PART 4 OF MACHINE AND CONTROLLER

27. Running the machine in MANUAL

28. INSERT KEY, DELETE KEY, READ / WRITE KEY } LINE MODE ONLY

29. The ϕ KEY -- the Q angle

1) The Qualifiers on Q
2) Example of initial positioning and cutting

BALL CUTTER.

1. A 30 degree down hemisphere.
2. A 45 degree up hemisphere.
3. A 30 degree cylindrical slot along X axis.
4. A 30 degree cylindrical slot at 45 degree to X axis.
5. An arc parallel to the X axis.

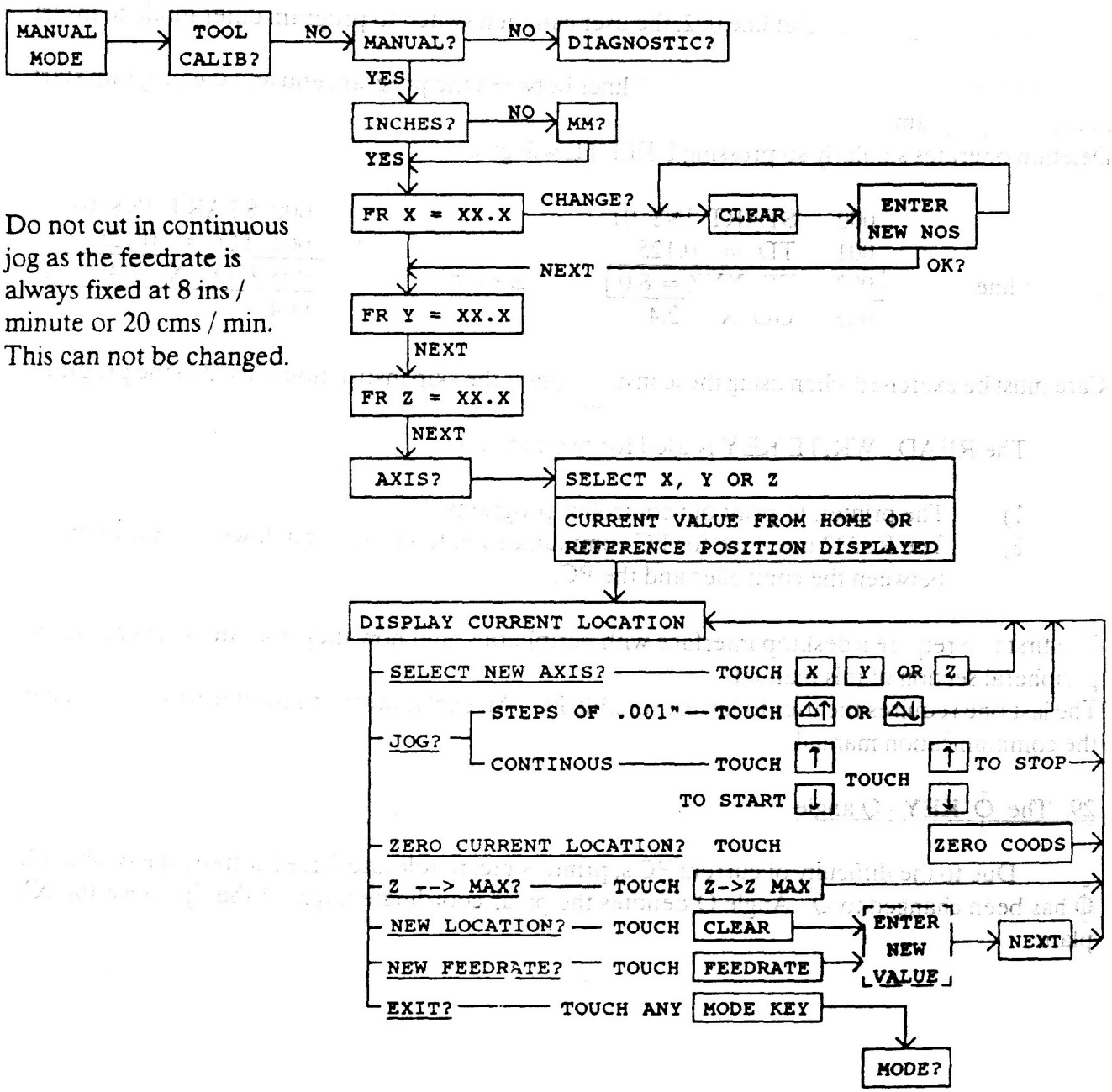
SQUARE END MILL

6. Positioning Outside and Inside.
7. A 45 degree up hemisphere.
8. A 30 degree down hemisphere.

27. Running the machine in MANUAL MODE

The purpose of this mode is to allow the user to do very simple operations without programming the controller in for example cutting tests, simple drilling etc. Only one axis is moved at a time and it is exactly as though you had handles on each axis with a digital read out on each axis except the controller moves theselected axis for you. To enter it press the MANUAL MODE KEY, answer NO to TOOL CALIB? and YES to MANUAL? The controller will ask questions INS / MM ?, FEEDRATE ON EACH AXIS ? then AXIS ?. Press X Y or Z. Remember the axes is at the HOME POSITION. You can jog down on Z, X, or Y and ZERO the tool at the edge (USE ZERO COODS KEY). Press CLEAR, enter the desired coordinate, then press NEXT and the tool will move to that coordinate.

Do not cut in continuous jog as the feedrate is always fixed at 8 ins / minute or 20 cms / min. This can not be changed.



28. INSERT, DELETE AND READ / WRITE KEY

These keys only operate in the LINE MODE. The first two allow the user to insert or delete a program line at the current line. Pressing SHIFT DOWN INSERT will automatically push the program down one line. Thus, for example if the program is as shown:

	000 START INS 01			000 START INS 01
	001 TD = 0.125			001 TD = 0.125
Current line	002 FR XYZ = 8.0		goes to	002
	003 GO X 2.4			003 FR XYZ = 8.0
				004 GO X 2.4

On pressing INSERT at line 002, the user can then switch to program enter mode to insert an additional instruction.
Insertion can only be done if there are blank lines between the program end and the program start of the next program.
Deletion operates similarly so pressing DELETE will give :-

	000 START INS 01			000 START INS 01
	001 TD = 0.125			001 TD = 0.125
Current line	002 FR XYZ = 8.0		goes to	003 GO X 2.4
	003 GO X 2.4			004

Care must be exercised when using these instructions if the skip instruction is used in the program.

The READ / WRITE KEY is used for two functions.

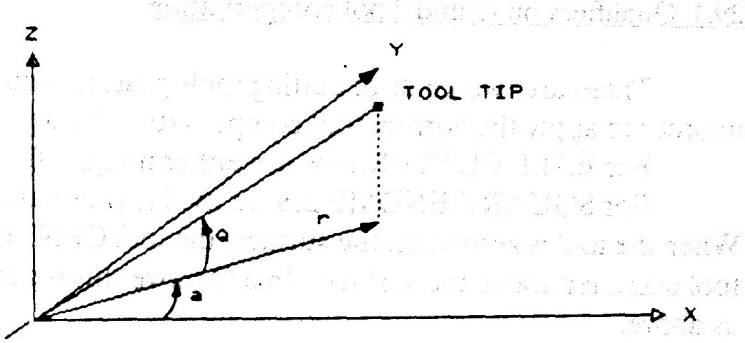
1) The printer, to print out controller programs.
2) The RS232 interface for PC communication to upload and download programs between the controller and the PC.

The first two require a desktop interface with peripherals, and how they operate is covered in the peripheral section of this manual.
The last one requires the user to have a suitable PC. An explanation of how it works is covered in the communication manual.

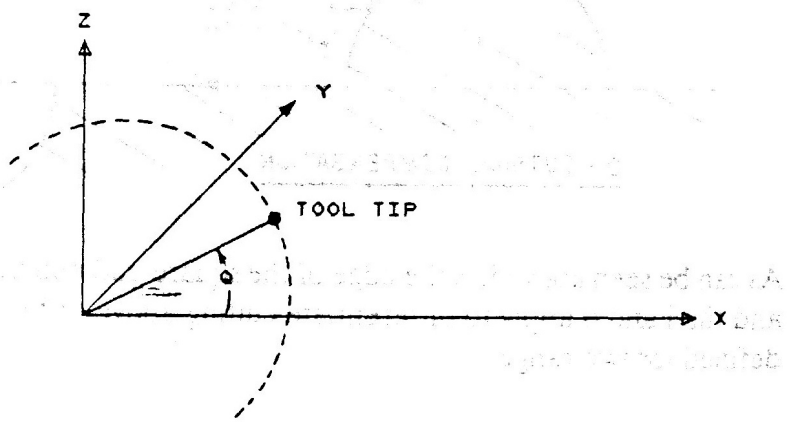
29. The Φ KEY - Q angle

Due to the difficulty of current PC's, printers etc. to tolerate Greek letters, the symbol phi Φ has been changed to Q. Angle Q denotes the polar coordinate angle of the tip above the XY plane.

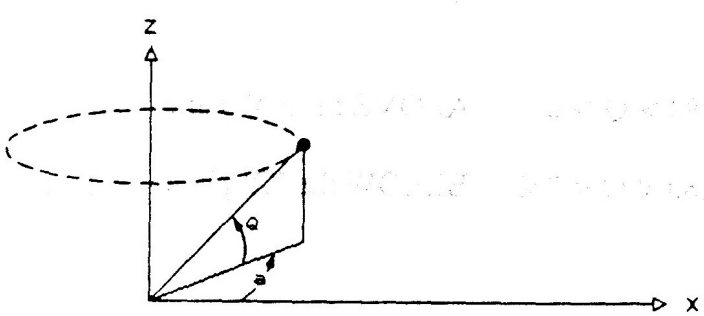
As we vary angle Q, the tool tip will move in an arc, in a plane at an angle a to the X axis. If we keep angle Q constant, but vary angle a we generate a circular arc in a plane parallel to the XY axes.



Suppose angle a = 0. Then we would see this:- As angle Q varies we cut a circle in the XZ plane.



Suppose angle Q = 45 . If we vary angle a we would see the tool tip move in a circle like so around the Z axis.



If we varied angles Q and a we would generate a sphere. If we set Q, then move for example X back and forth, then increment Q and so on, we would cut a cylindrical trench along the X axis. The cross section in the ZY plane would be a hemisphere.

29.1 Qualifiers on Q and Tool compensation

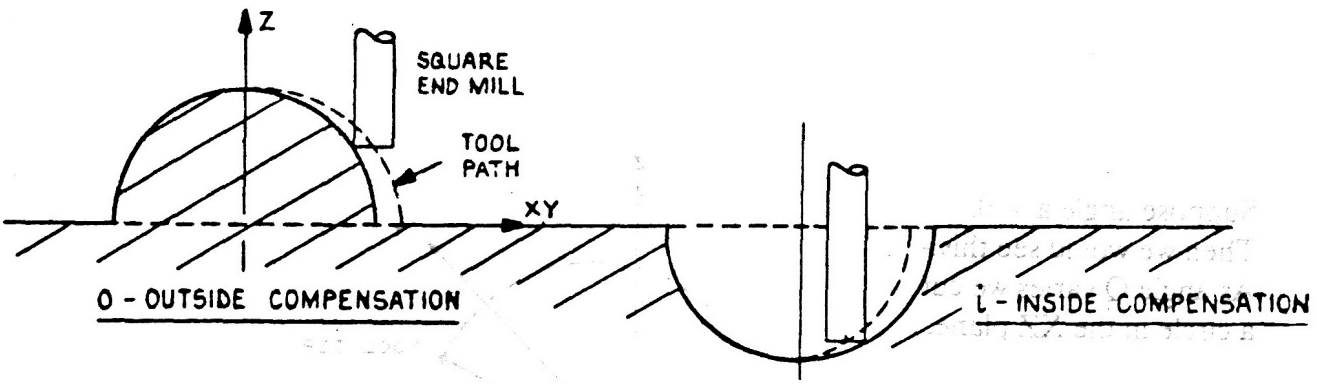
There are two kinds of cutting tools possible and the controller must know which is which in order to apply the correct tool compensation for a particular Q angle move.

For BALL CUTTERS we use either no qualifier blank, f (fast) and c (comeback)

For SQUARE ENDMILLS we use i (inside) and o (outside)

When the tool is zeroed on the surface, the tool CENTER in the case of the ball cutter is half the tool diameter above the surface. In a Q move this is automatically factored in if the qualifier is as above.

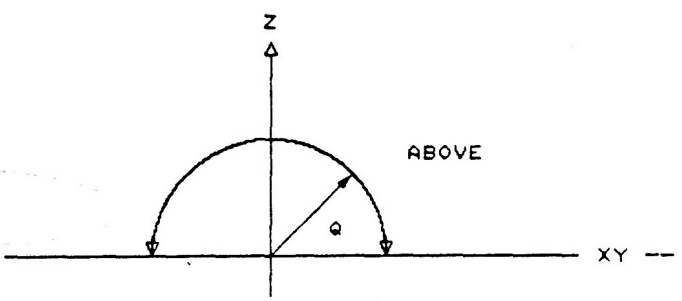
For a square end mill, i and o are used in a different sense but automatic compensation is still built in.

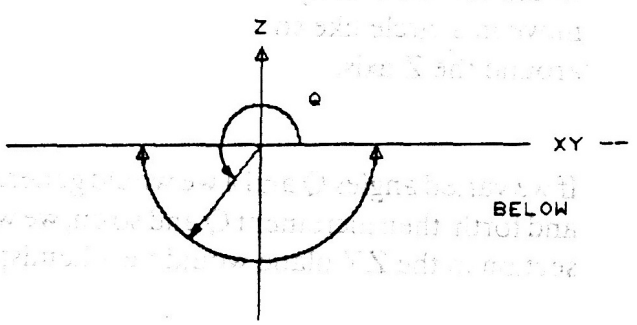


As can be seen above it is the edge of the square end mill that has to cut an arc not the tool center and the i and o apply to differentiate cutting above or below the XY plane. Consequently Q is defined for two ranges.

1. $180 > Q > 0$ ABOVE the XY plane

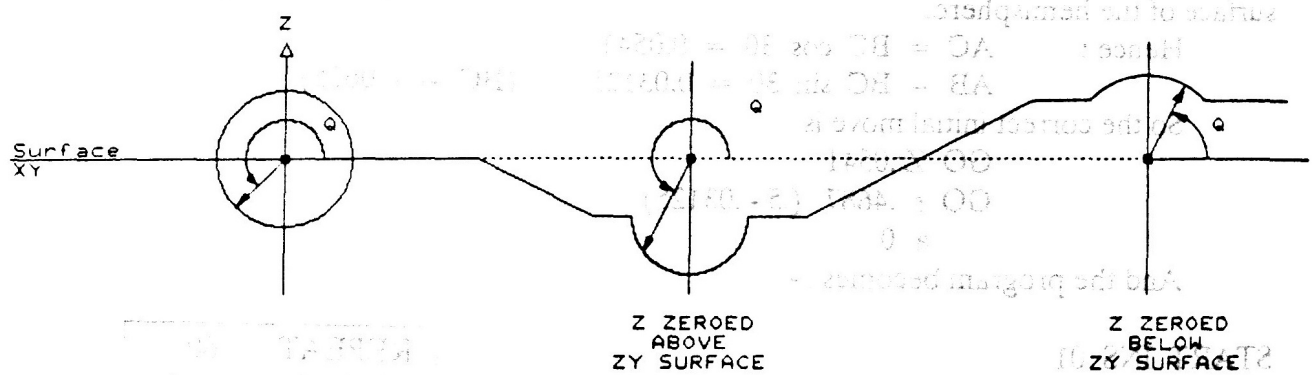
and 2. $180 < Q < 360$ BELOW the XY plane





NOTE: You have to make 2 Q moves if you are operating 90 to 270 degrees. The first Q move is 90 to 180 degrees, the second is 180 to 270 degrees.

To cut partial arcs, Z must be zeroed correctly above or below the surface. Actually Z is correct but the surface has dropped or heightened because we use the surface as the reference.



29.2 The Q instructions and how used

The instructions are simply with or without the appropriate qualifiers

GO Q + nnn . nnn	GO TO this absolute angle in degrees
GR Q + nnn . nnn	GO RELATIVE this amount of degrees from where you are.

To use them you need : -

1) To decide on a ball end mill cutter or a flat end mill one.
   If a flat end mill cutter, then all moves on Q should be qualified by inside or outside.
2) The tool must be initially positioned in space correctly. Examples follow.
3) The zero around which Q operates must be set correctly to correspond with the desired radius and angle.
4) Then the moves are generated with a combination of Q, X, Y or (r,a) to cut the required surface.
5) Check the program out in wax first.

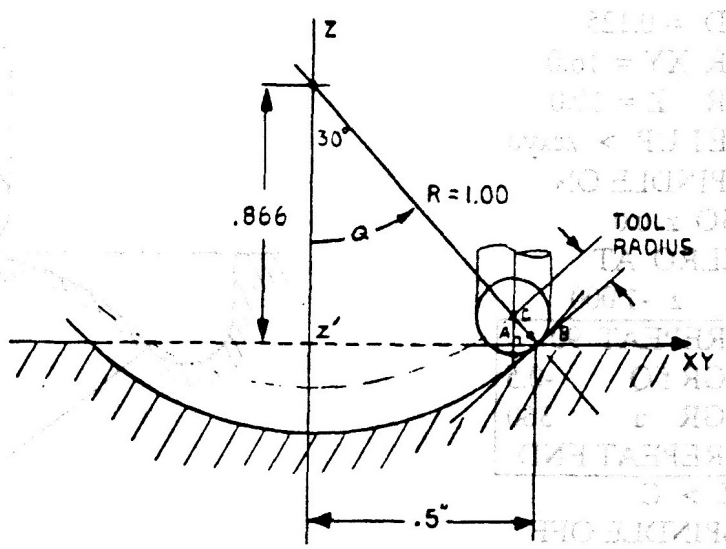
29.3 Examples of initial Positioning and Cutting

1) Cutting a 30 degree down hemisphere with a ball cutter

Suppose the radius R of the down hemisphere is 1 inch and the ball cutter diameter is .125 inches. The zero point on Z where we swing angle Q is

$$R \cos Q = 1 \times \cos 30$$
$$= \underline{0.866}$$

The surface radius of the hemisphere Z'B = R sin Q = r x sin 30 = 0.5



As can be seen, with the ball cutter positioned correctly, the tool has to be raised by the amount AC and the radius shortened by the amount AB. This will position the ball end mill tangentially to the surface of the hemisphere.

Hence : AC = BC cos 30 = 0.0541
AB = BC sin 30 = 0.03125 (BC = 0.0625)

So the correct initial move is

GO Z-.0541
GO r .4687 (.5 - .03125)
a 0

And the program becomes : -

```
START INS 01
TD = 0.125
FR XY =   16.0
FR  Z =   10.0
SET UP > zcxyu
SPINDLE ON

GO   z-    .0541      INITIAL POSITION      Z > C
GO   r     .4687      OF TOOL               SPINDLE OFF
     a     0.0                              END

ZERO AT                 SET CENTER
     z     0.8660       OF SPHERE
```

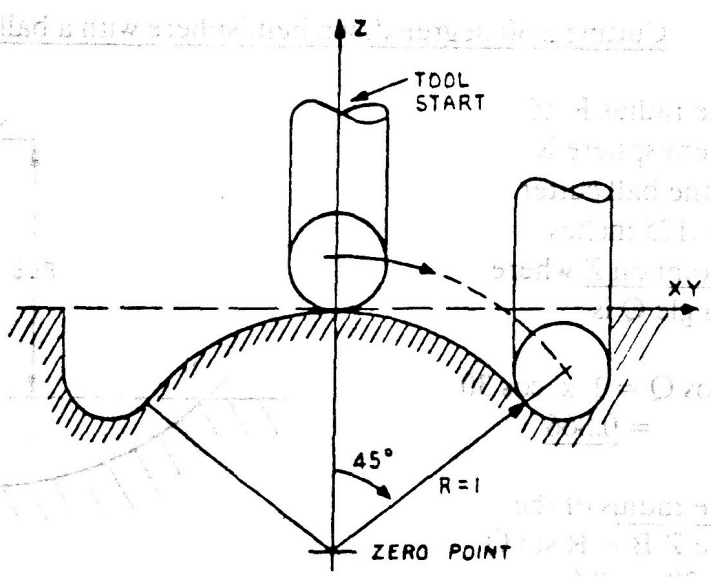
```
REPEAT    60
GR f  Q   -0.5
GR    a   360.0
REPEAT END
```

A horizontal circle is cut with Q getting smaller by 0.5 degrees on each repeat (60 x 0.5 = 30 degrees).

2) Cutting an up 45 degree hemisphere with a ball cutter

The center of the hemisphere is 1 inch below the surface. The program becomes : -

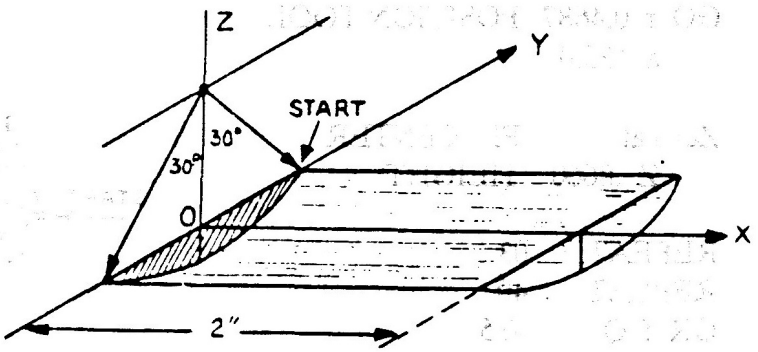
```
START INS 01
TD = 0.125
FR XY = 16.0
FR  Z = 10.0
SET UP > zcxyu
SPINDLE ON
GO z 0.0
ZERO AT
   z -1.000
REPEAT 90
GR f Q    -0.5
GR  a     360
REPEAT END
Z > C
SPINDLE OFF
END
```



The critical program section is outlined. On each repeat we move Q incrementally in 0.5 degree steps then rotate in a circle in the XY plane.

3) Cutting a circular slot along the X axis, with a ball cutter

The simplest way to do this is to move the tool back and forth along the X axis while moving Q in small increments.
The critical section becomes:-

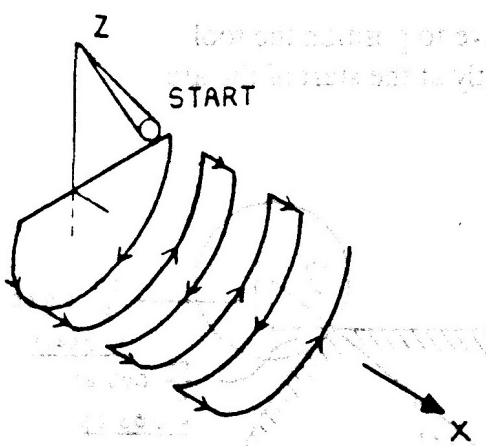



```
GO  Z  0.0541   POSITION TOOL OUT
GO  r  0.4687   ALONG THE
    a  90.0     Y AXIS
ZERO AT         FIX CENTER HEIGHT
    Z  .866
```

```
REPEAT    03
REPEAT    40
 GR f Q   -0.5
 GR c X   2.0
REPEAT END
REPEAT END
```

Move Q 120 times, 0.5 degrees (=60 degrees)
Move X along 2 inches and come back.
or we can do this by incrementing along X, re-zeroing X, then swinging Q from 240 degrees to 300 degrees.

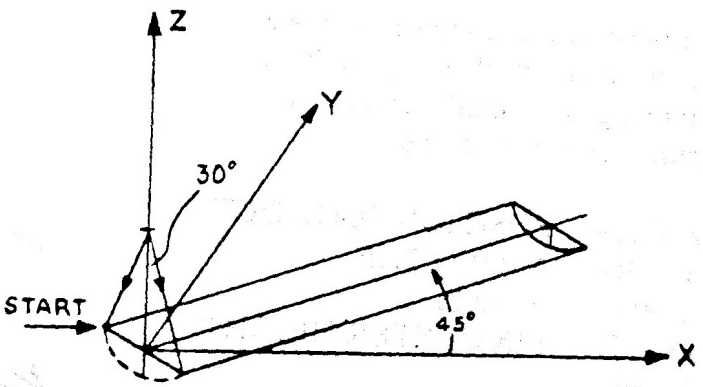
```
REPEAT    10

GO   Q    240.00
GR   X    .1

ZERO      X

GO   Q    300.00
GO   X    .1

ZERO      X

REPEAT END
```



Incrementing .1 along X on each Q swing.

4) A 30 degree cylindrical slot at 45 degrees to the x axis

Again the simplest way to do this is to move the tool back and forth along the slot, then to move Q incrementally.



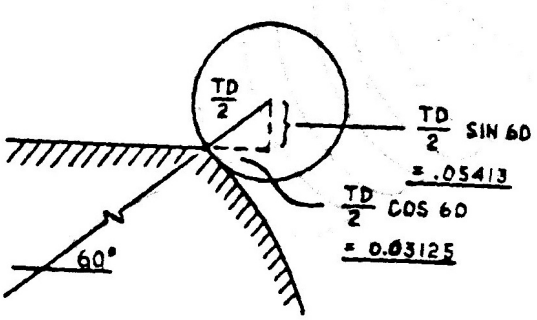

```
GO  Z-0.0541
GO  r 0.4687   POSITION TOOL
    a 135.0

Zero at        FIX CENTER
    Z .8660    HEIGHT

REPEAT    03
REPEAT    40
GR f Q    -0.5
GR   X    1.4142    Go out at 45 degrees
     Y    1.4142          and
GR   X   -1.4142      come back
     Y   -1.4142
REPEAT END
REPEAT END
```

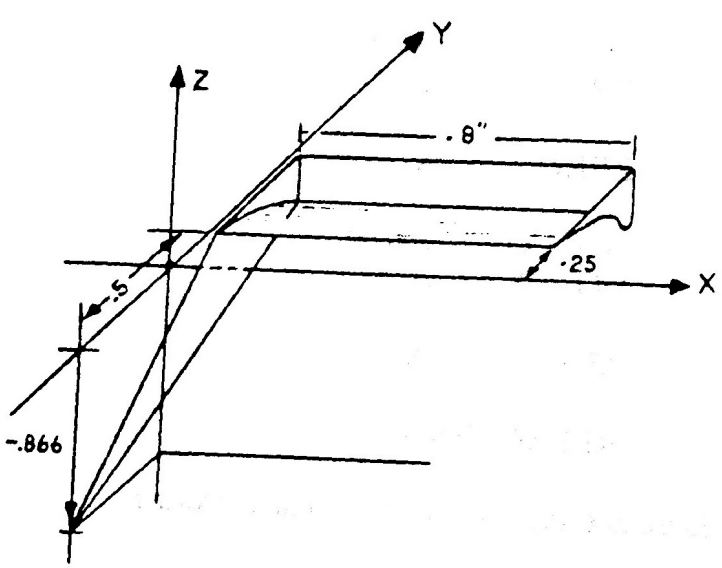
NOTE : Since we can't do REPEAT 120 we simply break it into two repeats of 3 and 40.

5) An arc parallel to the X axis

Using a ball end mill of diameter .125 and an R = 1

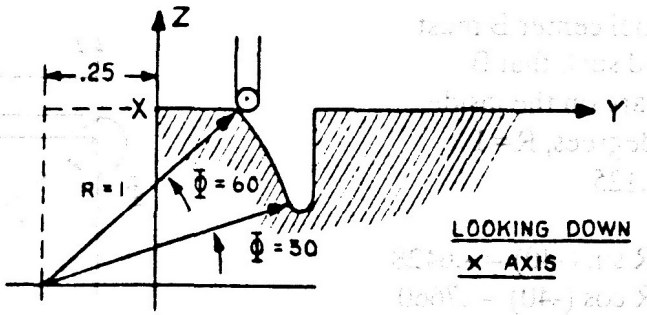
We have to position the tool correctly at the start of the arc.





The instructions are : -

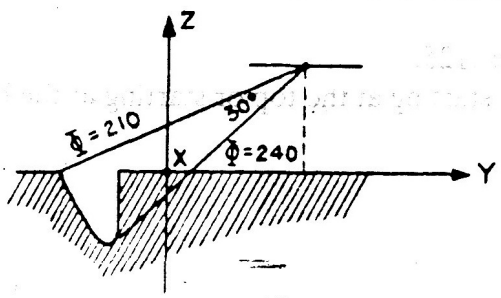
GO Y .2813 (.25 + 03125)
GO Z .0541



Next we zero the axis about which Q moves :-

ZERO AT
Z - .866
Y - .25
Then REPEAT 60
GR f Q -0.5
GR c X 0.8
REPEAT END

This produces a convex arc. By moving the zero above the surface we can generate a concave arc. Like so : -

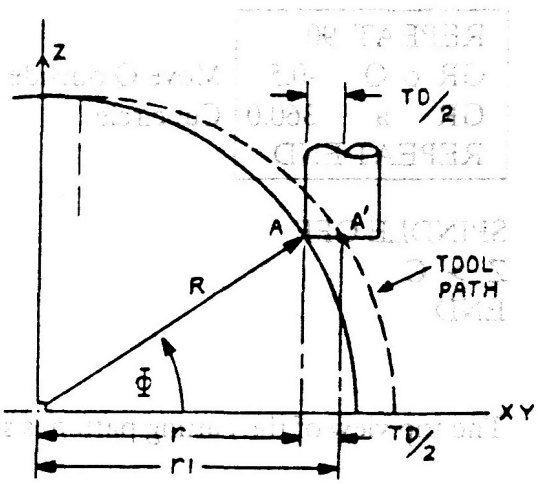


6) SQUARE END MILL

The user must position the square end mill initially correctly and then any Q moves, using i inside or o outside, will compensate automatically to ensure that the tool edge traces an arc.

For outside compensation

The edge of the end mill must be touching the arc A at the initial starting point. So the center must be at A .



Suppose Q = 40 degrees,
R = 1 and TD = .125.

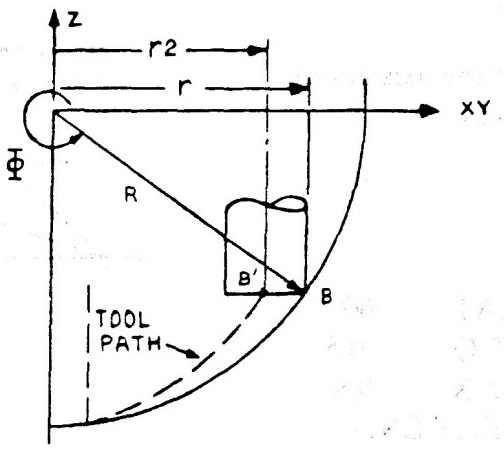
Then z = R sin 40 = 0.6428
r = R cos 40 = 0.7660

So the tool center is positioned at (z, r1)

where z = 0.6428
r1 = 0.766 + TD / 2 = 0.8285.

For inside compensation

Again the tool center B must be positioned such that B touches the arc on the inside.
If Q = 320 degrees, R=1 and TD = .125



Then z = R sin (-40) = -.6428
r = R cos (-40) = .7660

So r2 = .7660 - TD/2 = .7035
and the tool is positioned at

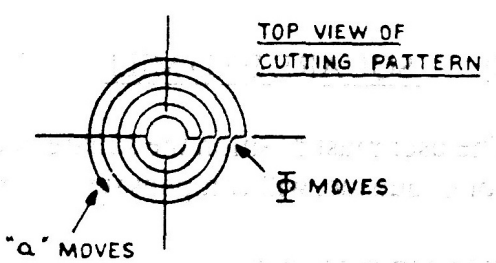
(z , r2) = (-.6428, .7035)

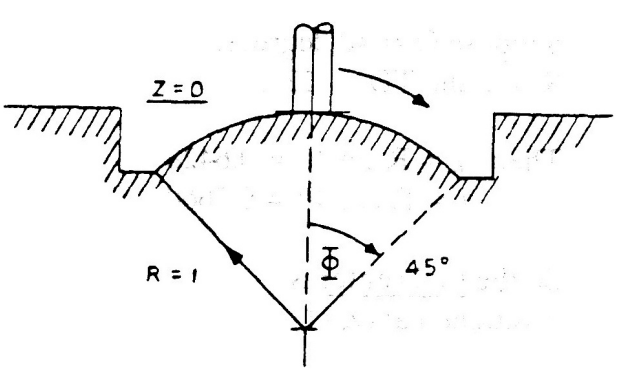
7) A 45 degree up hemisphere with a square end mill

R = 1 and the tool diameter is .125.
There are two ways to do this, starting at the top or starting at the bottom.

Starting at the top

```
START INS 01
TD =        0.125
FR XY =     16.0
FR  Z =     10.0
SET UP > zcxyu
SPINDLE ON
GO   Z      0.0
ZERO AT
     Z      -1.0    Set center 1.0 below

 REPEAT 90
 GR o Q     -0.5    Move Q outside .5 degrees
 GR   a     360.0   Cut circle
 REPEAT END

SPINDLE OFF
Z > C
END
```



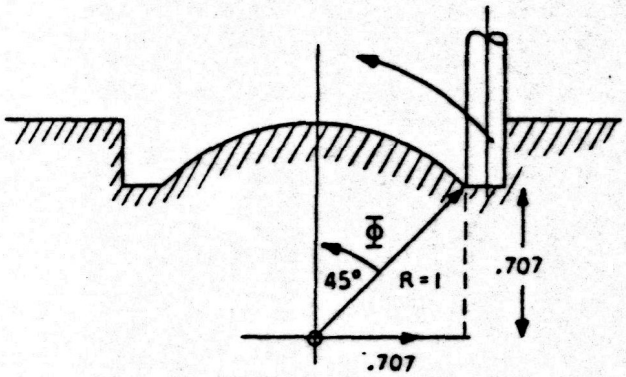


The top view of the cutting patten is shown opposite.

Starting at the bottom

Replace the box above by

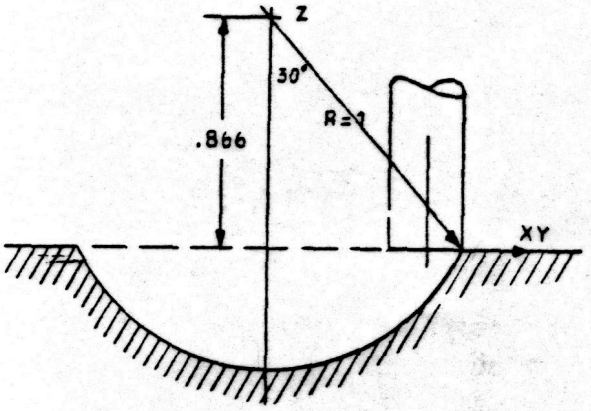
```
GO r 0.7695 (.707 + TD/2)
GO Z 0.707
REPEAT 90
GR o Q .5
GR   a 360.0
REPEAT END
```



8) A 30 degree down hemisphere with a square end mill.

Again R = 1 and the tool is .125
Circular cutting pattern

```
START INS 01
TD =        0.125
FR XY =     16.0
FR   Z =    10.0
SET UP > zcxyu
SPINDLE ON
GO   Z      0.0
ZERO AT
     Z      0.8660
GO i r      0.5
     a      0.0
REPEAT 60
GR i Q      -0.5
GR   a      360.0
REPEAT END
SPINDLE OFF
Z > C
END
```



Arcing cutting pattern

Replace the above box by

```
REPEAT 90
 GO i r 0.5
 GO   z 0.866
 GO i Q 240.0
 GO   a 2.0
 GO i Q 300.0
 GR   a 2.0
REPEAT END
```