HAND OUT 02: APT PROGRAMMING NOTES

APT stands for Automatically Programmed Tool. It is a language that defines the tool path with respect to the part geometry, and often forms the basis for post-processor generated NC files.

The APT language consists of four types of statements. **Geometry** statements will be used to specify the elemental features defining the part shape. **Motion** statements are used to specify the path taken by the tool. **Post-processor** statements control the machinery, controlling coolants as well as the feeds and speeds. **Auxiliary** statements complete the picture, specifying the part, required tools, etc. The following sections describe each of the APT statements.

Geometry Statements

All geometric elements must be defined before tool motion may be programmed. Geometry statements associate a symbol with a description of the geometric element and its parameters. The general form for a geometry statement is:

symbol = geometric type/parametric description

The symbol consists of up to six alpha-numeric characters, containing at least one alpha character, and avoiding APT reserved words. The symbols provide a means to name the geometric features. The equals sign separates the symbol from the geometric type.

The geometric type describes these features. **POINT**, **LINE**, **PLANE**, and **CIRCLE** are valid APT geometric types. The forward slash character separates the geometric type from the parametric description of the feature.

The parametric description specifies the location and size of the feature. It may include dimensional data, positional data, and other APT words relating the feature to previously defined APT symbols. The APT language provides a rich means to specify the geometry, as is evidenced by the following examples.

To specify a point:

P0 = **POINT**/1.0, 1.2, 1.3	*specifies a point at XYZ coordinates 1.0, 1.2, and 1.3, respectively.*
P1 = **POINT/INTOF** L1, L2	*specifies a point at the intersection of lines L1 and L2, which must have been defined prior to the statement.*
P2 = **POINT/YLARGE**, **INTOF**, L3, C1	*specifies a point at the intersection of line L3 an*d circle C1 at a Y position above the center point of the circle.

To specify a line:

L1 = **LINE**/P0, P1	*specifies a line by two points, previously defined.*
L1 = **LINE**/1.0, 1.2, 1.3, 2.0, 2.1, 2.3	*specifies a line by two points, given as explicit coordinates.*
L2 = **LINE**/P2, **PARLEL**, L1	*specifies a line through point P2 and parallel to line L1.*
L3 = **LINE**/P1, **RIGHT**, **TANTO**, C1	*specifies a line through point P1 and tangent to circle C1 on the right side of the center point.*
L4 = **LINE**/P1, **ATANGL**, 45, L1	*specifies a line through point P1 at an angle of 45° to line L1.*

To specify a plane:

PL0 = **PLANE**/P0, P1, P2 *specifies a plane through three, non-colinear, previously defined points.*

PL1 = **PLANE**/P3, **PARLEL**, PL0 *specifies a plane through a point P3 parallel to a plane PL0.*

To specify a circle:

C0 = **CIRCLE/CENTER**, P0, **RADIUS**, 1.0 *specifies a circle of radius 1 from a center point of P0.*

Lines and planes extend infinitely. Circles are always complete. The same geometry may be defined only once, and may not have more than one symbol.

Motion Statements

The format for motion commands follows the pattern:

motion/description

The initial motion starts from a home position, and takes the form:

FROM/P0 or **FROM/** 0.0, 1.0, 2.0

The **FROM** motion statement occurs only once for each set of a motion type, at the start of the set of motions.

Contouring motion – is the most common motion used in APT programming, and these statements specify the tool path continuously throughout the motion. They make use of three surfaces: (a) **drive**; (b) **check**; and (c) **part** surfaces.

Drive surfaces represent the surface along which the vertical edges of the tool will follow. Part surfaces specify the surfaces the tip of the tool will follow. And check surfaces describe where the tool will come to rest after it has completed the motion of the current step. There are four locations for the tool to stop with respect to a check surface. These four possibilities each have their own modifier words.

The **TO** modifier stops the tool when the ***first surface*** of the tool would come into contact with the check surface. The **ON** modifier stops the tool where the ***center point*** of the tool would come into contact with the check surface. The **PAST** modifier stops the tool where the ***last surface*** of the tool would contact the check surface. And the **TANTO** modifier stops the tool at the point of circular tangency with the ***edge*** of the tool.

The initial contouring motion statement is the **GO/TO**, which defines the initial drive, part and check surfaces. It takes the form:

GO/TO, drive surface, **TO**, part surface, **TO**, check surface

An example would be:

GO/TO, L1, **TO**, PL1, **TO**, L2 specifying that the tool should use line L1 as the drive surface, plane P1 as the part surface, and line L2 as the check surface.

Note: the **GOTO** and the **GO/TO** statements ***are not the same***. The former specifies **point to point** motion (see below), and the latter initiates **contouring** motion.

Continuing contouring motion statements are given from the vantage point of a person sitting on the top of the tool. The motion words are: (a) **GOLFT**; (b) **GORGT**; (c) **GOFWD**; (d) **GOBACK**; (e) **GOUP**; and (f) **GODOWN**. The sense of these words depends on the direction the tool has been coming from, and is depicted in Figure 2:

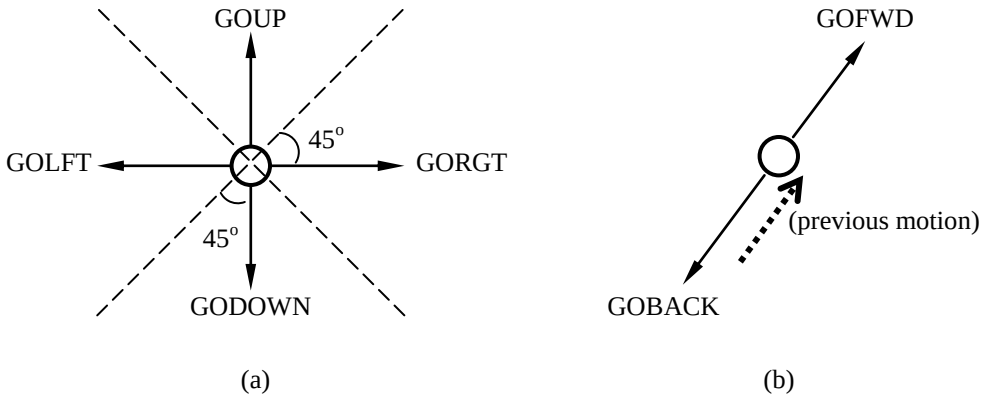

Figure 1. Motion Continuation Statements

Point to point motion – may be specified as absolute, or as incremental (relative to the last point visited). An example of absolute, point to point motion is:

GOTO/P0

An example of incremental, point to point motion is:

GODLTA/1.0, 2.0, 3.0

Point to point motion is useful in peck drilling or similar operations, since the motion path in-between the points is unimportant.

Post-Processor Statements

These statements provide processing parameters to the post-processor program. Typical programs will require parameters for feeds, speed, and other tool/spindle/machine controls. Examples:

SPINDL/600	specifies the spindle to be 600 rpm.
FEDRAT/6.0	specifies a feed rate of 6 inches per minute.
TURRET/T2	specifies loading tool # 2 in the turret.

A final post-processor statement must specify to the post-processor program what type of machine is intended for the final NC code, and the specific controller to generate the code for. An example is:

MACHIN/MILL,2	specifies a mill machine type, and controller type 2

Auxiliary Statements

These statements complete the APT programming language, and include the FINI statement to mark the end of the program as well as statements to define the width of the tool. An example of the latter is:

CUTTER/0.25	specifies a quarter-inch cutter diameter.

The computer would then know to calculate a 0.125 inch offset to accommodate the cutter diameter in computing the center of the tool.

Example APT Problem:

An APT program for the profiling of the part in Figure 2 is to be generated. The processing parameters are: (a) feed rate is 5.39 inches per minute; (b) spindle speed is 573 revolutions per minute; (c) a coolant is to be used to flush the chips; (d) the cutter diameter is to be 0.5 inches, and (e) the tool home position is (0, -1, 0). (Adapted from Groover, M. P. (1980). *Automation, Production Systems, and Computer-Aided Manufacturing.* Englewood Cliffs, NJ: Prentice-Hall. pp. 253-255.)

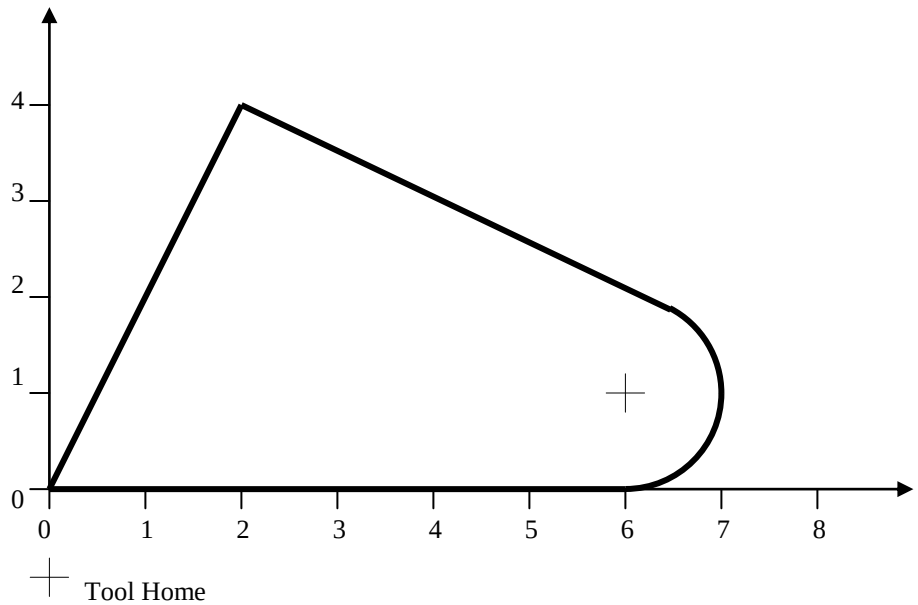

Figure 2. APT Program Workpiece

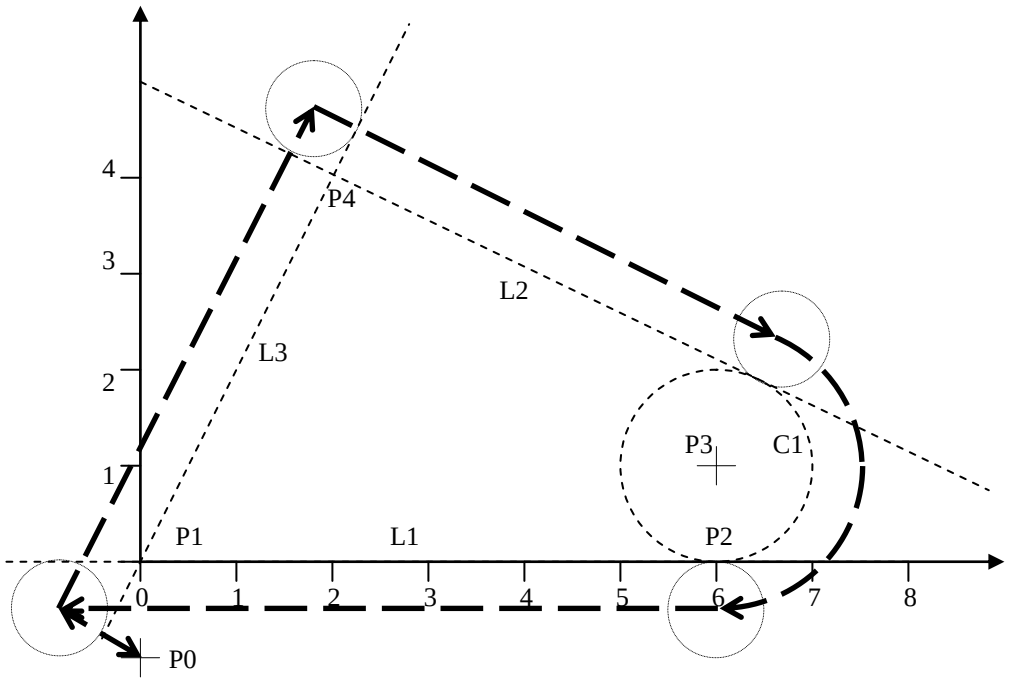

Figure 3. APT Geometry and Tool Path for Workpiece

APT Program Listing

PARTNO EXAMPLE	labels the program "EXAMPLE"
MACHIN/MILL, 1	selects the target machine and controller type
CUTTER/0.5000	specifies the cutter diameter
P0 = POINT/0, -1.0, 0	geometry statements to specify the pertinent surfaces of the part
P1 = POINT/0, 0, 0	
P2 = POINT/6.0, 0, 0	
P3 = POINT/6.0, 1.0, 0	
P4 = POINT/2.0, 4.0, 0	
L1 = LINE/P1, P2	
C1 = CIRCLE/CENTER, P3, RADIUS, 1.0	
L2 = LINE/P4, LEFT, TANTO, C1	
L3 = LINE/P1, P4	
PL1 = PLANE/P1, P2, P3	
SPINDL/573	sets the spindle speed to 573 rpm
FEDRAT/5.39	sets the feed rate to 5.39 ipm
COOLNT/ON	turns the coolant on
FROM/P0	gives the starting position for the tool
GO/PAST, L3, TO, PL1, TO, L1	initializes contouring motion; drive, part, and check surfaces
GOUP/L3, PAST, L2	motion statements to contour the part in a clockwise direction
GORGT/L2, TANTO, C1	
GOFWD/C1, ON, P2	
GOFWD/L1, PAST, L3	
RAPID	move rapidly once cutting is done
GOTO/P0	return to the tool home position
COOLNT/OFF	turn the coolant off
FINI	end program

APT Vocabulary

The APT programming language has over 400 words. The Chapter 6 Appendix in the Groover text (pp. 196 – 209) lists several useful words. It is suggested that the diligent student review this appendix, and note the particularly useful/trickier words in her/his engineering notebook.