SECTION VII

PROGRAMMING EXAMPLE

7.1 ENGINEERING

7.1.1 The Drawing

Figure 7-1 shows the part to be machined. Its shape, size, tolerances, material etc. make this part practical and eminently suited to manufacture on a multi-function machine.

7.1.2 Tooling and Methods

Because of the rectangular shape of the stock in this example we can hold the part in a vise, or if sufficient parts have to be manufactured a multi-station fixture would be suitable.

To process this part the following order of operations will be used:

- Spot Drill
- Drill
- Mill Holes and Pocket
- Ball End Mill, Slope,
- Spherical Shape and Letters

The cutting tool list can be generated very readily and has been used in this manual in Section VII as Figure 7-2. Some points to note are:

The specific cutting tool sizes, and preset lengths can now be established. The TLO data sheet Figure 7-3 can be prepared.

Finally, Figure 7-4 can be generated to establish proper feeds and speeds from surface cutting speeds and chip loads.

7.2 PROGRAMMING

7.2.1 The Start Point and Fixturing Setup

It is quite evident that the operator will have no difficulty setting up a vise, indicating its square and finding the coordinates in X and Y of the lower left-hand corner of the fixed jaw.

The part when set on parallels and projecting above the vise approximately 1/4" will provide a ready platform to set the knee of the machine. With the tip of the tool at

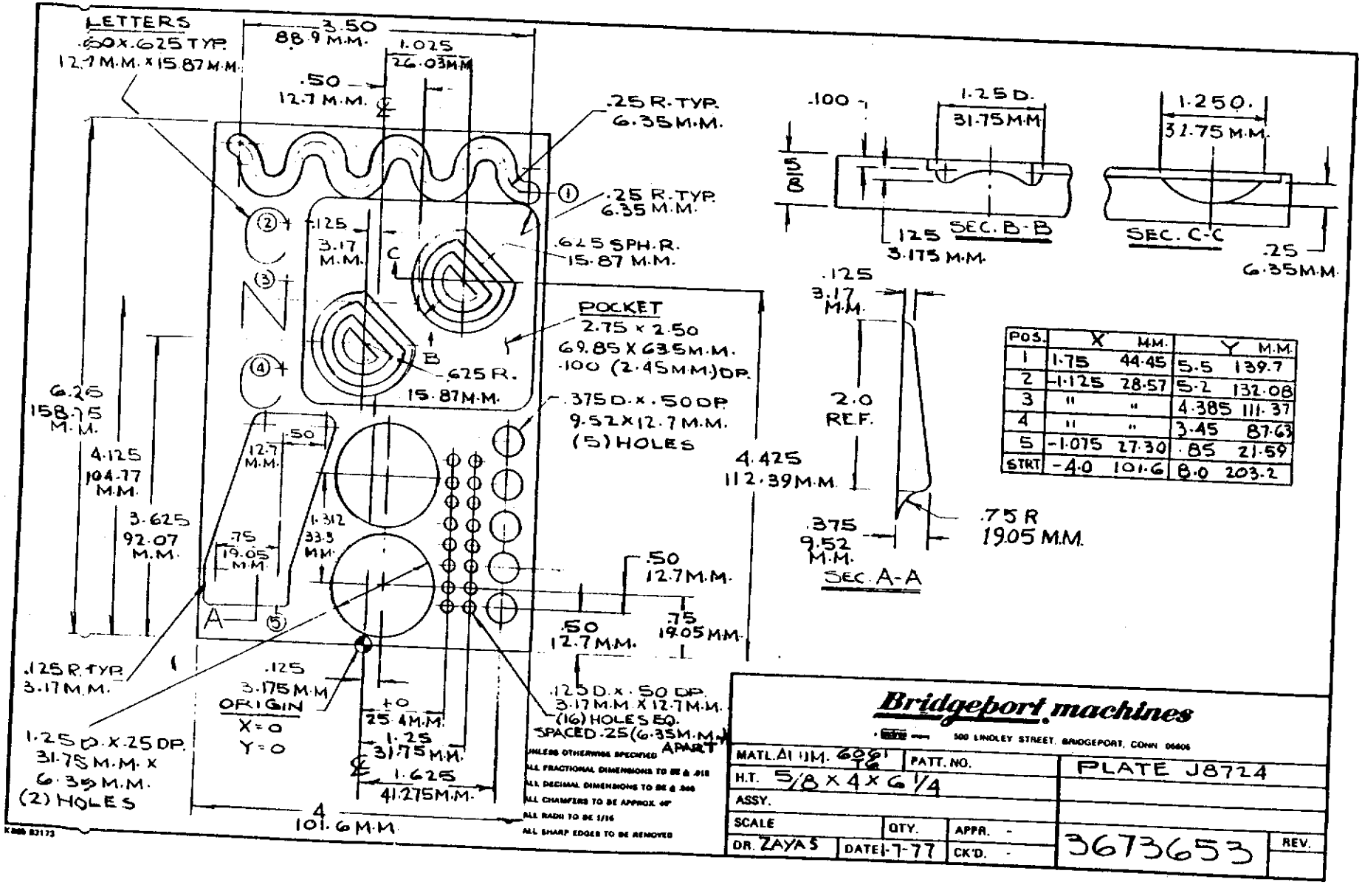

Figure 7-1. Drawing of Plate 3673653

Bridgeport machines
a Textron company

500 LINDLEY STREET, BRIDGEPORT, CONN. 06606

PART NAME: PLATE
PART NUMBER: 3673653
SPINDLE TYPE #30
JOB NO.: 8724
SHEET 1 OF 1

TOOL DESCRIPTION AND TOOL PRESETTING DATA

TOOL NO.	DESCRIPTION	TOOL HOLDER			ADAPTER (IF ANY)			TOOL EXTENSION (C) INS.	TOTAL DISTANCE GAGE LINE TO TIP OF TOOL (A+B+C) INS.	
		PART NO.	COLLET	GAGE TO NOSE (A) INS.	PART NO.	COLLET	EXTENSION (B) INS.		FRACT.	DECIMAL
1	1/2 DIA. GLENBARD SPOT DRILL	1570155	1570188	2 1/2				2	4 1/2	4.500
2	1/8 DIA. HI-SPIRAL DRILL	1570155	1570164	2 1/2				1 3/4	4 1/4	4.250
3	3/8 DIA. HI-SPIRAL DRILL	1570155	1570180	2 1/2				1 3/4	4 1/4	4.250
4	1/2 DIA. (2) FLUTE END MILL	1570342		1 3/4				1 1/4	3	3.000
5	1/4 DIA. (2) FL. BALL E.M.	1570341		1 3/4				1	2 3/4	2.750

FORM BP116

Figure 7-2 Plate 3673653 - Presetting Data

Bridgeport TEXTRON

Bridgeport Machines Division, Textron Inc. — 500 LINDLEY STREET, BRIDGEPORT, CONN. 06606

PART NAME PLATE

PART NUMBER 3673653

TOOL SETTING DATA

MACHINE

JOB NO 8724

SHEET 1 OF 1

FOR TOOL LENGTH OFFSET OF ANY TOOL TO A SINGLE CLEARANCE PLANE

TLO OF TOOL (LONGEST TOOL LENGTH - ITS TLO) MINUS ACTUAL SET LENGTH OF TOOL

FOR CUTTER DIAMETER COMPENSATION OF ANY TOOL

CUT COMP. PROGRAMMED CUTTER DIA. MINUS ACTUAL CUTTER DIA

STATION NO	TOOL NUMBER	DESCRIPTION	SEQ NO	LENGTH TO BE SET	ACTUAL SET LENGTH	PROGRAM DIAMETER	ACTUAL DIAMETER	STATION NO	T L O	CUT DIA COMP
T01		1/2 DIA. SPOT DRILL	1	4.500				T01		
T02		1/8 DIA. DRILL	40	4.250				T02		
T03		3/8 DIA. DRILL	60	4.250				T03		
T04		1/2 DIA. ENDMILL	80	3.000				T04		
T05		1/4 DIA. BALL END MILL	145	2.750				T05		
T06								T06		
T07								T07		
T08								T08		
T09								T09		
T10								T10		
T11								T11		
T12								T12		
T13								T13		
T14								T14		
T15								T15		
T16								T16		
T17								T17		
T18								T18		
T19								T19		
T20								T20		
T21								T21		
T22								T22		
T23								T23		
T24								T24		

F-127A

Figure 7-3. Plate 3673653 - Tool Setting Data

Bridgeport machines
a textron company

500 LINDLEY STREET, BRIDGEPORT, CONN. 06606

PART NAME: PLATE SPINDLE TYPE: #30 JOB NO.: 8724

PART NUMBER: 3673653 MATERIAL: 6061-T6 ALUM SHEET 1 OF 1

MACHINING DATA AND MACHINING CYCLE TIME

TOOL NO.	OP NO.	OPERATION DESCRIPTION	SPINDLE DATA		TOOL LOAD			PER OPERATION		OPS OR HOLES	TOTAL MINUTES
			SURFACE FT/MIN	RPM	INCHES PER FLUTE	INCHES PER REV.	FEED INS/MIN	INS.	MINS.		
1	10	SPOT DRILL (16) 1/8 H.		2400			10	.1	.01	16	.16
	20	SPOT DRILL (5) 3/8 H.						.4	.04	5	.20
2	30	DRILL (16) 1/8 HOLES		4200			7	.6	.09	16	1.4
3	40	DRILL (5) 3/8 HOLES		2400			137	.6	.044	5	.22
4	50	MILL (2) 1.25 HOLES		2400			4	2	.5	2	1.0
	60	MILL 2.75 x 2.5 POCKET					15	30	2.0	1	2.0
5	70	MILL SLOPED POCKET		3000			12	48	4.0	1	4.0
	80	MILL (2) .625 SPH. RA.					20	15	.75	2	1.5
	90	MILL TANGENT RADII					10	8	.8	1	.8
	100	MILL LETTERS					10	5	.5	1	.5
										TOTAL	11.78

FORM #F114

Figure 7-4. Plate 3673653 - Machining Data

ZABS = 0.0 (i.e. extended its TLO), instructions to the operator will be that the knee be set with a 1.0" guage block between the tip of the tool and the top of the workpiece.

The start point will be at the back of the machine table and just sufficiently far away from the vise to give Tool Change clearance. The part in the vise is high enough above the table surface to give the necessary tool change vertical clearance.

7.2.2 Programming Consideration

Entirely independent of the cutting tool lengths an arbitrary plane 1.0" above the work surface will be established as the TLO reference plane where ZABS = 0.0. The program will be run in absolute coordinates with an origin x = 0, y = 0 at the lower center of the part. The tool change point becomes x = -4.0" and Y = 8.0", see the setup instruction (Figure 7-5).

7.2.3 The Program (Figure 7-6 consisting of two sheets)

%	Rewind Stop Code (for paper tape control only).
T1/.5	Presets Tool Length Offset For Tool No. 1 to .500.
T2/.738	Presets Tool Length Offset For Tool No. 2 to .738.
T3/.713	Presets Tool Length Offset For Tool No. 3 to .713.
T4/1.050	Presets Tool Length Offset For Tool No. 4 to 1.050.
T5/2.121	Presets Tool Length Offset For Tool No. 5 to 2.121.
G4/3	Presets dwell time to .05 seconds. This dwell time will be in effect whenever a G82 or G89 command is programmed.
#1	Start defining a Macro sub program called #1.
=N30/4	Call a Loop which will repeat through Seq. No. 30 (4) times.
N30G91Y.5	Move Y Axis in the incremental (G91) mode a value of .500.
$	Termac (terminate the definition of Macro #1).
#2	Start defining a Macro sub program called #2.
=N31/7	Call a Loop which will repeat through Seq. No. 31 (7) times.

N31G91Y*	Move Y Axis in the incremental (G91) mode some variable Y value (*). This variable will be given a value when the Macro is called.
$	Termac (terminate the definition of Macro #2).
N27G0G90X-4.0Y8.0T1M6	Set the control to the proper modes (G90) absolute, (G0) Rapid. X & Y establish the coordinates of starting position, T1M6 cause the Z Absolute value to be set to the TLO for Tool 1.
N28X1.0Y.5Z-.95	Move the tool to the X Y & Z co-ordinates to begin the spot drill operation. The X & Y Axis will position first to their coordinates, then the Z Axis will Rapid down from its offset through Zero to .95 below Z Zero.
N29G81Y.5Z.12F120	The cycle is set (G81) drilling and one coordinate is repeated (Y.5). The Z will move an incremental distance (.07 + .05) providing a .0075 chamfer on the hole to be drilled .125 diameter later. The feed rate is set to 12 inches per minute.
#3	Start defining Macro #3.
=#2Y*.25	Call Macro #2. Set Y (*) variable to .25.
N32X.25	Move X Axis .25.
=#2Y*-.25	Call Macro #2. Set Y (*) variable to -.25.
$	Termac
=#3	Call Macro #3 which will cause (2) Rows of (8) holes to be spot drilled. The cycle was set at Seq. No. 8.
N33G90G82X1.625Y.5Z.245	Position in the absolute mode (G90) and spot drill, using G82 spotface cycle. The Z depth is (.195 + .05) providing a .0075 chamfer for a .375 dia. drill. The feed rate is still 12 IPM.
=#1	Call Macro #1 which will cause (4) more holes to be spot drilled per the cycle set at Seq. No. 15.

N40G0G90X0Y0T2M6	(G0) cancel cycle, set the control in rapid & (G90) absolute modes. Move Y to a clear location for tool change, T2 M6. Set the Z absolute value to the TLO for Tool 2 and stop the control.
N50X1.0Y.5Z-.95	
N55G87Y.5Z.6Z.15F90	
= #3	
N60G0G90X0Y0T3M6	Drilling the 1/8 holes & 3/8 holes similar to above.
N70X1.625Y.5Z-.95	
N75G81Y.5Z.6F137	
= #1	
N80G0G90X0Y0T4M6	N80 load 1/2 dia. End Mill. Sets Z abs register at TLO value for Tool No. 4. Stops control.
N90X.125Y.75Z-.95	Position X, Y & Z.
=N120/2	Call a Loop. Repeat the program through Seq. No. 120 (2) times.
N95G1G91Y-.3Z-.3F80	Set control in feed (G1) & Incremental (G91) modes. Move Y & Z Axes to feed End Mill into work.
N100Y.3	Feed Y Axis back to center of bore.
N105G79J.36	Call for rough bore milling cycle (G79). J.36 will be radius generated at tool center.
N110G1Z50	Feed tool away from bottom of bore, plus Z .005.
N115G79J.375	Call for finish bore milling cycle.
N120G0Y1.312Z.295	Rapid position Z plus .295; then Y plus 1.312.
N125G0G90X.5Y3.9Z-.95	Set system in Absolute (G90) mode position over start of pocket.
N130G1Y4.125Z-1.1F80	Feed (G1) into work in Y & Z (center of pocket) at a feed of 8 IPM.

N140G78X1.125X.2Y1.0Y1778F200	Call Pocket milling cycle (G78). The first X value (1.125) is the distance from the center of the pocket to the pocket wall less the cutter radius measured in X. The second X value is the X axis stepover (.2). The first Y value (1.0) is the distance from the center of the Pocket to the Pocket wall less the cutter radius measured in Y. The second Y value is the Y stepover (.1778). F200 is the feed rate.
N145G0G90X0Y0T5M6	Tool change, load 1/8 dia. ball End Mill. Sets Z abs register at TLO value for Tool No. 5. Stops control.
N150X-1.1Y.8Z-.95	Rapid Position X & Y; then Z axes to start milling sloped pocket.
N155G1G91X.5Y1.725Z-.175F90	Set system in Incr. (G91) mode; feed tool into upper part of pocket.
N160X-.5Y-1.7Z-.25F40	Feed tool into lower part of pocket.
=N180/12	Call a Loop which will repeat through Seq. No. 180 (12) times.
N165X-291F90	Pick Incr. of X-.0291 feed 9 IPM.
N170X.5Y1.7Z.25F150	Feed up the slope.
N175X-291	Pick Incr. X-.0291.
N180X-.5Y-1.7Z-.25	Feed down the slope.
N185X.725Y-250	Feed X & Y into lower left corner of pocket to start boundary pass.

N190X.5Y1.75Z2550 N200X-.75 N210X-.5Y-1.75Z-.26 N215X.75	Complete boundary pass around sloped pocket.
=N620/12	Call a loop which will repeat through Seq. No. 620 (12) times.
N605G2G19Y-.5Z.375J.6591K.3579F80	Mill a partial arc in a clockwise (G2) direction in the (G19) plane. (G2) must be programmed before (G19), the YZ plane.
N610G1X-.031	Pick increment X-.0312 in linear feed (G1).
N615G3G19Y.5Z-.375J.1591K.7329	Mill an arc in a counterclockwise (G3) direction, (G19) must be restated as it was cancelled by (G1).
N620G1X-.031	Pick increment X-.0312 in linear feed (G1).
N625G2G19Y-.5Z.375J.6591K.3579	Mill the last pass of an arc in a clockwise (G2) direction.
N217G0G90X10250Y49250Z-.95	Rapid Position (G0) over start of spherical radius contour (female) in Absolute (G90) mode. The tool will move up before the X Y positioning move.
N220Z-1.05	Rapid down in Z above start point.
N225G1G91Z-.15F30	Feed into work (G1); set system in increment (G91) mode.
#5	Start definition of Macro #5.
N228X.5Y-.5F40	Feed along straight side of contour.

N230G2X-.5Y-.5I.5	Set system in circular interpolation clockwise (G2); move X & Y .5 along a radius of .500 (I.5) (fourth quadrant).
N231X-.5Y.5J.5	Continue along the same radius, cutting the next (third) quadrant.
N232X.5Y.5I.5	Continue along the same radius, cutting the next (second) quadrant.
N235G1X4636Y-.5Z*F240	Step over to the next radius in X Axis; change the Z Axis some variable (*) value; feed at 24 IPM.
N240G2G99X-4636Y-4636I4636	Set system in Circ. Inter. CLW (G2) and override the automatic deceleration and acceleration (G99) for feed rates above 2.8 IPM.

From here to the end of the macro ($) the program continues to generate the spherical contour.

N241G99X-4636Y4636J4636

N242X4636Y4636I4636

N245G1X4017Y-4636Z*

N250G2G99X-4017Y-4017I4017

N251G99X-4017Y4017J4017

N252X4017Y4017I4017

N255G1X3384Y-4017Z*

N260G2G99X-3384Y-3384I3384

N261G99X-3384Y3384J3384

N262X3384Y3384I3384

N260G1X2740Y-3384Z*

N265G2G99X-2740Y-2740I2740F180

```
N266G99X-2740Y2740J2740

N267X2740Y2740I2740

G1X2085Y-2740Z*

N275G2G99X-2085Y-2085I2085

N276G99X-2085Y2085J2085

N277X2085Y2085I2085

N280G1X1423Y-2085Z*

N285G2G99X-1423Y-1423I1423F120

N286G99X-1423Y1423J1423

N287X1423Y1423I1423

N290G1X757Y-1423Z*

N295G2G99X-757Y-757I757

N296G99X-757Y757J757

N297X757Y757I757

$                                    Termac (termination of Macro #5)

=#5Z*-172Z*-258Z*-220Z*-182Z*-143Z*-143Z*-164
                                     Call Macro #5 to generate the
                                     female (minus Z* Values)
                                     spherical contour.

N297G0G90X-.125Y4.125Z-.95           Rapid position (G0) over start of
                                     male spherical contour.

N298Z-1.05                           Rapid down in Z.

N299G1G91Z-.1875F40                  Feed into work.

=#5Z*172Z*258Z*220Z*182Z*143Z*143Z*164
                                     Call Macro #5 to generate the
                                     male (plus Z* values) spherical
                                     contour.
```

N300G0G90X1.75Y5.5Z-.95	Rapid to start of wavy contour.
N305G1G91Z-.11F70	Feed into start point at 7 IPM.
=N325/3	Call a Loop which will repeat through Seq. No. 325 (3) times.
N310G2G99X-.25Y.25J.25F120	Circ. Interp. CLW (G2) generating a .25 radius (third quadrant) Acc. & Deceleration override (G99).
N315G3G99X-.25Y.25I.25	Circ. Interp. CCLW (G3) (first quadrant)
N320G99X-.25Y-.25J.25	Continue same radius (second quadrant).
N325G2G99X-.25Y-.25I.25	Circ. Interp. CLW (G2) (fourth quadrant).
N330G99X-.25Y.25J.25	After completing the Loop, continue the same radius (third quadrant).
N335G3X-.25Y.25I.25	Circ. Interp. CCLW (G3) last arc.
N340G0G90X-11250Y5.2Z-.95	Rapid position to start point of top letter C.
#4	Start definition of Macro #4.
N345G1G91Z-.1F70	Feed (G1) into work 7 IPM Incr. (G91).
N350G3G99X-.15Y.05I.15J.2F120	Circ. Interp. CCLW (G3) mill part of an arc. Override acceleration & deceleration (G99).
N355G1G99X-.1	Mill Straight (G1).

```
N360G3G99X-.25Y-.25J.25
N365G1G99Y-1250
N370G3G99X.25Y-.25I.25
N375G1G99X.1
N380G3X.15Y.05J.25
$
```

Complete the Letter C Macro.

```
=#4
```

Call Macro #4. Mill top letter C.

```
N385G0G90X-11250Y43850Z-.95
```

Rapid position to start of Letter N.

```
N390G1G91Z-.1F70
```

Feed (G1) into work.

```
N395Y-6250F120
```

Mill down straight side; feed 12 IPM.

```
N400X-.5Y6250
```

Mill up angle.

```
N405Y-6250
```

Mill down other straight side.

```
N410G0G90X-11250Y3.45Z-.95
```

Rapid Position to start of bottom letter C.

```
=#4
```

Call Macro #4. Mill bottom letter C.

```
N4001G0G90X-4.0Y8.0M2
```

Retract the Quill to the Home Position. Rapid position to the start location in X & Y. Rewind to top of stored part program.

```
E
```

Rewind Command (Used only for paper tape control when first entering the program into storage.)

SET-UP INSTRUCTIONS
DEMO PART #8724

1. Set 6.250 x 4.0 x .625 Block in vise.

2. Pick up front left hand corner of piece.

3. In MDI Mode preset X & Y Axis, G92X-2.0Y0.

4. Set longest tool T.L.O. Value to 0.5. Adjust Knee to touch off on 1.0 Set Block (Top of Set Block equals Zero "Z").

5. Set T.L.O. for each additional tool by Manual Touch Off method.

TOOL LIST FOR DEMO #8724

1.	1/2" Spot Drill	2400 RPM
2.	1/8" Drill	4200 RPM
3.	3/8" Drill	2400 RPM
4.	1/2" End Mill	2400 RPM
5.	1/4" Ball End Mill	3000 RPM

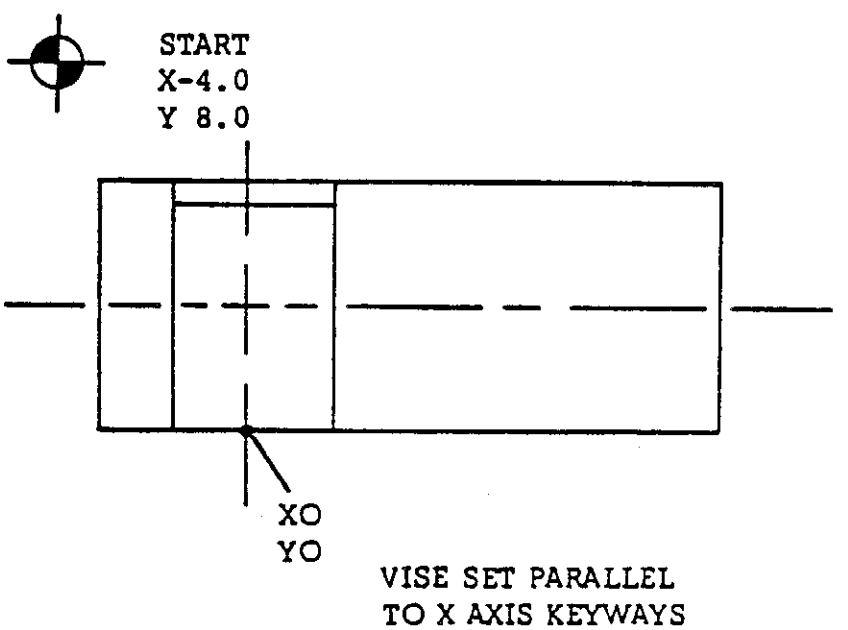

Figure 7-5. Set-Up Instructions

```
%T1/.5
T2/.738
T3/.713
T4/1.05
T5/2.121
G4/3
#1
=N30/4
N30G91Y.5
$
#2
=N31/7
N31G91Y*
$
N27G0G90X-4.0Y8.0T1M6
N28X1.0Y.5Z-.95
N29G81Y.5Z.12F120
#3
=#2Y*.25
N32X.25
=#2Y*-.25
$
=#3
N33G90G82X1.625Y.5Z.245
=#1
N40G0G90X0Y0T2M6
N50X1.0Y.5Z-.95
N55G87Y.5Z.6Z.15F90
=#3
N60G0G90X0Y0T3M6
N70X1.625Y.5Z-.95
N75G81Y.5Z.6F137
=#1
N80G0G90X0Y0T4M6
N90X.125Y.75Z-.95
=N120/2
N95G1G91Y-.3Z-.3F80
N100Y.3
N105G79J.36
N110G1Z50
N115G79J.375
N120G0Y1.312Z.295
N125G0G90X.5Y3.9Z-.95
N130G1Y4.125Z-1.1F80
N140G78X1.125X.2Y1.0Y177BF200
N145G0G90X0Y0T5M6
N150X-1.1Y.8Z-.95
N155G1G91X.5Y1.725Z-.175F90
N160X-.5Y-1.7Z-.25F40
=N180/12
N165X-291F90
N170X.5Y1.77.25F150
N175X-291
N180X-.5Y-1.7Z-.25
N185X.725Y-250
N190X.5Y1.75Z2550
N200X-.75
N210X-.5Y-1.75Z-.26
N215X.75
=N620/12
N605G2G19Y-.5Z.375J.6591K.3579F80
N610G1X-.031
N615G3G19Y.5Z-.375J.1591K.7329
N620G1X-.031
N625G2G19Y-.5Z.375J.6591K.3579
N217G0G90X10250Y49250Z-.95
N220Z-1.05
N225G1G91Z-.15F30
#5
```

Figure 7-6. Sample Program (Sheet 1 of 2)

```
N228X.5Y-.5F40
N230G2X-.5Y-.5I.5
N231X-.5Y.5J.5
N232X.5Y.5I.5
N235G1X4636Y-.5Z*F240
N240G2G99X-4636Y-4636I4636
N241G99X-4636Y4636J4636
N242X4636Y4636I4636
N245G1X4017Y-4636Z*
N250G2G99X-4017Y-4017I4017
N251G99X-4017Y4017J4017
N252X4017Y4017I4017
N255G1X3384Y-4017Z*
N260G2G99X-3384Y-3384I3384
N261G99X-3384Y3384J3384
N262X3384Y3384I3384
N260G1X2740Y-3384Z*
N265G2G99X-2740Y-2740I2740F180
N266G99X-2740Y2740J2740
N267X2740Y2740I2740
G1X2085Y-2740Z*
N275G2G99X-2085Y-2085I2085
N276G99X-2085Y2085J2085
N277X2085Y2085I2085
N280G1X1423Y-2085Z*
N285G2G99X-1423Y-1423I1423F120
N286G99X-1423Y1423J1423
N287X1423Y1423I1423
N290G1X757Y-1423Z*
N295G2G99X-757Y-757I757
N296G99X-757Y757J757
N297X757Y757I757
$
=#5Z*-172Z*-258Z*-220Z*-182Z*-143Z*-143Z*-164
N297G0G90X-.125Y4.125Z-.95
N298Z-1.05
N299G1G91Z-.1875F40
=#5Z*172Z*258Z*220Z*182Z*143Z*143Z*164
N300G0G90X1.75Y5.5Z-.95
N305G1G91Z-.11F70
=N325/3
N310G2G99X-.25Y.25J.25F120
N315G3G99X-.25Y.25I.25
N320G99X-.25Y-.25J.25
N325G2G99X-.25Y-.25I.25
N330G99X-.25Y.25J.25
N335G3X-.25Y.25I.25
N340G0G90X-11250Y5.2Z-.95
#4
N345G1G91Z-.1F70
N350G3G99X-.15Y.05I.15J.2F120
N355G1G99X-.1
N360G3G99X-.25Y-.25J.25
N365G1G99Y-1250
N370G3G99X.25Y-.25I.25
N375G1G99X.1
N380G3X.15Y.05J.25
$
=#4
N385G0G90X-11250Y4.850Z-.95
N390G1G91Z-.1F70
N395Y-6250F120
N400X-.5Y6250
N405Y-6250
N410G0G90X-11250Y3.45Z-.95
=#4
N4001G0G90X-4.0Y8.0M2
E
```

Figure 7-6. Sample Program (Sheet 2 of 2)