP
             GO TO 25
          53 IF ((IB4+IB3)/2-I) 54,54,55
          55 RISE=AL1+2.*AL2*((AA-B3)/(B4-B3))**2
             AL(J)=4.*AL2*(AA-B3)/((B4-B3)**2)
      C      IST PARABOLIC UP
             GO TO 25
          54 RISE=AL1+AL2*(1.-2.*(1.-(AA-B3)/(B4-B3))**2)
             AL(J)=4.*AL2*(1./(B4-B3)-(AA-B3)/((B4-B3)**2))
      C      IIND PARABOLIC UP
             GO TO 25
          12 RISE=AL1+AL2
             AL(J)=0.0
             GO TO 25
          14 IF(IC3.EQ.2) GO TO 15
             IF (IC3.EQ.1) GO TO 56
             RISE=AL4+AL3/2.*(1.+COS(3.1416*(AA-B5)/(B6-B5)))
             AL(J)=AL3/2.*(-3.1416/(B6-B5)*SIN(3.1416*(AA-B5)/(B6-B5)))
      C      HARMONIC DOWN
             GO TO 25
          15 RISE=AL4+AL3*(1.-(AA-B5)/(B6-B5)+1./6.2832*SIN(6.2832*(AA-B5)/
            1(B6-B5)))
             AL(J)=AL3  *(-1./(B6-B5)+1./(B6-B5)*COS(6.2832*(AA-B5)/(B6-B5)))
      C      CYCLOIDAL DOWN
             GO TO 25
          56 IF((IB6+IB5)/2-I) 57,57,58
          58 RISE=AL4+AL3*(1.-2.*((AA-B5)/(B6-B5))**2)
             AL(J)=-4.*AL3*(AA-B5)/((B6-B5)**2)
      C      IST PARABOLIC DOWN
             GO TO 25
          57 RISE=AL4+2.*AL3*(1.-(AA-B5)/(B6-B5))**2
             AL(J)=4.*AL3*((AA-B5)/((B6-B5)**2)-1./(B6-B5))
```

```
      C     IIND PARABOLIC DOWN
            GO TO 25
         17 RISE=AL4
            AL(J)=0.0
            GO TO 25
         19 IF(IC4.EQ.2) GO TO 20
            IF (IC4.EQ.1) GO TO 59
            RISE=AL4/2.*(1.+COS(3.1416*(AA-B7)/(BB-B7)))
```

FORTRAN IV G LEVEL 21 ROSCAM DATE = 74035 11/49/09 PAGE 0003

```
            AL(J)=AL4/2.*(-3.1416/(BB-B7)*SIN(3.1416*(AA-B7)/(BB-B7)))
      C     HARMONIC DOWN
            GO TO 25
         20 RISE=AL4*(1.-(AA-B7)/(BB-B7)+1./6.2832*SIN(6.2832*(AA-B7)/
           1(BB-B7)))
            AL(J)=AL4   *(-1./(BB-B7)+1./(BB-B7)*COS(6.2832*(AA-B7)/(BB-B7)))
      C     CYCLOIDAL DOWN
            GO TO 25
         59 IF((BB+B7)/2-I) 60,60,61
         61 RISE=AL4*(1.-2.*((AA-B7)/(BB-B7))**2)
            AL(J)=-4.*AL4*(AA-B7)/((BB-B7)**2)
      C     IST PARABOLIC DOWN
            GO TO 25
         60 RISE=2.*AL4*(1.-(AA-B7)/(BB-B7))**2
            AL(J)=4.*AL4*((AA-B7)/((BB-B7)**2)-1./(BB-B7))
      C     IIND PARABOLIC DOWN
            GO TO 25
         22 RISE=0.0
            AL(J)=0.0
         21 CONTINUE
         25 H(J)=HH+RISE
            TAU(J)=I
            PRANGL(J)=ATAN(AL(J)/H(J))
            COSB=(H(J)*H(J)+FRAME*FRAME-ARM*ARM)/(2.*H(J)*FRAME)
            SINB=SQRT(1.-COSB*COSB)
            BETA=ATAN(SINB/COSB)
            IF(BETA.LT.0.0) BETA=-BETA
         27 XC(J)=H(J)*COS(AA+BETA)
            YC(J)=H(J)*SIN(AA+BETA)
            GAMMA=AA+BETA-PRANGL(J)
            XP(J)=XC(J)-ROLD*COS(GAMMA)
            YP(J)=YC(J)-ROLD*SIN(GAMMA)
            CX(J)=XC(J)-(ROLD+.01)*COS(GAMMA)
            CY(J)=YC(J)-(ROLD+.01)* SIN(GAMMA)
            IF(PAMAX.GE.ABS(PRANGL(J))) GO TO 26
            PAMAX=ABS(PRANGL(J))
            K=J
            GAM=GAMMA
            BET=BETA+AA
            PAM=PAMAX/.01745
         26 CONTINUE
        110 CONTINUE
            WRITE(6,122) PAM,K
        122 FORMAT(1H1,20HMAX.PRESSURE ANGLE =,F6.1,23H DEGREES AND OCCURS FOR
           1,I4,24H DEGREES OF CAM ROTATION)
            AB1=AB1*1./60.
            AB2=AB2*1./60.
            AB3=AB3*1./60.
            AB4=AB4*1./60.
            AB5=AB5*1./60.
```

```
0148          AB6=AB6*1./60.
0149          AB7=AB7*1./60.
0150          AB8=AB8*1./60.
0151          AB9=AB9*1./60.
0152          YAXIS=AL1+AL2
0153          ROLD=ROLD-.015
0154          DO 150 J=1,361
0155          I=J-1
```



```
0156          A=I
0157          PATH(J)=H(J)-HH
0158      150 ANGLE(J)=A*1./60.
0159          BCIRCL=HH-ROLD
0160          POX=(H(K)+3.*ROLD)*COS(BET)
0161          POY=(H(K)+3.*ROLD)*SIN(BET)
0162          BOX=(3.*ROLD)*COS(GAM)
0163          BOY=(3.*ROLD)*SIN(GAM)
0164          I2=IB2-IB1
0165          I3=IB3-IB2
0166          I4=IB4-IB3
0167          I5=IB5-IB4
0168          I6=IB6-IB5
0169          I7=IB7-IB6
0170          I8=IB8-IB7
0171          I9=IB9-IB8
0172          WRITE(6,500)
0173      500 FORMAT(1H1,36HRADIAL FOLLOWER WITH OSCILLATING ARM)
0174          WRITE(6,501)
0175      501 FORMAT(1H0,41HTHE FOLLOWING INPUT PARAMETERS ARE GIVEN.)
0176          WRITE(6,502) AL1,AL2
0177      502 FORMAT(1H ,19HFIRST CAM LIFT=AL1=,F6.2,10X,18HSEC. CAM LIFT=AL2=,
             1  F6.2)
0178          WRITE(6,503) AL3,AL4
0179      503 FORMAT(1H ,19HFIRST CAM FALL=AL3=,F6.2,10X,18HSEC. CAM FALL=AL4=,
             1  F6.2)
0180          WRITE(6,504) IB1,I2,I3,I4,I5,I6,I7,I8,I9
0181      504 FORMAT(1H ,'I ST. DWELL=',I5,2X,'DEGREES OF CAM ROTATION'/1H ,'I ST
             1T. RISE=',I5,2X,'DEGREES OF CAM ROTATION'/1H ,'II ND. DWELL=',I5,
             22X,'DEGREES OF CAM ROTATION'/1H ,'II ND. RISE=',I5,2X,'DEGREES OF
             3CAM ROTATION'/1H ,'3 RD.DWELL=',I5,2X,'DEGREES OF CAM ROTATION'/
             41H ,'I ST. FALL=',I5,2X,'DEGREES OF CAM ROTATION'/1H ,'4 TH.
             5DWELL=',I5,2X,'DEGREES OF CAM ROTATION'/1H ,'II ND. FALL=',I5,2X,
             6'DEGREES OF CAM ROTATION'/1H ,'5 TH.DWELL=',I5,2X,'DEGREES OF CAM
             7ROTATION')
0182          IF(IC1.EQ.3)  GO TO 550
0183          IF (IC1.EQ.1) GO TO 62
0184          WRITE(6,551)
0185      551 FORMAT(1H 20HFIRST RISE=CYCLOIDAL)
0186          GO TO 552
0187      550 WRITE(6,553)
0188      553 FORMAT(1H ,26HFIRST RISE=SIMPLE HARMONIC)
0189          GO TO 552
0190       62 WRITE (6,63)
0191       63 FORMAT (1H ,20HFIRST RISE=PARABOLIC)
0192      552 IF(IC2.EQ.3) GO TO 555
0193          IF (IC2.EQ.1) GO TO 64
0194          WRITE(6,554)
0195      554 FORMAT(1H+,30X,21HSECOND RISE=CYCLOIDAL)
0196          GO TO 556
```

```
  555 WRITE(6,557)
  557 FORMAT(1H+,30X,27HSECOND RISE=SIMPLE HARMONIC)
      GO TO 556
   64 WRITE (6,65)
   65 FORMAT (1H+,30X,21HSECOND RISE=PARABOLIC)
  556 IF (IC3.EQ.3) GO TO 560
      IF (IC3.EQ.1) GO TO 66
      WRITE(6,558)
```

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```
  558 FORMAT(1H ,20HFIRST FALL=CYCLOIDAL)
      GO TO 561
  560 WRITE(6,559)
  559 FORMAT(1H ,26HFIRST FALL=SIMPLE HARMONIC)
      GO TO 561
   66 WRITE (6,67)
   67 FORMAT (1H ,20HFIRST FALL=PARABOLIC)
  561 IF(IC4.EQ.3) GO TO 565
      IF (IC4.EQ.1) GO TO 68
      WRITE(6,562)
  562 FORMAT(1H+,30X,21HSECOND FALL=CYCLOIDAL)
      GO TO 564
  565 WRITE(6,563)
  563 FORMAT(1H+,30X,27HSECOND FALL=SIMPLE HARMONIC)
      GO TO 564
   68 WRITE (6,69)
   69 FORMAT (1H+,30X,21HSECOND FALL=PARABOLIC)
  564 CONTINUE
      WRITE(6,505)
  505 FORMAT(1H ,22HCLOCKWISE CAM ROTATION)
      WRITE(6,508)
  508 FORMAT(1H0,46HTHE FOLLOWING VALUES ARE THE OUTPUT PARAMETERS)
      WRITE(6,509) PAM,K
  509 FORMAT(1H ,24HTHE MAX. PRESSURE ANGLE=,F6.2,29H DEGREES AND WHICH
     1OCCURS FOR,I4,24H DEGREES OF CAM ROTATION)
      WRITE(6,512)
  512 FORMAT(1H ,80HTHE COORDINATES OF THE CONTACT POINT 'P' AND THE CEN
     1TER 'C' OF THE FOLLOWER ARE:)
      WRITE(6,515)
  515 FORMAT(1H ,65HINPUT ANGLE THETA     COORDINATES OF 'P'       COORD
     1INATES OF 'C')
      DO 513 J=1,361
  513 WRITE(6,514) IBJ(J),XP(J),YP(J),XC(J),YC(J)
  514 FORMAT(1H ,12X,I5,3X,2F10.4,5X,2F10.4)
      IF(IPLOT.EQ.1) GO TO 70
      CALLPLOT(15.,-30.,-3)
      CALLPLOT(0.,15.,-3)
      GO TO 71
   70 CALLPLOT(10.,-11.,-3)
      CALLPLOT(0.,5.5,-3)
   71 CONTINUE
      CALL CIRCLE(0.,0.,0.,360.,.25,.25,0.0,3)
      CALLCIRCLE(0.,0.,0.,360.,BCIRCL,BCIRCL,0.5,2)
      CALLPLOT(0.,0.,+3)
      CALLPLOT(FRAME,0.,-2)
      CALLCIRCLE(0.,0.,0.,360.,.2,.2,0.0,2)
      CALLCIRCLE(0.,0.,0.,360.,.1,.1,0.0,3)
      CALLPLOT(-FRAME,0.,-3)
      CALLPLOT(XC(1),YC(1),+2)
      CALLPLOT(FRAME,0.,+2)
```

```
      CALLPLOT(XC(1),YC(1),+3)
      CALLCIRCLE(XC(1),YC(1),0.,360.,.1,.1,0.0,3)
      CALLCIRCLE(XC(1),YC(1),0.,360.,ROLD,ROLD,0.0,3)
      CALLCIRCLE(XC(1),YC(1),0.,360.,RULD,RULD,0.0,3)
      CALLPLOT(XC(1),YC(1),+3)
      DO 28 J=1,361
   28 CALLPLOT(XC(J),YC(J),+2)
      CALLPLOT(XP(1),YP(1),+3)
```

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```
      DO 29 J=1,361
   29 CALLPLOT(XP(J),YP(J),+2)
      CALLPLOT(CX(1),CY(1),+3)
      DO 30 J=1,361
   30 CALLPLOT(CX(J),CY(J),+2)
      CALLPLOT(0.,0.,+3)
      CALLPLOT(ROX,ROY,+2)
      CALLPLOT(XP(K),YP(K),-3)
      CALLCIRCLE(0.,0.,0.,360.,.05,.05,0.0,3)
      CALLPLOT(0.,0.,-3)
      CALLPLOT(ROX,ROY,-2)
      CALLSYMBOL(.1,.1,.1,18HMAX.PRESSURE ANGLE,0.,18)
      CALLNUMBER(.1,-.2,.1,PAM,0.,-1)
      CALLSYMBOL(.40,-.2,.1,7HDEGREES,0.,7)
      CALLPLOT(-ROX,-ROY,-3)
      CALLPLOT(-XP(K),-YP(K),-3)
      CALLPLOT(XC(1),YC(1),+3)
      DO 170 J=11,351,10
  170 CALLCIRCLE(XC(J),YC(J),0.,360.,ROLD,ROLD,0.5,3)
      CALLSYMBOL(-1.5,-1.5,.1,18HCLOCKWISE ROTATION,0.,18)
      IF(IPLOT.EQ.11) GO TO 35
      CALLPLOT(10.,-30.,-3)
      GO TO 36
   35 CALLPLOT(10.,-11.,-3)
   36 CALLPLOT(0.,2.,-3)
      CALLSYMBOL(0.,-1.,.2,22HCLOCKWISE CAM ROTATION,0.,22)
      CALL AXIS(0.,0.,20HINPUT ANGLE. DEGREES,-20,6.,0.,0.,60.,10.)
      CALL AXIS(0.,0.,19HDISPLACEMENT INCHES,19,3.,   90.,0.,1.,10.)
      CALL PLOT(0.,0.,-3)
      DO 155 J=1,361
  155 CALL PLOT(ANGLE(J),PATH(J),+2)
      CALLPLOT(AB1,0.,+3)
      CALLPLOT(AB1,YAXIS,+2)
      CALLPLOT(AB2,YAXIS,+3)
      CALLPLOT(AB2,0.,+2)
      CALLPLOT(AB3,0.,+3)
      CALLPLOT(AB3,YAXIS,+2)
      CALLPLOT(AB4,YAXIS,+3)
      CALLPLOT(AB4,0.,+2)
      CALLPLOT(AB5,0.,+3)
      CALLPLOT(AB5,YAXIS,+2)
      CALLPLOT(AB6,YAXIS,+3)
      CALLPLOT(AB6,0.,+2)
      CALLPLOT(AB7,0.,+3)
      CALLPLOT(AB7,YAXIS,+2)
      CALLPLOT(AB8,YAXIS,+3)
      CALLPLOT(AB8,0.,+2)
      CALLPLOT(AB9,0.,+3)
      CALLPLOT(AB9,YAXIS,+2)
      RETURN
      END
```

```
      SUBROUTINECIRCLE (C,B,THO,THF,RO,RF,DI,LC)
      COMMONDA
      DIMENSIONDA(2500)
      IF (LC.EQ.2)GOTO301
      IF (LC.EQ.3)GOTO302
  301 CONTINUE
      CALLPLOT(C, B ,-3)
      CALLSYMBOL(.0,0.0,0.125,3,0.0,-1)                              CIS00090
      IF (RO.LE.RF) R=RF
      IF (RO.GL.RF) R= RO
      DO9K=1,4                                                       CIS00100
      IF(K.EQ.1)CALLPLOT(  +0.125,.0,3)                              CIS00110
      IF(K. EQ.1)CALLPLOT(  +0 .125+R,.0,2)                          CIS00120
      IF      ( K  .EQ. 2      ) CALLPLOT(  - .125     ,  0.0   ,3)CIS00130
      IF      (K   .EQ.2       ) CALLPLOT ( -.125-R    ,  0.0   ,2)CIS00140
      IF      (K   .EQ.     3  ) CALLPLOT (0.0         ,  +.125 ,3)CIS00150
      IF      (K   .EQ.   3    ) CALLPLOT(0.0,  +.125+R,          2)CIS00160
      IF      (K   .EQ.  4     ) CALLPLOT(0.0,  -0.125           ,3)CIS00170
      IF      (K   .EQ.  4     ) CALLPLOT(0.0 ,  -0.125-R        ,2)CIS00180
    9 CONTINUE                                                         CIS00190
      CALLPLOT(0.0,0.0,3)
      CALLPLOT(-C,-B,-3)
  302 CONTINUE
      DI=ABS(DI)
      KNT = 0
      CALLWHERE(DTH,DTH,FCTR)
      FCTR=ABS(FCTR)
  201 FORMAT(1X,2F50.25)                                               15
      WRITE(6,201)RO,RF
      DTH=(.15/(RO+RF))/FCTR
      WRITE(6,201)DTH,FCTR
      TO=THO/57.2958
      TF = THF / 57.2958
      WRITE(6,201)TO,TF                                                C19.5
      X = C + RO * COS(TO)
      WRITE(6,201)X
      TN = (TF - TO) / DTH                                             CIRC0120
      WRITE( 6,      201)C,TN
      IF (TF - TO) 102,10,104
  102 TN = ABS(TN)
      DTH = -DTH
      WRITE( 6,      201)TN,DTH
  104 Y = B + RO *  SIN(TO)                                            CIRC0160
      WRITE(6,201) Y
      N=TN+0.5
      WRITE( 6,      202)B,N
  202 FORMAT(1X,F50.25,I50)                                            CIRC30
      CALL PLOT (X,Y,3)
      DO 110  I = 1,N                                                  CIRC0180
      TO = TO + DTH                                                    CIRC0190
      SN = I
      PN = RO + (SN/TN) * (RF - RO)
      X = PN * COS(TO) + C
      Y = PN * SIN(TO) + B
      IF ( KNT ) 112,112,111                                           CIRC0240
  112 I2 = 2.5 + DI
      IF(I.LE.3)WRITE(6,203)I2
      KNT=2
      DI=-DI                                                           40    27
  111 KNT=KNT-1
      IF(I.LE.3)WRITE(6,203) I,KNT,DI,TO,SN,PN,X,Y                     CIRCLE42
  203 FORMAT(1X,2I15,6F15.6)                                           CIRC43
  110 CALL PLOT (X,Y,I2)                                               CIRC0290
   10 RETURN
      END
```

```
RADIAL FOLLOWER WITH OSCILLATING ARM

THE FOLLOWING INPUT PARAMETERS ARE GIVEN.
FIRST CAM LIFT=AL1=  0.0             SEC. CAM LIFT=AL2=  0.75
FIRST CAM FALL=AL3=  0.75            SEC. CAM FALL=AL4=  0.0
I ST. DWELL=    0  DEGREES OF CAM ROTATION
I ST. RISE=    0  DEGREES OF CAM ROTATION
II ND. DWELL=     0  DEGREES OF CAM ROTATION
II ND. RISE=  150  DEGREES OF CAM ROTATION
3 RD.DWELL=  100  DEGREES OF CAM ROTATION
I ST. FALL=   80  DEGREES OF CAM ROTATION
4 TH.        DWELL=   30  DEGREES OF CAM ROTATION
II ND. FALL=    0  DEGREES OF CAM ROTATION
5 TH.DWELL=    0  DEGREES OF CAM ROTATION
FIRST RISE=CYCLOIDAL              SECOND RISE=CYCLOIDAL
FIRST FALL=SIMPLE HARMONIC     SECOND FALL=SIMPLE HARMONIC
CLOCKWISE CAM ROTATION

THE FOLLOWING VALUES ARE THE OUTPUT PARAMETERS
THE MAX. PRESSURE ANGLE= 14.13 DEGREES AND WHICH OCCURS FOR 294 DEGREES OF CAM ROTATION
THE COORDINATES OF THE CONTACT POINT 'P' AND THE CENTER 'C' OF THE FOLLOWER ARE:
```

INPUT ANGLE THETA	COORDINATES OF 'P'		COORDINATES OF 'C'	
0	1.6250	1.8998	1.9550	2.2798
1	1.5916	1.9279	1.9097	2.3135
2	1.5576	1.9555	1.8693	2.3465
3	1.5231	1.9825	1.8280	2.3788
4	1.4880	2.0090	1.7863	2.4103
5	1.4525	2.0350	1.7440	2.4412
6	1.4164	2.0604	1.7012	2.4714
7	1.3799	2.0853	1.6578	2.5009
8	1.3428	2.1096	1.6140	2.5297
9	1.3052	2.1334	1.5697	2.5578
10	1.2673	2.1567	1.5249	2.5852
11	1.2289	2.1794	1.4797	2.6119
12	1.1900	2.2015	1.4340	2.6379
13	1.1507	2.2231	1.3878	2.6633
14	1.1109	2.2441	1.3413	2.6879
15	1.0707	2.2646	1.2943	2.7118
16	1.0301	2.2845	1.2469	2.7350
17	0.9891	2.3038	1.1991	2.7576
18	0.9477	2.3226	1.1509	2.7794
19	0.9060	2.3408	1.1023	2.8006
20	0.8639	2.3584	1.0533	2.8211
21	0.8212	2.3754	1.0041	2.8438
22	0.7783	2.3919	0.9543	2.8599
23	0.7351	2.4078	0.9042	2.8783
24	0.6914	2.4231	0.8538	2.8960
25	0.6475	2.4378	0.8030	2.9130
26	0.6032	2.4519	0.7519	2.9292
27	0.5585	2.4654	0.7005	2.9448
28	0.5136	2.4783	0.6487	2.9597
29	0.4683	2.4906	0.5966	2.9739

30	0.4227	2.5023	0.5442	2.9873
31	0.3769	2.5133	0.4914	3.0001
32	0.3307	2.5238	0.4384	3.0121
33	0.2842	2.5336	0.3850	3.0233
34	0.2375	2.5428	0.3313	3.0339
35	0.1905	2.5513	0.2774	3.0437
36	0.1432	2.5591	0.2231	3.0527
37	0.0957	2.5664	0.1686	3.0610
38	0.0480	2.5729	0.1138	3.0685
39	0.0000	2.5788	0.0588	3.0753
40	-0.0482	2.5840	0.0035	3.0813
41	-0.0966	2.5885	-0.0521	3.0865
42	-0.1452	2.5923	-0.1079	3.0909
43	-0.1940	2.5954	-0.1639	3.0944
44	-0.2430	2.5977	-0.2202	3.0972
45	-0.2922	2.5994	-0.2767	3.0991
46	-0.3415	2.6003	-0.3334	3.1002
47	-0.3909	2.6005	-0.3903	3.1005
48	-0.4405	2.5999	-0.4473	3.0999
49	-0.4902	2.5986	-0.5046	3.0984
50	-0.5401	2.5965	-0.5620	3.0960
51	-0.5900	2.5937	-0.6195	3.0928
52	-0.6400	2.5900	-0.6772	3.0886
53	-0.6900	2.5856	-0.7350	3.0835
54	-0.7402	2.5803	-0.7928	3.0775
55	-0.7903	2.5743	-0.8508	3.0706
56	-0.8405	2.5674	-0.9089	3.0627
57	-0.8907	2.5597	-0.9670	3.0539
58	-0.9408	2.5512	-1.0251	3.0440
59	-0.9910	2.5418	-1.0832	3.0332
60	-1.0410	2.5316	-1.1414	3.0214
61	-1.0911	2.5205	-1.1995	3.0086
62	-1.1410	2.5096	-1.2576	2.9948
63	-1.1908	2.4958	-1.3156	2.9800
64	-1.2406	2.4822	-1.3735	2.9642
65	-1.2891	2.4676	-1.4313	2.9473
66	-1.3396	2.4522	-1.4890	2.9293
67	-1.3888	2.4359	-1.5466	2.9103
68	-1.4378	2.4187	-1.6039	2.8903
69	-1.4867	2.4005	-1.6611	2.8692
70	-1.5353	2.3816	-1.7180	2.8470
71	-1.5836	2.3617	-1.7746	2.8237
72	-1.6316	2.3409	-1.8310	2.7994
73	-1.6793	2.3192	-1.8871	2.7740
74	-1.7268	2.2966	-1.9428	2.7475
75	-1.7738	2.2731	-1.9982	2.7199
76	-1.8235	2.2487	-2.0532	2.6912
77	-1.8668	2.2233	-2.1078	2.6614
78	-1.9127	2.1971	-2.1619	2.6376
79	-1.9581	2.1700	-2.2156	2.5996
80	-2.0031	2.1420	-2.2687	2.5656
81	-2.0476	2.1131	-2.3213	2.5315

82	-2.0916	2.0833	-2.3734	2.4963
83	-2.1350	2.0526	-2.4249	2.4601
84	-2.1780	2.0211	-2.4757	2.4227
85	-2.2203	1.9886	-2.5259	2.3844
86	-2.2620	1.9554	-2.5755	2.3449
87	-2.3032	1.9212	-2.6243	2.3045
88	-2.3437	1.8862	-2.6724	2.2630
89	-2.3835	1.8504	-2.7198	2.2205
90	-2.4226	1.8138	-2.7663	2.1769
91	-2.4611	1.7763	-2.8121	2.1324
92	-2.4988	1.7380	-2.8570	2.0869
93	-2.5357	1.6990	-2.9010	2.0404
94	-2.5719	1.6591	-2.9441	1.9930
95	-2.6074	1.6185	-2.9863	1.9447
96	-2.6420	1.5772	-3.0276	1.8954
97	-2.6758	1.5351	-3.0679	1.8452
98	-2.7087	1.4922	-3.1072	1.7942
99	-2.7408	1.4487	-3.1455	1.7423
100	-2.7720	1.4045	-3.1827	1.6896
101	-2.8023	1.3596	-3.2189	1.6360
102	-2.8316	1.3140	-3.2540	1.5816
103	-2.8601	1.2678	-3.2879	1.5265
104	-2.8876	1.2210	-3.3208	1.4707
105	-2.9142	1.1735	-3.3525	1.4141
106	-2.9397	1.1255	-3.3830	1.3568
107	-2.9643	1.0770	-3.4124	1.2988
108	-2.9879	1.0278	-3.4405	1.2402
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113	-3.0903	0.7749	-3.5628	0.9386
114	-3.1077	0.7229	-3.5834	0.8767
115	-3.1239	0.6706	-3.6028	0.8144
116	-3.1391	0.6179	-3.6209	0.7516
117	-3.1532	0.5648	-3.6377	0.6885
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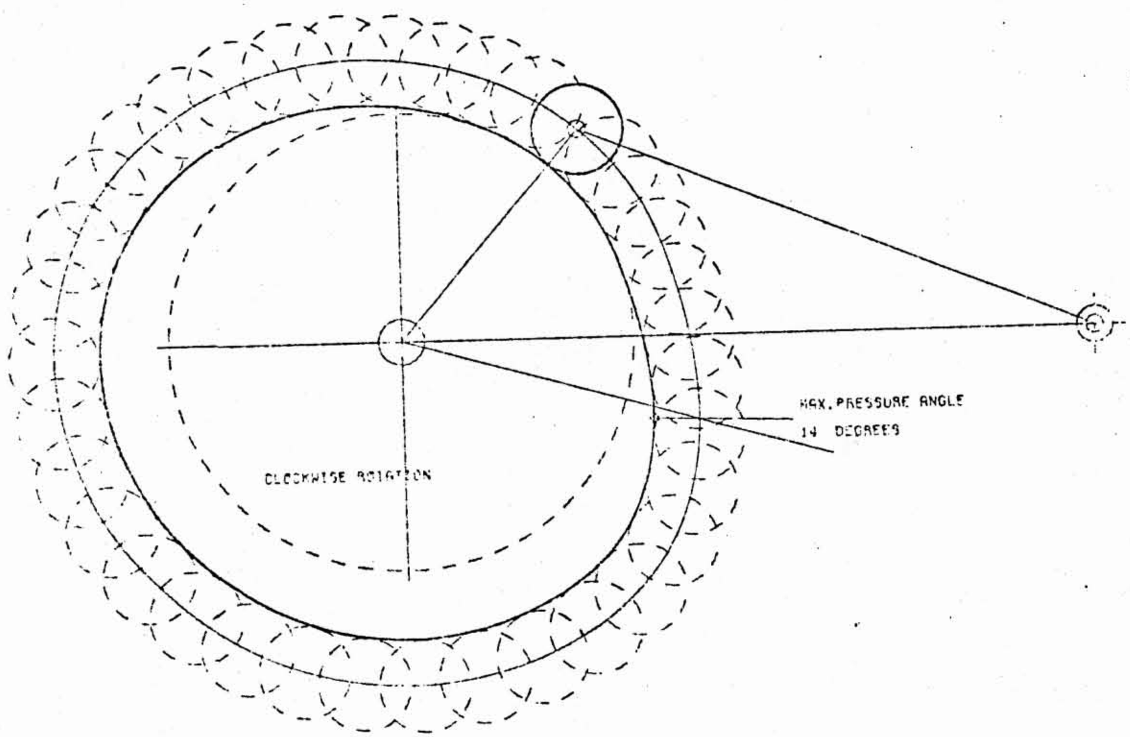
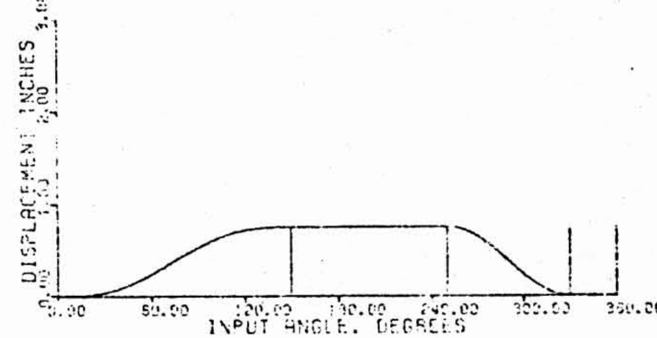
```

```
2        0   -0.500000    0.300000    2.000000    0.500000    3.091458    1.620204
2
3        1    0.500000    0.450000    3.000000    0.500000    3.064013    1.689927
      0.5000000000000000000000000             0.5000000000000000000000000
      0.1499999761581421000000000             1.0000000000000000000000000
      0.0                                     6.2831830978393560000000000
      2.8184576034545900000000000
      2.3184576034545900000000000            41.8878936767578100000000000
      1.9038772583007810000000000
      1.9038772583007810000000000                                  42
3
1        1   -0.500000    0.150000    1.000000    0.500000    2.812842    1.978596
2        0   -0.500000    0.300000    2.000000    0.500000    2.796125    2.051637
2
3        1    0.500000    0.450000    3.000000    0.500000    2.768681    2.121360
```





CLOCKWISE CAM ROTATION

```
FORTRAN IV G LEVEL  21                MAIN              DATE = 74035          22/16/16              PAGE 0001

              DIMENSION WR(2500)
              CALL PLOTS (WR,2500)
              READ(5,40)BC,EXC,ECT
           40 FORMAT(4F10.2)
              ARM=SQRT(EXC*EXC +ECT*ECT)
              BET=ATAN(EXC/ECT)
              GAM=BET + 1.5708
              FRAME=SQRT(BC*BC+ARM*ARM - 2.*ARM*BC*COS(GAM))
              CALL FOSCAM(FRAME,ARM,BC)
              CALL PLOT(0.,0.,999)
              STOP
              END
```

```
FORTRAN IV G LEVEL  21                FOSCAM            DATE = 74035          22/16/16              PAGE 0001

              SUBROUTINE FOSCAM(FRAME,ARM,BC)
              DIMENSION OC(361),TOE(361),TEA(361),SIGMA(361),BETA(361)
              DIMENSION ANGLE(361),PATH(361)
              DIMENSION AL(361),EL(361)
              DIMENSION XP(361),YP(361)
              DIMENSION IBJ(361)
              READ(5,40) AL1,AL2,AL3,AL4
              READ(5,41) IC1,IC2,IC3,IC4
              READ(5,42) IB1,IB2,IB3,IB4,IB5,IB6,IB7,IB8,IB9
              READ(5,43) IPLOT,MCW,EC,ECC
           40 FORMAT(4F10.2)
           41 FORMAT(4I10)
           42 FORMAT(9I5)
           43 FORMAT(2I10,2F10.0)
              AEL=0.
              K=1
              G=FRAME*FRAME-ARM*ARM
              PHE=ATAN(ECC/BC)
              DO 110 J=1,361
              I=J-1
              A=I
              AA=A*.01745
              AB1=IB1
              AB2=IB2
              AB3=IB3
              AB4=IB4
              AB5=IB5
              AB6=IB6
              AB7=IB7
              AB8=IB8
              AB9=IB9
              B1=AB1*.01745
              B2=AB2*.01745
              B3=AB3*.01745
              B4=AB4*.01745
              B5=AB5*.01745
              B6=AB6*.01745
              B7=AB7*.01745
              B8=AB8*.01745
              B9=AB9*.01745
              IF(IB1-I)1,1,2
            1 IF(IB2-I) 3,3,4
            3 IF(IB3-I) 6,6,7
            6 IF(IB4-I) 8,8,9
            8 IF(IB5-I) 11,11,12
           11 IF(IB6-I) 13,13,14
           13 IF(IB7-I) 16,16,17
           16 IF(IB8-I) 18,18,19
           19 GO TO 22
            2 RISE=0.0
```

```
              AL(J)=0.0
              GO TO 25
            4 IF(IC1.EQ.2) GO TO 5
              IF (IC1.EQ.1) GO TO 250
              RISE=AL1/2.*(1.-COS(3.1416*(AA-B1)/(B2-B1)))
              AL(J)=AL1/2.*(3.1416/(B2-B1)*SIN(3.1416*(AA-B1)/(B2-B1)))
              GO TO 25
            5 RISE=AL1*((AA-B1)/(B2-B1)-1./6.2832*SIN(6.2832*(AA-B1)/(B2-B1)))
```

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```
              AL(J)=AL1*(1./(B2-B1)-1./(B2-B1)*COS(6.2832*(AA-B1)/(B2-B1)))
              GO TO 25
          25. IF ((B2+B1)/2-I) 251,251,252
          252 RISE=2.*AL1*((AA-B1)/(B2-B1))**2
              AL(J)=4.*AL1*(AA-B1)/((B2-B1)**2)
        C     IST PARABOLIC UP
              GO TO 25
          251 RISE=AL1*(1.-2.*(1.-(AA-B1)/(B2-B1))**2)
              AL(J)=4.*AL1*(1./(B2-B1)-(AA-B1)/((B2-B1)**2))
        C     IIND PARABOLIC UP
              GO TO 25
            7 RISE=AL1
              AL(J)=0.0
              GO TO 25
            9 IF(IC2.EQ.2) GO TO 10
              IF (IC2.EQ.1) GO TO 253
              RISE=AL1+AL2/2.*(1.-COS(3.1416*(AA-B3)/(B4-B3)))
              AL(J)=AL2/2.*(3.1462/(B4-B3)*SIN(3.1416*(AA-B3)/(B4-B3)))
              GO TO 25
           10 RISE=AL1+AL2*((AA-B3)/(B4-B3)-1./6.2832*SIN(6.2832*(AA-B3)/(B4-B3)
             1))
              AL(J)=AL2*(1./(B4-B3)-1./(B4-B3)*COS(6.2832*(AA-B3)/(B4-B3)))
              GO TO 25
          253 IF((B4+B3)/2-I) 254,254,255
          255 RISE=AL1+2.*AL2*((AA-B3)/(B4-B3))**2
              AL(J)=4.*AL2*(AA-B3)/((B4-B3)**2)
        C     IST PARABOLIC UP
              GO TO 25
          254 RISE=AL1+AL2*(1.-2.*(1.-(AA-B3)/(B4-B3))**2)
              AL(J)=4.*AL2*(1./(B4-B3)-(AA-B3)/((B4-B3)**2))
        C     IIND PARABOLIC UP
              GO TO 25
           12 RISE=AL1+AL2
              AL(J)=0.0
              GO TO 25
           14 IF(IC3.EQ.2) GO TO 15
              IF (IC3.EQ.1) GO TO 256
              RISE=AL4+AL3/2.*(1.+COS(3.1416*(AA-B5)/(B6-B5)))
              AL(J)=AL3/2.*(-3.1416/(B6-B5)*SIN(3.1416*(AA-B5)/(B6-B5)))
              GO TO 25
           15 RISE=AL4+AL3*(1.-(AA-B5)/(B6-B5)+1./6.2832*SIN(6.2832*(AA-B5)/
             1(B6-B5)))
              AL(J)=AL3  *(-1./(B6-B5)+1./(B6-B5)*COS(6.2832*(AA-B5)/(B6-B5)))
              GO TO 25
          256 IF(((B6+B5)/2-I) 257,257,258
          258 RISE=AL4+AL3*(1.-2.*((AA-B5)/(B6-B5))**2)
              AL(J)=-4.*AL3*(AA-B5)/((B6-B5)**2)
        C     IST PARABOLIC DOWN
              GO TO 25
          257 RISE=AL4+2.*AL3*(1.-(AA-B5)/(B6-B5))**2
```

```
      AL(J)=4.*AL3*((AA-B5)/((B6-B5)**2)-1./(B6-B5))
C     IIND PARABOLIC DOWN
      GO TO 25
   17 RISE=AL4
      AL(J)=0.0
      GO TO 25
   19 IF(IC4.EQ.2) GO TO 20
      IF (IC4.EQ.1) GO TO 259
```



```
      RISE=AL4/2.*(1.+COS(3.1416*(AA-B7)/(B8-B7)))
      AL(J)=AL4/2.*(-3.1416/(B8-B7)*SIN(3.1416*(AA-B7)/(B8-B7)))
      GO TO 25
   20 RISE=AL4*(1.-(AA-B7)/(B8-B7)+1./6.2832*SIN(6.2832*(AA-B7)/
     1(B8-B7)))
      AL(J)=AL4  *(-1./(B8-B7)+1./(B8-B7)*COS(6.2832*(AA-B7)/(B8-B7)))
      GO TO 25
  259 IF ((IB8+IB7)/2-I) 260,260,261
  261 RISE=AL4*(1.-2.*((AA-B7)/(B8-B7))**2)
      AL(J)=-4.*AL4*(AA-B7)/((B8-B7)**2)
C     IST PARABOLIC DOWN
      GO TO 25
  260 RISE=2.*AL4*(1.-(AA-B7)/(B8-B7))**2
      AL(J)=4.*AL4*((AA-B7)/((B8-B7)**2)-1./(B8-B7))
C     IIND PARABOLIC DOWN
      GO TO 25
   22 RISE=0.0
      AL(J)=0.0
   21 CONTINUE
   25 OC(J)=RC+RISE
      IBJ(J)=I
      ANGLE(J)=A/60.
      PATH(J)=RISE
      AU=2.*OC(J)*FRAME
      BU=OC(J)**2+G
      CTOE=BU/AU
      STOE= SQRT(1.-CTOE*CTOE)
      TOE(J)=ATAN(STOE/CTOE)
      AV=2.*OC(J)*ARM
      BV=OC(J)**2-G
      CTEA=BV/AV
      STEA=SQRT(1.-CTEA*CTEA)
      TEA(J)=ATAN(STEA/CTEA)
      IF(TEA(J).LT.0.0) TEA(J)=3.1415+TEA(J)
      TEA(J)=TEA(J) - PHE
      SIGMA(J)=3.1415-TOE(J)-TEA(J)
      BETA(J)=3.1415-SIGMA(J)
      ONE=OC(J)**2*ARM**2
      ANE=OC(J)**2*FRAME**2
      TWO=4.*ONE-BV*BV
      TWA=4.*ANE-BU*BU
      THREE=SQRT(TWO)
      THRAA=SQRT(TWA)
      U=THREE/BV
      V=THRAA/BU
      DV=(BU*TWA**(-.5)*(2.*FRAME**2-G-OC(J)**2)-THRAA)*2.*OC(J)*AL(J)
     1     /(BU*BU)
      DU=(BV*TWO**(-.5)*(2.*ARM**2+G-OC(J)**2)-THREE)*2.*OC(J)*AL(J)
     1   /(BV*BV)
      DTEA=1./(1.+U*U)*DU
```

```
      DTOE=1./(1.+V*V)*DV
      DB=DTEA+DTOE
      FPTH=DB
      EL(J)=-FRAME*COS(BETA(J))/(1.+FPTH)
      BOB=BETA(J)/.01745
      XOLD =FRAME-ECC*SIN(BETA(J))+EL(J)*COS(BETA(J))
      YOLD = ECC*COS(BETA(J))+EL(J)*SIN(BETA(J))
      IF(AEL.GT.EL(J)) GO TO 60
```



```
      AEL=EL(J)
      K=J
      GAMA=AA/.01745
   60 CONTINUE
      IF(MCW.EQ.1) GO TO 200
      AA=-AA
  200 XP(J)=XOLD*COS(AA)-YOLD*SIN(AA)
      YP(J)=XOLD*SIN(AA)+YOLD*COS(AA)
   10 CONTINUE
      XE=-ECC*SIN(BETA(1))
      YE=ECC*COS(BETA(1))
      POX=FRAME+AEL*COS(BETA(1))+XE
      POY=AEL*SIN(BETA(1))+YE
      PAX=POX-XE
      PAY=POY-YE
      PBX=FRAME-XE
      PBY=-YE
      PEX=FRAME+XE
      PEY=YE
      CIRA=BETA(1)/.01745 + 90.
      CIRB=CIRA + 180.
      AB1=AB1*1./60.
      AB2=AB2*1./60.
      AB3=AB3*1./60.
      AB4=AB4*1./60.
      AB5=AB5*1./60.
      AB6=AB6*1./60.
      AB7=AB7*1./60.
      AB8=AB8*1./60.
      AB9=AB9*1./60.
      YAXIS=AL1+AL2
      I2=IB2-IB1
      I3=IB3-IB2
      I4=IB4-IB3
      I5=IB5-IB4
      I6=IB6-IB5
      I7=IB7-IB6
      I8=IB8-IB7
      I9=IB9-IB8
      WRITE(6,500)
  500 FORMAT (1H1,35HFLAT-FACED OSCILLATING CAM FOLLOWER)
      WRITE(6,501)
  501 FORMAT(1H0,41HTHE FOLLOWING INPUT PARAMETERS ARE GIVEN.)
      WRITE(6,502) AL1,AL2
  502 FORMAT(1H ,19HFIRST CAM LIFT=AL1=,F6.2,10X,18HSEC. CAM LIFT=A 2=,
     1 F6.2)
      WRITE(6,503) AL3,AL4
  503 FORMAT(1H ,19HFIRST CAM FALL=AL3=,F6.2,10X,18HSEC. CAM FALL=AL4=,
     1 F6.2)
      WRITE(6,504) IB1,I2,I3,I4,I5,I6,I7,I8,I9
```

```
      504 FORMAT(1H ,11H1 ST.DWELL=,I5,2X,7HDEGREES,8X,10H1 ST.RISE=,I5,2X,
         17HDEGREES/1H ,11H2 ND.DWELL=,I5,2X,7HDEGREES,8X,10H2 ND.RISE=,I5,
         22X,7HDEGREES/1H ,11H3 RD.DWELL=,I5,2X,7HDEGREES,8X,10H1 ST.FALL=,
         3I5,2X,7HDEGREES/1H ,11H4 TH.DWELL=,I5,2X,7HDEGREES,8X,10H2 ND.FALL
         4,I5,2X,7HDEGREES/1H ,11H5 TH.DWELL=,I5,2X,7HDEGREES)
          IF(IC1.EQ.3)  GO TO 550
          IF (IC1.EQ.1) GO TO 262
          WRITE(6,551)
```

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```
      551 FORMAT(1H 20HFIRST RISE=CYCLOIDAL)
          GO TO 552
      550 WRITE(6,553)
      553 FORMAT(1H ,26HFIRST RISE=SIMPLE HARMONIC)
          GO TO 552
      262 WRITE (6,263)
      263 FORMAT (1H ,20HFIRST RISE=PARABOLIC)
      552 IF(IC2.EQ.3) GO TO 555
          IF (IC2.EQ.1) GO TO 264
          WRITE(6,554)
      554 FORMAT(1H+,30X,21HSECOND RISE=CYCLOIDAL)
          GO TO 556
      555 WRITE(6,557)
      557 FORMAT(1H+,30X,27HSECOND RISE=SIMPLE HARMONIC)
          GO TO 556
      264 WRITE (6,265)
      265 FORMAT (1H+,30X,21HSECOND RISE=PARABOLIC)
      556 IF (IC3.EQ.3) GO TO 560
          IF (IC3.EQ.1) GO TO 266
          WRITE(6,558)
      558 FORMAT(1H ,20HFIRST FALL=CYCLOIDAL)
          GO TO 561
      560 WRITE(6,559)
      559 FORMAT(1H ,26HFIRST FALL=SIMPLE HARMONIC)
          GO TO 561
      266 WRITE (6,267)
      267 FORMAT (1H ,20HFIRST FALL=PARABOLIC)
      561 IF(IC4.EQ.3) GO TO 565
          IF (IC4.EQ.1) GO TO 268
          WRITE(6,562)
      562 FORMAT(1H+,30X,21HSECOND FALL=CYCLOIDAL)
          GO TO 564
      565 WRITE(6,563)
      563 FORMAT(1H+,30X,27HSECOND FALL=SIMPLE HARMONIC)
          GO TO 564
      268 WRITE (6,269)
      269 FORMAT (1H+,30X,21HSECOND FALL=PARABOLIC)
      564 CONTINUE
          IF(MCW.NE.1) GO TO 510
          WRITE(6,505) MCW
      505 FORMAT(1H ,41HCLOCKWISE CAM ROTATION IDENTIFIED BY MCW=,I2)
          GO TO 511
      510 WRITE(6,506) MCW
      506 FORMAT(1H ,49HCOUNTER CLOCKWISE CAM ROTATION IDENTIFIED BY MCW=,
         1 I2)
      511 WRITE(6,507) ECC,IPLOT
      507 FORMAT(1H 13HECCENTRICITY=,F5.2/1X,63HTHE SIZE OF THE PLOT PAPER I
         1S SELECTED BY IDENTIFYING 'IPLOT'= ,I4)
          WRITE(6,508)
      508 FORMAT(1H0,46HTHE FOLLOWING VALUES ARE THE OUTPUT PARAMETERS)
```

```
      WRITE (6,509) AEL,K
  509 FORMAT (1H ,24HTHE MINIMUM FACE LENGTH=,F10.2,6HINCHES,/1H ,16HWHI
     1CH OCCURS FOR,I4,23HDEGREES OF CAM ROTATION)
      WRITE(6,512)
  512 FORMAT (1H ,45HTHE COORDINATES OF THE CONTACT POINT 'P' ARE:)
      WRITE(6,515)
  515 FORMAT (1H ,40HINPUT ANGLE THETA     COORDINATES OF 'P')
      DO 513 J=1,360
```



```
  513 WRITE (6,514) IBJ(J),XP(J),YP(J)
  514 FORMAT (1H ,12X,I5,3X,2F10.4)
      IF(IPLOT.EQ.1) GO TO 70
      CALLPLOT(15.,-30.,-3)
      CALLPLOT(0.,15.,-3)
      GO TO 71
   70 CONTINUE
      CALLPLOT(10.,-11.,-3)
      CALLPLOT(0.,5.5,-3)
   71 CONTINUE
      CALLCIRCLE(0.,0.,0.,360.,BC,BC,0.5,3)
      CALLCIRCLE(0.,0.,0.,360.,.2,.2,0.0,2)
      CALLPLOT(0.,0.,-3)
      CALLPLOT(XP(1),YP(1),+2)
      CALLPLOT(FRAME,0.,+2)
      CALLPLOT(0.,0.,+2)
      CALLPLOT(PLX,PEY,+3)
      CALLPLOT(PGX,PDY,+2)
      CALLPLOT(PAX,PAY,+2)
      CALLPLOT(PBX,PBY,+2)
      CALLCIRCLE(FRAME,0.,CIRA,CIRB,ECC,ECC,0.0,2)
      CALLCIRCLE(FRAME,0.,0.,360.,.1,.1,0.0,3)
      CALLCIRCLE(FRAME,0.,0.,360.,.15,.15,0.0,2)
      CALLPLOT(XP(K),YP(K),+3)
      CALLCIRCLE(XP(K),YP(K),0.,360.,.05,.05,0.0,3)
      CALLPLOT(XP(1),YP(1),+3)
      DO 79 J=1,361
   79 CALLPLOT(XP(J),YP(J),+2)
      CALLPLOT(-1.,-.75,-3)
      IF(MCW.EQ.1) GO TO 220
      CALLSYMBOL(0.,0.,.1,20HC.CLOCKWISE ROTATION,0.,20)
      GO TO 221
  220 CONTINUE
      CALLSYMBOL(0.,0.,.1,18HCLOCKWISE ROTATION,0.,19)
  221 CONTINUE
      CALLSYMBOL(0.,-.15,.1,15HMIN.FACE LENGTH,0.,15)
      CALLNUMBER(0.,-.3,.1,AEL,0.,2)
      CALLSYMBOL(.7,-.3,.1,6HINCHES,0.,6)
      IF(IPLOT.EQ.1) GO TO 35
      CALLPLOT(10.,-30.,-3)
      CALLPLOT(0.,2.,-3)
      GO TO 36
   35 CONTINUE
      CALLPLOT(10.,-11.,-3)
      CALL PLOT(0.,2.,-3)
   36 CONTINUE
      IF(MCW.EQ.1) GO TO 230
      CALLSYMBOL(0.,-1.,.2,24HC.CLOCKWISE CAM ROTATION,0.,24)
      GO TO 231
  230 CONTINUE
```

```
      CALLSYMBOL(0.,-1.,.2,22HCLOCKWISE CAM ROTATION,0.,22)
  231 CONTINUE
      CALL AXIS(0.,0.,20HINPUT ANGLE, DEGREES,-20,6.,0.,0.,60.,10.)
      CALL AXIS(0.,0.,19HDISPLACEMENT INCHES,19,3.,  90.,0.,1.,10.)
      CALL PLOT(0.,0.,-3)
      DO 155 J=1,360
  155 CALL PLOT(ANGLE(J),PATH(J),+2)
      CALLPLOT(AB1,0.,+3)
```

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```
      CALLPLOT(AB1,YAXIS,+2)
      CALLPLOT(AB2,YAXIS,+3)
      CALLPLOT(AB2,0.,+2)
      CALLPLOT(AB3,YAXIS,+2)
      CALLPLOT(AB3,0.,+3)
      CALLPLOT(AB4,YAXIS,+3)
      CALLPLOT(AB4,0.,+2)
      CALLPLOT(AB5,0.,+3)
      CALLPLOT(AB5,YAXIS,+2)
      CALLPLOT(AB6,YAXIS,+3)
      CALLPLOT(AB6,0.,+2)
      CALLPLOT(AB7,0.,+3)
      CALLPLOT(AB7,YAXIS,+2)
      CALLPLOT(AB8,YAXIS,+3)
      CALLPLOT(AB8,0.,+2)
      CALLPLOT(AB9,0.,+3)
      CALLPLOT(AB9,YAXIS,+2)
      CALLPLOT(10.,-5.,-3)
      RETURN
      END
```

FLAT-FACED OSCILLATING CAM FOLLOWER

```
THE FOLLOWING INPUT PARAMETERS ARE GIVEN.
FIRST CAM LIFT=AL1=  0.0            SEC. CAM LIFT=A 2=  0.75
FIRST CAM FALL=AL3=  0.75           SEC. CAM FALL=AL4=  0.0
1 ST.DWELL=    0  DEGREES         1 ST.RISE=     0  DEGREES
2 ND.DWELL=    0  DEGREES         2 ND.RISE=   150  DEGREES
3 RD.DWELL=  10.  DEGREES         1 ST.FALL=    80  DEGREES
4 TH.DW-LL=   30  DEGREES         2 ND.FALL,     0  DEGREES
5 TH.DWELL=    0  DEGREES
FIRST RISE=CYCLOIDAL            SECOND RISE=CYCLOIDAL
FIRST FALL=SIMPLE HARMONIC      SECOND FALL=SIMPLE HARMONIC
CLOCKWISE CAM ROTATION IDENTIFIED BY MCW= 1
ECCENTRICITY= 0.50
THE SIZE OF THE PLOT PAPER IS SELECTED BY IDENTIFYING 'IPLOT'=   11

THE FOLLOWING VALUES ARE THE OUTPUT PARAMETERS
THE MINIMUM FACE LENGTH=       4.42INCHES
WHICH OCCURS FOR  64DEGREES OF CAM ROTATION
THE COORDINATES OF THE CONTACT POINT 'P' ARE:
```

INPUT ANGLE THETA	COORDINATES OF 'P'	
0	1.0604	1.6962
1	1.0374	1.7146
2	0.9997	1.7327
3	0.9682	1.7505
4	0.9364	1.7680
5	0.9031	1.7851
6	0.8695	1.8019
7	0.8351	1.8183
8	0.8000	1.8343
9	0.7643	1.8499
10	0.7279	1.8650
11	0.6908	1.8796
12	0.6531	1.8938
13	0.6147	1.9074
14	0.5757	1.9205
15	0.5361	1.9330
16	0.4959	1.9450
17	0.4551	1.9564
18	0.4138	1.9672
19	0.3719	1.9773
20	0.3296	1.9868
21	0.2868	1.9957
22	0.2435	2.0039
23	0.1997	2.0114
24	0.1556	2.0182
25	0.1111	2.0243
26	0.0662	2.0297
27	0.0210	2.0344
28	-0.0246	2.0383
29	-0.0704	2.0415
30	-0.1164	2.0439

31	-0.1626	2.0455
32	-0.2090	2.0464
33	-0.2556	2.0466
34	-0.3023	2.0460
35	-0.3491	2.0446
36	-0.3959	2.0424
37	-0.4427	2.0395
38	-0.4895	2.0358
39	-0.5362	2.0313
40	-0.5829	2.0261
41	-0.6294	2.0202
42	-0.6758	2.0135
43	-0.7220	2.0061
44	-0.7679	1.9980
45	-0.8136	1.9892
46	-0.8590	1.9796
47	-0.9041	1.9695
49	-0.9488	1.9586
49	-0.9931	1.9471
50	-1.0370	1.9350
51	-1.0805	1.9222
52	-1.1234	1.9089
53	-1.1659	1.8950
54	-1.2078	1.8806
55	-1.2492	1.8657
56	-1.2900	1.8502
57	-1.3302	1.8343
58	-1.3697	1.8179
59	-1.4086	1.8010
60	-1.4469	1.7833
61	-1.4844	1.7662
62	-1.5213	1.7482
63	-1.5574	1.7299
64	-1.5929	1.7112
65	-1.6276	1.6923
66	-1.6616	1.6731
67	-1.6949	1.6537
68	-1.7274	1.6340
69	-1.7592	1.6141
70	-1.7902	1.5940
71	-1.8205	1.5737
72	-1.8501	1.5533
73	-1.8789	1.5328
74	-1.9070	1.5121
75	-1.9344	1.4913
76	-1.9611	1.4704
77	-1.9871	1.4494
78	-2.0124	1.4283
79	-2.0371	1.4072
80	-2.0611	1.3860
81	-2.0844	1.3647
82	-2.1072	1.3433

83	-2.1292	1.3214
84	-2.1508	1.2999
85	-2.1717	1.2783
86	-2.1922	1.2567
87	-2.2120	1.2350
88	-2.2314	1.2132
89	-2.2503	1.1913
90	-2.2687	1.1693
91	-2.2866	1.1471
92	-2.3040	1.1249
93	-2.3211	1.1025
94	-2.3377	1.0799
95	-2.3539	1.0572
96	-2.3697	1.0343
97	-2.3851	1.0112
98	-2.4002	0.9879
99	-2.4149	0.9643
100	-2.4292	0.9405
101	-2.4432	0.9164
102	-2.4569	0.8921
103	-2.4702	0.8674
104	-2.4832	0.8424
105	-2.4958	0.8170
106	-2.5082	0.7913
107	-2.5202	0.7653
108	-2.5319	0.7388
109	-2.5433	0.7120
110	-2.5543	0.6847
111	-2.5650	0.6570
112	-2.5753	0.6288
113	-2.5853	0.6002
114	-2.5949	0.5711
115	-2.6042	0.5415
116	-2.6131	0.5114
117	-2.6215	0.4808
118	-2.6296	0.4498
119	-2.6373	0.4182
120	-2.6445	0.3860
121	-2.6512	0.3534
122	-2.6575	0.3202
123	-2.6634	0.2865
124	-2.6687	0.2522
125	-2.6735	0.2175
126	-2.6778	0.1822
127	-2.6815	0.1463
128	-2.6847	0.11[illegible]
129	-2.6873	0.0731
130	-2.6893	0.0357
131	-2.6906	-0.0022
132	-2.6914	-0.0406
133	-2.6914	-0.0795
134	-2.6908	-0.1189

135	-2.6895	-0.1587
136	-2.6875	-0.1990
137	-2.6848	-0.2397
138	-2.6813	-0.2809
139	-2.6771	-0.3225
140	-2.6720	-0.3644
141	-2.6662	-0.4068
142	-2.6596	-0.4495
143	-2.6522	-0.4925
144	-2.6439	-0.5359
145	-2.6348	-0.5796
146	-2.6248	-0.6235
147	-2.6140	-0.6677
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149	-2.5896	-0.7569
150	-2.5761	-0.8017
151	-2.5617	-0.8465
152	-2.5465	-0.8911
153	-2.5306	-0.9354
154	-2.5139	-0.9794
155	-2.4964	-1.0231
156	-2.4782	-1.0665
157	-2.4592	-1.1096
158	-2.4395	-1.1524
159	-2.4190	-1.1948
160	-2.3978	-1.2368
161	-2.3758	-1.2784
162	-2.3532	-1.3197
163	-2.3298	-1.3606
164	-2.3057	-1.4010
165	-2.2809	-1.4410
166	-2.2554	-1.4806
167	-2.2292	-1.5197
168	-2.2023	-1.5584
169	-2.1748	-1.5966
170	-2.1466	-1.6343
171	-2.1178	-1.6715
172	-2.0883	-1.7082
173	-2.0582	-1.7444
174	-2.0274	-1.7800
175	-1.9960	-1.8151
176	-1.9641	-1.8497
177	-1.9315	-1.8837
178	-1.8983	-1.9171
179	-1.8646	-1.9499
180	-1.8303	-1.9822
181	-1.7954	-2.0138
182	-1.7600	-2.0448
183	-1.7241	-2.0752
184	-1.6876	-2.1050
185	-1.6506	-2.1341
186	-1.6131	-2.1626

187	-1.5751	-2.1904
188	-1.5367	-2.2176
189	-1.4977	-2.2440
190	-1.4584	-2.2698
191	-1.4185	-2.2949
192	-1.3783	-2.3193
193	-1.3376	-2.3430
194	-1.2965	-2.3660
195	-1.2550	-2.3883
196	-1.2132	-2.4098
197	-1.1709	-2.4306
198	-1.1283	-2.4507
199	-1.0854	-2.4700
200	-1.0421	-2.4885
201	-0.9986	-2.5064
202	-0.9547	-2.5234
203	-0.9105	-2.5397
204	-0.8660	-2.5552
205	-0.8213	-2.5699
206	-0.7764	-2.5838
207	-0.7311	-2.5970
208	-0.6857	-2.6094
209	-0.6401	-2.6209
210	-0.5943	-2.6317
211	-0.5482	-2.6417
212	-0.5021	-2.6508
213	-0.4557	-2.6592
214	-0.4093	-2.6667
215	-0.3627	-2.6735
216	-0.3160	-2.6794
217	-0.2692	-2.6845
218	-0.2223	-2.6888
219	-0.1753	-2.6922
220	-0.1283	-2.6949
221	-0.0813	-2.6967
222	-0.0342	-2.6977
223	0.0129	-2.6979
224	0.0599	-2.6973
225	0.1070	-2.6958
226	0.1540	-2.6935
227	0.2010	-2.6905
228	0.2479	-2.6865
229	0.2947	-2.6818
230	0.3415	-2.6762
231	0.3881	-2.6699
232	0.4347	-2.6627
233	0.4811	-2.6547
234	0.5273	-2.6459
235	0.5734	-2.6363
236	0.6193	-2.6259
237	0.6650	-2.6147
238	0.7106	-2.6027

239	0.7559	-2.5899
240	0.8009	-2.5763
241	0.8458	-2.5619
242	0.8904	-2.5468
243	0.9347	-2.5309
244	0.9787	-2.5142
245	1.0224	-2.4967
246	1.0658	-2.4785
247	1.1089	-2.4595
248	1.1516	-2.4393
249	1.1940	-2.4193
250	1.2361	-2.3981
251	1.2528	-2.3893
252	1.2702	-2.3798
253	1.2981	-2.3695
254	1.3067	-2.3504
255	1.3257	-2.3466
256	1.3453	-2.3339
257	1.3654	-2.3204
258	1.3860	-2.3060
259	1.4070	-2.2907
260	1.4285	-2.2744
261	1.4503	-2.2573
262	1.4724	-2.2391
263	1.4949	-2.2200
264	1.5175	-2.2000
265	1.5405	-2.1789
266	1.5636	-2.1568
267	1.5868	-2.1337
268	1.6101	-2.1096
269	1.6335	-2.0844
270	1.6568	-2.0582
271	1.6801	-2.0310
272	1.7034	-2.0028
273	1.7265	-1.9735
274	1.7494	-1.9432
275	1.7721	-1.9119
276	1.7945	-1.8795
277	1.8167	-1.8463
278	1.8385	-1.8119
279	1.8599	-1.7766
280	1.8809	-1.7403
281	1.9015	-1.7030
282	1.9215	-1.6647
283	1.9410	-1.6255
284	1.9599	-1.5354
285	1.9784	-1.5446
286	1.9961	-1.5027
287	2.0131	-1.4599
288	2.0294	-1.4162
289	2.0449	-1.3716
290	2.0597	-1.3262

291	2.0736	-1.2800
292	2.0867	-1.2330
293	2.0992	-1.1852
294	2.1104	-1.1367
295	2.1208	-1.0874
296	2.1303	-1.0373
297	2.1389	-0.9866
298	2.1464	-0.9352
299	2.1530	-0.8831
300	2.1585	-0.8304
301	2.1639	-0.7770
302	2.1663	-0.7230
303	2.1686	-0.6684
304	2.1698	-0.6133
305	2.1698	-0.5576
306	2.1687	-0.5014
307	2.1664	-0.4447
308	2.1630	-0.3875
309	2.1583	-0.3299
310	2.1524	-0.2718
311	2.1453	-0.2133
312	2.1369	-0.1544
313	2.1273	-0.0951
314	2.1164	-0.0355
315	2.1043	0.0243
316	2.0909	0.0845
317	2.0761	0.1449
318	2.0601	0.2056
319	2.0428	0.2664
320	2.0242	0.3274
321	2.0043	0.3885
322	1.9830	0.4496
323	1.9605	0.5109
324	1.9367	0.5721
325	1.9116	0.6332
326	1.8853	0.6943
327	1.8576	0.7553
328	1.8288	0.8160
329	1.7987	0.8766
330	1.7674	0.9369
331	1.7508	0.9676
332	1.7337	0.9980
333	1.7160	1.0281
334	1.6978	1.0578
335	1.6791	1.0873
336	1.6598	1.1164
337	1.6401	1.1452
338	1.6199	1.1737
339	1.5991	1.2018
340	1.5779	1.2295
341	1.5562	1.2568
342	1.5341	1.2838

```
343      1.5114    1.3104
344      1.4883    1.3365
345      1.4648    1.3623
346      1.4408    1.3877
347      1.4164    1.4126
348      1.3915    1.4371
349      1.3662    1.4612
350      1.3405    1.4848
351      1.3144    1.5079
352      1.2879    1.5306
353      1.2610    1.5529
354      1.2337    1.5746
355      1.2060    1.5959
356      1.1780    1.6167
357      1.1496    1.6370
358      1.1209    1.6569
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         2.0000000000000000000000000
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         0.0                                                          168
3
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2           0      -0.500000      0.075000      2.000000      2.000000      1.994377      0.149859
2
3           1       0.500000      0.112500      3.000000      2.000000      1.987357      0.224526
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         0.3749999403953552000000000                  1.0000000000000000000000000
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         0.1999999880790710000000000
         0.0                                         16.7551574707031200000000000
         0.0
         0.0                                                          17
2
1           1       0.0           0.375000      1.000000      0.200000      0.186101      0.073254
2           0       0.0           0.750000      2.000000      0.200000      0.146338      0.136328
2
3           1       0.0           1.124999      3.000000      0.200000      0.086235      0.180453
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         4.4521598815917970000000000
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        -0.4241032004356384000000000
         0.0                                                          21
2
1           1       0.0           4.304182      1.000000      0.500000      4.518511     -0.458917
2           0       0.0           4.454182      2.000000      0.500000      4.589319     -0.483425
2
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   4.71699333190918000000000000                  8.37757587432861400000000000
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   0.0                                                          8
2
1        1      0.0        0.750000      1.000000      0.100000      4.790162      0.068164
2        0      0.0        1.500000      2.000000      0.100000      4.724067      0.099749
2
3        1      0.0        2.250000      3.000000      0.100000      4.654176      0.077807
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   0.50000000000000000000000000                  1.00000000000000000000000000
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   0.0
   0.0                                                          13
2
1        1      0.0        0.500000      1.000000      0.150000      4.848630      0.071914
2        0      0.0        1.000000      2.000000      0.150000      4.796038      0.126221
2
3        1      0.0        1.500000      3.000000      0.150000      4.727603      0.149624
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   1.50000000000000000000000000                  1.00000000000000000000000000
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2
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2        0      0.0        3.000000      2.000000      0.050000     -1.606949      1.736938
2
3        1      0.0        4.500000      3.000000      0.050000     -1.567988      1.681006
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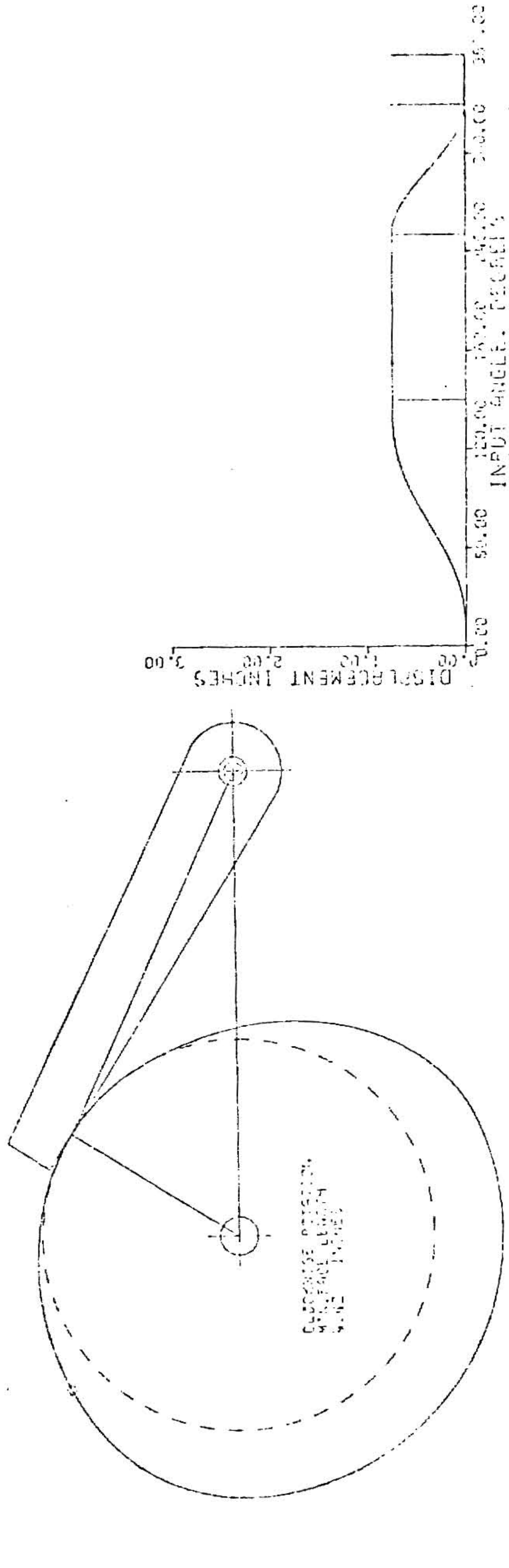

CLOCKWISE CAM ROTATION

FORTRAN IV G LEVEL 21 MAIN DATE = 74036 11/09/08 PAGE 0001

```
      DIMENSION HR(2500)
      CALL PLOTS (HR,2500)
      HH=2.5
      ROLD=.4
      CALL CAMROL (HH,ROLD)
      CALL PLOT (0.,0.,999)
      STOP
      END
```

FORTRAN IV G LEVEL 21 CAMROL DATE = 74036 11/09/08 PAGE 0001

```
      SUBROUTINE CAMROL(HH,ROLD)
      DIMENSION IBJ(361)
      DIMENSION PATH(361), ANGLE(361)
      DIMENSION AL(361),PRANGL(361),XC(361),YC(361),XP(361),YP(361)
      DIMENSION H(361),R(361)
      DIMENSION CX(361),CY(361)
      READ(5,40) AL1,AL2,AL3,AL4
      READ(5,41) IC1,IC2,IC3,IC4
      READ(5,42) IB1,IB2,IB3,IB4,IB5,IB6,IB7,IB8,IB9
      READ(5,43) IPLOT,MCW,ECC
   40 FORMAT(4F10.2)
   41 FORMAT(4I10)
   42 FORMAT(9I5)
   43 FORMAT(2I1 ,F10.2)
      HSTART=SQRT(HH*HH+ECC*ECC)
      PAMAX=0.0
      K=1
      DO 110 J=1,361
      I=J-1
      A=I
      AA=A*.01745
      AB1=IB1
      AB2=IB2
      AB3=IB3
      AB4=IB4
      AB5=IB5
      AB6=IB6
      AB7=IB7
      AB8=IB8
      AB9=IB9
      B1=AB1*.01745
      B2=AB2*.01745
      B3=AB3*.01745
      B4=AB4*.01745
      B5=AB5*.01745
      B6=AB6*.01745
      B7=AB7*.01745
      B8=AB8*.01745
      B9=AB9*.01745
      IF(IB1-I) 1,1,2
    1 IF(IB2-I) 3,3,4
    3 IF(IB3-I) 6,6,7
    6 IF(IB4-I) 8,8,9
    8 IF(IB5-I) 11,11,12
   11 IF(IB6-I) 13,13,14
   13 IF(IB7-I) 16,16,17
   16 IF(IB8-I) 18,18,19
   18 GO TO 22
    2 RISE=0.0
      AL(J)=0.0
```

```
0051          GO TO 25
0052        4 IF(IC1.EQ.2) GO TO 5
0053          IF (IC1.EQ.1) GO TO 250
0054          RISE=AL1/2.*(1.-COS(3.1416*(AA-B1)/(B2-B1)))
0055          AL(J)=AL1/2.*(3.1416/(B2-B1)*SIN(3.1416*(AA-B1)/(B2-B1)))
       C      HARMONIC UP
0056          GO TO 25
0057        5 RISE=AL1*((AA-B1)/(B2-B1)-1./6.2832*SIN(6.2832*(AA-B1)/(B2-B1)))
```

FORTRAN IV G LEVEL 21 CAMROL DATE = 74036 11/09/00 PAGE 0002

```
0058          AL(J)=AL1*(1./(B2-B1)-1./(B2-B1)*COS(6.2832*(AA-B1)/(B2-B1)))
       C      CYCLOIDAL UP
0059          GO TO 25
0060      250 IF ((IB2+IB1)/2-I) 251,251,252
0061      252 RISE=2.*AL1*((AA-B1)/(B2-B1))**2
0062          AL(J)=4.*AL1*(AA-B1)/((B2-B1)**2)
       C      1ST PARABOLIC UP
0063          GO TO 25
0064      251 RISE=AL1*(1.-2.*(1.-(AA-B1)/(B2-B1))**2)
0065          AL(J)=4.*AL1*(1./(B2-B1)-(AA-B1)/((B2-B1)**2))
       C      IIND PARABOLIC UP
0066          GO TO 25
0067        7 RISE=AL1
0068          AL(J)=0.0
0069          GO TO 25
0070        9 IF(IC2.EQ.2) GO TO 10
0071          IF (IC2.EQ.1) GO TO 253
0072          RISE=AL1+AL2/2.*(1.-COS(3.1416*(AA-B3)/(B4-B3)))
0073          AL(J)=AL2/2.*(3.1462/(B4-B3)*SIN(3.1416*(AA-B3)/(B4-B3)))
       C      HARMONIC UP
0074          GO TO 25
0075       10 RISE=AL1+AL2*((AA-B3)/(B4-B3)-1./6.2832*SIN(6.2832*(AA-B3)/(B4-B3)
             1))
0076          AL(J)=AL2*(1./(B4-B3)-1./(B4-B3)*COS(6.2832*(AA-B3)/(B4-B3)))
       C      CYCLOIDAL UP
0077          GO TO 25
0078      253 IF((IB4+IB3)/2-I) 254,254,255
0079      255 RISE=AL1+2.*AL2*((AA-B3)/(B4-B3))**2
0080          AL(J)=4.*AL2*(AA-B3)/((B4-B3)**2)
       C      1ST PARABOLIC UP
0081          GO TO 25
0082      254 RISE=AL1+AL2*(1.-2.*(1.-(AA-B3)/(B4-B3))**2)
0083          AL(J)=4.*AL2*(1./(B4-B3)-(AA-B3)/((B4-B3)**2))
       C      IIND PARABOLIC UP
0084          GO TO 25
0085       12 RISE=AL1+AL2
0086          AL(J)=0.0
0087          GO TO 25
0088       14 IF(IC3.EQ.2) GO TO 15
0089          IF (IC3.EQ.1) GO TO 256
0090          RISE=AL4+AL3/2.*(1.+COS(3.1416*(AA-B5)/(B6-B5)))
0091          AL(J)=AL3/2.*(-3.1416/(B6-B5)*SIN(3.1416*(AA-B5)/(B6-B5)))
       C      HARMINC DOWN
0092          GO TO 25
0093       15 RISE=AL4+AL3*(1.-(AA-B5)/(B6-B5)+1./6.2832*SIN(6.2832*(AA-B5)/
             1(B6-B5)))
0094          AL(J)=AL3   *(-1./(B6-B5)+1./(B6-B5)*COS(6.2832*(AA-B5)/(B6-B5)))
       C      CYCLOIDAL DOWN
0095          GO TO 25
0096      256 IF((IB6+IB5)/2-I) 257,257,258
```

```
0097          258 RISE=AL4+AL3*(1.-2.*((AA-B5)/(B6-B5))**2)
0098              AL(J)=-4.*AL3*(AA-B5)/((B6-B5)**2)
            C     IST PARABOLIC DOWN
0099              GO TO 25
0100          257 RISE=AL4+2.*AL3*(1.-(AA-B5)/(B6-B5))**2
0101              AL(J)=4.*AL3*((AA-B5)/((B6-B5)**2)-1./(B6-B5))
            C     IIND PARABOLIC DOWN
0102              GO TO 25

FORTRAN IV G LEVEL  21              CAMROL              DATE = 74036          11/09/08                PAGE 0003

0103           17 RISE=AL4
0104              AL(J)=0.0
0105              GO TO 25
0106           19 IF(IC4.EQ.2) GO TO 20
0107              IF (IC4.EQ.1) GO TO 259
0108              RISE=AL4/2.*(1.+COS(3.1416*(AA-B7)/(B8-B7)))
0109              AL(J)=AL4/2.*(-3.1416/(B8-B7)*SIN(3.1416*(AA-B7)/(B8-B7)))
            C     HARMONIC DOWN
0110              GO TO 25
0111           20 RISE=AL4*(1.-(AA-B7)/(B8-B7)+1./6.2832*SIN(6.2832*(AA-B7)/
                 1(B8-B7)))
0112              AL(J)=AL4  *(-1./(B8-B7)+1./(B8-B7)*COS(6.2832*(AA-B7)/(B8-B7)))
            C     CYCLOIDAL DOWN
0113              GO TO 25
0114          259 IF ((IB8+IB7)/2-I) 260,260,261
0115          261 RISE=AL4*(1.-2.*((AA-B7)/(B8-B7))**2)
0116              AL(J)=-4.*AL4*(AA-B7)/((B8-B7)**2)
            C     IST PARABOLIC DOWN
0117              GO TO 25
0118          260 RISE=2.*AL4*(1.-(AA-B7)/(B8-B7))**2
0119              AL(J)=4.*AL4*((AA-B7)/((B8-B7)**2)-1./(B8-B7))
            C     IIND PARABOLIC DOWN
0120              GO TO 25
0121           22 RISE=0.0
0122              AL(J)=0.0
0123           21 CONTINUE
0124           25 H(J)=HH+RISE
0125              IHJ(J)=I
0126              DELTA=ATAN(ECC/H(J))
0127              BETA=AA-DELTA
0128              R(J)=SQRT(H(J)*H(J)+ECC*ECC)
0129              XC(J)=R(J)*COS(BETA)
0130              YC(J)=R(J)*SIN(BETA)
0131              PRESS=ATAN(H(J)*AL(J)/(R(J)*R(J)))
0132              PHEE=BETA-PRESS
0133              PRANGL(J)=-PRESS-DELTA
0134              DIX=ROLD*COS(AA+PRANGL(J))
0135              DIY=ROLD*SIN(AA+PRANGL(J))
0136              XP(J)=XC(J)-DIX
0137              YP(J)=YC(J)-DIY
0138              CX(J)=XP(J)-.01*COS(AA+PRANGL(J))
0139              CY(J)=YP(J)-.01*SIN(AA+PRANGL(J))
0140              IF(PAMAX.GE.ABS(PRANGL(J))) GO TO 600
0141              PAMAX=ABS(PRANGL(J))
0142              K=J
0143              POX=ECC*SIN(AA)
0144              POY=-ECC*COS(AA)
0145              PXX=POX+4.*COS(AA)
0146              PYY=POY+4.*SIN(AA)
0147              IF(ECC) 26,26,27
```

```
0148          26 WLKX=XP(K)+2.*COS(PAMAX-6.282+AA)
0149             WLKY=YP(K)+2.*SIN(PAMAX-6.282+AA)
0150             GO TO 600
0151          27 WLKX=XP(K)+2.*COS(AA-PAMAX)
0152             WLKY=YP(K)+2.*SIN(AA-PAMAX)
0153         600 CONTINUE
0154         110 CONTINUE
0155             PAM=PAMAX/.01745
```

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```
0156             WRITE(6,122) PAM,K
0157         122 FORMAT(1H ,20HMAX.PRESSURE ANGLE =,F6.1,23H DEGREES AND OCCURS FOR
                1,I4,24H DEGREES OF CAM ROTATION)
0158             AB1=AB1*1./60.
0159             AB2=AB2*1./60.
0160             AB3=AB3*1./60.
0161             AB4=AB4*1./60.
0162             AB5=AB5*1./60.
0163             AB6=AB6*1./60.
0164             AB7=AB7*1./60.
0165             AB8=AB8*1./60.
0166             AB9=AB9*1./60.
0167             YAXIS=AL1+AL2
0168             DO 150 J=1,361
0169             I=J-1
0170             A=I
0171             PATH(J)=H(J)-HH
0172         150 ANGLE(J)=A*1./60.
0173             IF(MCW.EQ.1) GO TO 23
0174             DO 24 J=1,361
0175             YP(J)=-YP(J)
0176             CY(J)=-CY(J)
0177          24 YC(J)=-YC(J)
0178             WLKY=-WLKY
0179             PHY=-PHY
0180             PYY=-PYY
0181          23 CONTINUE
0182             I2=IB2-IB1
0183             I3=IB3-IB2
0184             I4=IB4-IB3
0185             I5=IB5-IB4
0186             I6=IB6-IB5
0187             I7=IB7-IB6
0188             I8=IB8-IB7
0189             I9=IB9-IB8
0190             WRITE(6,500)
0191         500 FORMAT(1H1,19HRADIAL CAM FOLLOWER)
0192             WRITE(6,501)
0193         501 FORMAT(1H ,41HTHE FOLLOWING INPUT PARAMETERS ARE GIVEN.)
0194             WRITE(6,502) AL1,AL2
0195         502 FORMAT(1H ,19HFIRST CAM LIFT=AL1=,F6.2,10X,18HSEC. CAM LIFT=AL2=,
                1 F6.2)
0196             WRITE(6,503) AL3,AL4
0197         503 FORMAT(1H ,19HFIRST CAM FALL=AL3=,F6.2,10X,18HSEC. CAM FALL=AL4=,
                1 F6.2)
0198             WRITE(6,504) IB1,I2,I3,I4,I5,I6,I7,I8,I9
0199         504 FORMAT(1H ,11H1 ST.DWELL=,I5,2X,7HDEGREES,8X,10H1 ST.RISE=,I5,2X,
                17HDEGREES/1H ,11H2 ND.DWELL=,I5,2X,7HDEGREES,8X,10H2 ND.RISE=,I5,
                22X,7HDEGREES/1H ,11H3 RD.DWELL=,I5,2X,7HDEGREES,8X,10H1 ST.FALL=,
                3I5,2X,7HDEGREES/1H ,11H4 TH.DWELL=,I5,2X,7HDEGREES,8X,10H2 ND.FALL
```

```
     4,I5,2X,7HDEGREES/1H ,11H5 TH.DWELL=,I5,2X,7HDEGREES)
      IF(IC1.EQ.3)  GO TO 550
      IF (IC1.EQ.1) GO TO 262
      WRITE(6,551)
  551 FORMAT(1H 20HFIRST RISE=CYCLOIDAL)
      GO TO 552
  550 WRITE(6,553)
  553 FORMAT(1H ,26HFIRST RISE=SIMPLF HARMONIC)

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      GO TO 552
  262 WRITE (6,263)
  263 FORMAT (1H ,20HFIPST RISE=PARABOLIC)
  552 IF(IC2.EQ.3) GO TO 555
      IF (IC2.EQ.1) GO TO 264
      WRITE(6,554)
  554 FORMAT(1H+,30X,21HSECOND RISE=CYCLOIDAL)
      GO TO 556
  555 WRITE(6,557)
  557 FORMAT(1H+,30X,27HSECOND RISE=SIMPLE HARMONIC)
      GO TO 556
  264 WRITE (6,265)
  265 FORMAT (1H+,30X,21HSECOND RISE=PARABOLIC)
  556 IF (IC3.EQ.3) GO TO 560
      IF (IC3.EQ.1) GO TO 266
      WRITE(6,558)
  558 FORMAT(1H ,20HFIRST FALL=CYCLOIDAL)
      GO TO 561
  560 WRITE(6,559)
  559 FORMAT(1H ,26HFIRST FALL=SIMPLE HARMONIC)
      GO TO 561
  266 WRITE (6,267)
  267 FORMAT (1H ,20HFIRST FALL=PARABOLIC)
  561 IF(IC4.EQ.3) GO TO 565
      IF (IC4.EQ.1) GO TO 268
      WRITE(6,562)
  562 FORMAT(1H+,30X,21HSECOND FALL=CYCLOIDAL)
      GO TO 564
  565 WRITE(6,563)
  563 FORMAT(1H+,30X,27HSECOND FALL=SIMPLE HARMONIC)
      GO TO 564
  268 WRITE (6,269)
  269 FORMAT (1H+,30X,21HSECOND FALL=PARABOLIC)
  564 CONTINUE
      IF(MCW.EQ.1) GO TO 510
      WRITE(6,505) MCW
  505 FORMAT(1H ,41HCLOCKWISE CAM ROTATION IDENTIFIED BY MCW=,I2)
      GO TO 511
  510 WRITE(6,506) MCW
  506 FORMAT(1H ,49HCOUNTER CLOCKWISE CAM ROTATION IDENTIFIED BY MCW=,
     1 I2)
  511 WRITE(6,507) ECC,IPLOT
  507 FORMAT(1H 13HECCENTRICITY=,F5.2/62HTHE SIZE OF THE PLOT PAPER IS S
     1ELECTED BY IDENTIFYING 'IPLOT'=,I4)
      WRITE(6,508)
  508 FORMAT(1H ,46HTHE FOLLOWING VALUES ARE THE OUTPUT PARAMETERS)
      WRITE(6,509) PAM,K
  509 FORMAT(1H ,24HTHE MAX. PRESSURE ANGLE=,F6.2,28HDEGREES AND WHICH O
     1CCURS FOR,I4,23HDEGREES OF CAM ROTATION)
      WRITE(6,512)
```

```
      512 FORMAT(1H ,80HTHE COORDINATES OF THE CONTACT POINT 'P' AND THE CEN
         1TER 'C' OF THE FOLLOWER ARE:)
          WRITE(6,515)
      515 FORMAT(1H ,65HINPUT ANGLE THETA      COORDINATES OF 'P'       COORD
         1INATES OF 'C')
          DO 513 J=1,360
      513 WRITE(6,514) IBJ(J),XP(J),YP(J),XC(J),YC(J)
      514 FORMAT(1H ,12X,I5,3X,2F10.4,5X,2F10.4)
```

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```
          IF(IPLOT.EQ.11) GO TO 70
          CALLPLOT(15.,-30.,-3)
          CALLPLOT(0.,15.,-3)
          GO TO 71
       70 CALLPLOT(10.,-11.,-3)
          CALLPLOT(0.,5.5,-3)
       71 CONTINUE
          CALLPLOT(POX,POY,+3)
          CALLPLOT(PXX,PYY,+2)
          CALL PLOT(0.,0.,+3)
          IF(ECC.EQ.0.0) GO TO 118
          EEC=ABS(ECC)
          CALL CIRCLE(0.,0.,0.,360.,EEC,EEC,0.5,2)
          CALL CIRCLE(0.,0.,0.,360.,.25,.25,0.0,3)
          GO TO 119
      118 CALL CIRCLE(0.,0.,0.,360.,.25,.25,0.,2)
          CALL CIRCLE(0.,0.,0.,360.,ECC,ECC,0.5,2)
      119 CONTINUE
          CALLCIRCLE(XP(K),YP(K),0.,360.,.05,.05,0.0,3)
          CALLPLOT(XP(K),YP(K),+3)
          CALLPLOT(WLKX,WLKY,-2)
          CALLSYMBOL(0.,0.,.1,18HMAX.PRESSURE ANGLE,0.,18)
          CALL NUMBER(0.,-.2,.1,PAM,0.,-1)
          CALLSYMBOL(.38,-.2,.1,7HDEGREES,0.,7)
          CALLPLOT(-WLKX,-WLKY,-3)
          CALLPLOT(XC(1),YC(1),+3)
          DO 115 J=1,361
      115 CALLPLOT(XC(J),YC(J),+2)
          DO 170 J=11,351,10
      170 CALLCIRCLE(XC(J),YC(J),0.,360.,ROLD,ROLD,0.5,3)
          CALLPLOT(XP(1),YP(1),+3)
          DO 116 J=1,361
      116 CALLPLOT(CX(J),CY(J),+2)
          DO 117 J=1,361
      117 CALLPLOT(XP(J),YP(J),+2)
          IF(MCW.NE.1) GO TO 200
          CALLSYMBOL(-1.5,-1.5,.1,18HCLOCKWISE ROTATION,0.,18)
          GO TO 210
      200 CALLSYMBOL(-1.5,-1.5,.1,26HCOUNTER CLOCKWISE ROTATION,0.,26)
      210 CONTINUE
          CALLPLOT(XC(1),YC(1),-3)
          CALL CIRCLE(0.,0.,0.,360.,ROLD,ROLD,0.0,3)
          CALL CIRCLE(0.,0.,90.,270.,.125,.125,0.0,3)
          CALLPLOT(0.,-.125,+3)
          CALLPLOT(2.,-.125,+2)
          CALLPLOT(2.,+.125,+2)
          CALLPLOT(0.,+.125,+2)
          IF(IPLOT.EQ.11) GO TO 35
          CALLPLOT(10.,-30.,-3)
          GO TO 36
```

```
      35 CALLPLOT(10.,-11.,-3)
      36 CALLPLOT(0.,2.,-3)
         IF(MCW.NE.1) GO TO 120
         CALLSYMBOL(0.,-1.,.2,22HCLOCKWISE CAM ROTATION,0.,22)
         GO TO 121
     120 CALLSYMBOL(0.,-1.,.2,30HCOUNTER CLOCKWISE CAM ROTATION,0.,30)
     121 CONTINUE
         CALL AXIS(0.,0.,20HINPUT ANGLE. DEGREES,-20,6.,0.,0.,60.,10.)
```

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```
         CALL AXIS(0.,0.,19HDISPLACEMENT INCHES,19,3.,   90.,0.,1.,10.)
         CALL PLOT(0.,0.,-3)
         DO 155 J=1,361
     155 CALL PLOT(ANGLE(J),PATH(J),+2)
         CALLPLOT(AB1,0.,+3)
         CALLPLOT(AB1,YAXIS,+2)
         CALLPLOT(AB2,YAXIS,+3)
         CALLPLOT(AB2,0.,+2)
         CALLPLOT(AB3,0.,+3)
         CALLPLOT(AB3,YAXIS,+2)
         CALLPLOT(AB4,YAXIS,+3)
         CALLPLOT(AB4,0.,+2)
         CALLPLOT(AB5,0.,+3)
         CALLPLOT(AB5,YAXIS,+2)
         CALLPLOT(AB6,YAXIS,+3)
         CALLPLOT(AB6,0.,+2)
         CALLPLOT(AB7,0.,+3)
         CALLPLOT(AB7,YAXIS,+2)
         CALLPLOT(AB8,YAXIS,+3)
         CALLPLOT(AB8,0.,+2)
         CALLPLOT(AB9,0.,+3)
         CALLPLOT(AB9,YAXIS,+2)
         RETURN
         END
```

RADIAL CAM FOLLOWER

```
THE FOLLOWING INPUT PARAMETERS ARE GIVEN.
FIRST CAM LIFT=AL1=  0.0              SEC. CAM LIFT=AL2=  0.75
FIRST CAM FALL=AL3=  0.75             SEC. CAM FALL=AL4=  0.0
1 ST.DWELL=    0  DEGREES           1 ST.RISE=     0  DEGREES
2 ND.DWELL=       DEGREES           2 ND.RISE=   150  DEGREES
3 RD.DWELL=  100  DEGREES           1 ST.FALL=    90  DEGREES
4 TH.DWELL=   30  DEGREES           2 ND.FALL,     0  DEGREES
5 TH.DWELL=    0  DEGREES
FIRST RISE=CYCLOIDAL              SECOND RISE=CYCLCIDAL
FIRST FALL=SIMPLE HARMONIC        SECOND FALL=SIMPLE HARMONIC
CLOCKWISE CAM ROTATION IDENTIFIED BY MCW= 2
ECCENTRICITY= 1.00
HE SIZE OF THE PLOT PAPER IS SELECTED BY IDENTIFYING 'IPLOT'=  11

THE FOLLOWING VALUES ARE THE OUTPUT PARAMETERS
THE MAX. PRESSURE ANGLE= 29.730DEGREES AND WHICH OCCURS FOR  66DEGREES OF CAM ROTATION
THE COORDINATES OF THE CONTACT POINT 'P' AND THE CENTER 'C' OF THE FOLLOWER ARE:
```

INPUT ANGLE THETA	COORDINATES OF 'P'		COORDINATES OF 'C'	
0	2.1286	0.8514	2.5000	1.0000
1	2.1432	0.8141	2.5171	0.9562
2	2.1571	0.7765	2.5304	0.9122
3	2.1704	0.7386	2.5459	0.8678
4	2.1831	0.7004	2.5637	0.8232
5	2.1951	0.6619	2.5778	0.7783
6	2.2066	0.6231	2.5911	0.7352
7	2.2174	0.5841	2.6037	0.6879
8	2.2276	0.5448	2.6156	0.6425
9	2.2372	0.5052	2.6267	0.5965
10	2.2462	0.4654	2.6371	0.5505
11	2.2546	0.4254	2.6467	0.5043
12	2.2624	0.3852	2.6557	0.4580
13	2.2695	0.3447	2.6639	0.4114
14	2.2761	0.3041	2.6715	0.3647
15	2.2820	0.2632	2.6783	0.3178
16	2.2874	0.2221	2.6844	0.2707
17	2.2921	0.1808	2.6898	0.2235
18	2.2962	0.1394	2.6945	0.1761
19	2.2997	0.0978	2.6985	0.1286
20	2.3026	0.0560	2.7019	0.0810
21	2.3049	0.0140	2.7045	0.0332
22	2.3066	-0.0281	2.7064	-0.0147
23	2.3077	-0.0704	2.7076	-0.0628
24	2.3082	-0.1128	2.7082	-0.1109
25	2.3080	-0.1553	2.7080	-0.1592
26	2.3073	-0.1980	2.7071	-0.2075
27	2.3059	-0.2407	2.7056	-0.2560
28	2.3039	-0.2837	2.7033	-0.3045
29	2.3012	-0.3267	2.7004	-0.3532
30	2.2980	-0.3698	2.6967	-0.4019
31	2.2941	-0.4130	2.6923	-0.4506

32	2.2896	-0.4563	2.6872	-0.4997
33	2.2844	-0.4996	2.6814	-0.5486
34	2.2786	-0.5431	2.6749	-0.5977
35	2.2722	-0.5866	2.6676	-0.6468
36	2.2651	-0.6301	2.6597	-0.6959
37	2.2573	-0.6737	2.6509	-0.7451
38	2.2489	-0.7174	2.6415	-0.7943
39	2.2399	-0.7610	2.6313	-0.8436
40	2.2301	-0.8047	2.6203	-0.8928
41	2.2197	-0.8484	2.6086	-0.9421
42	2.2086	-0.8920	2.5961	-0.9914
43	2.1968	-0.9357	2.5828	-1.0406
44	2.1843	-0.9793	2.5687	-1.0899
45	2.1711	-1.0228	2.5539	-1.1391
46	2.1573	-1.0663	2.5382	-1.1883
47	2.1427	-1.1098	2.5218	-1.2374
48	2.1274	-1.1531	2.5045	-1.2864
49	2.1113	-1.1964	2.4864	-1.3354
50	2.0946	-1.2396	2.4675	-1.3842
51	2.0771	-1.2826	2.4477	-1.4330
52	2.0589	-1.3255	2.4271	-1.4816
53	2.0399	-1.3682	2.4057	-1.5301
54	2.0202	-1.4108	2.3834	-1.5784
55	1.9998	-1.4531	2.3602	-1.6265
56	1.9786	-1.4953	2.3362	-1.6744
57	1.9566	-1.5372	2.3113	-1.7221
58	1.9339	-1.5789	2.2855	-1.7696
59	1.9104	-1.6203	2.2589	-1.8168
60	1.8862	-1.6615	2.2313	-1.8637
61	1.8612	-1.7023	2.2029	-1.9103
62	1.8354	-1.7428	2.1735	-1.9566
63	1.8089	-1.7830	2.1433	-2.0025
64	1.7816	-1.8229	2.1122	-2.0481
65	1.7535	-1.8623	2.0801	-2.0933
66	1.7247	-1.9014	2.0472	-2.1380
67	1.6951	-1.9400	2.0134	-2.1823
68	1.6648	-1.9782	1.9786	-2.2262
69	1.6337	-2.0159	1.9431	-2.2695
70	1.6018	-2.0532	1.9065	-2.3123
71	1.5692	-2.0899	1.8691	-2.3546
72	1.5359	-2.1261	1.8308	-2.3963
73	1.5018	-2.1618	1.7916	-2.4375
74	1.4670	-2.1969	1.7516	-2.4779
75	1.4314	-2.2314	1.7107	-2.5178
76	1.3951	-2.2653	1.6689	-2.5570
77	1.3582	-2.2986	1.6263	-2.5954
78	1.3205	-2.3312	1.5829	-2.6332
79	1.2822	-2.3631	1.5385	-2.6701
80	1.2431	-2.3943	1.4934	-2.7063
81	1.2034	-2.4248	1.4475	-2.7417
82	1.1631	-2.4546	1.4008	-2.7763
83	1.1221	-2.4836	1.3534	-2.8100

84	1.0805	-2.5119	1.3051	-2.8428
85	1.0382	-2.5593	1.2562	-2.8747
86	0.9954	-2.5659	1.2065	-2.9057
87	0.9521	-2.5917	1.1561	-2.9357
88	0.9081	-2.6166	1.1050	-2.9648
89	0.8635	-2.6407	1.0533	-2.9926
90	0.8185	-2.6639	1.0039	-3.0199
91	0.7729	-2.6861	0.9479	-3.0458
92	0.7269	-2.7075	0.8943	-3.0708
93	0.6804	-2.7279	0.8401	-3.0946
94	0.6334	-2.7474	0.7854	-3.1174
95	0.586[illegible]	-2.7659	0.7302	-3.139[illegible]
96	0.5332	-2.7834	0.6744	-3.1595
97	0.4900	-2.7999	0.6182	-3.1788
98	0.4414	-2.8154	0.5615	-3.1970
99	0.3925	-2.8299	0.5044	-3.2139
100	0.3432	-2.8434	0.4470	-3.2297
101	0.2937	-2.8559	0.3891	-3.2443
102	0.2439	-2.8673	0.3310	-3.2577
103	0.1938	-2.8776	0.2725	-3.2698
104	0.1435	-2.8869	0.2130	-3.2807
105	0.0930	-2.8951	0.1548	-3.2903
106	0.0423	-2.9023	0.0955	-3.2987
107	-0.0086	-2.9084	0.0361	-3.3059
108	-0.0595	-2.9134	-0.0234	-3.3117
109	-0.1107	-2.9173	-0.0831	-3.3164
110	-0.1619	-2.9201	-0.1429	-3.3197
111	-0.2131	-2.9219	-0.2027	-3.3217
112	-0.2645	-2.9225	-0.2626	-3.3225
113	-0.3155	-2.9221	-0.3225	-3.3221
114	-0.3671	-2.9206	-0.3823	-3.3203
115	-0.4184	-2.9180	-0.4422	-3.3175
116	-0.4696	-2.9143	-0.5019	-3.3130
117	-0.5208	-2.9095	-0.5615	-3.3074
118	-0.5718	-2.9037	-0.6210	-3.3006
119	-0.6228	-2.8967	-0.6803	-3.2926
120	-0.6736	-2.8887	-0.7394	-3.2833
121	-0.7242	-2.8797	-0.7983	-3.2728
122	-0.7747	-2.8696	-0.8570	-3.2610
123	-0.8249	-2.8584	-0.9154	-3.2480
124	-0.8749	-2.8462	-0.9735	-3.2339
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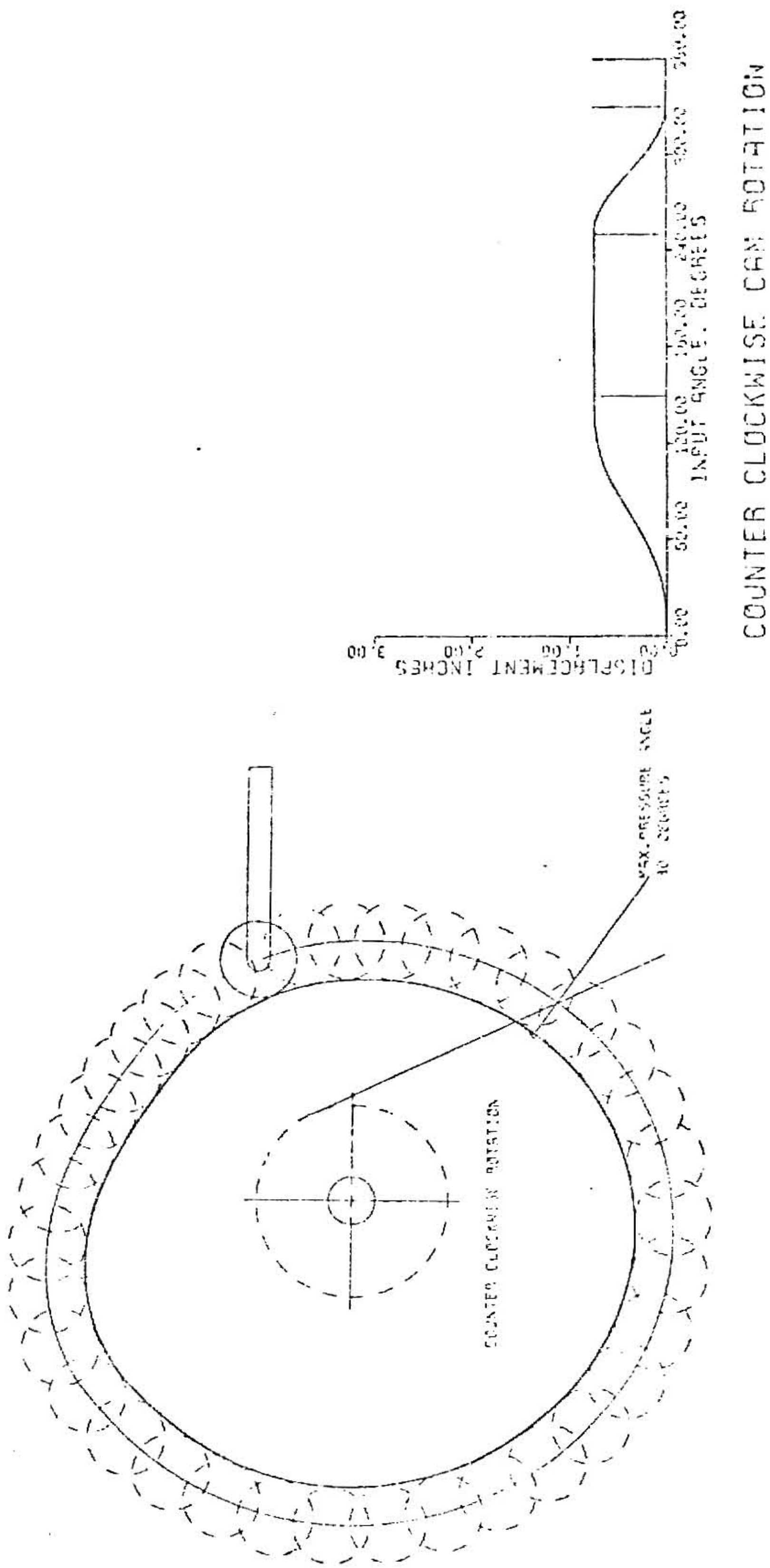
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INPUT ANGLE, DEGREES
COUNTER CLOCKWISE CAM ROTATION

FORTRAN IV G LEVEL 21 MAIN DATE = 74035 22/19/13 PAGE 0001

```
      DIMENSION WR(2500)
      CALLPLOTS (WR,25.0)
      AH=2.5
      CALL CAMFLT (AH)
      CALL PLOT (0.,0.,999)
      STOP
      END
```

FORTRAN IV G LEVEL 21 CAMFLT DATE = 74035 22/19/13 PAGE 0001

```
      SUBROUTINE CAMFLT(AH)
      DIMENSION H(361),AL(361),PHEE(361)
      DIMENSION PATH(361), ANGLR(361)
      DIMENSION BETA(361),DIST(361),XP(361),YP(361)
      DIMENSION XC(361),YC(361),ALL(361),QAX(361),QAY(361),QBX(361)
      DIMENSION QBY(361),QCX(361),QCY(361),QDX(361),QDY(361)
      DIMENSION QPX(361),QPY(361)
      DIMENSION IBJ(361)
      READ(5,40) AL1,AL2,AL3,AL4
      READ(5,41) IC1,IC2,IC3,IC4
      READ(5,42) IB1,IB2,IB3,IB4,IB5,IB6,IB7,IB8,IB9
      READ(5,43) IPLOT,MCW,LCC
   40 FORMAT(4F10.2)
   41 FORMAT(4I1.)
   42 FORMAT(9I5)
   43 FORMAT(2I10,F10.2)
      H(1)=AH
      ALMAX=0.
      K=1
      PRESS=0.0
      DO 110 J=1,361
      I=J-1
      A=I
      AA=A*.01745
      AB1=IB1
      AB2=IB2
      AB3=IB3
      AB4=IB4
      AB5=IB5
      AB6=IB6
      AB7=IB7
      AB8=IB8
      AB9=IB9
      B1=AB1*.01745
      B2=AB2*.01745
      B3=AB3*.01745
      B4=AB4*.01745
      B5=AB5*.01745
      B6=AB6*.01745
      B7=AB7*.01745
      B8=AB8*.01745
      B9=AB9*.01745
      IF(IB1-I)1,1,2
    1 IF(IB2-I) 3,3,4
    3 IF(IB3-I) 6,6,7
    6 IF(IB4-I) 8,8,9
    8 IF(IB5-I) 11,11,12
   11 IF(IB6-I) 13,13,14
   13 IF(IB7-I) 16,16,17
   16 IF(IB8-I) 18,18,19
```

```
   18 GO TO 22
    2 RISE=0.0
      AL(J)= .0
      GO TO 25
    4 IF(IC1.EQ.2) GO TO 5
      IF (IC1.EQ.1) GO TO 250
      RISE=AL1/2.*(1.-COS(3.1416*(AA-B1)/(B2-B1)))
      AL(J)=AL1/2.*(3.1416/(B2-B1)*SIN(3.1416*(AA-B1)/(B2-B1)))
```



```
      GO TO 25
    5 RISE=AL1*((AA-B1)/(B2-B1)-1./6.2832*SIN(6.2832*(AA-B1)/(B2-B1)))
      AL(J)=AL1*(1./(B2-B1)-1./(B2-B1)*COS(6.2832*(AA-B1)/(B2-B1)))
      GO TO 25
  250 IF ((IB2+IB1)/2-I) 251,251,252
  252 RISE=2.*AL1*((AA-B1)/(B2-B1))**2
      AL(J)=4.*AL1*(AA-B1)/((B2-B1)**2)
C     IST PARABOLIC UP
      GO TO 25
  251 RISE=AL1*(1.-2.*(1.-(AA-B1)/(B2-B1))**2)
      AL(J)=4.*AL1*(1./(B2-B1)-(AA-B1)/((B2-B1)**2))
C     IIND PARABOLIC UP
      GO TO 25
    7 RISE=AL1
      AL(J)=0.0
      GO TO 25
    9 IF(IC2.EQ.2) GO TO 10
      IF (IC2.EQ.1) GO TO 253
      RISE=AL1+AL2/2.*(1.-COS(3.1416*(AA-B3)/(B4-B3)))
      AL(J)=AL2/2.*(3.1462/(B4-B3)*SIN(3.1416*(AA-B3)/(B4-B3)))
      GO TO 25
   10 RISE=AL1+AL2*((AA-B3)/(B4-B3)-1./6.2832*SIN(6.2832*(AA-B3)/(B4-B3
     1))
      AL(J)=AL2*(1./(B4-B3)-1./(B4-B3)*COS(6.2832*(AA-B3)/(B4-B3)))
      GO TO 25
  253 IF((IB4+IB3)/2-I) 254,254,255
  255 RISE=AL1+2.*AL2*((AA-B3)/(B4-B3))**2
      AL(J)=4.*AL2*(AA-B3)/((B4-B3)**2)
C     IST PARABOLIC UP
      GO TO 25
  254 RISE=AL1+AL2*(1.-2.*(1.-(AA-B3)/(B4-B3))**2)
      AL(J)=4.*AL2*(1./(B4-B3)-(AA-B3)/((B4-B3)**2))
C     IIND PARABOLIC UP
      GO TO 25
   12 RISE=AL1+AL2
      AL(J)=0.0
      GO TO 25
   14 IF(IC3.EQ.2) GO TO 15
      IF (IC3.EQ.1) GO TO 256
      RISE=AL4+AL3/2.*(1.+COS(3.1416*(AA-B5)/(B6-B5)))
      AL(J)=AL3/2.*(-3.1416/(B6-B5)*SIN(3.1416*(AA-B5)/(B6-B5)))
      GO TO 25
   15 RISE=AL4+AL3*(1.-(AA-B5)/(B6-B5)+1./6.2832*SIN(6.2832*(AA-B5)/
     1(B6-B5)))
      AL(J)=AL3   *(-1./(B6-B5)+1./(B6-B5)*COS(6.2832*(AA-B5)/(B6-B5)))
      GO TO 25
  256 IF((IB6+IB5)/2-I) 257,257,258
  258 RISE=AL4+AL3*(1.-2.*((AA-B5)/(B6-B5))**2)
      AL(J)=-4.*AL3*(AA-B5)/((B6-B5)**2)
C     IST PARABOLIC DOWN
```

```
             GO TO 25
       257 RISE=AL4+2.*AL3*(1.-(AA-B5)/(B6-B5))**2
           AL(J)=4.*AL3*((AA-B5)/((B6-B5)**2)-1./(B6-B5))
     C     FIND PARABOLIC DOWN
           GO TO 25
        17 RISE=AL4
           AL(J)=0.0
           GO TO 25
```

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```
        19 IF(IC4.EQ.2) GO TO 20
           IF (IC4.EQ.1) GO TO 259
           RISE=AL4/2.*(1.+COS(3.1416*(AA-B7)/(B8-B7)))
           AL(J)=AL4/2.*(-3.1416/(B8-B7)*SIN(3.1416*(AA-B7)/(B8-B7)))
           GO TO 25
        20 RISE=AL4*(1.-(AA-B7)/(B8-B7)+1./6.2832*SIN(6.2832*(AA-B7)/
          1(B8-B7)))
           AL(J)=AL4  *(-1./(B8-B7)+1./(B8-B7)*COS(6.2832*(AA-B7)/(B8-B7)))
           GO TO 25
       259 IF ((IB8+IB7)/2-I) 260,260,261
       261 RISE=AL4*(1.-2.*((AA-B7)/(B8-B7))**2)
           AL(J)=-4.*AL4*(AA-B7)/((B8-B7)**2)
     C     IST PARABOLIC DOWN
           GO TO 25
       260 RISE=2.*AL4*(1.-(AA-B7)/(B8-B7))**2
           AL(J)=4.*AL4*((AA-B7)/((B8-B7)**2)-1./(B8-B7))
     C     FIND PARABOLIC DOWN
           GO TO 25
        22 RISE=0.0
           AL(J)=0.0
        21 CONTINUE
        25 H(J)=H(1)+RISE
           INJ(J)=I
           ANGLE(J)=A/60.
           PATH(J)=RISE
           PHE(J)=ATAN(AL(J)/H(J))
           BETA(J)=AA+PHE(J)
           DIST(J)=SQRT(H(J)*H(J)+AL(J)*AL(J))
           XP(J)=DIST(J)*COS(BETA(J))
           YP(J)=DIST(J)*SIN(BETA(J))
           XC(J)=H(J)*COS(AA) + ECC*COS(AA-1.5708)
           YC(J)=H(J)*SIN(AA) + ECC*SIN(AA-1.5708)
           ALL(J)=SQRT((XP(J)-XC(J))**2+(YP(J)-YC(J))**2)
           IF(ALMAX.LE.ALL(J)) GO TO 26
           GO TO 27
        26 ALMAX=ALL(J)
           K=J
           ROTA=2.*ALMAX
        27 CONTINUE
       110 CONTINUE
           A-C=ABS(ECC)
           L=K-1
           DO 29 J=1,K,L
           A=J-1
           AA=A*.01745
           SIA=SIN(AA)
           CIA=COS(AA)
           OCX(J)=(ALMAX + .25)*SIA
           OCY(J)=-(ALMAX+.25)*CIA
           OPX(J)=-OCX(J)
```

```
      QPY(J)=-QCY(J)
      DIX=.25*CIA
      DIY=.25*SIA
      QBX(J)=QCX(J)+DIX
      QBY(J)=QCY(J)+DIY
      QDX(J)=2.*CIA
      QDY(J)=2.*SIA
      QDXX=QDX(J)+1.25
```

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```
      QDYY=QDY(J)-.2
      QAX(J)=QPX(J)+DIX
      QAY(J)=QPY(J)+DIY
   29 CONTINUE
      AB1=AB1*1./60.
      AB2=AB2*1./60.
      AB3=AB3*1./60.
      AB4=AB4*1./60.
      AB5=AB5*1./60.
      AB6=AB6*1./60.
      AB7=AB7*1./60.
      AB8=AB8*1./60.
      AB9=AB9*1./60.
      YAXIS=AL1+AL2
      IF(MCW.EQ.1) GO TO 50
      DO 51 J=1,361
      YP(J)=-YP(J)
   51 YC(J)=-YC(J)
      DO 52 J=1,KKL
      QAY(J)=-QAY(J)
      QBY(J)=-QBY(J)
      QCY(J)=-QCY(J)
      QPY(J)=-QPY(J)
   52 QDY(J)=-QDY(J)
      QDYY=-QDYY
   50 CONTINUE
      I2=IB2-IB1
      I3=IB3-IB2
      I4=IB4-IB3
      I5=IB5-IB4
      I6=IB6-IB5
      I7=IB7-IB6
      I8=IB8-IB7
      I9=IB9-IB8
      WRITE(6,500)
  500 FORMAT(1H1,23HFLAT-FACED CAM FOLLOWER)
      WRITE(6,501)
  501 FORMAT(1H ,41HTHE FOLLOWING INPUT PARAMETERS ARE GIVEN.)
      WRITE(6,502) AL1,AL2
  502 FORMAT(1H ,19HFIRST CAM LIFT=AL1=,F6.2,10X,18HSEC. CAM LIFT=A 2=,
     1 F6.2)
      WRITE(6,503) AL3,AL4
  503 FORMAT(1H ,19HFIRST CAM FALL=AL3=,F6.2,10X,18HSEC. CAM FALL=AL4=,
     1 F6.2)
      WRITE(6,504) IB1,I2,I3,I4,I5,I6,I7,I8,I9
  504 FORMAT(1H ,11H1 ST.DWELL=,I5,2X,7HDEGREES,8X,10H1 ST.RISE=,I5,2X,
     17HDEGREES/1H ,11H2 ND.DWELL=,I5,2X,7HDEGREES,8X,10H2 ND.RISE=,I5,
     22X,7HDEGREES/1H ,11H3 RD.DWELL=,I5,2X,7HDEGREES,8X,10H1 ST.FALL=,
     3I5,2X,7HDEGREES/1H ,11H4 TH.DWELL=,I5,2X,7HDEGREES,8X,10H2 ND.FALL
     4,I5,2X,7HDEGREES/1H ,11H5 TH.DWELL=,I5,2X,7HDEGREES)
```

```
          IF(IC1.EQ.3)  GO TO 550
          IF (IC1.EQ.1) GO TO 262
          WRITE(6,551)
    551   FORMAT(1H ,20HFIRST RISE=CYCLOIDAL)
          GO TO 552
    550   WRITE(6,553)
    553   FORMAT(1H ,26HFIRST RISE=SIMPLE HARMONIC)
          GO TO 552
```



```
    262   WRITE (6,263)
    263   FORMAT (1H ,20HFIRST RISE=PARABOLIC)
    552   IF(IC2.EQ.3) GO TO 555
          IF (IC2.EQ.1) GO TO 264
          WRITE(6,554)
    554   FORMAT(1H+,30X,21HSECOND RISE=CYCLOIDAL)
          GO TO 556
    555   WRITE(6,557)
    557   FORMAT(1H+,30X,27HSECOND RISE=SIMPLE HARMONIC)
          GO TO 556
    264   WRITE (6,265)
    265   FORMAT (1H+,30X,21HSECOND RISE=PARABOLIC)
    556   IF (IC3.EQ.3) GO TO 560
          IF (IC3.EQ.1) GO TO 266
          WRITE(6,558)
    558   FORMAT(1H ,20HFIRST FALL=CYCLOIDAL)
          GO TO 561
    560   WRITE(6,559)
    559   FORMAT(1H ,26HFIRST FALL=SIMPLE HARMONIC)
          GO TO 561
    266   WRITE (6,267)
    267   FORMAT (1H ,20HFIRST FALL=PARABOLIC)
    561   IF(IC4.EQ.3) GO TO 565
          IF (IC4.EQ.1) GO TO 268
          WRITE(6,562)
    562   FORMAT(1H+,30X,21HSECOND FALL=CYCLOIDAL)
          GO TO 564
    565   WRITE(6,563)
    563   FORMAT(1H+,30X,27HSECOND FALL=SIMPLE HARMONIC)
          GO TO 564
    268   WRITE (6,269)
    269   FORMAT (1H+,30X,21HSECOND FALL=PARABOLIC)
    564   CONTINUE
          IF(MCW.NE.1) GO TO 510
          WRITE(6,505) MCW
    505   FORMAT(1H ,41HCLOCKWISE CAM ROTATION IDENTIFIED BY MCW=,I2)
          GO TO 511
    510   WRITE(6,506) MCW
    506   FORMAT(1H ,49HCOUNTER CLOCKWISE CAM ROTATION IDENTIFIED BY MCW=,
         1   I2)
    511   WRITE(6,507) ECC,IPLOT
    507   FORMAT(1H 13HECCENTRICITY=,F5.2/1X,63HTHE SIZE OF THE PLOT PAPER I
         1S SELECTED BY IDENTIFYING 'IPLOT'= ,I4)
          WRITE(6,508)
    508   FORMAT(1H0,46HTHE FOLLOWING VALUES ARE THE OUTPUT PARAMETERS)
          WRITE(6,509) ROTA,K
    509   FORMAT(1H ,24HTHE MINIMUM FACE LENGTH=,F10.2,18HINCHES (DIAMETER),
         1/1H ,16HWHICH OCCURS FOR, I4,23HDEGREES OF CAM ROTATION)
          WRITE(6,512)
    512   FORMAT(1H ,80HTHE COORDINATES OF THE CONTACT POINT 'P' AND THE CEN
```

```
      1TER 'C' OF THE FOLLOWER ARE:)
      WRITE(6,515)
  515 FORMAT(1H ,65HINPUT ANGLE THETA  .  COORDINATES OF 'P'       COORD
     1INATES OF 'C')
      DO 513 J=1,360
  513 WRITE(6,514) IBJ(J),XP(J),YP(J),XC(J),YC(J)
  514 FORMAT(1H ,12X,I5,3X,2F10.4,5X,2F10.4)
      IF(IPLOT.EQ.11) GO TO 70
```



```
      CALLPLOT(15.,-30.,-3)
      CALLPLOT(0.,15.,-3)
      GO TO 71
   70 CONTINUE
      CALLPLOT(10.,-11.,-3)
      CALLPLOT(0.,5.5,-3)
   71 CONTINUE
      CALLCIRCLE(0.,0.,0.,360.,AEC,AEC,0.5,2)
      CALLCIRCLE(0.,0.,0.,360.,.25,.25,0.0,2)
      CALLPLOT(XP(K),YP(K),+3)
      CALLCIRCLE(XP(K),YP(K),0.,360.,.05,.05,0.0,2)
      CALLPLOT(0.,0.,3)
      CALLPLOT(XP(1),YP(1),+3)
      DO 28 J=1,360
   28 CALLPLOT(XP(J),YP(J),+2)
      CALLPLOT(XC(1),YC(1),-3)
      J=1
   31 CALLPLOT(OCX(J),OCY(J),+2)
      CALLPLOT(OBX(J),OBY(J),2)
      CALLPLOT(OAX(J),OAY(J),+2)
      CALLPLOT(OPX(J),OPY(J),+2)
      CALLPLOT(0.,0.,+2)
      CALLPLOT(ODX(J),ODY(J),+2)
      CALLPLOT(0.,0.,+3)
      IF(J.EQ.1) GO TO 32
      GO TO 33
   32 J=K
      CALLPLOT(-XC(1),-YC(1),-3)
      CALLCIRCLE(0.,0.,0.,360.,.1,.1,0.0,2)
      CALLPLOT(XC(J),YC(J),-3)
      GO TO 31
   33 CONTINUE
      CALLSYMBOL(ODX(J),ODY(J),.1,12HMIN.FOLLOWER,0.,12)
      CALLSYMBOL(ODX(J),ODYY,.1,26HFACE LENGTH          INCHES,0.,26)
      CALLNUMBER(ODXX,ODYY,.1,ROTA,0.,2)
      CALLPLOT(0.,0.,-3)
      IF(IPLOT.EQ.11) GO TO 35
      CALLPLOT(10.,-30.,-3)
      CALLPLOT(0.,2.,-3)
      GO TO 36
   35 CONTINUE
      CALLPLOT(10.,-11.,-3)
      CALL PLOT(0.,2.,-3)
   36 CONTINUE
      IF(NCW.NE.1) GO TO 120
      CALLSYMBOL(0.,-1.,.2,22HCLOCKWISE CAM ROTATION,0.,22)
      GO TO 121
  120 CALLSYMBOL(0.,-1.,.2,30HCOUNTER CLOCKWISE CAM ROTATION,0.,30)
  121 CONTINUE
      CALL AXIS(0.,0.,20HINPUT ANGLE. DEGREES,-20,6.,0.,0.,60.,10.)
```

```
      CALL AXIS(0.,0.,19HDISPLACEMENT INCHES,19,3.,   90.,0.,1.,10.)
      CALL PLOT(0.,0.,-3)
      DO 155 J=1,360
  155 CALL PLOT(ANGLE(J),PATH(J),+2)
      CALLPLOT(AB1,0.,+3)
      CALLPLOT(AB1,YAXIS,+2)
      CALLPLOT(AB2,YAXIS,+3)
      CALLPLOT(AB2,0.,+2)
```

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```
      CALLPLOT(AB3,0.,+3)
      CALLPLOT(AB3,YAXIS,+2)
      CALLPLOT(AB4,YAXIS,+3)
      CALLPLOT(AB4,0.,+2)
      CALLPLOT(AB5,0.,+3)
      CALLPLOT(AB5,YAXIS,+2)
      CALLPLOT(AB6,YAXIS,+3)
      CALLPLOT(AB6,0.,+2)
      CALLPLOT(AB7,0.,+3)
      CALLPLOT(AB7,YAXIS,+2)
      CALLPLOT(AB8,YAXIS,+3)
      CALLPLOT(AB8,0.,+2)
      CALLPLOT(AB9,0.,+3)
      CALLPLOT(AB9,YAXIS,+2)
      CALLPLOT(10.,-5.,-3)
      RETURN
      END
```

FLAT-FACED CAM FOLLOWER

THE FOLLOWING INPUT PARAMETERS ARE GIVEN.

FIRST CAM LIFT=AL1= 0.0	SEC. CAM LIFT=A 2= 0.75
FIRST CAM FALL=AL3= 0.75	SEC. CAM FALL=AL4= 0.0
1 ST.DWELL= 0 DEGREES	1 ST.RISE= 0 DEGREES
2 ND.DWELL= 0 DEGREES	2 ND.RISE= 150 DEGREES
3 RD.DWELL= 1 DEGREES	1 ST.FALL= 87 DEGREES
4 TH.DWELL= 30 DEGREES	2 ND.FALL= 0 DEGREES
5 TH.DWELL= 0 DEGREES	
FIRST RISE=CYCLOIDAL	SECOND RISE=CYCLOIDAL
FIRST FALL=SIMPLE HARMONIC	SECOND FALL=SIMPLE HARMONIC

COUNTER CLOCKWISE CAM ROTATION IDENTIFIED BY MCW= 2
ECCENTRICITY= 1.00
THE SIZE OF THE PLOT PAPER IS SELECTED BY IDENTIFYING 'IPLOT'= 11

THE FOLLOWING VALUES ARE THE OUTPUT PARAMETERS
THE MINIMUM FACE LENGTH= 3.15INCHES (DIAMETER),
WHICH OCCURS FOR 76DEGREES OF CAM ROTATION
THE COORDINATES OF THE CONTACT POINT 'P' AND THE CENTER 'C' OF THE FOLLOWER ARE:

INPUT ANGLE THETA	COORDINATES OF 'P'		COORDINATES OF 'C'	
0	2.5000	0.0	2.5000	1.0000
1	2.4996	-0.0439	2.5171	0.9562
2	2.4985	-0.0882	2.5334	0.9122
3	2.4965	-0.1331	2.5489	0.8678
4	2.4937	-0.1784	2.5637	0.8232
5	2.4901	-0.2241	2.5779	0.7783
6	2.4857	-0.2703	2.5911	0.7332
7	2.4804	-0.3178	2.6037	0.7879
8	2.4742	-0.3633	2.6156	0.6423
9	2.4671	-0.4111	2.6267	0.5965
10	2.4592	-0.4567	2.6371	0.5505
11	2.4503	-0.5066	2.6467	0.5043
12	2.4405	-0.5549	2.6557	0.4580
13	2.4297	-0.6034	2.6639	0.4114
14	2.4180	-0.6521	2.6715	0.3647
15	2.4054	-0.7010	2.6783	0.3178
16	2.3917	-0.7502	2.6844	0.2707
17	2.3771	-0.7994	2.6898	0.2235
18	2.3616	-0.8488	2.6945	0.1761
19	2.3450	-0.8983	2.6985	0.1286
20	2.3275	-0.9478	2.7019	0.0810
21	2.3090	-0.9974	2.7045	0.0332
22	2.2894	-1.0470	2.7064	-0.0147
23	2.2689	-1.0965	2.7076	-0.0628
24	2.2474	-1.1460	2.7082	-0.1109
25	2.2249	-1.1955	2.7080	-0.1592
26	2.2014	-1.2446	2.7071	-0.2075
27	2.1770	-1.2936	2.7056	-0.2560
28	2.1516	-1.3425	2.7033	-0.3045
29	2.1252	-1.3911	2.7004	-0.3532
30	2.0978	-1.4395	2.6967	-0.4019

31	2.0695	-1.4876	2.6923	-0.4508
32	2.0402	-1.5353	2.6872	-0.4997
33	2.0101	-1.5827	2.6814	-0.5486
34	1.9790	-1.6296	2.6749	-0.5977
35	1.9470	-1.6762	2.6676	-0.6468
36	1.9141	-1.7223	2.6597	-0.6959
37	1.8804	-1.7679	2.6509	-0.7451
38	1.8458	-1.8129	2.6415	-0.7943
39	1.8104	-1.8575	2.6313	-0.8436
40	1.7742	-1.9014	2.6203	-0.8928
41	1.7372	-1.9449	2.6086	-0.9421
42	1.6994	-1.9875	2.5961	-0.9914
43	1.6609	-2.0295	2.5828	-1.0406
44	1.6216	-2.0709	2.5687	-1.0899
45	1.5817	-2.1116	2.5539	-1.1391
46	1.5411	-2.1515	2.5382	-1.1883
47	1.4998	-2.1907	2.5218	-1.2374
48	1.4579	-2.2291	2.5045	-1.2864
49	1.4154	-2.2667	2.4864	-1.3354
50	1.3724	-2.3035	2.4675	-1.3842
51	1.3288	-2.3394	2.4477	-1.4330
52	1.2846	-2.3745	2.4271	-1.4816
53	1.2400	-2.4088	2.4057	-1.5301
54	1.1950	-2.4421	2.3834	-1.5784
55	1.1495	-2.4746	2.3602	-1.6265
56	1.1036	-2.5061	2.3362	-1.6744
57	1.0573	-2.5368	2.3113	-1.7221
58	1.0107	-2.5665	2.2855	-1.7695
59	0.9638	-2.5953	2.2589	-1.8167
60	0.9165	-2.6231	2.2313	-1.8637
61	0.8691	-2.6500	2.2029	-1.9103
62	0.8213	-2.6759	2.1735	-1.9566
63	0.7734	-2.7009	2.1433	-2.0025
64	0.7253	-2.7249	2.1122	-2.0481
65	0.6770	-2.7479	2.0801	-2.0932
66	0.6287	-2.7700	2.0472	-2.1380
67	0.5802	-2.7911	2.0134	-2.1823
68	0.5316	-2.8112	1.9786	-2.2262
69	0.4830	-2.8304	1.9430	-2.2695
70	0.4343	-2.8486	1.9065	-2.3123
71	0.3856	-2.8658	1.8691	-2.3546
72	0.3370	-2.8821	1.8309	-2.3963
73	0.2884	-2.8974	1.7916	-2.4375
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75	0.1913	-2.9253	1.7107	-2.5178
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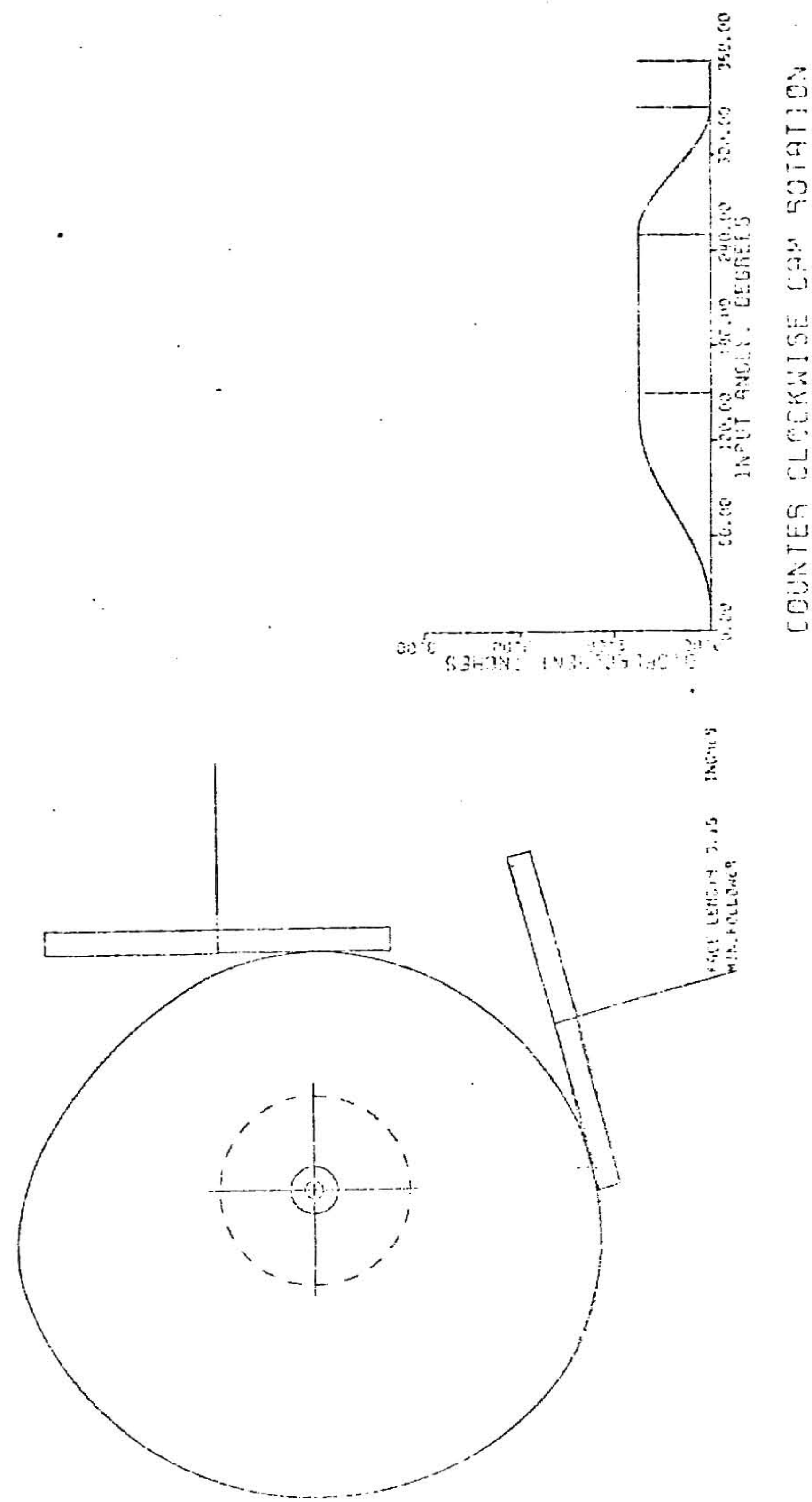
      0.0                                        6.28318309783935600000000
      0.0999999642372131000000000
      0.0                                        8.37757587432861400000000
      0.0
      0.0                                                     8
2
1          1     0.0          0.750000     1.000000     0.100000     0.073169      0.068164
2          0     0.0          1.500000     2.000000     0.100000     0.007074      0.099749
2
3          1     0.0          2.250000     3.000000     0.100000    -0.052817      0.077807
```


INPUT ANGLE, DEGREES
COUNTER CLOCKWISE CAM ROTATION

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COMPUTER METHOD OF DETERMINING CAM PROFILES

by

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ABSTRACT

This thesis introduces the use of the cal-comp plotter, a computer facility, through subroutine programs developed to draw cam mechanisms having different types of followers. The programs are:

1. ROSCAM - to develop the profile of a cam with an oscillating roller follower.
2. FOSCAM - to draw a cam mechanism having a flat-faced oscillating follower.
3. CAMROL - to produce a profile of a cam with a translating roller follower.
4. CAMFLT - to develop the profile of a cam having a flat-faced translating follower.

Main programs which use these subroutines have been developed. The subroutines were modified to operate correctly and to increase profile capabilities. Input and output are standardized. The cam theory in its specific relation to the contents of the subroutines is developed. The graphical equivalent of the function of the subroutines is given for a comparison between methods. The auxiliary subprograms and subroutine entries that are involved in the main subroutines (ROSCAM, FOSCAM, CAMFLT, CAMROL) are described by illustrations. To aid in the use of the programs, some remarks drawing attention to the assumptions of subroutines and samples of programs run are given.