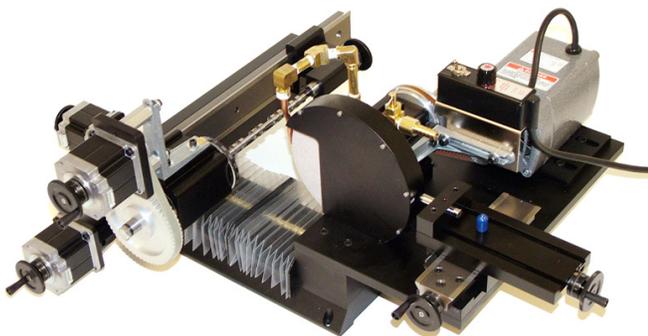**SHERLINE PRODUCTS**

INCORPORATED 1974

Using the Sherline CNC Cam Grinder

P/N 8650 (without computer)
P/N 8655 (with computer)

Updated 12/30/15

The Sherline CNC cam grinder.

Introduction

When building a small engine, the camshaft is one of the more difficult components to make. There are ways to make a mechanical grinder to do the job using patterns and ways to make built-up cams, but this is one job where computer control really makes sense. A specially developed Sherline software program allows you to input simple measurements taken from your cam drawing and output the g-code needed to run the CNC stepper motors that control the rotation of the cam and the shape of the lobe. Keep in mind that this grinder can also be used for grinding small cams for other prototype applications besides model engines.

The Sherline cam grinder was designed to be affordable and accurate. We have assumed that the user has some knowledge of g-code, CNC and how to square up or "tram in" a machine so all axes are properly aligned. The machine is carefully pre-aligned at the factory, but rough handling in shipping could knock something out of alignment. As with any new machine tool, it is the responsibility of the operator to assure that it is properly aligned in all directions before attempting to accurately grind a cam. Illustrated instructions are provided with the machine showing how to unpack, assemble and align it.

The grinder itself features the solid, well-engineered construction you have come to expect from Sherline machine

tools. If you are making a few cams for your own use, making cams for others for sale or a club looking to invest in a machine for use of all the members, this machine will offer a way to take advantage of modern CNC technology to make accurate, well-formed cams with much less time and effort compared to manual methods.

Features:

- Powerful 1/2 HP grinder motor
- 3 DC stepper motors with manual control handwheels
- Flexible way covers on Y-axis keeps water and grinding debris off Y-axis leadscrew
- Holds cam blanks up to 9" long
- Tough black anodized finish on aluminum parts
- Standard 1-year Sherline warranty
- 6" grinding wheel and built-in diamond wheel dresser included
- Laser engraved degree collar on spindle headstock
- Brass coolant plumbing factory assembled
- Available with or without computer and drivers (for those who already have a Sherline CNC mill or lathe)
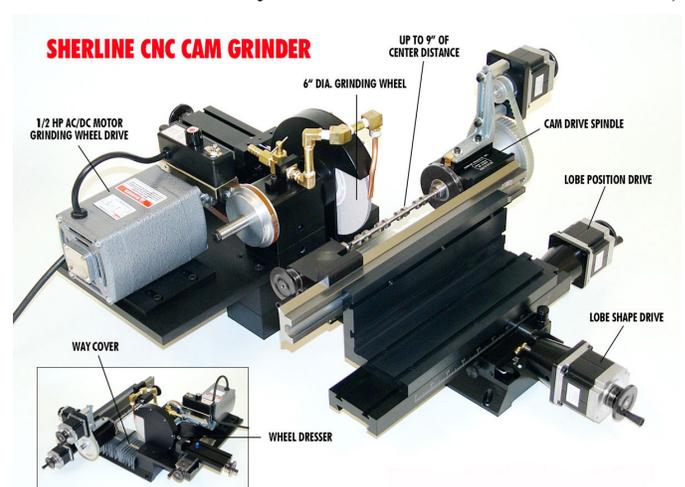
Major components of the Sherline cam grinder.

12/30/15

Parts You Will Need to Purchase

Certain common parts are not supplied with your cam grinder. These are easily purchased locally, which will save you our markup and the cost of shipping. These are:

1. A garage floor oil drip pan. These can be purchased at most auto parts stores and are usually made from galvanized metal and are about 24" x 36" and ½" deep. You will drill a drain hole in this pan at one edge where the bottom and side surfaces intersect. The pan is placed under the cam grinder on a table or workbench with the drain hole hanging over the edge of the table or bench. We suggest placing a spacer about 1/2" thick under the side of the pan opposite from the drain hole to help the coolant flow toward the drain hole.

2. A 5-gallon plastic bucket. These can be purchased at Home Depot or other home supply stores for about $3.00.

3. A small submersible electric pump with an outlet fitting for ½" tubing. These are available at home supply stores for small fountains and garden water features.

4. About 4' to 6' of ½" diameter rubber or clear plastic water hose or tubing.

Assembly

Illustrated assembly and alignment instructions accompany each Sherline cam grinder that is shipped to the customer. Due to their nature they cannot be shipped totally assembled. Various sub-assemblies are packed for shipping that will need to be assembled and aligned. Below are some basic safety and other steps to account for the components that are purchased by the user locally:

1. Perform a "ring" test (see following text inset) on the grinding wheel to check for potential cracks. Instructions on how to do this are included below and with the wheel. This is IMPORTANT, as a cracked grinding wheel can fly apart at high speed and cause serious damage or injury.

2. Remove the five small SHCS that hold the grinding wheel cover plate to the wheel guard. Install the grinding wheel onto the wheel arbor and replace the wheel cover plate. Make sure there is a paper "washer" on either side of the wheel before installing it.

3. Remove the 10-32 SHCS that is located in the top of the grinding wheel headstock. Using this screw, install the brass plumbing assembly for the coolant onto the top of the grinding wheel headstock. Center the water nozzle in front of the grinding wheel.

4. Set the metal drip pan on your workbench or table with the drain hole you drilled overhanging the edge of the bench by a few inches.

5. Place the 5-gallon bucket you purchased on the floor under the drain hole.

6. Hook the ½" OD plastic tubing to the aquarium pump and place it in the bucket. Attach the other end of the tubing to the brass fitting on the coolant nozzle fixture.

How to Perform a Ring Test on a Grinding Wheel.

One method of grinding wheel inspection is called ring testing. OSHA, ANSI and the grinding wheel manufacturers require this method of grinding wheel inspection. It must be performed BEFORE the wheel is mounted on a grinding machine. Ring testing depends on the damping characteristics of a cracked wheel to alter the sound emitted when the wheel is tapped lightly. It is subject to interpretation by the inspector and is primarily applicable to vitrified bonded wheels. To perform the ring test, wheels should be tapped gently with a light nonmetallic implement, such as the handle of a screw driver for light wheels. Here's how:

- Tap wheels about 45 degrees each side of the vertical line and about 1" or 2" from the periphery. Rotate the wheel 45 degrees and repeat the test.

- A sound and undamaged wheel will give a clear tone. If cracked, there will be a dead sound and not a clear ring and the wheel shall not be used.

- Wheels must be dry and free of sawdust when applying the ring test, otherwise the sound may be deadened. The ring test is not applicable to certain wheels because of their size, shape or composition.

For additional information on this topic or any other grinding wheel safety information, please review ANSI (ANSI B7.1), OSHA and literature provided by the grinding wheel and machine manufacturer.

Creating CNC Cam Grinding programs

By Joe Martin

How the Sherline Cam Grinder Came Into Existence

I was puttering around in my shop working on a model four cylinder Seal engine wondering if I had the patience to build a camshaft. I have to admit it seemed like too much of a chore now that I knew so much about CNC machines and what they were capable of doing. Before long I was thinking more about making a small CNC cam grinder by using many of the parts I already manufacture than building the engine. It's something I enjoy doing, and within a day I pretty much knew how I was going to build it. I soon was assembling the components it'd take to build a one of a kind prototype Sherline Cam Grinding machine. I didn't realize that this was going to be the easy part.

I knew it was going to take special software to control this cam grinder. At that time my plan was to use MS's Excel® program to produce this program. I've used Excel many times in the past to produce many complex programs. It took me a couple of weeks of straining my brain with the Excel program before I realized just how complex the project I was about to get seriously involved in was, and I just didn't have the higher math skills to accomplish it. I had one more ace in the hole, a smart kid who wrote some code for me years ago who was no longer a kid. I was

lucky that Michael was still available to help me develop the algorithms and code needed to make this machine possible. The actual program took us a couple of years to complete of spare time work to complete. We then installed the controls and program on an industrial CNC system on a full size CNC grinder and made a cam grinder out of it. The program we developed for this grinder had quite a few complex features not needed for the Sherline Cam Grinder and worked very well.

I decided I was too old to manufacture and market a product as complex as the full size cam grinder and looking for a buyer of our design; however, I decided to market the Sherline Cam Grinder with a Lite version of the cam program designed specifically to control the grinder we'll manufacture for building model engines. It obviously will not be a money maker for Sherline because of its specialized nature but that never stopped me in the past.

Although our CNC machines use a Linux operating system, the Sherline Cam Interpreter Michael and I developed uses the MS Windows® operating system to allow it to be more compatible with existing cad programs. Also, if you don't understand g-code it is completely explained in full in the CNC System 6.0 Operating Instructions that I also wrote. It's not necessary to know anything but the basic straight moves to understand cam programming because the machine doesn't use the complex features of g-code writing such as circle and arc commands to generate cam shapes. They will be generated by the configuration of the machine working with the Sherline Interpreter which generates the g-code to grind these complex shapes very accurately; however, you can't beat having a friend help you get started who has worked with Sherline CNC mills with the EMC programming system.

An Overview of How this Program Controls the Machine
The y-axis moves the slide in and out controlling the depth of the grind, the x-axis moves the table that the camshaft is mounted on left and right controlling what cam lobe is being ground and the z-axis rotates the camshaft. I didn't use the a-axis designation usually assigned to rotary devices because the methods of removing material are closer to a milling machine which most operators are familiar with.

The reason I chose to use the z-axis to rotate the camshaft is it'd allow any Sherline computer with EMC loaded to control the Sherline Cam Grinder. Remember the rotary a-axis on a standard computer is set up to control their rotary table that has a ratio of 72 to 1 while the cam grinder has a ratio of 4 to one. If you think about it 4 revolutions on the z-axis would move the z-axis 0.200 inches; therefore, four revolutions of the stepper motor equals one revolution of the spindle allowing easy calculations to convert degrees to an inch movement.

You will not be completing a single cam lobe at a time if you use the program as designed. You'll be partially forming each lobe on the shaft with each pass and eventually completing each lobe, one after another, in a single pass. This eliminates problems with hot spots that could warp the camshaft.

The wheel must be wider than the cam lobe but not so wide that it interferes with the lobes next to it. The x-axis zero position will be located at the center of the width of the first cam lobe closest to the tailstock with the center of the grinding wheel face aligned with this point. All x-axis moves will be measured from this point and the x-axis movements will always be in a positive direction until each lobe has had a portion of the lobe formed. The grinding wheel will then return to its home position and stop.

To control the depth of the grind you'll have the y-axis backed off and your first passes will only come in contact with the camshaft for a portion of the revolution of the cam's lowest points, return to its home position and the stop. The following passes will use exactly the same program with the only difference being the manual advancement of the y-axis between passes. This could be programmed but it'd be a waste of time when you are only producing a single camshaft. One of the advantages of small stepper motors Sherline uses is you can over-ride its position and re-position the y-axis slide in small amounts, usually around 0.005″, between passes without turning the machine off. Of course, the last two passes will be what is needed to control the final size.

After mounting any grinding wheel, new or used, the wheel must be dressed until it is running true because they usually run slightly off center. Dressing the wheel too often will never cause a problem; however, not dressing it enough can cause big problems.

Therefore, you must occasionally dress the wheel with a diamond when the wheel gets dull and stops cutting. An additional pair of x, y manual slides mounted behind the grinding wheel to control the movement of the diamond. You can tell when the wheel is getting dull because it'll it sound like it's rubbing instead of cutting and generating more heat. A wheel that is cutting properly makes a scratching noise. Dress about 0.0005″ in each direction a couple of times. Leave the diamond parked off to the side but do not back it away from the wheel. The diamond should be moved across the grinding wheel quickly to produce sharp surface. If the diamond is moved slowly it will cut a flat surface on the grit and work poorly. You want the diamond to break the abrasive grit so it leaves lots of sharp cutting edges. It's also a good idea to rotate the diamond to a new position at the start of every couple of jobs to keep it sharp. If the new

diamond position doesn't cut the wheel well move it again.

After dressing the wheel the y-axis is then moved in the exact amount the diamond removed from the grinding wheel. Remember this number isn't the diameter change. It's the change in the radius that affects the wheel to cam contact location which is the amount the diamond was moved in.

It's also worth noting that the z-axis should always move in a positive direction which is clockwise when viewed from the tailstock end. It doesn't make any difference what direction the z-axis moves when it's positioning. The reason for this is the camshaft will be fed into the grinding wheel from the bottom up. This eliminates much of the problem of having the grinding wheel "pull" the work into the wheel. Climb milling on a mill creates a similar problem as an example.

Developing the Program

Before you can produce a program you have to understand that a computer can't work with an old drawing with a few dimensions on it. You have to produce accurate information that describes the cam in a method the computer can use by creating a table of the angle and radius dimensions that describe the cam shape. The camshaft we'll be working on is for the Howell V-4 Engine that I recently made for the engine we have running at the museum. It uses two camshafts with each having four cam lobes.

I believe the easiest method to produce a high quality camshaft program is to develop a table that describes the cam by angle and radius of both the intake and exhaust cams with a cad drawing program. It isn't necessary to make a lift table for every cam lobe on the shaft. We can use standard g-code programming to change BDC (Bottom Dead Center) starting point. What we need at this time is only the shape of the exhaust and intake cams. The Sherline Cam Interpreter can use these points to produce a program to produce a properly formed smooth cam.

Although the instructions may seem cumbersome I checked from the time it took from when the computer booted up until the final Cam Grinding Code program for the entire camshaft was created and it took me less than two hours. This did not include the time it took to create the Cad drawing of the cams or the table. Remember that to arrive at these numbers in any other fashion would take many hours and wouldn't be as accurate.

Think about forming a perfect camshaft for multi cylinder engines by pushing a button! The future is now!

Create the Cad Drawing

1. First, draw the angled lines using your Cad program. I used AutoCAD LT. First I drew a circle with the needed angled lines in it with the Top Dead Center (TDC) at 0°. The top 32° (16° on either side of center) is divided into 2° increments followed by two 4° increments, one on either side of center. The remainder of the circle is divided into 5° increments. The only angles

the processing program will accept are these angles. Then I drew the cam from the designer's drawings in a separate location on the same sheet. When working with a cad system you may find this drawing can be improved when working from an old set of plans drawn before cad systems were available. I then copy and paste the angled lines onto the cam drawing. By working in this manner these lines don't interfere with making an accurate shaped cam with smooth blended lines.

Next, I use the "trim" command to remove the excess angled lines out side of the cam shape. The easiest way to document the length of these lines is to use the "Properties" command, which will give you the exact length of the line after it has been trimmed.

If the cam is symmetrical only one side has to be measured and duplicated on either the cad or mechanical drawing.
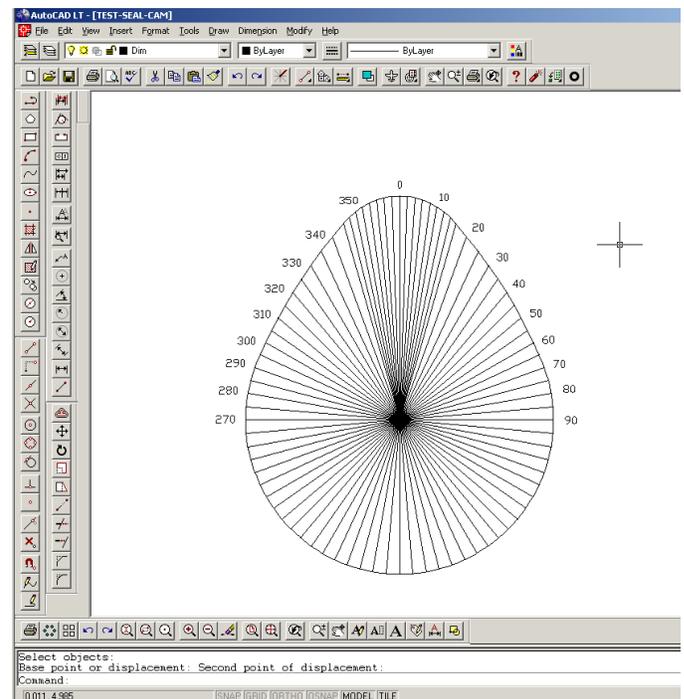
2. **…or Create a scaled up mechanical drawing**

   You'll find a sheet drawing of the angled lines that you can print and make a ten times size drawing of the cam or whatever works. Draw the cam accurately and measure the length of the lines with calipers. A pin in the center of the will allow you to swing the drawing around it making it easier to measure; however, you must allow for it and it'd be wise to put a couple of layers of masking tape behind the center mark to keep it from tearing. Write the lengths down as you measure them and the program that creates the g-code will allow you to enter this scale factor eliminating of dividing each one individually. The drawing below is a thumbnail sketch of a drawing aid that can be printed:
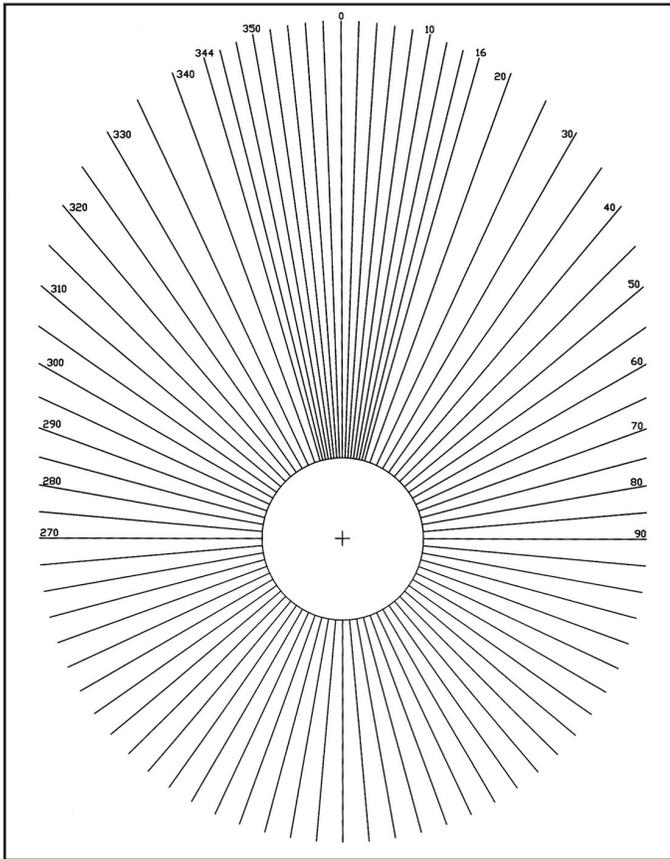
Because the Howell intake and exhaust cams are symmetrical it was only necessary to measure 90° of the cam to produce the info needed in this drawing of the intake cam lobe. From this point on I will only use the info that I obtained with a mechanical drawing to prove it isn't necessary to have a CAD system to produce a good cam. The cam was drawn at a scale of 20 to 1 to take advantage of the accuracy that can be gained at a larger scale. The full dimensions at this scale will be entered in to the Sherline cam processor.
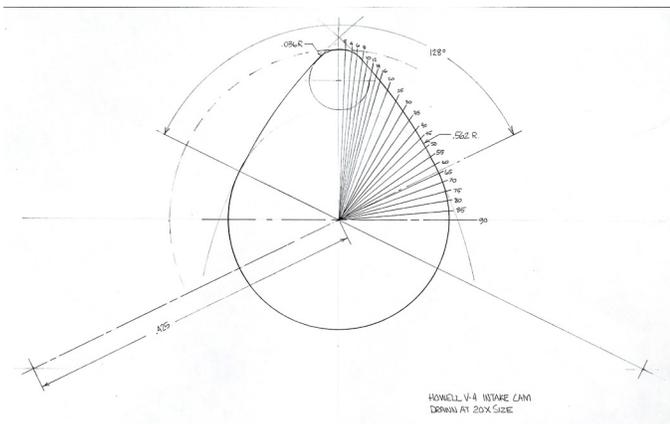
Again: The only angles the processing program will accept are the angles shown. The above drawing was scaled 20 times larger. In this drawing, measuring the points shown in the first 65-70° will provide all the different numbers you need, **but you must enter all the dimensions asked for from 0° to 360° in the table.**

3. **Create a lift table using a spreadsheet program**

   I've only used MS Excel® for this, but I'm quite sure

any spreadsheet program will work. First enter the angles in column A. In column B the distance to center is entered to the corresponding angles. Of course, there are many ways to accomplish the same thing. For example, you could enter the distances straight into the Cam Interpreter, but this wouldn't leave you with a useful record.

Working with the Sherline Cam Interpreter

4. **Opening the Cam Interpreter Program**

   To open the program on the Sherline web site, refer to the sheet that came with your cam grinder that has your personal access code hand written on it. (It will be the same as the address to these instructions except the file extension is .EXE instead of .HTM.. T h i s is your personal link to a very specialized program that you shouldn't allow to be used by anyone other than yourself. I've invested thousands of dollars in development of this software. Purchase of the cam grinder entitles you to a license to use it, but Sherline retains ownership of the program itself, which is copyrighted.

The Data Input window above of the Sherline Cam Interpreter will appear on your monitor and is now ready to accept data. First enter the present diameter of your grinding wheel accurate to 0.030″. The input is limited and must be between 6 and 4 inches. Anything over 6″ is too large for the Sherline Cam Grinder and below 4 inches would be considered too small.

Next the scale factor is entered. If you created the cam shape drawing actual size with a cad drawing and you are sure of the dimensions enter 1; however, if you made a scaled up manual drawing you can enter the scaling factor eliminating the job of calculating the actual number.

5. At this time you have a choice: You can enter the angled line lengths directly into the Interpreter or copy and paste them in from the Excel sheet.

   Remember the program will only accept data for the degrees shown and they must all be entered. A blank spot will not allow the interpreter to operate. It should also be noted that there isn't any way of saving the information entered into the online interpreter, which is why I recommended first entering the dimensions into a program such as Excel where it can be saved. Of course, the output from the interpreter can be copied and saved in Notepad.

6. Get the data from the Excel program by highlighting just the two columns of data where there is data, not the entire column. Copy and paste the data into the interpreter in the blank section off to the right. Click on [LOAD DISTANCES]. If there is an error in your data you'll get an error message. If not, the interpreter will now look like this:
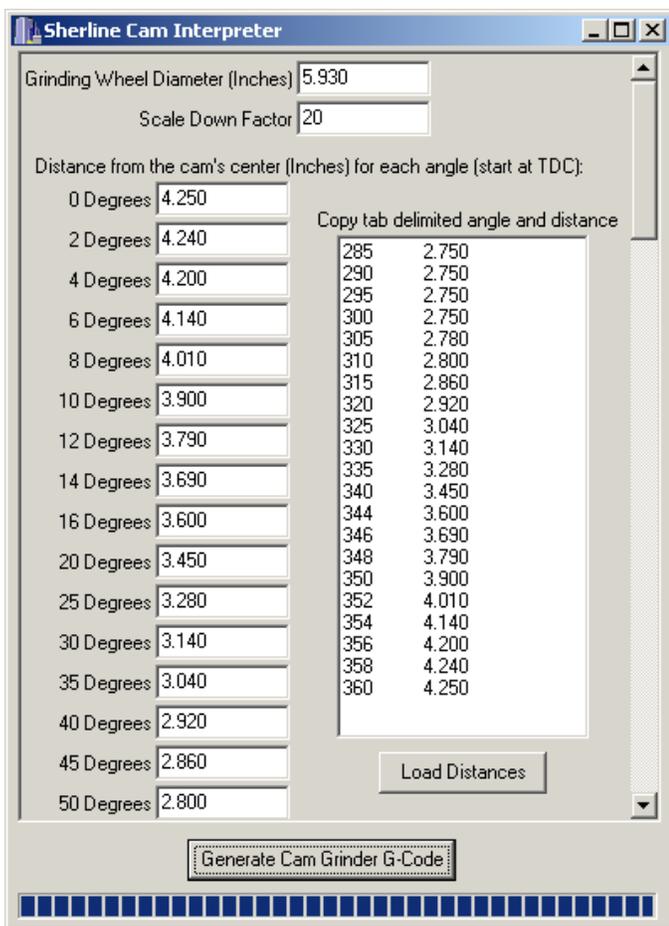
7. The data now has been successfully loaded. Click on [Generate Cam Grinder g-code], and the screen will switch to this:
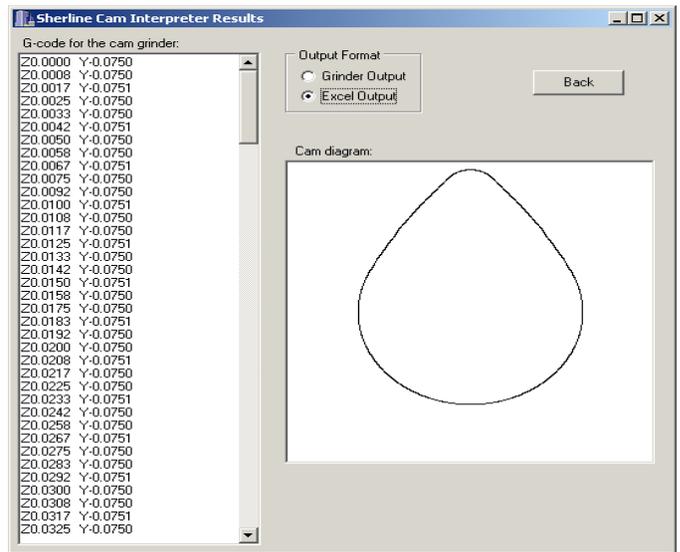
Note that the 20 times scaling used has been processed out when these numbers were generated. I used the Excel output button so the generated code can be copied and pasted back into the Excel program. The cam shape that appears has been generated from the numbers produced by the interpreter which have been calculated for every 1.5 degrees. Look at it closely and make sure it's a relatively smooth curve; however, you may see slight imperfections because of the magnification of the generated cam shape. Any major imperfections must be found and corrected on the drawing and by reprocessing the data.

To the left we have the g-code needed to produce only the cam shape we have designed. If you change the size any significant amount the cams shape will also change! The grinder always creates a curved surface. It's not a series of short straight sections because z-axis is rotating as the y-axis moves in or out.

8. At this time it's a good idea to save the program back to the Excel program because you may want to compare it with future versions. There is a button that changes this information to the Excel format. Click on it and there will be a space between the Z- and Y-axis. Right
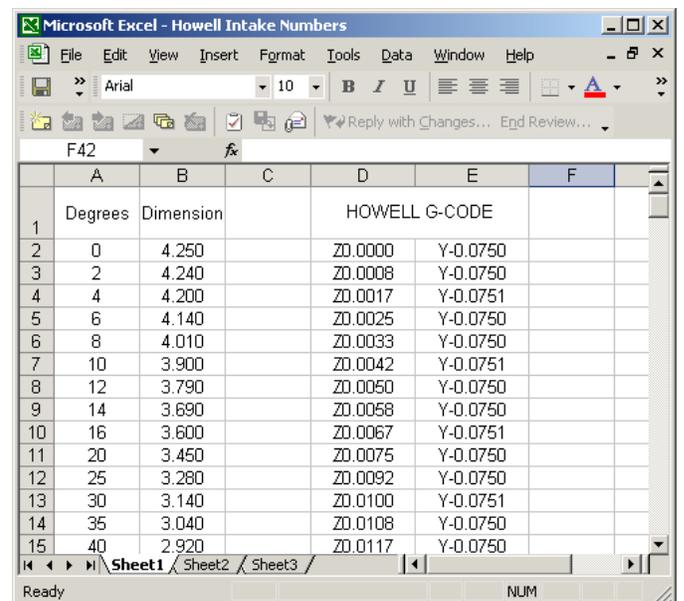
click on the code and select [Select All]. Next, right click and select [Copy]. Next, go to the Excel sheet and paste the copied information into cell F2 and save.

Now we have the information saved for future use should the need arise. I visualize a time in the future when model engine builders are not just satisfied with an engine that just runs, and they will start working with cams to get more performance.

9. The next process is to save the data in a format that can be entered into a g-code program. To accomplish this we go back to the Interpreter and click on [Grinder Output]. Right click on g-code data and copy it again. I believe the Notepad program has a bug in it. If the data appears scrambled paste it into a MS Word® program and copy and paste it back into a new Notepad box.

Next, left click on the MS's [Start] button, usually in the lower left section of the monitor's screen and open a program called Notepad. Paste the copied data into the blank sheet. It will look like this after doing so:
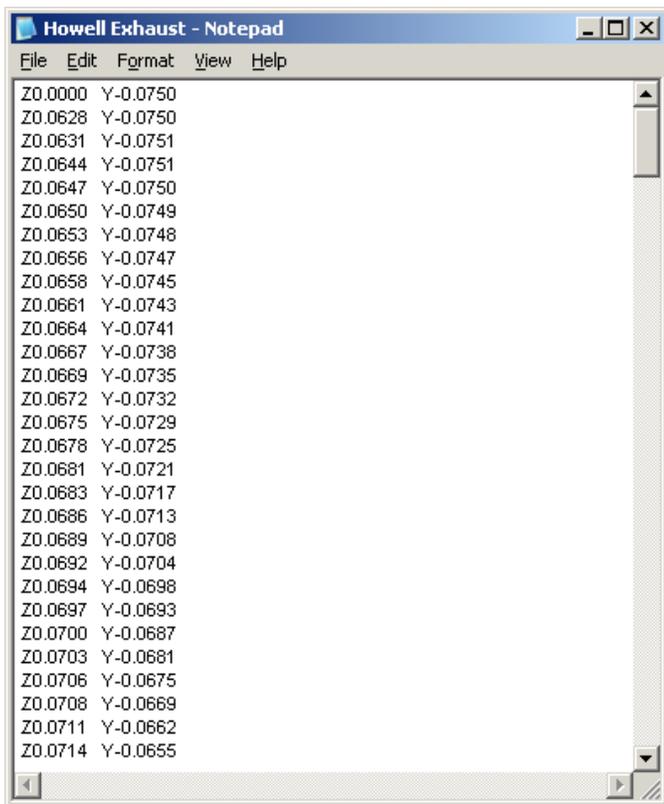
The purpose of using Notepad is to convert the data into a .txt format that is acceptable to the EMC program and to allow you to save it as a file that the EMC program will accept. To accomplish this click on [File] [Save As] and enter a File Name to identify it in the future.
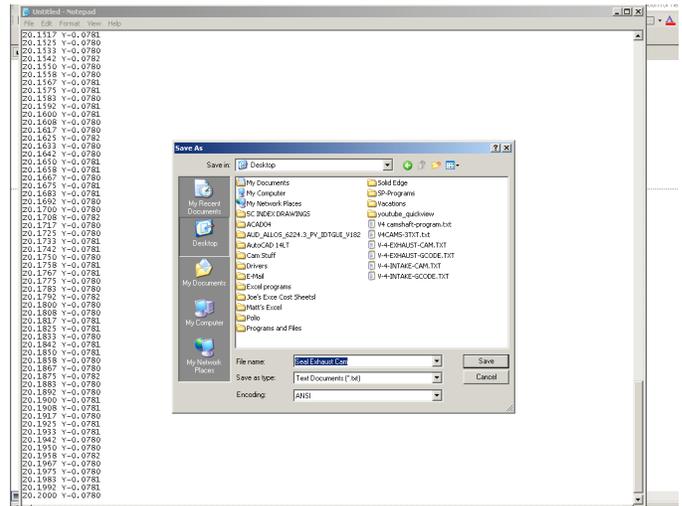
It's important to realize that the g-code program created starts grinding on the Bottom Dead Center (BDC), which is the least critical section of the cam and will be 180° from the highest point of the cam even if this point wasn't called zero. I also edited in a feed rate change to slow down the feed rate as it passed over TDC section of the cam. TDC will always be y-0.000. The f1 feed rate I used isn't really 1″ per minute because it's driving a rotary device, but it is 30°/sec and just about right for this application. I used f0.4 as the cam lobe was ground over the TDC section. I did this to maintain maximum accuracy in the most critical area of the cam lobe.

10) Save to your Desktop under any name you wish, and we'll now have the code it takes to produce a single cam lobe on a Sherline Cam Grinder. I always save programs I'm working with on the Desktop because they are easy to find.

11) Using the same methods I created the g-code for the exhaust cam.
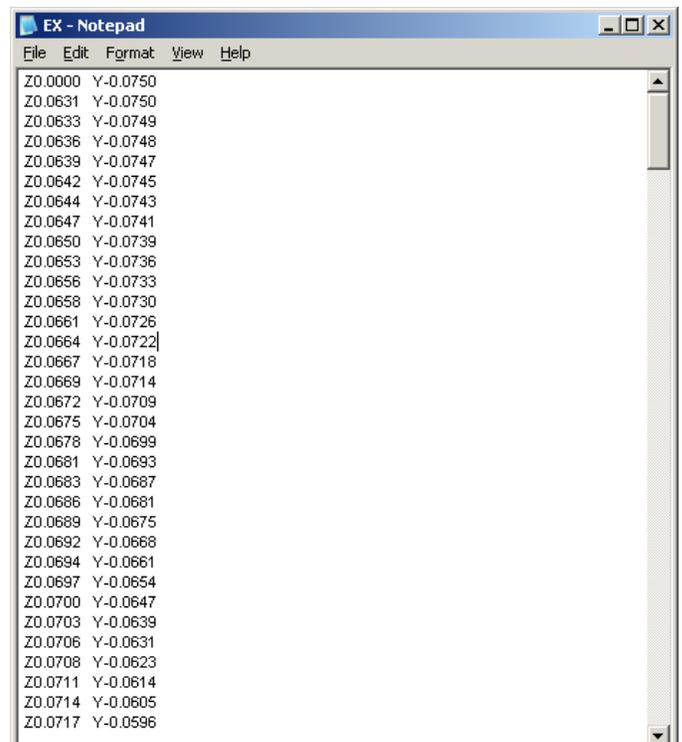
In order for this program to run properly all the process (steps) we just used to create this code must be used, and the only changes allowed must be changed in the original drawing and then the new information is reprocessed.

The following program was written to generate the camshaft for a model 4-cylinder, four stroke engine a group associated with my foundation is building: http://www.craftsmanshipmuseum.com/HowellV4.htm. The Howell V-4 has different shaped intake and exhaust cams.

What can be very confusing is to know what direction the engine designer is working from when they call out the TDC angles for their cam lobes. A positive z-axis number will rotate in a clockwise direction when viewed from the tailstock end towards the headstock. A mistake here means starting over. A simple check for your program is grinding a wooden dowel to see if it looks right. Have a vacuum available to minimize dust. You can take 0.020″ pass on wood without any problem, and it isn't necessary to form a complete lobe. Just enough to give you a general idea what the finished camshaft will look like.

If this format is used the most complex camshaft programs can be put together as a sequence of tasks that simplify the whole process.

Again!!!

Before we start I want you again to take the time to understand that I'm driving the rotary motion of the camshaft with the z-axis. I'm driving the camshaft headstock with a standard Sherline stepper motor with a ratio of four to one. Four turns of the stepper motor on the z-axis would be 0.200″ of movement; however, when we use it in this manner it's moving the camshaft one complete revolution. A feed rate of f1=30° per second.

To convert the 0.200 to the actual degrees needed divide it by 360 and multiply the answer by the required degrees.

Example: My first cam lobe needed its bottom dead center (BDC) to be located at 90°. Therefore 0.200/360*90=0.050
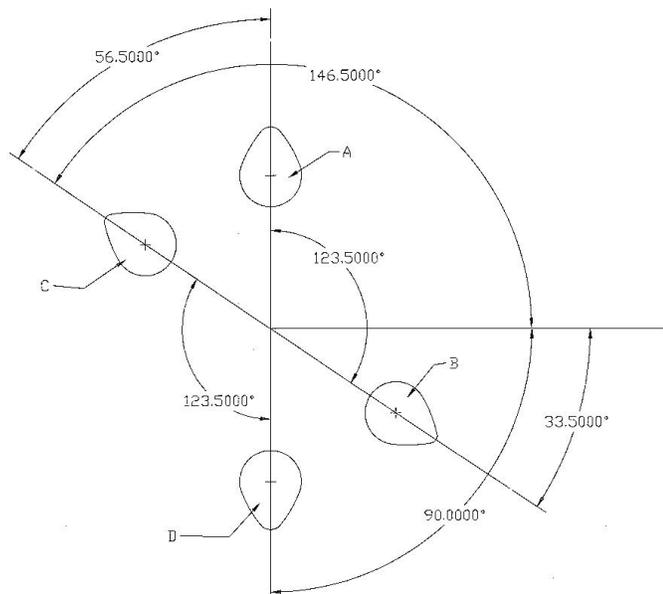
A and D cam lobes are Exhaust and B and C are Intake. This drawing has been done in cad but there's no reason it can't be a simple sketch to keep tract of the angles needed to grind the cam. This camshaft will be used in a Jerry Howell V-4. We are looking at the camshaft to be from the tailstock end of the Sherline cam grinder. The grinding wheel is located off to the left. You can do this anyway that works but I choose to have the first cam lobe closest to the tailstock set with top dead center (TDC) set at zero. This allows you to have a good chance putting a completed camshaft back on the cam grinder to make a change by finding TDC with an indicator. This drawing should be double; in fact, triple checked to be sure there are no errors. An error at this point will only produce scrap!

The explanations for the code are written below each line in green italic.

%

Start and end EMC programs with %

(Howell V-4 camshaft)

(4 cyl – 2 Like Camshafts - 4 lobes each - Ex-In-In-Ex)

It's always a good idea when writing long programs to add information that may clarify the program in the future in parentheses. Note that anything written within the parentheses will have no effect on the g-code.

g00 g20 g40 g49 g90 x0 y0.5 z0 a0

The first line of the program should always have the above information to cancel out any unwanted data in your computer and locate the home position. You should have read and understand basic g code program before attempting to write a program for the Sherline grinder. You don't have to learn complex programming methods such as the use of g41 but you need to know basic moves and rules. Note that the y-axis is backed off to its home position 0.5. The only time this position is used is to put the y-axis slide in a home position out of the way to load the camshaft.

y0.100

The program is in rapid feed (g00) and a good time to move the part closer to the grinding wheel before setting the slow feed rate to save time.

z0.50 (A cam lobe)

The first cam lobe defined as "A" had a cam top dead center of 0°; therefore this code indexes the camshaft to have the starting point BDC on center facing the grinding wheel.

g92 z0

The g92 resets the z position to 0. No movement will take place. The purpose of this command is to eliminate the need to write different programs for each cam lobe that's located at different angles throughout the camshaft.

y-0.0740

This move will also rapidly move the grinding wheel within 0.010″ to the part.

g01 y-0.0750 f0.2

This slow feed rate will allow the grinder to grind straight

into the cam lobe, which requires a slower feed rate.

f1.

This code establishes a feed rate of one inch a minute; however, the z-axis isn't controlling the z-axis. It's controlling the rotary motion and the feed will be f1=30°/sec.

(Exhaust Cam.txt>>>>>>>>>>>>>>>>>>>>)

The code generated by the Sherline Interpreter should be inserted below the above line. For this particular engine the first cam is an exhaust cam, but it would be wise to enter the camshaft lobe layout directly into this program at the very start. I also believe it's a good idea to leave the bunch of arrows or whatnot to the first line of each individual cam program so they can be easily found in programs because of its length.

g00 y0.100

This move is to get grinding wheel clear of camshaft after the cam lobe has been ground; however, there's always a possibility that this number must be changed because of size, tooling or the layout of the particular camshaft you are building.

z0

In order to cancel the g92 that was entered to relocate the new z-axis zero position that was entered just before this lobe was ground we must be in go back to that same position which z0 movement will do.

g92.2

The g92.2 command cancels the offset and the camshaft will move back to the zero position.

g00 g90 x0.430 z0

This move switches the feed rate back to rapid moves the x-axis to the next cam lobe. From this point on I'm only going to comment on things I haven't already commented on.

z-0.0186 (B cam lobe) N*ote the movement is in a minus direction which is CCW and the shortest distance.*

g92 z0

y-0.065

g01 f0.2

y-0.075

f1

(Intake Cam.txt<<<<<<<<<<<<<<<<<<<<<<<<)

Enter code here

g00 y0.100

z0

g92.2

g00 g90 x1.570 z0

z0.0814 (C cam lobe)

g92 z0

y-0.065

g01 f0.2

y-0.075

f1

(Intake Cam.txt<<<<<<<<<<<<<<<<<<<<<<<<)

Enter code here

g00 y0.100

z0

g92.2

g00 g90 x1.312 z0

z-0.050 (D cam lobe)

g92 z0

y-0.065

g01 f0.2

y-0.075

f1

(Exhaust Cam.txt>>>>>>>>>>>>>>>>>>>>>>>)

g00 y0.100

z0

g92.2

g00 y0.500

Retract wheel well clear of camshaft before rapid feeding home.

z0

g92.2

g00 g90 x0 y0.5 z0

Home position

%

The Final Product

The following code is the code I wrote to produce a cam for the Howell V-4 engine. Although it is over 1100 lines long it really isn't that hard for you to produce now that I figured out the exact sequences required. A new point was created for every 1.5° making 240 lines per lobe; therefore, most of the code has been added 240 lines at a time. Please note that I used red for the exhaust and blue for the intake code that was produced by the Sherline cam software. I also highlighted in purple the code written between cam lobes with the only numbers that need adjusting in green. Of course, the y-axis points will be different between camshafts but not different between cam lobes, which is why I didn't highlight them.

Now, think about what had to be done to produce this very complex piece of code. You had to create drawings in cad or files describing the shape of the exhaust and intake cams. You loaded this information into the Sherline number cruncher and inserted these results into the proper places in the sample program. You also filled in the information that's highlighted in red in the sample program after this section. That's about as good as it will ever get to produce

a complex camshaft in a home workshop.

And there you have it—a complete program to produce a cam for a Howell V-4 engine and a method to produce a camshaft for most any model engine built today. It should be obvious that if a camshaft has more than four lobes that the program would just be more of the same.

%

(HOWELL V4 – camshaft PROGRAM2)

(GRINDING WHEEL 5.940")

(MINUS SIGN ON z-AXIS TURNS CAMSHAFT)

(CCW WHEN VIEWED FROM TAILSTOCK END)

(CAMSHAFT GEAR END - TAILSTOCK END)

(V4 cyl – 2CAMSHAFTS – 4 lobes Ex-In-In-Ex)

g00 g20 g40 g49 g90 x0 y0.5 z0 a0

y0.100

z0.050 (EXHAUST - ANGLE 90°) (TAILSTOCK END)

g92 z0

y-0.0650

g01 f0.2

y-0.0750

f1

(V-4-EXHAUST>>>>>>>>>>>>>>>>>>>>)

Z0.0000 Y-0.0750

Z0.0631 Y-0.0750

Z0.0633 Y-0.0749

Z0.0636 Y-0.0748

Z0.0639 Y-0.0747

Z0.0642 Y-0.0745

Z0.0644 Y-0.0743

Z0.0647 Y-0.0741

Z0.0650 Y-0.0739

Z0.0653 Y-0.0736

Z0.0656 Y-0.0733

Z0.0658 Y-0.0730

Z0.0661 Y-0.0726

Z0.0664 Y-0.0722

Z0.0667 Y-0.0718

Z0.0669 Y-0.0714

Z0.0672 Y-0.0709

Z0.0675 Y-0.0704

Z0.0678 Y-0.0699

Z0.0681 Y-0.0693

Z0.0683 Y-0.0687

Z0.0686 Y-0.0681

Z0.0689 Y-0.0675

Z0.0692 Y-0.0668

Z0.0694 Y-0.0661

Z0.0697 Y-0.0654

Z0.0700 Y-0.0647

Z0.0703 Y-0.0639

Z0.0706 Y-0.0631

Z0.0708 Y-0.0623

Z0.0711 Y-0.0614

Z0.0714 Y-0.0605

Z0.0717 Y-0.0596

Z0.0719 Y-0.0586

Z0.0722 Y-0.0577

Z0.0725 Y-0.0567

Z0.0728 Y-0.0556

Z0.0731 Y-0.0546

Z0.0733 Y-0.0535

Z0.0736 Y-0.0524

Z0.0739 Y-0.0514

Z0.0742 Y-0.0503

Z0.0744 Y-0.0493

Z0.0747 Y-0.0483

Z0.0750 Y-0.0472

Z0.0753 Y-0.0463

Z0.0756 Y-0.0453

Z0.0758 Y-0.0443

Z0.0761 Y-0.0433

Z0.0764 Y-0.0424

Z0.0767 Y-0.0415

Z0.0769 Y-0.0405

Z0.0772 Y-0.0396

Z0.0775 Y-0.0387

Z0.0778 Y-0.0378

Z0.0781 Y-0.0369

Z0.0783 Y-0.0360

Z0.0786 Y-0.0351

Z0.0789 Y-0.0342

Z0.0792 Y-0.0334

Z0.0794 Y-0.0325

Z0.0797 Y-0.0317

Z0.0800 Y-0.0309

Z0.0803 Y-0.0301

Z0.0806 Y-0.0293

Z0.0808 Y-0.0284

Z0.0811 Y-0.0276
Z0.0814 Y-0.0269
Z0.0817 Y-0.0261
Z0.0819 Y-0.0253
Z0.0822 Y-0.0246
Z0.0825 Y-0.0238
Z0.0828 Y-0.0231
Z0.0831 Y-0.0224
Z0.0833 Y-0.0217
Z0.0836 Y-0.0210
Z0.0839 Y-0.0203
Z0.0842 Y-0.0196
Z0.0844 Y-0.0190
Z0.0847 Y-0.0183
Z0.0850 Y-0.0177
Z0.0853 Y-0.0170
Z0.0856 Y-0.0164
Z0.0858 Y-0.0158
Z0.0861 Y-0.0152
Z0.0864 Y-0.0146
Z0.0867 Y-0.0140
Z0.0869 Y-0.0134
Z0.0872 Y-0.0129
Z0.0875 Y-0.0123
Z0.0878 Y-0.0118
Z0.0881 Y-0.0113
Z0.0883 Y-0.0108
Z0.0886 Y-0.0103
Z0.0889 Y-0.0098
Z0.0892 Y-0.0093
Z0.0894 Y-0.0088
Z0.0897 Y-0.0084
Z0.0900 Y-0.0080
Z0.0903 Y-0.0075
Z0.0906 Y-0.0071
Z0.0908 Y-0.0067
Z0.0911 Y-0.0063
Z0.0914 Y-0.0059
Z0.0917 Y-0.0055
Z0.0919 Y-0.0052
Z0.0922 Y-0.0048
Z0.0925 Y-0.0045
Z0.0928 Y-0.0042
Z0.0931 Y-0.0038

Z0.0933 Y-0.0035
Z0.0936 Y-0.0033
Z0.0939 Y-0.0030
Z0.0942 Y-0.0027
Z0.0944 Y-0.0025
Z0.0947 Y-0.0022 F0.5
Z0.0950 Y-0.0020
Z0.0953 Y-0.0018
Z0.0956 Y-0.0016
Z0.0958 Y-0.0014
Z0.0961 Y-0.0012
Z0.0964 Y-0.0010
Z0.0967 Y-0.0009
Z0.0969 Y-0.0008
Z0.0972 Y-0.0006
Z0.0975 Y-0.0005
Z0.0978 Y-0.0004
Z0.0981 Y-0.0003
Z0.0983 Y-0.0002
Z0.0986 Y-0.0002
Z0.0989 Y-0.0001
Z0.0992 Y-0.0001
Z0.0994 Y0.0000
Z0.1006 Y0.0000
Z0.1008 Y-0.0001
Z0.1011 Y-0.0001
Z0.1014 Y-0.0002
Z0.1017 Y-0.0002
Z0.1019 Y-0.0003
Z0.1022 Y-0.0004
Z0.1025 Y-0.0005
Z0.1028 Y-0.0006
Z0.1031 Y-0.0008
Z0.1033 Y-0.0009
Z0.1036 Y-0.0010
Z0.1039 Y-0.0012
Z0.1042 Y-0.0014
Z0.1044 Y-0.0016
Z0.1047 Y-0.0018
Z0.1050 Y-0.0020 F1
Z0.1053 Y-0.0022
Z0.1056 Y-0.0025
Z0.1058 Y-0.0027
Z0.1061 Y-0.0030

Z0.1064 Y-0.0033
Z0.1067 Y-0.0035
Z0.1069 Y-0.0038
Z0.1072 Y-0.0042
Z0.1075 Y-0.0045
Z0.1078 Y-0.0048
Z0.1081 Y-0.0052
Z0.1083 Y-0.0055
Z0.1086 Y-0.0059
Z0.1089 Y-0.0063
Z0.1092 Y-0.0067
Z0.1094 Y-0.0071
Z0.1097 Y-0.0075
Z0.1100 Y-0.0080
Z0.1103 Y-0.0084
Z0.1106 Y-0.0088
Z0.1108 Y-0.0093
Z0.1111 Y-0.0098
Z0.1114 Y-0.0103
Z0.1117 Y-0.0108
Z0.1119 Y-0.0113
Z0.1122 Y-0.0118
Z0.1125 Y-0.0123
Z0.1128 Y-0.0129
Z0.1131 Y-0.0134
Z0.1133 Y-0.0140
Z0.1136 Y-0.0146
Z0.1139 Y-0.0152
Z0.1142 Y-0.0158
Z0.1144 Y-0.0164
Z0.1147 Y-0.0170
Z0.1150 Y-0.0177
Z0.1153 Y-0.0183
Z0.1156 Y-0.0190
Z0.1158 Y-0.0196
Z0.1161 Y-0.0203
Z0.1164 Y-0.0210
Z0.1167 Y-0.0217
Z0.1169 Y-0.0224
Z0.1172 Y-0.0231
Z0.1175 Y-0.0238
Z0.1178 Y-0.0246
Z0.1181 Y-0.0253
Z0.1183 Y-0.0261

Z0.1186 Y-0.0269
Z0.1189 Y-0.0276
Z0.1192 Y-0.0284
Z0.1194 Y-0.0293
Z0.1197 Y-0.0301
Z0.1200 Y-0.0309
Z0.1203 Y-0.0317
Z0.1206 Y-0.0325
Z0.1208 Y-0.0334
Z0.1211 Y-0.0342
Z0.1214 Y-0.0351
Z0.1217 Y-0.0360
Z0.1219 Y-0.0369
Z0.1222 Y-0.0378
Z0.1225 Y-0.0387
Z0.1228 Y-0.0396
Z0.1231 Y-0.0405
Z0.1233 Y-0.0415
Z0.1236 Y-0.0424
Z0.1239 Y-0.0433
Z0.1242 Y-0.0443
Z0.1244 Y-0.0453
Z0.1247 Y-0.0463
Z0.1250 Y-0.0472
Z0.1253 Y-0.0483
Z0.1256 Y-0.0493
Z0.1258 Y-0.0503
Z0.1261 Y-0.0514
Z0.1264 Y-0.0524
Z0.1267 Y-0.0535
Z0.1269 Y-0.0546
Z0.1272 Y-0.0557
Z0.1275 Y-0.0567
Z0.1278 Y-0.0577
Z0.1281 Y-0.0587
Z0.1283 Y-0.0596
Z0.1286 Y-0.0605
Z0.1289 Y-0.0614
Z0.1292 Y-0.0623
Z0.1294 Y-0.0631
Z0.1297 Y-0.0639
Z0.1300 Y-0.0647
Z0.1303 Y-0.0654
Z0.1306 Y-0.0662

Z0.1308 Y-0.0669
Z0.1311 Y-0.0675
Z0.1314 Y-0.0682
Z0.1317 Y-0.0688
Z0.1319 Y-0.0693
Z0.1322 Y-0.0699
Z0.1325 Y-0.0704
Z0.1328 Y-0.0709
Z0.1331 Y-0.0714
Z0.1333 Y-0.0718
Z0.1336 Y-0.0722
Z0.1339 Y-0.0726
Z0.1342 Y-0.0730
Z0.1344 Y-0.0733
Z0.1347 Y-0.0736
Z0.1350 Y-0.0739
Z0.1353 Y-0.0741
Z0.1356 Y-0.0743
Z0.1358 Y-0.0745
Z0.1361 Y-0.0747
Z0.1364 Y-0.0748
Z0.1367 Y-0.0749
Z0.1369 Y-0.0750
Z0.2000 Y-0.0750
G00 y0.100
z0
g92.2
g00 g90 x.430 z0
z-0.0186
g92 z0
y-0.0650
g01 f0.2
y-0.0750
f1
 (V-4-INTAKE>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>)
Z0.0000 Y-0.0750
Z0.0628 Y-0.0750
Z0.0631 Y-0.0751
Z0.0644 Y-0.0751
Z0.0647 Y-0.0750
Z0.0650 Y-0.0749
Z0.0653 Y-0.0748
Z0.0656 Y-0.0747
Z0.0658 Y-0.0745

Z0.0661 Y-0.0743
Z0.0664 Y-0.0741
Z0.0667 Y-0.0738
Z0.0669 Y-0.0735
Z0.0672 Y-0.0732
Z0.0675 Y-0.0729
Z0.0678 Y-0.0725
Z0.0681 Y-0.0721
Z0.0683 Y-0.0717
Z0.0686 Y-0.0713
Z0.0689 Y-0.0708
Z0.0692 Y-0.0704
Z0.0694 Y-0.0698
Z0.0697 Y-0.0693
Z0.0700 Y-0.0687
Z0.0703 Y-0.0681
Z0.0706 Y-0.0675
Z0.0708 Y-0.0669
Z0.0711 Y-0.0662
Z0.0714 Y-0.0655
Z0.0717 Y-0.0648
Z0.0719 Y-0.0641
Z0.0722 Y-0.0633
Z0.0725 Y-0.0625
Z0.0728 Y-0.0617
Z0.0731 Y-0.0608
Z0.0733 Y-0.0599
Z0.0736 Y-0.0590
Z0.0739 Y-0.0581
Z0.0742 Y-0.0572
Z0.0744 Y-0.0562
Z0.0747 Y-0.0552
Z0.0750 Y-0.0542
Z0.0753 Y-0.0531
Z0.0756 Y-0.0520
Z0.0758 Y-0.0509
Z0.0761 Y-0.0499
Z0.0764 Y-0.0488
Z0.0767 Y-0.0477
Z0.0769 Y-0.0466
Z0.0772 Y-0.0456
Z0.0775 Y-0.0445
Z0.0778 Y-0.0435
Z0.0781 Y-0.0424

Z0.0783 Y-0.0414

Z0.0786 Y-0.0404

Z0.0789 Y-0.0394

Z0.0792 Y-0.0384

Z0.0794 Y-0.0374

Z0.0797 Y-0.0365

Z0.0800 Y-0.0355

Z0.0803 Y-0.0346

Z0.0806 Y-0.0337

Z0.0808 Y-0.0328

Z0.0811 Y-0.0318

Z0.0814 Y-0.0309

Z0.0817 Y-0.0300

Z0.0819 Y-0.0292

Z0.0822 Y-0.0283

Z0.0825 Y-0.0275

Z0.0828 Y-0.0266

Z0.0831 Y-0.0258

Z0.0833 Y-0.0250

Z0.0836 Y-0.0242

Z0.0839 Y-0.0234

Z0.0842 Y-0.0226

Z0.0844 Y-0.0218

Z0.0847 Y-0.0211

Z0.0850 Y-0.0204

Z0.0853 Y-0.0196

Z0.0856 Y-0.0189

Z0.0858 Y-0.0182

Z0.0861 Y-0.0175

Z0.0864 Y-0.0168

Z0.0867 Y-0.0161

Z0.0869 Y-0.0155

Z0.0872 Y-0.0149

Z0.0875 Y-0.0142

Z0.0878 Y-0.0136

Z0.0881 Y-0.0130

Z0.0883 Y-0.0124

Z0.0886 Y-0.0118

Z0.0889 Y-0.0113

Z0.0892 Y-0.0107

Z0.0894 Y-0.0102

Z0.0897 Y-0.0097

Z0.0900 Y-0.0092

Z0.0903 Y-0.0087

Z0.0906 Y-0.0082

Z0.0908 Y-0.0077

Z0.0911 Y-0.0073

Z0.0914 Y-0.0068

Z0.0917 Y-0.0064

Z0.0919 Y-0.0060

Z0.0922 Y-0.0056

Z0.0925 Y-0.0052

Z0.0928 Y-0.0048

Z0.0931 Y-0.0045

Z0.0933 Y-0.0041

Z0.0936 Y-0.0038

Z0.0939 Y-0.0035

Z0.0942 Y-0.0032

Z0.0944 Y-0.0029 F0.5

Z0.0947 Y-0.0026

Z0.0950 Y-0.0023

Z0.0953 Y-0.0021

Z0.0956 Y-0.0018

Z0.0958 Y-0.0016

Z0.0961 Y-0.0014

Z0.0964 Y-0.0012

Z0.0967 Y-0.0011

Z0.0969 Y-0.0009

Z0.0972 Y-0.0007

Z0.0975 Y-0.0006

Z0.0978 Y-0.0005

Z0.0981 Y-0.0004

Z0.0983 Y-0.0003

Z0.0986 Y-0.0002

Z0.0989 Y-0.0001

Z0.0992 Y-0.0001

Z0.0994 Y0.0000

Z0.1006 Y0.0000

Z0.1008 Y-0.0001

Z0.1011 Y-0.0001

Z0.1014 Y-0.0002

Z0.1017 Y-0.0003

Z0.1019 Y-0.0004

Z0.1022 Y-0.0005

Z0.1025 Y-0.0006

Z0.1028 Y-0.0007

Z0.1031 Y-0.0009

Z0.1033 Y-0.0010

Z0.1036 Y-0.0012	Z0.1158 Y-0.0226
Z0.1039 Y-0.0014 F1	Z0.1161 Y-0.0233
Z0.1042 Y-0.0016	Z0.1164 Y-0.0241
Z0.1044 Y-0.0018	Z0.1167 Y-0.0250
Z0.1047 Y-0.0021	Z0.1169 Y-0.0258
Z0.1050 Y-0.0023	Z0.1172 Y-0.0266
Z0.1053 Y-0.0026	Z0.1175 Y-0.0274
Z0.1056 Y-0.0029	Z0.1178 Y-0.0283
Z0.1058 Y-0.0031	Z0.1181 Y-0.0291
Z0.1061 Y-0.0034	Z0.1183 Y-0.0300
Z0.1064 Y-0.0038	Z0.1186 Y-0.0309
Z0.1067 Y-0.0041	Z0.1189 Y-0.0318
Z0.1069 Y-0.0044	Z0.1192 Y-0.0327
Z0.1072 Y-0.0048	Z0.1194 Y-0.0336
Z0.1075 Y-0.0052	Z0.1197 Y-0.0346
Z0.1078 Y-0.0056	Z0.1200 Y-0.0355
Z0.1081 Y-0.0060	Z0.1203 Y-0.0365
Z0.1083 Y-0.0064	Z0.1206 Y-0.0374
Z0.1086 Y-0.0068	Z0.1208 Y-0.0384
Z0.1089 Y-0.0072	Z0.1211 Y-0.0394
Z0.1092 Y-0.0077	Z0.1214 Y-0.0404
Z0.1094 Y-0.0082	Z0.1217 Y-0.0414
Z0.1097 Y-0.0086	Z0.1219 Y-0.0424
Z0.1100 Y-0.0092	Z0.1222 Y-0.0434
Z0.1103 Y-0.0097	Z0.1225 Y-0.0445
Z0.1106 Y-0.0102	Z0.1228 Y-0.0455
Z0.1108 Y-0.0107	Z0.1231 Y-0.0466
Z0.1111 Y-0.0113	Z0.1233 Y-0.0477
Z0.1114 Y-0.0118	Z0.1236 Y-0.0487
Z0.1117 Y-0.0124	Z0.1239 Y-0.0499
Z0.1119 Y-0.0130	Z0.1242 Y-0.0509
Z0.1122 Y-0.0136	Z0.1244 Y-0.0520
Z0.1125 Y-0.0142	Z0.1247 Y-0.0531
Z0.1128 Y-0.0148	Z0.1250 Y-0.0542
Z0.1131 Y-0.0155	Z0.1253 Y-0.0552
Z0.1133 Y-0.0161	Z0.1256 Y-0.0562
Z0.1136 Y-0.0168	Z0.1258 Y-0.0572
Z0.1139 Y-0.0175	Z0.1261 Y-0.0581
Z0.1142 Y-0.0182	Z0.1264 Y-0.0590
Z0.1144 Y-0.0189	Z0.1267 Y-0.0599
Z0.1147 Y-0.0196	Z0.1269 Y-0.0608
Z0.1150 Y-0.0203	Z0.1272 Y-0.0617
Z0.1153 Y-0.0211	Z0.1275 Y-0.0625
Z0.1156 Y-0.0218	Z0.1278 Y-0.0633

Z0.1281 Y-0.0641
Z0.1283 Y-0.0648
Z0.1286 Y-0.0655
Z0.1289 Y-0.0662
Z0.1292 Y-0.0669
Z0.1294 Y-0.0675
Z0.1297 Y-0.0681
Z0.1300 Y-0.0687
Z0.1303 Y-0.0693
Z0.1306 Y-0.0698
Z0.1308 Y-0.0704
Z0.1311 Y-0.0708
Z0.1314 Y-0.0713
Z0.1317 Y-0.0717
Z0.1319 Y-0.0721
Z0.1322 Y-0.0725
Z0.1325 Y-0.0729
Z0.1328 Y-0.0732
Z0.1331 Y-0.0735
Z0.1333 Y-0.0738
Z0.1336 Y-0.0741
Z0.1339 Y-0.0743
Z0.1342 Y-0.0745
Z0.1344 Y-0.0747
Z0.1347 Y-0.0748
Z0.1350 Y-0.0749
Z0.1353 Y-0.0750
Z0.1356 Y-0.0751
Z0.1358 Y-0.0751
Z0.1361 Y-0.0752
Z0.1364 Y-0.0751
Z0.1369 Y-0.0751
Z0.1372 Y-0.0750
Z0.2000 Y-0.0750
G00 y0.100
z0
g92.2
g00 g90 x1.570 z0
z0.0814
g92 z0
y-0.0650
g01 f0.2
y-0.0750
f1

(V-4-INTAKE>>>>>>>>>>>>>>>>>>>>>>>>>)
Z0.0000 Y-0.0750
Z0.0628 Y-0.0750
Z0.0631 Y-0.0751
Z0.0644 Y-0.0751
Z0.0647 Y-0.0750
Z0.0650 Y-0.0749
Z0.0653 Y-0.0748
Z0.0656 Y-0.0747
Z0.0658 Y-0.0745
Z0.0661 Y-0.0743
Z0.0664 Y-0.0741
Z0.0667 Y-0.0738
Z0.0669 Y-0.0735
Z0.0672 Y-0.0732
Z0.0675 Y-0.0729
Z0.0678 Y-0.0725
Z0.0681 Y-0.0721
Z0.0683 Y-0.0717
Z0.0686 Y-0.0713
Z0.0689 Y-0.0708
Z0.0692 Y-0.0704
Z0.0694 Y-0.0698
Z0.0697 Y-0.0693
Z0.0700 Y-0.0687
Z0.0703 Y-0.0681
Z0.0706 Y-0.0675
Z0.0708 Y-0.0669
Z0.0711 Y-0.0662
Z0.0714 Y-0.0655
Z0.0717 Y-0.0648
Z0.0719 Y-0.0641
Z0.0722 Y-0.0633
Z0.0725 Y-0.0625
Z0.0728 Y-0.0617
Z0.0731 Y-0.0608
Z0.0733 Y-0.0599
Z0.0736 Y-0.0590
Z0.0739 Y-0.0581
Z0.0742 Y-0.0572
Z0.0744 Y-0.0562
Z0.0747 Y-0.0552
Z0.0750 Y-0.0542
Z0.0753 Y-0.0531

Z0.0756 Y-0.0520
Z0.0758 Y-0.0509
Z0.0761 Y-0.0499
Z0.0764 Y-0.0488
Z0.0767 Y-0.0477
Z0.0769 Y-0.0466
Z0.0772 Y-0.0456
Z0.0775 Y-0.0445
Z0.0778 Y-0.0435
Z0.0781 Y-0.0424
Z0.0783 Y-0.0414
Z0.0786 Y-0.0404
Z0.0789 Y-0.0394
Z0.0792 Y-0.0384
Z0.0794 Y-0.0374
Z0.0797 Y-0.0365
Z0.0800 Y-0.0355
Z0.0803 Y-0.0346
Z0.0806 Y-0.0337
Z0.0808 Y-0.0328
Z0.0811 Y-0.0318
Z0.0814 Y-0.0309
Z0.0817 Y-0.0300
Z0.0819 Y-0.0292
Z0.0822 Y-0.0283
Z0.0825 Y-0.0275
Z0.0828 Y-0.0266
Z0.0831 Y-0.0258
Z0.0833 Y-0.0250
Z0.0836 Y-0.0242
Z0.0839 Y-0.0234
Z0.0842 Y-0.0226
Z0.0844 Y-0.0218
Z0.0847 Y-0.0211
Z0.0850 Y-0.0204
Z0.0853 Y-0.0196
Z0.0856 Y-0.0189
Z0.0858 Y-0.0182
Z0.0861 Y-0.0175
Z0.0864 Y-0.0168
Z0.0867 Y-0.0161
Z0.0869 Y-0.0155
Z0.0872 Y-0.0149
Z0.0875 Y-0.0142

Z0.0878 Y-0.0136
Z0.0881 Y-0.0130
Z0.0883 Y-0.0124
Z0.0886 Y-0.0118
Z0.0889 Y-0.0113
Z0.0892 Y-0.0107
Z0.0894 Y-0.0102
Z0.0897 Y-0.0097
Z0.0900 Y-0.0092
Z0.0903 Y-0.0087
Z0.0906 Y-0.0082
Z0.0908 Y-0.0077
Z0.0911 Y-0.0073
Z0.0914 Y-0.0068
Z0.0917 Y-0.0064
Z0.0919 Y-0.0060
Z0.0922 Y-0.0056
Z0.0925 Y-0.0052
Z0.0928 Y-0.0048
Z0.0931 Y-0.0045
Z0.0933 Y-0.0041
Z0.0936 Y-0.0038
Z0.0939 Y-0.0035
Z0.0942 Y-0.0032 F0.5
Z0.0944 Y-0.0029
Z0.0947 Y-0.0026
Z0.0950 Y-0.0023
Z0.0953 Y-0.0021
Z0.0956 Y-0.0018
Z0.0958 Y-0.0016
Z0.0961 Y-0.0014
Z0.0964 Y-0.0012
Z0.0967 Y-0.0011
Z0.0969 Y-0.0009
Z0.0972 Y-0.0007
Z0.0975 Y-0.0006
Z0.0978 Y-0.0005
Z0.0981 Y-0.0004
Z0.0983 Y-0.0003
Z0.0986 Y-0.0002
Z0.0989 Y-0.0001
Z0.0992 Y-0.0001
Z0.0994 Y0.0000
Z0.1006 Y0.0000

Z0.1008 Y-0.0001
Z0.1011 Y-0.0001
Z0.1014 Y-0.0002
Z0.1017 Y-0.0003
Z0.1019 Y-0.0004
Z0.1022 Y-0.0005
Z0.1025 Y-0.0006
Z0.1028 Y-0.0007
Z0.1031 Y-0.0009
Z0.1033 Y-0.0010
Z0.1036 Y-0.0012
Z0.1039 Y-0.0014
Z0.1042 Y-0.0016
Z0.1044 Y-0.0018 F1
Z0.1047 Y-0.0021
Z0.1050 Y-0.0023
Z0.1053 Y-0.0026
Z0.1056 Y-0.0029
Z0.1058 Y-0.0031
Z0.1061 Y-0.0034
Z0.1064 Y-0.0038
Z0.1067 Y-0.0041
Z0.1069 Y-0.0044
Z0.1072 Y-0.0048
Z0.1075 Y-0.0052
Z0.1078 Y-0.0056
Z0.1081 Y-0.0060
Z0.1083 Y-0.0064
Z0.1086 Y-0.0068
Z0.1089 Y-0.0072
Z0.1092 Y-0.0077
Z0.1094 Y-0.0082
Z0.1097 Y-0.0086
Z0.1100 Y-0.0092
Z0.1103 Y-0.0097
Z0.1106 Y-0.0102
Z0.1108 Y-0.0107
Z0.1111 Y-0.0113
Z0.1114 Y-0.0118
Z0.1117 Y-0.0124
Z0.1119 Y-0.0130
Z0.1122 Y-0.0136
Z0.1125 Y-0.0142
Z0.1128 Y-0.0148

Z0.1131 Y-0.0155
Z0.1133 Y-0.0161
Z0.1136 Y-0.0168
Z0.1139 Y-0.0175
Z0.1142 Y-0.0182
Z0.1144 Y-0.0189
Z0.1147 Y-0.0196
Z0.1150 Y-0.0203
Z0.1153 Y-0.0211
Z0.1156 Y-0.0218
Z0.1158 Y-0.0226
Z0.1161 Y-0.0233
Z0.1164 Y-0.0241
Z0.1167 Y-0.0250
Z0.1169 Y-0.0258
Z0.1172 Y-0.0266
Z0.1175 Y-0.0274
Z0.1178 Y-0.0283
Z0.1181 Y-0.0291
Z0.1183 Y-0.0300
Z0.1186 Y-0.0309
Z0.1189 Y-0.0318
Z0.1192 Y-0.0327
Z0.1194 Y-0.0336
Z0.1197 Y-0.0346
Z0.1200 Y-0.0355
Z0.1203 Y-0.0365
Z0.1206 Y-0.0374
Z0.1208 Y-0.0384
Z0.1211 Y-0.0394
Z0.1214 Y-0.0404
Z0.1217 Y-0.0414
Z0.1219 Y-0.0424
Z0.1222 Y-0.0434
Z0.1225 Y-0.0445
Z0.1228 Y-0.0455
Z0.1231 Y-0.0466
Z0.1233 Y-0.0477
Z0.1236 Y-0.0487
Z0.1239 Y-0.0499
Z0.1242 Y-0.0509
Z0.1244 Y-0.0520
Z0.1247 Y-0.0531
Z0.1250 Y-0.0542

Z0.1253 Y-0.0552	G00 y0.100
Z0.1256 Y-0.0562	z0
Z0.1258 Y-0.0572	g92.2
Z0.1261 Y-0.0581	g00 g90 x2.000 z0
Z0.1264 Y-0.0590	z-0.0500
Z0.1267 Y-0.0599	g92 z0
Z0.1269 Y-0.0608	y-0.0650
Z0.1272 Y-0.0617	g01 f0.2
Z0.1275 Y-0.0625	Y-0.0750
Z0.1278 Y-0.0633	F1
Z0.1281 Y-0.0641	(V-4-EXHAUST>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>)
Z0.1283 Y-0.0648	Z0.0000 Y-0.0750
Z0.1286 Y-0.0655	Z0.0631 Y-0.0750
Z0.1289 Y-0.0662	Z0.0633 Y-0.0749
Z0.1292 Y-0.0669	Z0.0636 Y-0.0748
Z0.1294 Y-0.0675	Z0.0639 Y-0.0747
Z0.1297 Y-0.0681	Z0.0642 Y-0.0745
Z0.1300 Y-0.0687	Z0.0644 Y-0.0743
Z0.1303 Y-0.0693	Z0.0647 Y-0.0741
Z0.1306 Y-0.0698	Z0.0650 Y-0.0739
Z0.1308 Y-0.0704	Z0.0653 Y-0.0736
Z0.1311 Y-0.0708	Z0.0656 Y-0.0733
Z0.1314 Y-0.0713	Z0.0658 Y-0.0730
Z0.1317 Y-0.0717	Z0.0661 Y-0.0726
Z0.1319 Y-0.0721	Z0.0664 Y-0.0722
Z0.1322 Y-0.0725	Z0.0667 Y-0.0718
Z0.1325 Y-0.0729	Z0.0669 Y-0.0714
Z0.1328 Y-0.0732	Z0.0672 Y-0.0709
Z0.1331 Y-0.0735	Z0.0675 Y-0.0704
Z0.1333 Y-0.0738	Z0.0678 Y-0.0699
Z0.1336 Y-0.0741	Z0.0681 Y-0.0693
Z0.1339 Y-0.0743	Z0.0683 Y-0.0687
Z0.1342 Y-0.0745	Z0.0686 Y-0.0681
Z0.1344 Y-0.0747	Z0.0689 Y-0.0675
Z0.1347 Y-0.0748	Z0.0692 Y-0.0668
Z0.1350 Y-0.0749	Z0.0694 Y-0.0661
Z0.1353 Y-0.0750	Z0.0697 Y-0.0654
Z0.1356 Y-0.0751	Z0.0700 Y-0.0647
Z0.1358 Y-0.0751	Z0.0703 Y-0.0639
Z0.1361 Y-0.0752	Z0.0706 Y-0.0631
Z0.1364 Y-0.0751	Z0.0708 Y-0.0623
Z0.1369 Y-0.0751	Z0.0711 Y-0.0614
Z0.1372 Y-0.0750	Z0.0714 Y-0.0605
Z0.2000 Y-0.0750	Z0.0717 Y-0.0596

```
Z0.0719 Y-0.0586          Z0.0842 Y-0.0196
Z0.0722 Y-0.0577          Z0.0844 Y-0.0190
Z0.0725 Y-0.0567          Z0.0847 Y-0.0183
Z0.0728 Y-0.0556          Z0.0850 Y-0.0177
Z0.0731 Y-0.0546          Z0.0853 Y-0.0170
Z0.0733 Y-0.0535          Z0.0856 Y-0.0164
Z0.0736 Y-0.0524          Z0.0858 Y-0.0158
Z0.0739 Y-0.0514          Z0.0861 Y-0.0152
Z0.0742 Y-0.0503          Z0.0864 Y-0.0146
Z0.0744 Y-0.0493          Z0.0867 Y-0.0140
Z0.0747 Y-0.0483          Z0.0869 Y-0.0134
Z0.0750 Y-0.0472          Z0.0872 Y-0.0129
Z0.0753 Y-0.0463          Z0.0875 Y-0.0123
Z0.0756 Y-0.0453          Z0.0878 Y-0.0118
Z0.0758 Y-0.0443          Z0.0881 Y-0.0113
Z0.0761 Y-0.0433          Z0.0883 Y-0.0108
Z0.0764 Y-0.0424          Z0.0886 Y-0.0103
Z0.0767 Y-0.0415          Z0.0889 Y-0.0098
Z0.0769 Y-0.0405          Z0.0892 Y-0.0093
Z0.0772 Y-0.0396          Z0.0894 Y-0.0088
Z0.0775 Y-0.0387          Z0.0897 Y-0.0084
Z0.0778 Y-0.0378          Z0.0900 Y-0.0080
Z0.0781 Y-0.0369          Z0.0903 Y-0.0075
Z0.0783 Y-0.0360          Z0.0906 Y-0.0071
Z0.0786 Y-0.0351          Z0.0908 Y-0.0067
Z0.0789 Y-0.0342          Z0.0911 Y-0.0063
Z0.0792 Y-0.0334          Z0.0914 Y-0.0059
Z0.0794 Y-0.0325          Z0.0917 Y-0.0055
Z0.0797 Y-0.0317          Z0.0919 Y-0.0052
Z0.0800 Y-0.0309          Z0.0922 Y-0.0048
Z0.0803 Y-0.0301          Z0.0925 Y-0.0045
Z0.0806 Y-0.0293          Z0.0928 Y-0.0042
Z0.0808 Y-0.0284          Z0.0931 Y-0.0038
Z0.0811 Y-0.0276          Z0.0933 Y-0.0035
Z0.0814 Y-0.0269          Z0.0936 Y-0.0033
Z0.0817 Y-0.0261          Z0.0939 Y-0.0030
Z0.0819 Y-0.0253          Z0.0942 Y-0.0027
Z0.0822 Y-0.0246          Z0.0944 Y-0.0025
Z0.0825 Y-0.0238          Z0.0947 Y-0.0022
Z0.0828 Y-0.0231          Z0.0950 Y-0.0020 F0.5
Z0.0831 Y-0.0224          Z0.0953 Y-0.0018
Z0.0833 Y-0.0217          Z0.0956 Y-0.0016
Z0.0836 Y-0.0210          Z0.0958 Y-0.0014
Z0.0839 Y-0.0203          Z0.0961 Y-0.0012
```

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Z0.0964 Y-0.0010        Z0.1094 Y-0.0071
Z0.0967 Y-0.0009        Z0.1097 Y-0.0075
Z0.0969 Y-0.0008        Z0.1100 Y-0.0080
Z0.0972 Y-0.0006        Z0.1103 Y-0.0084
Z0.0975 Y-0.0005        Z0.1106 Y-0.0088
Z0.0978 Y-0.0004        Z0.1108 Y-0.0093
Z0.0981 Y-0.0003        Z0.1111 Y-0.0098
Z0.0983 Y-0.0002        Z0.1114 Y-0.0103
Z0.0986 Y-0.0002        Z0.1117 Y-0.0108
Z0.0989 Y-0.0001        Z0.1119 Y-0.0113
Z0.0992 Y-0.0001        Z0.1122 Y-0.0118
Z0.0994 Y0.0000         Z0.1125 Y-0.0123
Z0.1006 Y0.0000         Z0.1128 Y-0.0129
Z0.1008 Y-0.0001        Z0.1131 Y-0.0134
Z0.1011 Y-0.0001        Z0.1133 Y-0.0140
Z0.1014 Y-0.0002        Z0.1136 Y-0.0146
Z0.1017 Y-0.0002        Z0.1139 Y-0.0152
Z0.1019 Y-0.0003        Z0.1142 Y-0.0158
Z0.1022 Y-0.0004        Z0.1144 Y-0.0164
Z0.1025 Y-0.0005        Z0.1147 Y-0.0170
Z0.1028 Y-0.0006        Z0.1150 Y-0.0177
Z0.1031 Y-0.0008        Z0.1153 Y-0.0183
Z0.1033 Y-0.0009        Z0.1156 Y-0.0190
Z0.1036 Y-0.0010        Z0.1158 Y-0.0196
Z0.1039 Y-0.0012        Z0.1161 Y-0.0203
Z0.1042 Y-0.0014        Z0.1164 Y-0.0210
Z0.1044 Y-0.0016 F1     Z0.1167 Y-0.0217
Z0.1047 Y-0.0018        Z0.1169 Y-0.0224
Z0.1050 Y-0.0020        Z0.1172 Y-0.0231
Z0.1053 Y-0.0022        Z0.1175 Y-0.0238
Z0.1056 Y-0.0025        Z0.1178 Y-0.0246
Z0.1058 Y-0.0027        Z0.1181 Y-0.0253
Z0.1061 Y-0.0030        Z0.1183 Y-0.0261
Z0.1064 Y-0.0033        Z0.1186 Y-0.0269
Z0.1067 Y-0.0035        Z0.1189 Y-0.0276
Z0.1069 Y-0.0038        Z0.1192 Y-0.0284
Z0.1072 Y-0.0042        Z0.1194 Y-0.0293
Z0.1075 Y-0.0045        Z0.1197 Y-0.0301
Z0.1078 Y-0.0048        Z0.1200 Y-0.0309
Z0.1081 Y-0.0052        Z0.1203 Y-0.0317
Z0.1083 Y-0.0055        Z0.1206 Y-0.0325
Z0.1086 Y-0.0059        Z0.1208 Y-0.0334
Z0.1089 Y-0.0063        Z0.1211 Y-0.0342
Z0.1092 Y-0.0067        Z0.1214 Y-0.0351
```

```
Z0.1217 Y-0.0360
Z0.1219 Y-0.0369
Z0.1222 Y-0.0378
Z0.1225 Y-0.0387
Z0.1228 Y-0.0396
Z0.1231 Y-0.0405
Z0.1233 Y-0.0415
Z0.1236 Y-0.0424
Z0.1239 Y-0.0433
Z0.1242 Y-0.0443
Z0.1244 Y-0.0453
Z0.1247 Y-0.0463
Z0.1250 Y-0.0472
Z0.1253 Y-0.0483
Z0.1256 Y-0.0493
Z0.1258 Y-0.0503
Z0.1261 Y-0.0514
Z0.1264 Y-0.0524
Z0.1267 Y-0.0535
Z0.1269 Y-0.0546
Z0.1272 Y-0.0557
Z0.1275 Y-0.0567
Z0.1278 Y-0.0577
Z0.1281 Y-0.0587
Z0.1283 Y-0.0596
Z0.1286 Y-0.0605
Z0.1289 Y-0.0614
Z0.1292 Y-0.0623
Z0.1294 Y-0.0631
Z0.1297 Y-0.0639
Z0.1300 Y-0.0647
Z0.1303 Y-0.0654
Z0.1306 Y-0.0662
Z0.1308 Y-0.0669
Z0.1311 Y-0.0675
Z0.1314 Y-0.0682
Z0.1317 Y-0.0688
Z0.1319 Y-0.0693
Z0.1322 Y-0.0699
Z0.1325 Y-0.0704
Z0.1328 Y-0.0709
Z0.1331 Y-0.0714
Z0.1333 Y-0.0718
Z0.1336 Y-0.0722
Z0.1339 Y-0.0726
Z0.1342 Y-0.0730
Z0.1344 Y-0.0733
Z0.1347 Y-0.0736
Z0.1350 Y-0.0739
Z0.1353 Y-0.0741
Z0.1356 Y-0.0743
Z0.1358 Y-0.0745
Z0.1361 Y-0.0747
Z0.1364 Y-0.0748
Z0.1367 Y-0.0749
Z0.1369 Y-0.0750
Z0.2000 Y-0.0750
G00 Y0.500
Z0
G92.2
G00 G90 X0 Y0.5 Z0
%
```

You may also consider writing this code using sun programs if you are using the Ubuntu version of EMC2. By using sub programs you could remove thousands of lines of code from a V-8 camshaft. The instructions to use sub programs have been added at the end of these instructions.

Grinding Your First Camshaft

The first step in building any camshaft is building a blank. Make the blank's diameter oversize in case it warps during heat treat. Usually the blank will be held with a 3-jaw chuck or a collet at the spindle end and be supported by the tailstock center at the other; therefore, you need a center hole on at least one end. Whatever the case, you have to provide a method of mounting the camshaft blank in the machine even if it you have to add material to its length. This can always be ground off after the cam lobes are formed. I would also recommend starting with a wooden dowel (the harder the wood the better) turned to the shape of your blank. Make two camshaft blanks in case you screw the first one up. The purpose of these wooden test cams is to make sure the lobes on your final camshaft will be pointed in the correct direction. Grind the wood blank exactly the same as you would grind the metal one using the directions below with the exception of taking 0.020" cuts.

Don't get eager and start grinding before the material has been heat treated. I think air hardening steel is the easiest to work with. Grinding before the shaft has been hardened has two disadvantages. 1) The steel doesn't grind well in a soft condition, and 2) a finished camshaft will warp when it is heat treated. After heat treating the blank, true it up by using the cam grinder as an OD grinder. I use my Sherline milling machine headstock in place of the cam grinder's headstock and work the machine manually. With the drivers turned off you can operate the grinder manually. Next use a

marking pen and blacken the surfaces that will be ground. This will allow you to easily distinguish the actual area being ground.

The Backplot feature of the EMC program will not do you much good with this program because of the way we use the z-axis.

The big no-no is crashing the grinder into the chucking device at the spindle end. There's no excuse for letting this happen, because you can just take the programmed largest x-axis number and check it against the point that a crash would occur to the edge of the grinding wheel. You can check this with a simple scale. Be sure to grease the support center of the camshaft before starting.

Cam Grinding Sequence

1) Power up the computer and load the Sherline Inch Program along with the camshaft program.

2) Turn on the stepper motor drivers and manually operate the x, y, and Z-axis motors to be sure the system is working properly.

3) Turn the stepper motor drivers off.

4) Manually center the grinding wheel opposite the first lobe blank closest to the tailstock.

5) Manually move the y-axis in a direction that positions the wheel and the camshaft blank within 0.015″ of one another.

6) Check x-axis movement available and be sure it agrees with program.

7) Set the z-axis at zero with the handwheel.

8) Set the feed rate over ride at 20%.

9) Zero all axes (Must be in manual) and adjust the y-axis readout (y0.500) for the Howell V-4 Engine to its home position.

10) Click on the [Auto] button.

11) Click on the [Run] button.

12) Watch the x,y,z position change slowly because of the 20% feed rate. Remember the slides will not be moving because the drivers are turned off.

13) The moment the z-axis numbers start to show movement click on [Stop]

14) Move the y-axis in until the grinding wheel touches the camshaft blank.

15) Turn on the stepper motor drivers and coolant.

16) Set the feed rate back to 50% for first pass.

17) Click on [Resume] and watch it run, but be prepared to click on [Stop]

18) If the program made it to the end and is in the correct location make sure the z-axis is on zero, if not, move it there by overriding the stepper motor.

19) Move the y-axis in 0.005″, set the feed rate at 100% and grind until finished.

The finished camshaft for a four cylinder inline Seal Engine

These are the camshafts that were produced while writing these instructions; however, the shaft ends haven't been ground to size yet.

Believe me, these instructions were many times more difficult to write than to do the actual cam grinding. I hope you find them useful and interesting. I rewrote these instructions after dealing with a few customers and tried to correct the parts they found confusing.

Thank you,
Sherline Products Inc.

The "o" command allows you to create Sub Programs

A sub program is a program within a program that is defined by the letter "o". EMC2 will not allow you to call up a sub program from another file. These Sub programs (or Subroutines) are entered at the beginning of the Main Program and are labeled by the letter "o" followed by a number followed by the word sub. You can't use a letter or letter and number to define a sub program. I find it wise to further define the sub program inside parentheses.

Example: o100 **call** (mill 2″ hole). A sub program may call up another sub program and they call this procedure "nesting." EMC2 will allow you to nest as many as ten sub programs together.

When the sub program is complete, you enter, for example: o100 **endsub** (mill 2″ hole). The words I highlighted in red must be entered in order for the "o" command to function.

Sub Programs offer a programmer a way to shorten a program by thousands of lines. They are similar to "canned cycles." Prior to canned cycles if you wanted to peck drill deep holes you had to program all of the z-axis moves one line at a time. This could take several lines of program for each hole. Canned cycles allowed you to put all of the drilling information on one line, and then program position moves for all of the holes.

Some general areas were sub programs are used are: 1) Parts that have the same shape cut in several different places. 2) Machining the same parts on several different fixtures. 3) Machining the same shape in different locations. Sub programs can be short and simple (#1) or very long and intricate.

EMC2 uses "o" codes (this is the letter o, it is not Zero) for programming sub programs.

Sub programs are usually written in a g91 incremental format; however, the g90 format of the cam g-code can be used in this case because the cam is always ground from the same location. Of course the x-axis location is different between lobes, but the x-axis moves are not part of the lobe grinding code. Normally, if g90 was used the sub program would only run in a single location; however, you could use g90 if you reset your home position with a g92 before calling up your sub program. This would be a better choice for long complex sub programs that would be difficult to read if written in incremental movements. Your choice.

This would be a typical sub program:

o200 sub (the starting code for the sub program within the main program. The word **sub** is required)

g91 g01 z-.3 f15.0

g00 z.300

x.25

g01 z-.3

g00 z.3

y.25

g01 z-.3

g00 z.3

x-.25

g01 z-.3

g00 z.3

o200 endsub (the ending code for the sub program within the sub program will locate the cutter in the exact same spot it was before the sub program was run)

This would be a typical main program that calls a sub program:

In the main program body you will move the cutter to the starting position for the shape or operation that you want to machine. Then you will call up the sub program using

an o-code. Your program will look something like this:

%

(Program Name)

o200 sub (It's best to have a standard format and my suggestion is to always enter all your sub programs at the beginning of your program.)

g91 g01 z-.3 f15.0

g00 z.300

x.25

g01 z-.3

g00 z.3

y.25

g01 z-.3

g00 z.3

x-.25

g01 z-.3

g00 z.3

o200 endsub

g90 g00 g40 g80 x1.0 y1.0 z0 (move into position for the starting point of the sub program)

o200 call (call up sub program o200)

g90 g00 x1.0 y-1.0 z0 (A g90 must be entered in the line of code calling for its next position move) (Be sure to have your spindle high enough to clear all obstacles such as clamping devices.)

o200 call (call up sub program o200)

As many times as needed.

Now every time the machine sees "o200 call" in the program, it will search for "o200 sub". Then it will run that section of the program until it reads "o200 endsub". At this point, the spindle will go back to the position it was before the "o200 call" was initiated and continue to run the main program.

%

(Main Program with a Sub Program Nesting Sample)

o200 sub (4 hole pattern)

g91 g01 z-.3 f15.0

g00 z.300

x.25

g01 z-.3

g00 z.3

y.25

g01 z-.3

g00 z.3

x-.25

g01 z-.3

g00 z.3

o300 call (x move)

o200 endsub

o300 sub (mill shape)

(mill shape g-code)

o300 endsub

(Main Program with a Sub Program Nesting Sample)

g90 g00 g40 g80 g54 g17 x0 y0 z0

g90 g00 x1.0 y1.0 (move into position for the starting point of the sub program)

o200 call (4 hole pattern)

g90 g00 x4.0 y1.0

o200 call (4 hole pattern)(Which also calls o300 sub (mill shape))

g90 g00 g40 g80 x0 y0 z0

m02

%

Again:

1. All o-codes must be numbers (Example: o200, o154, etc).

2. No letters or words are allowed after the o-code number except the words (sub, call and endsub).

3. No comments are allowed unless they are inside parentheses (xxxxx).