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1900 series

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MILMAP Numerical Control Program

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MILMAP Numerical Control Program

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Preface

The publication of this second edition of the MILMAP manual coincides with the availability of the program on the I.C.T. 1900 series of computers. Originally written for the Milwukee-Matic machining centres, the MILMAP numerical control language is now to be made available for other additional point-to-point, numerically-controlled machining centres and machine tools and in these cases, the structure has been changed to the processor-post-processor form.

The facilities of the program have been extended; in particular, additional patterns have been added for the point-to-point user and contouring of slopes and circular arcs are included for those users who have control units with the appropriate in-built interpolation features.

This manual is intended for the process planning engineer. He does not need computer knowledge but it is assumed that he is acquainted with numerically-controlled machine tools and their manual programming methods.

The appropriate 1900 series operating instructions are given in Appendix A. The program will run on computers of the 1900 series which have a 16K store and four magnetic tapes. A card reader, a line printer and a paper tape punch complete the necessary minimum specification.

1 Introduction to I.C.T. MILMAP

Most point-to-point, numerically-controlled machining centres and machine tools are controlled by punched paper tape which can be prepared manually from entries on a process planning sheet (known as the P.P.S.) using the manufacturer's coding instructions. MILMAP is a computer program designed by I.C.T. to remove a great deal of the laborious effort involved in preparing a process planning sheet and to produce the control paper tape automatically. The following are some of the advantages to be gained:

1 One of the most tedious aspects of manual programming is the computing of machine co-ordinates at which drilling, milling, etc., is to take place. This tedious routine is reduced by using a series of temporary axes selected for convenience by the part-programmer; MILMAP converts temporary co-ordinates to machine co-ordinates.

2 Many operations are in fact a series of smaller operations. For example, the operation 'Tap' implies three operations:

   (a) spot drill,

   (b) drill,

   (c) tap.

   In the preparation of the MILMAP P.P.S., the only instruction requiring to be specified is 'Tap'; MILMAP will generate the preceding instructions.

3 Using the MILMAP system, the user produces his Tool Store, in which, among other entries, he gives speed and feed of each tool in a standard material. He also produces a Material Store which gives correcting factors for other materials. On his P.P.S., the user will give a tool number for a certain operation. The speed and feed will be selected from the tool store and then corrected by the factors selected from the material store. A further correction of speed and feed can be made on the P.P.S. line to allow for special contingencies. The user will establish his Tool and Material Stores when he starts using MILMAP. They will then require amendment at infrequent intervals. Thus once established, feeds and speeds are automatically selected.

4 Operations are sequenced by the program to minimize total machine operation time for the job. The process planner does not have to consider this when he uses MILMAP.

5 The total machine operation time for a job on the machining centre or machine tool will be calculated. Thus, accurate cost estimates will be possible more quickly and more cheaply than is at present possible.

The complete MILMAP system consists of the following steps, illustrated in Figure 1.

1 Decide fixture and clamping of part to be machined.

2 Decide operations, tools and datum positions.

3 Complete P.P.S. in all details.

4 Punch and verify P.P.S. data in 80-column cards, and interpret.

5 Deliver these P.P.S. cards, with tool store cards and material store cards if either of these include changes, to computer staff.

6 Computer staff:

   (a) Mount the MILMAP program tape, and STORE tape.

   (b) Enter new tool store cards if supplied; if not use existing tool store on STORE tape.

   (c) Enter new material store cards if supplied; if not use existing material store on STORE tape.

   (d) Enter P.P.S. cards.

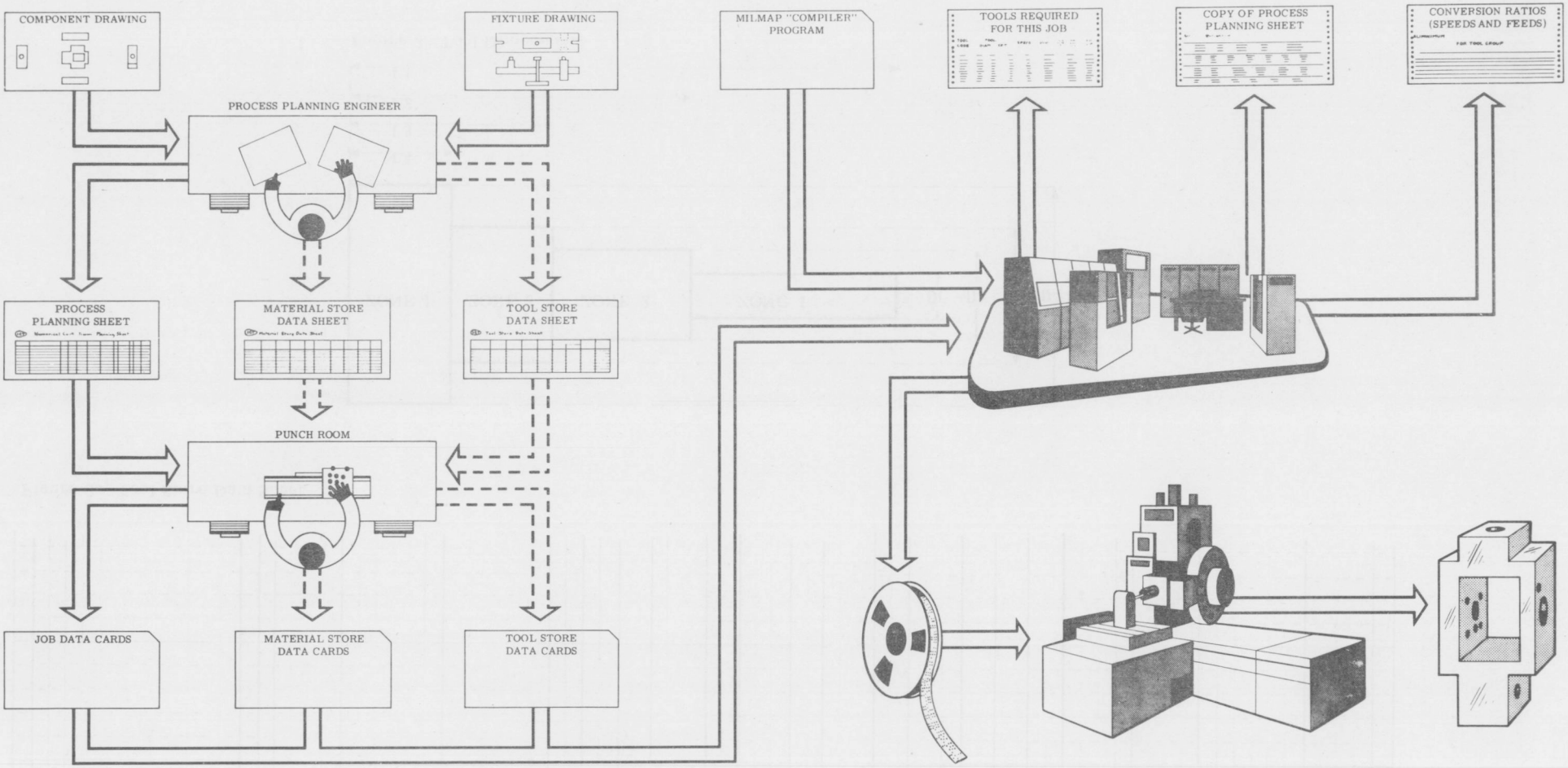
7 The computer will produce:

(a) The control tape.

(b) A print-out of input data and the resulting control tape instructions together with other useful information.

8 Check print-outs for errors in P.P.S.

9 Test-run on the machining centre or machine tool.



NOTE: The Tool Store and Material Store (shown created by means of broken line) need not be created for every job. Having been originally prepared when the system was initiated, the Tool Store and Material Store are only updated at infrequent intervals.

Figure 1: THE MILMAP SYSTEM

MILMAP 1900 TOOL STORE SHEET

TOOL DESRIPTION	TOOL CODE	TOOL: ZONE 1 DIA	TOOL: ZONE 1 SETTING	TOOL: ACTION	TOOL: TAPS T.P.I.	TOOL: ZONE 2 D	TOOL: ZONE 2 L	TOOL: ZONE 3 D	TOOL: ZONE 3 L	TOOL: ZONE 4 D	TOOL: ZONE 4 L	ST. MATL. SP. X IC FT. PER MIN.	ST. MATL. FD. .0001 PER REV.	PRECEEDING TOOL
1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9	20 1 2 3 4 5	6 7 8 9 30 1	2 3	4 5	6 7	8 9 40	1 2 3 4 5	6 7	8 9 50	1 2	3 4 5	6 7 8 9 60	1 2 3 4 5 6 7 8 9 70	1 2 3 4 5 6 7 8 9 80

Figure 2: Tool Store Data Sheet

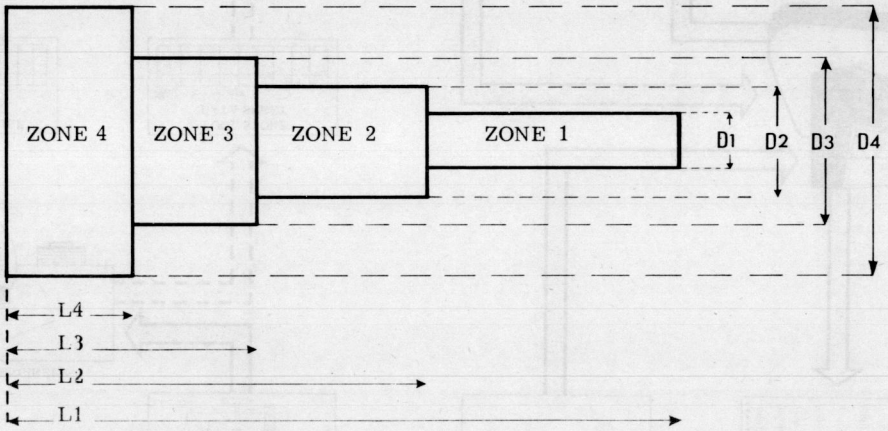


Figure 3: Tool Dimensions

2 The MILMAP Tool Store

GENERAL DESCRIPTION

A punched card is prepared for each tool used and the pack of tool cards is entered into the computer whenever a change is made. The computer program will record this data onto magnetic tape; consequently, when the content of the tool store has stabilized with few, if any, changes, the user will be able to carry forward his magnetic tape from run to run.

Tools must be given a four digit tool code number and the tool cards should be kept and entered into the computer as necessary in ascending order of tool number. The four digit code breaks into two sections of two digits each, representing

1 tool group number,

2 number within group.

Up to 29 groups are possible (31 for Milwaukee-Matic) and up to 99 tools are possible in each group (31 for Milwaukee-Matic). Tool group numbers can be allocated to any tool type except that taps must be allocated to groups 28 and 29 (Milwaukee-Matic must have taps in groups 30 and 31.)

TOOL DATA

The Tool Store Data Sheet (see Figure 2) is based on the 80-column card format and entries are made as follows:

Columns 2 to 13 : Tool Description

This is the description that will appear in the printed outputs.

Columns 16 to 19 : Tool Code

Columns 20 to 25 : Tool Diameter (Zone 1)

This is the actual tool diameter and is used in tool offset calculations. It is measured in inches and the decimal point is assumed to give two whole number digits and four places of decimals.

Columns 26 to 31 : Tool Setting Length (Zone 1)

This is the length of the tool from its foremost face to its rear location face (see Figure 3). It is also measured in inches and the decimal point is assumed to give two whole number digits and four places of decimals. This length plays an important part in all tool movements in the Z-direction, so it needs to be set accurately.

Columns 32 to 33 : Action Code

This is a distinctive two-digit number for each tool type. Drills have one number, taps another, reamers another, etc. The complete list of action codes is given in Figure 4.

Columns 34 to 35 : Threads per inch (for taps)

This is used in the choice of feeds and speeds and in the calculation of working depths.

Columns 36 to 37 : Extension Diameter (Zone 2)

Columns 38 to 40 : Extension Length (Zone 2)

Columns 41 to 42 : Extension Diameter (Zone 3)

Columns 43 to 45 : Extension Length (Zone 3)

Columns 46 to 47 : Extension Diameter (Zone 4)

Columns 48 to 50 : Extension Length (Zone 4)

These entries in inches describe the geometry of the tool (see Figure 3) and are used in the tests for tool interference. They are not given to the same accuracy as the main diameter and length. Diameters are given two digits with an assumed decimal point in between them; lengths are given three digits with an assumed decimal point between the second and third digits.

Columns 51 to 52 : Spindle Speed

This is the spindle speed for the standard material, medium cast-iron. It is expressed as a surface speed in x10 feet per minute and occupies two digits.

Columns 53 to 55 : Feed

This is the feed rate to be used in the standard material. It is expressed in .0001 inches per revolution.

Columns 76 to 79 : Preceding Tool Number

It is a necessary engineering practice to precede certain operations with other operations using a different tool. For example, one usually drills a hole before tapping it. In the MILMAP system, preceding actions are handled automatically and if a tool is given a preceding tool number in the tool store then that preceding tool operation will be generated even though there was no P.P.S. entry for it.

The columns of the card which are not allocated to MILMAP may be used or not used as the user wishes. I.C.T. intends to punch further tool data into their tool cards and to write other programs that will make use of them.

THE TOOL CARDS

The tool cards, fully interpreted, should be kept in their correct order in a safe place. When entered for a computer run, the pack of cards should be terminated with a card punched with asterisks in the first four columns, followed by a blank card. Each computer run must be specified correctly - see Chapter 10.

THE STORE MAGNETIC TAPE

The tool store and material store are recorded on the same magnetic tape, called 'STORE'. Computer runs can be made with an existing 'STORE' tape or with new tool and/or material data, in which case, a new 'STORE' tape will be written - see Chapter 10.

Action Code	Tool Type
01	Drills
02	Special drills
05	Countersinks
06	Spot drills
07	Centre drills
08	Spade drills
09	Shell drills
10	Drill counter bore
20	Reamers
22	Shell reamers
30	Boring bars
40	Shell end mills
42	End mills
44	Special end mills
50	Slot drills
51	Ball nose slot drills
60	Special cutters
61	Special cutters
75	Facing cutters
80	Taps

Figure 4: TOOL ACTION CODES

3 The MILMAP Material Store

The data entered in the material store data sheet, together with the tool store data, provides for the automatic selection of speeds and feeds by program. (The reader should note, however, that these values may be varied by any desired percentage by suitable entries on the process planning sheet.)

The speed and feed parameters entered on the tool store data sheet are based on the use of a standard material, i.e., medium cast iron. If other materials are to be machined, then conversion ratios must be provided to enable new speed and feed data to be computed. These conversion ratios are entered on the material store data sheet (see Figure 5).

A table of ratios has been established by I.C.T. for their own use. Other users may:

1 Use them without modification.

2 Alter them as they wish.

3 Re-establish the entire table.

I.C.T. will provide assistance in using or re-establishing this table of ratios.

It is found that the conversion ratios for surface cutting speed are independent of tool diameter, so that only one conversion ration is required for each combination of material and tool group.

With feed rates (specified in units of 0.0001 inches per revolution), the situation is different; it is found here that the material conversion ratio depends on the diameter of the tool concerned. It is sufficiently accurate to divide the range of diameters into four sections (as indicated in columns 11 to 16 of the material store data sheet), taking a mean figure for each section.

The four diameter ranges used in MILMAP are as follows:

up to 0.1 inches

up to 0.5 inches

up to 1.0 inches

above 1.0 inches

Therefore, for each combination of material and tool group, there is a total of five conversion ratios.

As an example, the five ratios for reaming soft cast iron are:

1.8 (for surface cutting speed)

1.3 (for feed rate up to diameter = 0.1 inches)

1.3 (for feed rate up to diameter = 0.5 inches)

1.6 (for feed rate up to diameter = 1.0 inches)

1.6 (for feed rate above diameter = 1.0 inches)

The complete conversion table consists of these five ratios for each combination of material and tool group.

FORMAT OF MATERIAL STORE DATA SHEET

Referring to Figure 5, it can be seen that the material store data sheet has five lines for each material, corresponding to the five conversion ratios described above. Each line holds 29 conversion ratios, that is one ratio for each group.

The data entered horizontally across the page is punched in the cards as indicated by the column numbers. This information is described (in column order) below.

NARRATIVE (COLUMN 1 TO 10) Narrative (Column 1 to 10)

The name of the material is entered in these columns. It is ignored by the program and entered only for the part programmer's use.

COLUMNS 11 TO 16 Columns 11 to 16

These columns are already completed on the sheet and are of no significance to the MILMAP program; they are included for the user's reference only and are not punched when the data cards are prepared.

LINE NUMBER (COLUMNS 18 TO 20) Line Number (Columns 18 to 20)

This is a three-digit number, right justified, which is used as the card sequence number. When the data cards are prepared, they are sorted in ascending sequence of line number.

MATERIAL CODES (COLUMNS 21 AND 22) Material Codes (Columns 21 and 22)

This is a two-digit code number for the material.

TOOL GROUPS 01 TO 29 (COLUMNS 23 TO 80) Tool Groups 01 to 29 (Columns 23 to 80)

The speed and feed ratios are determined and entered in the columns for the appropriate tool group. If a group is not being used, zeros must be entered. Milwaukee-Matics use Tool Groups 30 and 31 for taps, for which the same feeds and speeds are used for all materials. Other machining centres and machine tools must use Groups 28 and 29 for taps and can therefore have feeds and speeds corrected for material, like other tool types.

THE MATERIAL CARDS

The contents of the data sheet are punched, one line per card, in the columns indicated at the top of the sheet. The cards are then arranged in ascending sequence of line number. Subject to the availability of material codes, new materials may be inserted in the material store by the incorporation of five correctly punched cards for the material. The material cards, fully interpreted, should be kept in their correct order, in a safe place. When entered for a computer run, the pack should be terminated with a card punched with four asterisks in the first four columns, followed by a blank card. Each computer run must be specified correctly - see Chapter 10.

THE STORE MAGNETIC TAPE

The tool store and material store are recorded on the same magnetic tape called 'STORE'. Computer runs can be made with the existing 'STORE' tape or with new tool and/or material data, in which case, a new 'STORE' tape will be written - see Chapter 10.

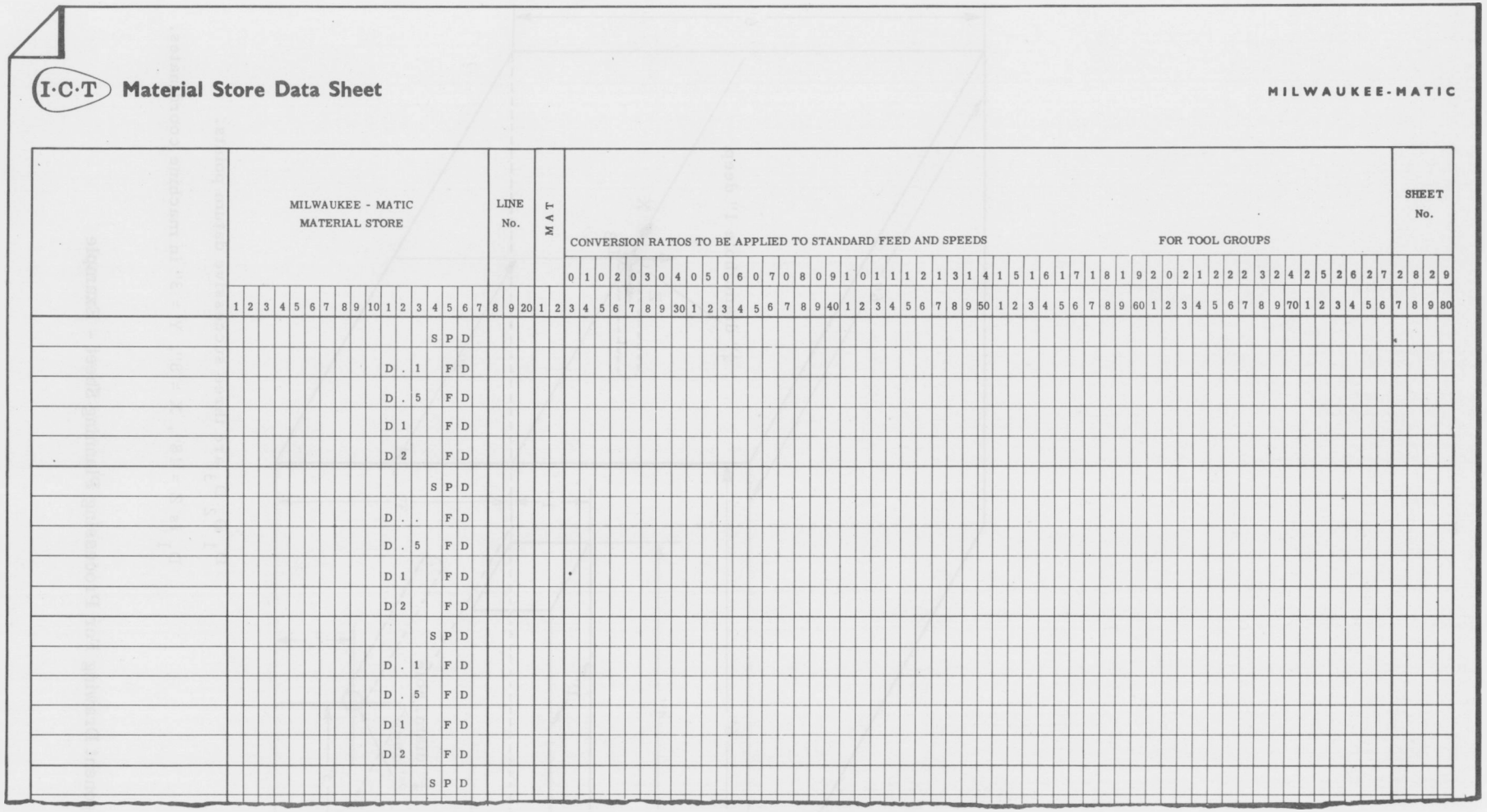
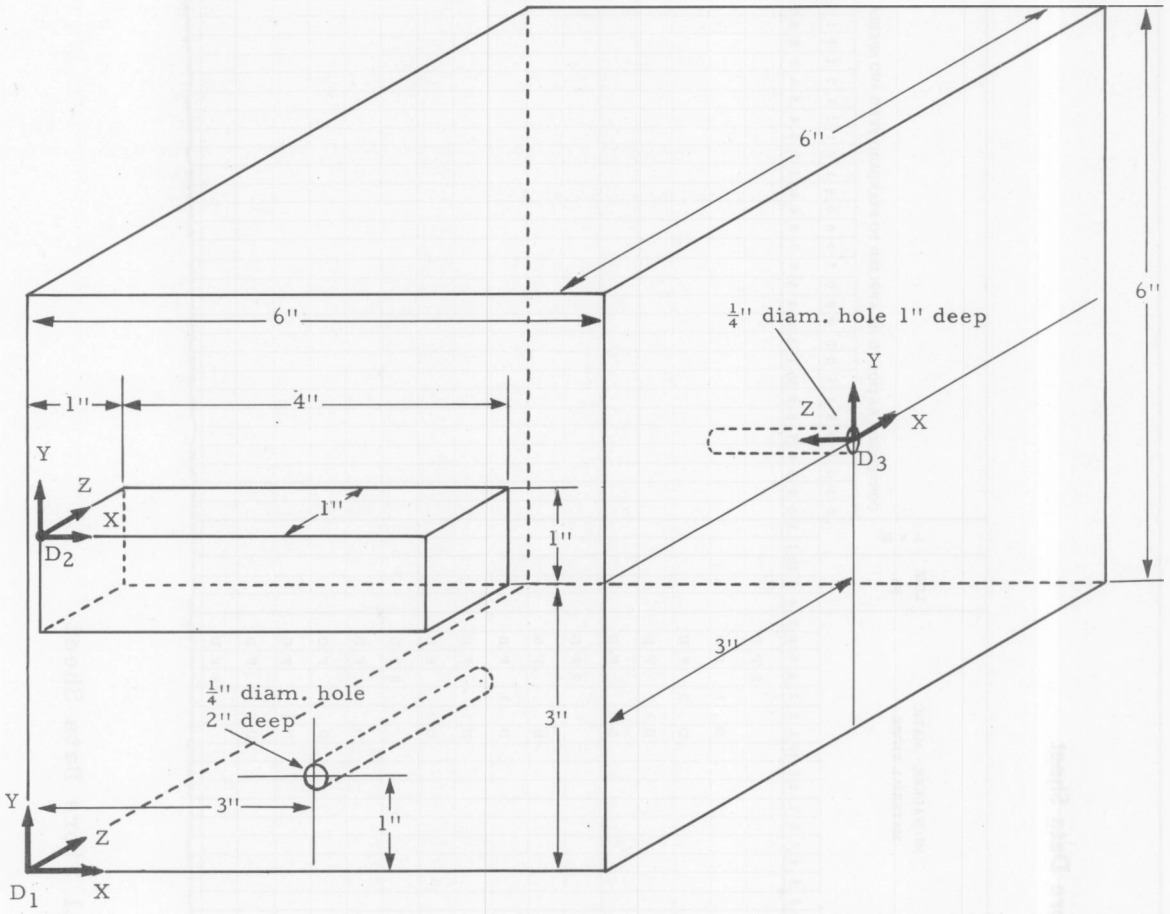


Figure 5: Material Store Data Sheet



D_1 D_2 D_3 are three successive datum points.

D_1 is Z = 18", X = 8", Y = 3" in machine coordinates.

Figure 6: Component Drawing For Processing Planning Sheet - Example

I·C·T Numerical Control Process Planning Sheet

SHEET 1 OF 1 SHEETS

	MODEL	PART No.	PART DESCRIPTION	OPN.	PROG.	DATE	MATERIAL	TAPE No.	
HEADER CARD (Sheet 1 only)	1 -5	6 -12	13 -42	43 -45	46 -48	49 -54	55 -62	63 -68	H 80

OPERATION	TOOL DIA.	LINE NUMBER	OP. CODE No.	TOOL CODE No.	(INDEX) SIDES RADIUS ON	(INDEX) SIDES RADIUS FINE	WORKING DEPTH Z (x y)	POINT A X (y)	POINT A Y (z)	POINT B X (y)	POINT B Y (z)	OFFSET	VARIATIONS TO STANDARDS SPD%	VARIATIONS TO STANDARDS FD%	ENTRY POINT SEQ. PRIORITY	MULTIPLE LOCATION LONGITUDINAL TOT. No.	MULTIPLE LOCATION LONGITUDINAL (X) INCREMENT	MULTIPLE LOCATION VERTICAL TOT. No.	MULTIPLE LOCATION VERTICAL (Y) INCREMENT
		1 -3	4 5	6 -7 8 -9	10 -12	13 -15	16 -18 19 -22	23 -25 26 -29	30 -32 33 -36	37 -39 40 -43	44 -46 47 -50	51 -53	54 -56	57 -59	60 -62	63 -64	65 -67 68 -71	72 -73	74 -76 77 -80
FIX (D_1) ALUMINIUM		001	01	10	000000		180000	080000	030000		090000								
GUARD		002	04				000000	000000	000000	060000	060000								
GUARD		003	04				010000	010000	030000	050000	040000								
DRILL	.25	004	20	0309			020000	030000	010000										
RELOCATE (D_2)		005	02		000000		- 010000	010000	040000										
MILL FACE	1.0	006	30	1504			000000	000000	000000	040000	- 010000								
RELOCATE (D_3)		007	02		090000		030000	050000	- 010000										
GUARD		008	04				000000	- 030000	030000	+ 030000	- 030000								
DRILL	.25	009	20	0309			010000	000000	000000										

FORM 6/830 (2.67)

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Figure 7: Example of Completed Process Planning Sheet

PART NAME: EXAMPLE 8(a) DRAWING:

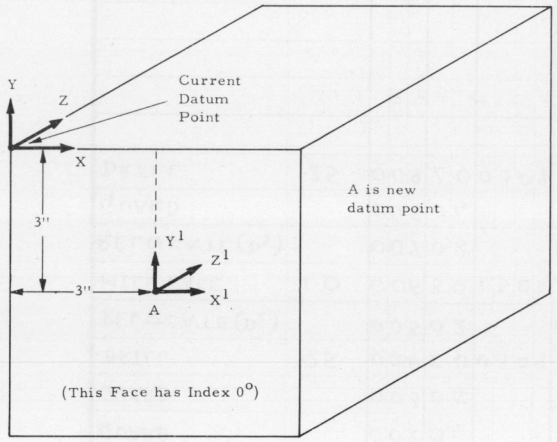
OPERATION	TOOL DIA.	OP. CODE No.	TOOL CODE No.	(INDEX) SIDES ON	(INDEX) SIDES FINE	WORKING DEPTH (Z)	POINT A (X)	POINT A (Y)
RELOCATE		0 2		0 0 0 0 0 0		0 0 0 0 0	0 3 0 0 0 0	- 0 3 0 0 0 0

PART NAME: EXAMPLE 8(b) DRAWING:

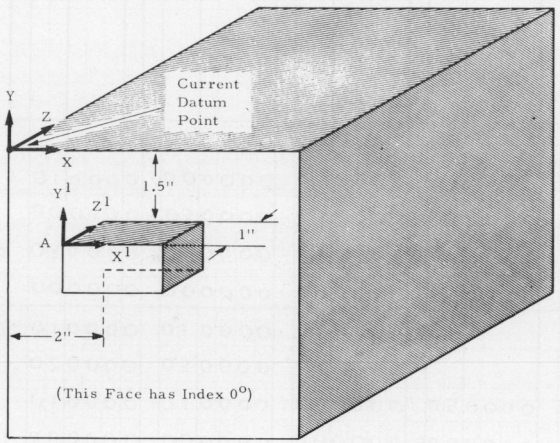
OPERATION	TOOL DIA.	OP. CODE No.	TOOL CODE No.	(INDEX) SIDES ON	(INDEX) SIDES FINE	WORKING DEPTH (Z)	POINT A (X)	POINT A (Y)
RELOCATE		0 2		0 0 0 0 0 0		- 0 1 0 0 0	0 2 0 0 0 0	- 0 1 5 0 0 0

PART NAME: EXAMPLE 8(c) DRAWING:

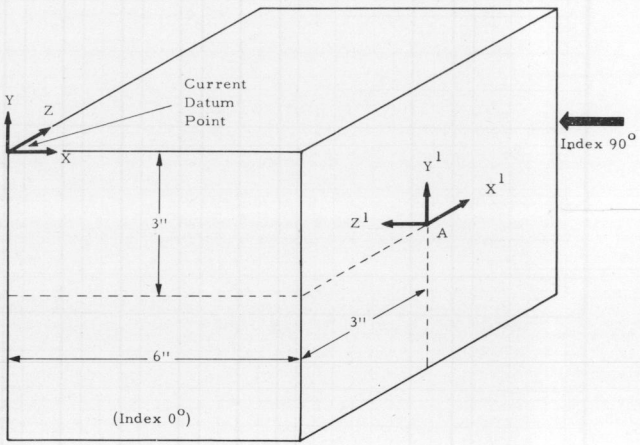
OPERATION	TOOL DIA.	OP. CODE No.	TOOL CODE No.	(INDEX) SIDES ON	(INDEX) SIDES FINE	WORKING DEPTH (Z)	POINT A (X)	POINT A (Y)
RELOCATE		0 2		0 9 0 0 0 0		0 3 0 0 0	0 6 0 0 0 0	- 0 3 0 0 0 0



(a)



(b)



(c)

Figure 8: Examples of Relocate Procedure

4 The Process Planning Sheet

The process planning sheet format (illustrated in Figure 7) is based on the 80-column punched card. This chapter explains some of the various types of entry that have to be made on the P.P.S., but details of the machining operations are deferred until later chapters.

The three-digit line number, in the case of a machining instruction, identifies the operation. It is convenient (but not necessary) to use the hundreds digit to identify the various faces of the workpiece, and the two remaining digits to number the operation locations within a face. (See the 'ballooning' technique employed in Chapter 11.) Line numbers on the tape must be in ascending order. Line number 001 is reserved for the FIX line.

Figures 6 and 7 show a simple machining example; the component drawing is shown in Figure 6 and the corresponding P.P.S. is shown in Figure 7. Various references to this example will be made throughout this and later chapters. A complete example is given in Chapter 11.

The information written on a P.P.S. is punched into cards as input to the MILMAP program, one line occupying one card. The header information at the top of the P.P.S. is also punched into a HEADER card. The first line of the P.P.S. proper is the FIX line that is punched into a FIX card. In a computer run, the HEADER card precedes the FIX card which preceds the other P.P.S. cards.

MILMAP usually runs as one program and the HEADER and FIX cards are read with the P.P.S. cards. When the program is in the processor-post-processor form, it will be possible to run each part as a separate program; in which case, HEADER and FIX cards will be required for both programs.

THE HEADER CARD

The header information is entered at the top of the P.P.S. and is punched on to a HEADER card. It contains details of the part to be machined and it is used to identify prints and tapes.

Card columns are allocated as follows:

Columns 1 to 5	MODEL
Columns 6 to 12	PART NUMBER
Columns 13 to 42	PART DESCRIPTION
Columns 43 to 45	OPERATION NUMBER
Columns 46 to 48	PART-PROGRAMMERS INITIALS
Columns 49 to 54	DATE
Columns 55 to 62	MATERIAL DESCRIPTION
Columns 63 to 66	TAPE NUMBER
Column 76	MODEL NUMBER

The single digit in column 76 identifies the particular machining centre or machine tool on which the job will be machined. It will select the post-processor and, in a future enhancement, will select a particular tool store. Model Numbers allocated to date are:

1 Milwaukee-Matic Model EA - 1

2 Milwaukee-Matic Model II - 2

3 Milwaukee-Matic Model III - 3

The other columns are for part-programmers' use. MODEL is for his description of the machine; e.g. MWK-2 for the Milwaukee-Matic Model II. The PART NUMBER entry is checked against the Run Card on an actual computer run - see Chapter 10. Otherwise, none of the entries therein are used in MILMAP calculations.

RELOCATION

Before describing the FIX card and its functions, the principle of relocation must be explained.

One of the principal difficulties in the manual programming system is the determination of the machine co-ordinates for every operation. This difficulty is obviated in MILMAP by allowing the planner to think in terms of temporary reference axes, which he can change at will. As in the manual system, he identifies himself with the machine tool spindle, and the three principal directions are as follows:

1 The X-co-ordinate increases horizontally to the right of the spindle.

2 The Y-co-ordinate increases vertically upwards from the spindle.

3 The Z-co-ordinate increases away from the spindle (i.e. at right angles to the XY plane).

It should be noted that, whereas in the manual system all co-ordinates are positive, in MILMAP they may be positive or negative, since the point of operation may be on either side of the current datum point.

Change of datum point is known as relocation and is introduced by the word RELOCATE (operation code 02) in the Operation column of the P.P.S. A relocation may consist of a simple translation of the axes parallel to themselves, or a translation followed by a rotation of the table to a new index. It is only necessary for the planner to determine the new datum position relative to the current axes, and to quote the new index position.

Relocation always requires a statement of the index position whether it has changed or not.

Three examples are given in Figure 8 to illustrate the relocate procedure. In each of the three diagrams, tne new datum point is at the Point A, and the new axes are labelled X , Y , Z to distinguish them from the current axes X Y Z.

1 In Figure 8(a) the co-ordinates of Point A relative to the current axes are X = 3 inches, Y = 3 inches, and Z = 0 inches. These values are entered in the appropriate columns of the P.P.S. There is no rotation of the table, and the previous index (for example, zero), must be repeated.

2 In Figure 8(b) the new datum point is in a different XY plane, but there is still no rotation of the table. The co-ordinates of Point A are X = 2 inches, Y = 1.5 inches, and Z = 1 inch and these values are entered as shown. Again the previous index value is repeated.

3 In Figure 8(c) the co-ordinates of the new datum point are X = 6 inches, Y = 3 inches, and Z = 3 inches. These values are entered as shown, together with the index of the face containing Point A, in this instance 90°.

Note that index values are quoted in degrees to an accuracy of three decimal places, with preceding zeros being entered and the decimal point being omitted. The initial datum point, i.e., the first current datum point, is defined in a Fix line.

THE FIX LINE

The first line of the P.P.S. completed by the planner must be a FIX line, which is punched on a FIX card, and serves three purposes:

1 It defines the material being used.

2 It gives the machine co-ordinates of the first datum point. For the version of the program that has processor and post-processor sections, the first datum must be the co-ordinates of the centre of rotation if the machine concerned has a rotating table. If this is not a suitable datum point at which to start, appropriate relocation must be made before part-programming proper begins.

3 It specifies the maximum height of the workpiece, including fixtures.

The entry under Line Number must be 001, and if, for example, aluminium is being used, the words FIX ALUMINIUM should appear in the Operation column. The operation code number for FIX is 01, and the material code number is entered under Tool Code Number.

It is essential for the Index column to be filled in thus; 000 000. This means that if operations are to begin in an index position other than 0°a Relocate must be stated in the next line.

As explained above, the Fix line also defines the position of the datum point of the initial set of planner's reference axes. The planner chooses some point on the first working face as his datum point which will be convenient for the first group of operations, and the X, Y and Z co-ordinates of this point relative to the machine axes are entered on the P.P.S.

The maximum Y-co-ordinate relative to machine axes, of either the component or the fixture, whichever is greater, is entered in column Y under Point B of the P.P.S. This value is rounded up to the

next higher 0.1 inches. The Fix line is the only line where co-ordinates relative to the machine datum are required. See as an example, line 001 in Figure 7.

MACHINING LINES

The majority of lines on the P.P.S. refer to machining operations, and details of these will be set out in later chapters. However, the following remarks apply generally to all machining operations.

Operation and Tool Diameter entries are for the planner's convenience only; they are not recognized by the computer program. Computer action is derived from operation code number. These code numbers will be listed in later chapters, where appropriate, and then again in Appendix A as a complete list.

The various interpretations of Working Depth will be explained in Chapters 5 and 6 on Machining Operations. Working Depth is expressed to an accuracy of four decimal places. Preceding zeros are entered, but the decimal point is omitted. Negative values require a minus sign, but plus signs are optional.

Point A and Point B record the X- and Y-co-ordinates. In the case of simple point operations, such as drilling, the X- and Y-co-ordinates are entered under Point A. In other machining operations, both Point A and Point B are used. The same entry format is used as under Working Depth, the co-ordinates being expressed to an accuracy of four decimal places.

Under Variations in Standard Speed and Feed, the user may specify, as a percentage, any variation from the speed and feed rate automatically determined from the tool store and material store tables. The variation may be from $\pm$ 1 to $\pm$ 99 and is entered in the appropriate column in the form $\pm$ NN. If an entry of - 30% is made, then the speed or feed is given a value which equals 70% of the given value.

GUARD TOWERS

It is an important feature of MILMAP that all tool paths between successive operating points are calculated by the computer, and in addition, the operations themselves are sequenced in such a manner that the overall time for the job is minimized. A method has been devised whereby it is possible to avoid having to retract the tool between successive operations. It is necessary to 'protect' certain regions from accidental infringements; these regions will include the working faces of the component, and parts of the fixture and clamping devices.

Since the computer cannot possibly form a picture of the boundaries of the various faces from information about the operational points in them, it is necessary to delineate these faces. This is done by means of guard towers. A guard tower is a cuboid (i.e. it is brick shaped) having its 'base' in the plane Z = 0, and projecting towards the spindle, so that its 'height' is measured towards the spindle. Its 'top' coincides with the area to be protected. The position of the guard tower is specified by the X- and Y-co-ordinates of two opposite corners of the base (or top), together with the height, which can only be zero or positive. This principle is illustrated in Figure 9.

A guard tower is specified for each face and plane of both component and fixture, and they may be superimposed, so that compound guard towers may be built up - see Figure 10. It is necessary to set up guard towers for each new index position.

The program has no means of detecting omissions of guard towers. There will, therefore, be no reminder to the process planning engineer if he forgets to specify guards for the fixture or non-operational faces.

It is not necessary to specify guard towers to great accuracy; it is sufficient that the faces of the guard tower enclose those regions to be protected from infringement.

During tool movements in the X and/or Y directions which do not involve machining, all guards entered on the P.P.S. will be automatically avoided. During tool movements in the Z direction and in the X and/or Y directions involving machining collision indications will be reported *. The part-programmer must check each indication and then take any action that is necessary to correct the faulty condition; for example, by re-positioning a fixture.

The following entries must be made on a Guard line:

Operation Code Number: This is entered as 03 or 04. 03 is to be used for areas that are not to be hit by the tool under any circumstances. 04 is to be used for machineable areas.

Height of Guard Towers: This is entered in the Working Depth column. It is always zero or positive.

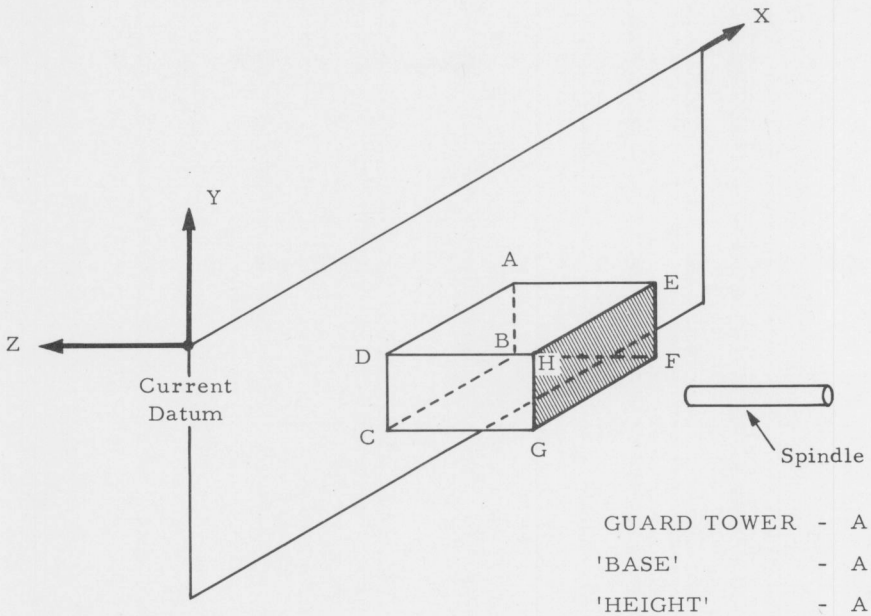
* On the Tape Image print.

Point A and Point B: The X- and Y-co-ordinates of two opposite corners of the base or top are entered under Point A and Point B.

For example of the use of the guard facility, see lines 2, 3 and 8 of the simple machining example given in Figures 6 and 7.

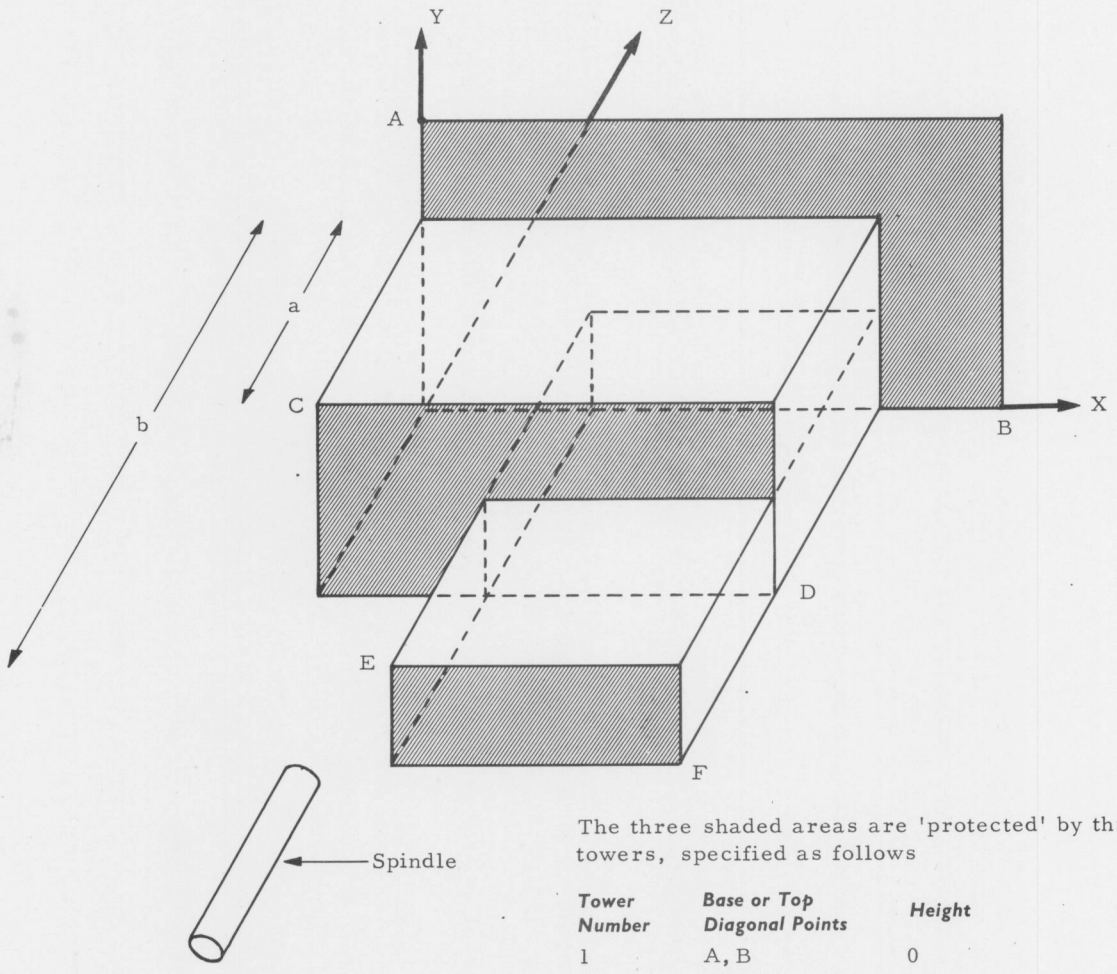
THE P.P.S. CARDS

The P.P.S. cards, headed by a HEADER and a FIX card, are terminated by a card punched with four asterisks in the first four columns, followed by a blank card, when entered for a computer run.



GUARD TOWER - A B C D E F G H
'BASE' - A B C D
'HEIGHT' - A E

Figure 9: Basic Guard Tower



The three shaded areas are 'protected' by three guard towers, specified as follows

Tower Number	*Base or Top Diagonal Points*	*Height*
1	A, B	0
2	C, D	a
3	E, F	b

Figure 10: Compound Guard Towers

5 Machining Operations 1: Operations at a point

GENERAL DESCRIPTION

The single-point operations described in this chapter are drill, bore, ream, and tap, all of which are concerned with the same sort of tool movement. Distinctions are made in the instructions between

1 tapping with a clockwise rotation as against tapping with an anticlockwise direction, and

2 boring, tapping and drilling 'blind' holes as distinct from 'through' holes.

Each of the operations can be requested with or without preceding actions. These preceding actions are generated automatically by the computer program according to the entries in the Tool Store. Suppose Tap Number 3002 is entered as requiring Drill Number 0206 to precede it and Drill Number 0206, in its turn, is entered as requiring Centre Drill Number 0618 to precede it, then if a part-programmer includes a 'tap' instruction with an Operation Code of 24 using Tap Number 3002, MILMAP will automatically generate instructions as though the part-programmer had written the full series of instructions - tap with 3002, drill with 0206, centre drill with 0618.

Single-point operation code numbers in the range 20 to 29 generate all preceding actions. If the range 10 to 19 is used, preceding actions are suppressed. The full list of single-point operation code numbers is given in Figure 11.

WORKING DEPTH

The entries in the Working Depth (W.D.) columns are the depths required. MILMAP makes standard engineering allowances in converting the required depths into tool movements:

Operation	Increment to W.D.
Drill to Depth only (10)	0.3 x Diameter if Drill; none otherwise
Bore (blind) (19, 29)	None
Drilling (11, 20)	0.1 ins + 0.3 x Diameter
Drilling to Depth	0.3 x Diameter
Tapping (14, 15, 24, 26, 27, 28)	six thread depths
All other single-point operations	0.2 ins

In addition, special corrections are made to preceding tool depths to ensure that a proper preparation has been made for the main tool. For example, a preceding drill before a tapping will receive an increment of six thread depths and a drilling allowance of 0.1 inches + 0.3 x Diameter.

DEEP DRILLING

If a working depth is specified that is greater than six tool diameters, when drilling, the operation will be carried out in stages as follows:

	Working Depth		Tool Motion
1	Between 6 and 12 tool diameters	(a)	Feed to depth of 6 x Diameter
		(b)	Withdraw clear
		(c)	Feed to working depth
		(d)	Withdraw clear
2	Greater than 12 diameters	(a)	Feed to depth of 6 x Diameter
		(b)	Withdraw clear
		(c)	Feed to depth of 12 x Diameter
		(d)	Withdraw clear
		(e)	Feed to working depth
		(f)	Withdraw clear

Operation	Operation Code
Drill to depth only	10
Drill to depth	25
Drill only	11
Drill	20
Tap C only *	14
Tap C *	24
Tap A only *	15
Tap A *	26
Bore only	13
Bore	23
Ream only	12
Ream	21

* C = Clockwise

A = Anti-Clockwise

Figure 11: Operation Code Numbers

6 Machining Operations 2: Patterns

Facilities are provided in MILMAP for the repetition of single-point operations, such as drilling or tapping, over specified patterns. P.P.S. entries are made as follows:

1 Rectangular Pattern (see Figure 12)

The position of any one of four corner points is entered as Point A on the P.P.S. The total number of columns and the X-increment between columns are entered under LONGITUDINAL; similarly, the total number of rows and the Y-increment between rows are entered under VERTICAL.

X and Y increments may be positive or negative depending on the corner point chosen as Point A. The number of rows/columns may not exceed 99.

It is not possible to omit certain holes from this type of pattern, as it is from the patterns which follow.

ENTRY POINT = 9 requests this pattern

2 Sloping Line Patterns (see Figure 13)

Regularly-spaced holes in a straight line, which slopes with respect to the X and Y axes, can be specified in two different ways. Entry point is used to choose the appropriate specification:

ENTRY POINT = 1 expects first and last hole co-ordinates to be specified as Point A, Point B, respectively, together with the number of holes requires in X TOTAL NUMBER. The number of holes include the first and the last.

ENTRY POINT = 2 expects first hole position in Point A, number of holes in X TOTAL NUMBER, spacing distance between holes in X-INCREMENT and the angle of inclination of the line of hole centres with respect to the X-axis in INDEX. The angle is entered as if the decimal point divided the six digits into three whole number digits and three decimal fraction digits.

3 Circular Patterns (see Figure 14)

Regularly-spaced holes around an arc of a circle can be specified in four different ways. Entry Point is used to select the appropriate specification.

ENTRY POINT = 3 is used when the points are positioned in a clockwise direction around the arc from the first point.

ENTRY POINT = 4 is used when positioning is in an anticlockwise direction.

ENTRY POINT = 3 or 4 requires:

XY co-ordinates of the first hole in Point A.
XY co-ordinates of the circle centre in Point B.
Radius of the circle in INDEX.
Angular spacing between holes in X-INCREMENT.
Total number of holes in X TOTAL NUMBER.

ENTRY POINT = 5 is the same as ENTRY POINT = 3 and

ENTRY POINT = 6 is the same as ENTRY POINT = 4, except that total angle of arc replaces angular spacing in X-INCREMENT.

Angular spacing and total angle of arc are given in the same form as angle in the sloping line pattern.

4 Two-dimensional Patterns (see Figure 15)

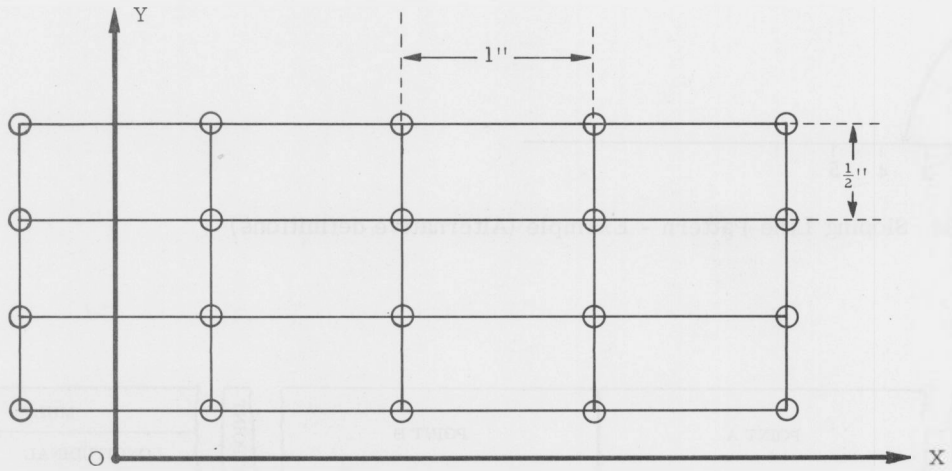
From the definition of two sloping line patterns, a parallelogram of points can be generated. ENTRY POINT = 7 or 8 must appear on two successive P.P.S. lines detailing sloping line patterns. If the sloping line patterns are to be defined as if ENTRY POINT = 1, then use ENTRY POINT = 7 in this case. If they are to be defined as if ENTRY POINT = 2, then use ENTRY POINT = 8.

EXCLUSION OF HOLES

Up to five specific holes in a pattern can be excluded by quoting hole number. Hole numbers are two-digit numbers and the first hole is numbered 01. Holes can be excluded in all patterns except 'Rectangular'.

The first excluded hole number is entered into Y TOTAL NUMBER. The second, third and fourth hole numbers are entered successively into Y-INCREMENT (see Figure 16).

In the case of the two-dimensional patterns, different exclusions can be requested on the two sides and these exclusions would apply throughout the parallelogram (see Figure 17).



Number of operations in X = 5

Number of operations in Y = 4

If Point A is taken as shown, the X and Y increments are 1.0 and 0.5 inches respectively.

The MULTIPLE LOCATION part of the P.P.S. is then completed as follows:

PRIORITY	MULTIPLE LOCATION					
	LONGITUDINAL			VERTICAL		
	TOT. No.		(X) INCREMENT	TOT. No.		(Y) INCREMENT
		±			±	
	05		0100000	04		005000

Figure 12: Rectangular Pattern - Example

(INDEX) SIDES RADIUS		POINT A				POINT B				ENTRY POINT	MULT LONGITUDINAL	
ON	FINE	X (y)		Y (z)		X (y)		Y (z)			TOT. No.	(X) INCREMENT
		±		±		±		±			±	
			00		00		50		100	1	6	
6344			00		00					2	6	2236

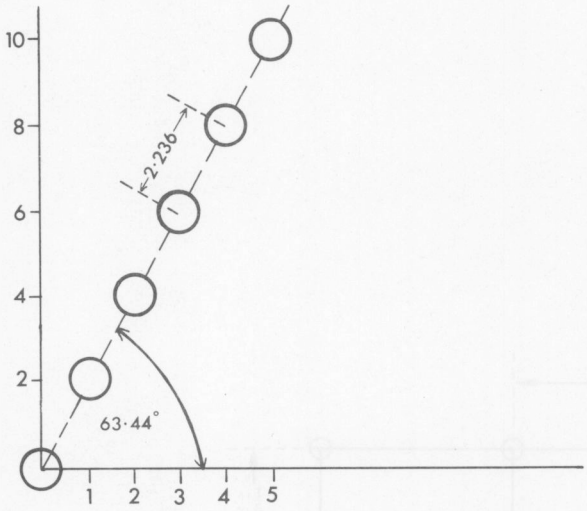


Figure 13: Sloping Line Pattern - Example (Alternative definitions)

(INDEX) SIDES RADIUS		POINT A				POINT B				ENTRY POINT	MULT LONGITUDINAL	
ON	FINE	X (y)		Y (z)		X (y)		Y (z)			TOT. No.	(X) INCREMENT
		±		±		±		±			±	
00200		-	02000		00000		00000		00000	3	5	045000
00200		-	02000		00000		00000		00000	5	5	180000

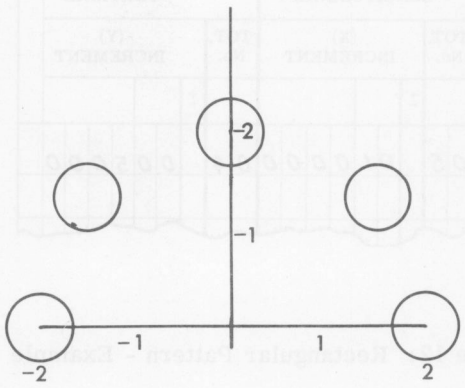


Figure 14: Circular Pattern - Example (Alternative definitions)

(INDEX) SIDES RADIUS		POINT A		POINT B				MULTIP		
								LONGITUDINAL		
ON	FINE	X (y)	Y (z)	X (y)	Y (z)	ENTRY POINT	SEQ. PRIORITY	TOT. No.	(X) INCREMENT	
			±	±	±				±	
		00	00	30	60	7		4		1
		00	00	00	30	7		4		
6344		00	00			8		4	2236	2
4500		00	00			8		4	1414	

ALTERNATIVE DEFINITIONS

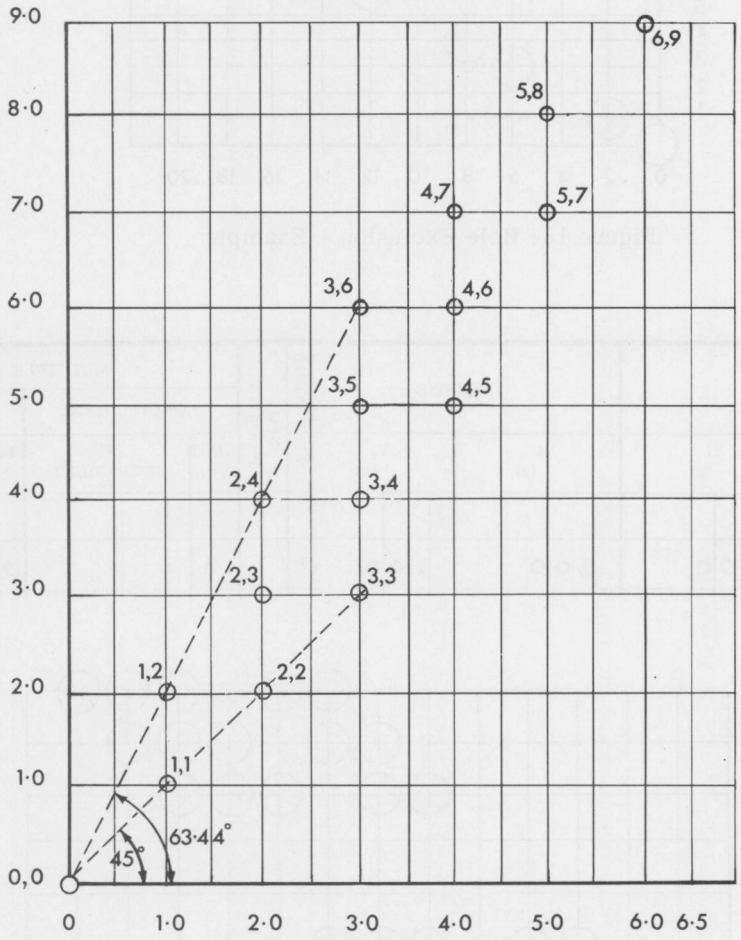


Figure 15: Two-Dimensional Pattern - Example

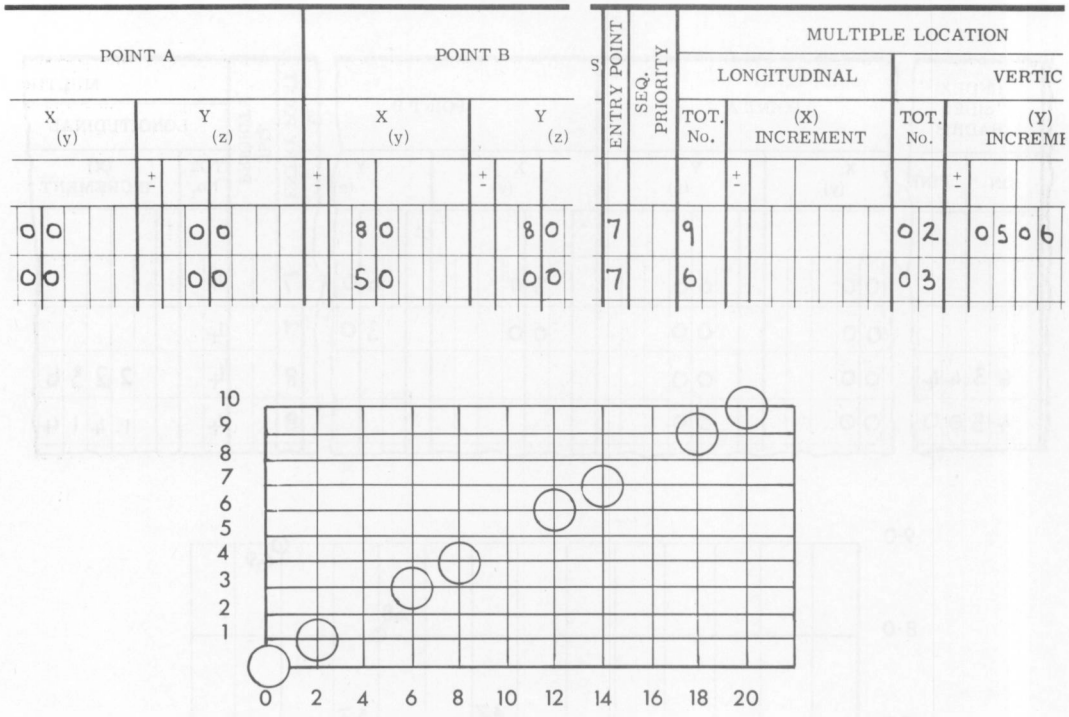


Figure 16: Hole Exclusion - Example

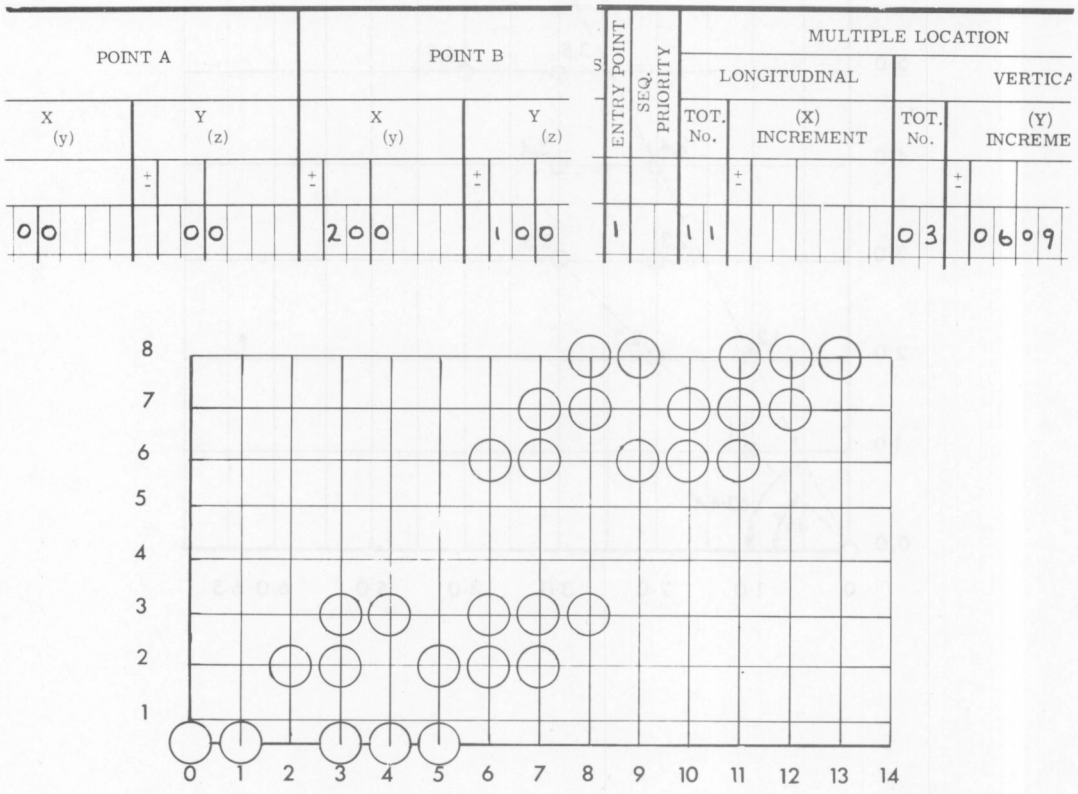


Figure 17: Hole Exclusion from Two-dimensional Pattern - Example

7 Machining Operations 3: Milling

This chapter describes those straight-line milling operations that can be specified. The tool movement must be parallel to the X or Y axis. Milling of slopes (straight lines not parallel to an axis) and of circular arcs are dealt with in the next chapter.

THE OPERATIONS

Operation codes are in the range 30 to 37, inclusive.

1 Mill Face Operation Code = 30 (see Figure 18)
The face is defined by the co-ordinates of either pair of opposite corners, entered as Point A and Point B on the P.P.S. The tool will be directed to traverse the face in a series of overlapping cuts in consecutive X and Y directions. Working depth is usually set to zero as the mill face operation is preparing a face whose Z value has been defined in a relocate statement. The entry point and direction of cut can be chosen by the part-programmer.

2 Mill Side Operation Code = 31 (see Figure 19)
The side to be milled must run parallel to the X or Y axis and is traversed in a single pass from Point A to Point B. The cutting is done by the side of the tool. Working depth should be entered as the width of the side as a minimum value. Practical considerations may demand a higher value than this.

3 Mill Line Operation Code = 32 (see Figure 20)
The line to be milled must run parallel to X or Y axis and is traversed in a single pass from Point A to Point B. Working depth is entered as the depth below the surface, at which milling takes place.

4 Mill Step Operation Code = 33 (see Figure 21)
Mill Step is like Mill Side except that the tool cuts at its tip as well as on the side. In this case, working depth must be given the value of the depth of the step.

5 Mill External Operation Code = 34 (see Figure 22)
This operation causes the cutter to machine around the outside of a framework and is similar to four Mill Sides. The frame is described by entering the co-ordinates of either pair of opposite corners as Point A and Point B. Entry point can be chosen by the part-programmer.

6 Mill Internal Operation Code = 35 (see Figure 23)
This operation causes the cutter to machine around the inside of a framework. Otherwise it is similar to Mill External.

7 Mill Recess Operation Code = 36 (see Figure 24)
The recess or pocket is defined by the co-ordinates of either pair of opposite corners entered as Point A and Point B on the P.P.S. and is traversed by a series of overlapping cuts in consecutive X and Y directions. Working depth gives the depth of cut as the bottom of the recess is cut as well as the sides.

8 Mill Fine Operation Code = 37
The usual technique used in milling is to do each accurate milling operation as two operations. In the first operation, most of the metal is removed by a rough mill using a tool that is expected to wear. A second operation giving an accurate fine mill is performed using a tool reserved for the purpose. The Mill Fine operation code is to signal that the fine milling of a previous rough mill is now to take place. Further details of this arrangement is given later in this chapter.

THE FORMAT FOR MILLING INSTRUCTIONS

Entries can be made in the following P.P.S. fields:

	Notes
Line Number	
Operation Code	30 to 37 inclusive.

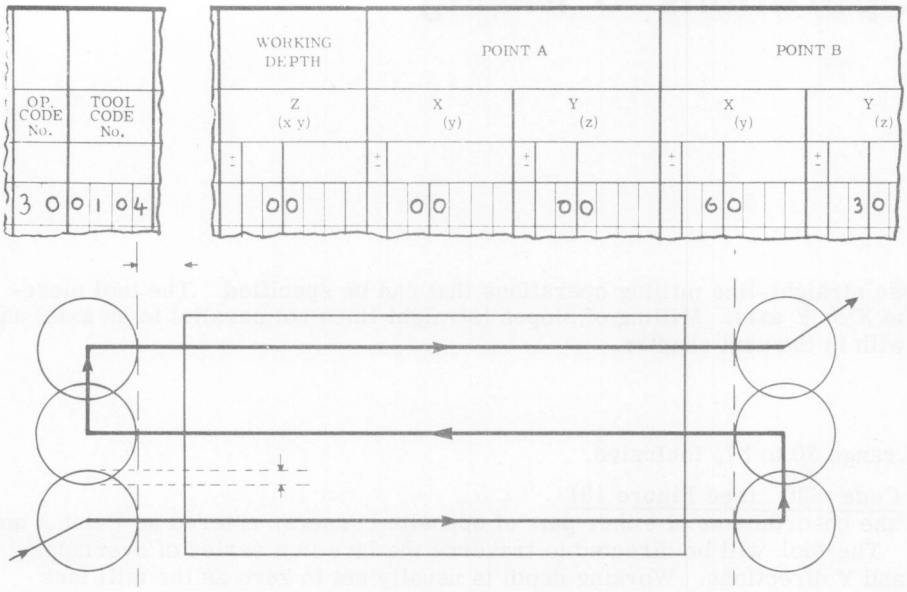


Figure 18: Mill Face (30) - Example

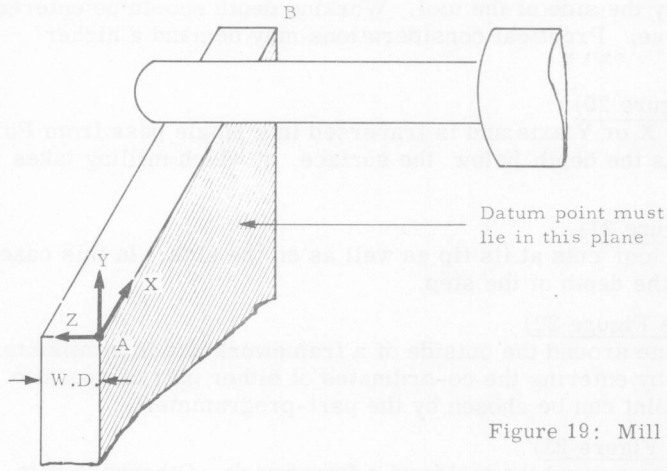


Figure 19: Mill Side - Example

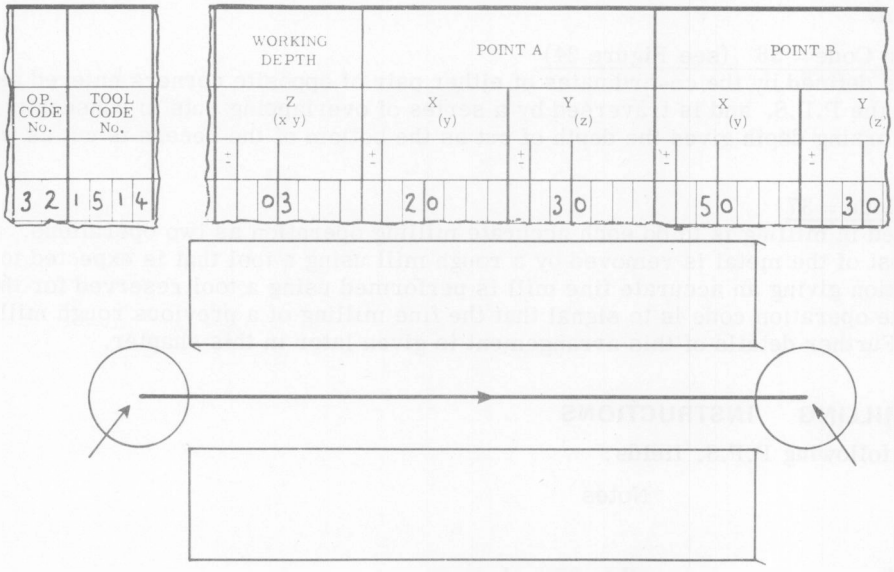


Figure 20: Mill Line - Example

Tool Code	
Sides ON	ABC, 3 characters
Sides FINE	EFG, 3 characters
Working Depth	
Point A, X, Y Point B, X, Y	Two points defining the line, the side or the rectangle
Offset	± H.I or ± 99
Variations to Standards	
Entry Point	J

Entries of Line Number, Operation Code, Tool Code Working Depth, Points A and B and Variations to Standards should be clear to the user. Entries of Sides On and Fine, Offset and Entry Point require explanation.

SIDES-ON ENTRIES

1 If a start is made on a milling operation with the tool at clearance position, then to reach the depth at which the mill is to take place, the tool may or may not have to enter the work (see Figure 25). In the one case, the tool is to move in the Z direction from clearance to working depth; in the other, the tool can move to working depth at rapid feed.

A, the first character of SIDES ON, is entered as 0 in the case in which the tools' feed rate is to be used, and entered as 1, if rapid feed is required.

2 At the end of one milling operation, it may be desirable to remain at that depth for the next milling operation (see Figure 26). In other cases, it may require retracting to clearance position. B, the second character of SIDES ON, is entered as 1 if the tool is to stay at working depth, and as 0 if the tool is to be retracted, at the end of the operation.

3 In the cases of Mill Side (31), Mill Step (33), Mill External (34) and Mill Internal (35) operations, an entry is required to distinguish the direction of the tool offset (see Figure 27). C, the third character of SIDES ON, is entered as L if the tool is to mill to the left of the work and is entered as R if it is to keep to the right.

SIDES-FINE ENTRIES

SIDES FINE entries detail rough mills that will require a subsequent fine mill with a tool of more accuracte dimensions. The actual fine mill will be performed when a MILL FINE operation (operation code 37) is encountered.

1 In the case of single pass milling with operation codes of 31, 32 and 33 and FACE MILL (30), the appropriate adjustments will be made for a roughing operation if the first character of SIDES FINE is an F. The actual adjustment made is .01 inches off the depth.

Line No.	Operation	Operation Code	Tool Code	Sides ON FINE	Point A	Point B
121	MILL LINE	32		110 F--	X_1Y_1	X_2Y_2

2 In the case of multi-pass milling with operation codes of 30, 34, 35, 36, each separate surface can be signalled for rough adjustment. Once again, the adjustment is .01 inches.

The sides are called T (topside), U (underside), R (right), L (left) and B (bottom) according to the convention in Figure 24. To call for rough adjustment:

(a) of one side, enter T--, or R--, or U--, or L--, or B--;

(b) of two sides, enter TU-, or RL-, or LB-, for example;

(c) of three sides, enter TRU, or RUL, or LTR, for example;

(d) of four sides, if operation is Mill External or Internal, enter ALL;

(e) of four sides, if operation is Mill Recess, enter NOT, or NOB, for example NOB means Not B; that is, it is calling for T, R, U and L sides to be roughed;

(f) of five sides, operation is Mill Recess, enter ALL.

		(INDEX) SIDES RADIUS		WORKING DEPTH	POINT A		POINT B	
OP. CODE No.	TOOL CODE No.	ON	FINE	Z (x y)	X (y)	Y (z)	X (y)	Y (z)
				±	±	±	±	±
33	1515			05	20	55	20	23

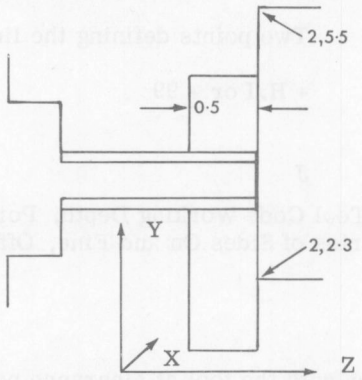


Figure 21: Mill Step - Example

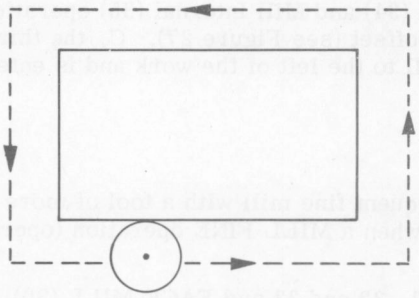


Figure 22: Mill External - Example

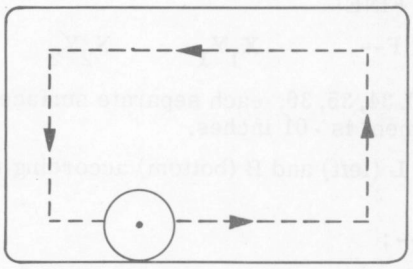


Figure 23: Mill Internal - Example

In the case of Mill Fine (operation code = 37), SIDES FINE will carry the Line Number of the rough mill concerned.

ROUGH/FINE MILLING

A milling instruction can call for rough milling. An example might be:

Line Number	Operation	Operation Code	Tool No.	Sides ON FINE	W.D.	Point A	Point B
123	MILL EXTERNAL	34	2324	OOR ALL	05.0000	X_1Y_1	X_2Y_2

This would result in tool number 2324 cutting a frame that would be ten-thousandths of an inch oversize in each direction.

Later in his program, the part-programmer can ask for the consequent fine milling. He does this with operation codes 37 (MILL FINE) and he would enter a line as follows:

Line Number	Operation	Operation Code	Tool No.	Sides ON FINE	W.D.	Point A	Point B
167	MILL FINE	37	2425	OOR 123			

The entry in SIDES FINE of 123 is the Line Number of the rough cut. The frame will now be cut to its proper dimensions. The part-programmer must enter Line Number, Operation, Operation Code, Sides On, which must repeat the Rough Mill's Sides-On, and Sides-Fine. Any other entries will be taken as changes to the Rough Mill for the Fine Mill. For example, if the part-programmer prefers to Fine Mill in the opposite direction to his Rough Mill, he must enter the rough Point B as Point A and the rough Point A as Point B, and alter Sides-On to OOL to give the proper offset.

OFFSET ENTRIES

Tool Offset is applied automatically in all cases of straight-line milling, except for the MILL LINE operation. In this case, the effective length of the line to be milled can be extended or contracted by a suitable entry in the offset columns of the P.P.S.:

1 If offset is left blank, no extension or contraction is made.

2 If an offset of +99 is quoted, the end points will be moved out, each by an amount equal to the radius of the cutter plus 0.2 inches. Similarly, if -99 is quoted, the end points will be moved inwards by the same amount.

3 If an offset of any other value is given, it is interpreted as an actual distance by which the points are to be moved. Positive numbers move the points outwards, negative numbers inwards. The range of values is 0.1 inches to 9.7 inches, the decimal point being assumed on entry. An entry of +15 means move outwards by 1.5 inches.

In FACE MILL operations, the Offset columns can be used to indicate a preferred cutting direction. If +99 is specified, the long cutting strokes will be in the vertical direction; if +98 is specified the long cuts are in the horizontal direction. If no entry is made, the long cutting strokes will be in the longer direction.

ENTRY POINT ENTRIES

Single-pass milling instructions will proceed from Point A to Point B.

Milling instructions involving rectangular movement will start at Entry Point = 1, 2, 3 or 4 if given, Point A if not. See Figure 28.

		(INDEX) SIDES RADIUS		WORKING DEPTH	POINT A		POINT B	
OP. CODE No.	TOOL CODE No.	ON	FINE	Z (x y)	X (y)	Y (z)	X (y)	Y (z)
				±	±	±	±	±
3 6	1 7 2 6			0 3	1 0	6 0	8 0	2 0

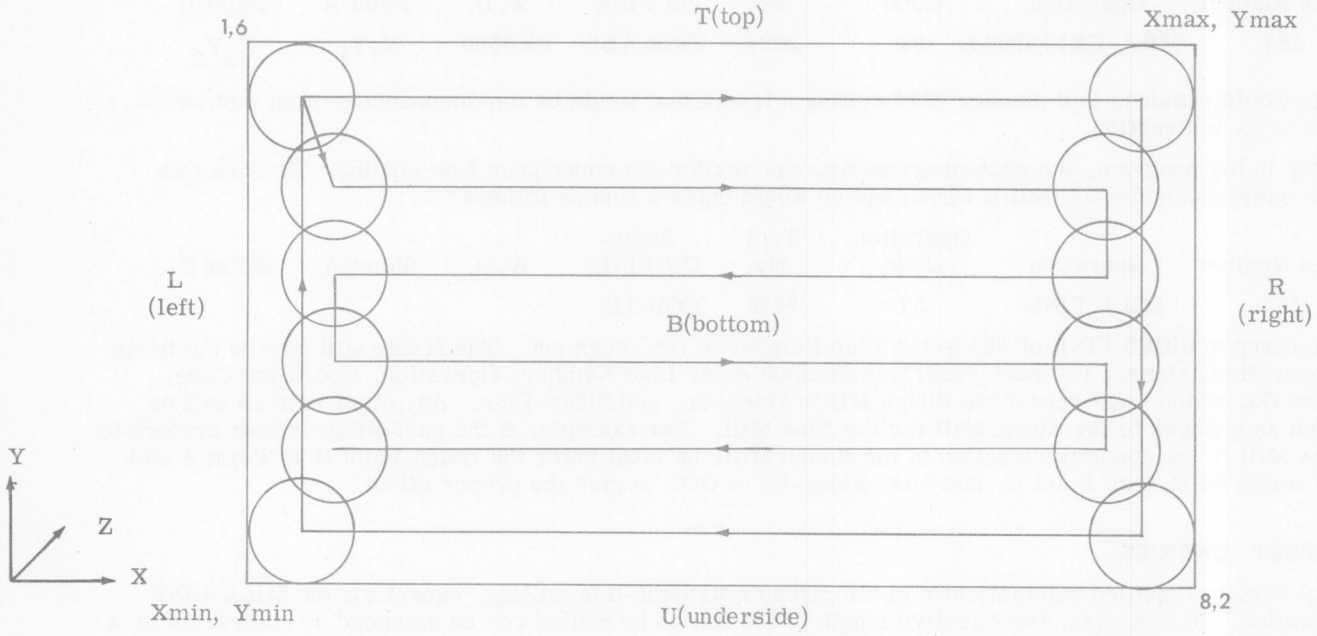


Figure 24: Mill Recess - Example

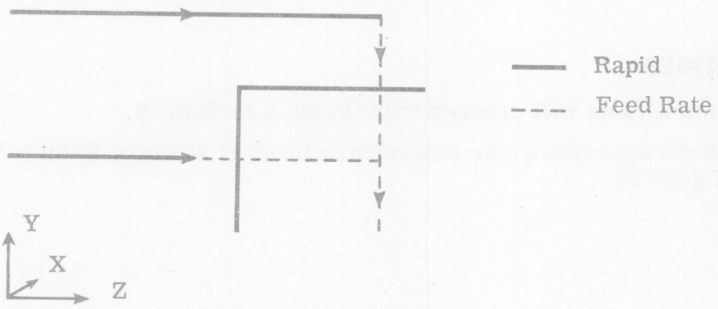


Figure 25: Choice of Feed Rates when Milling

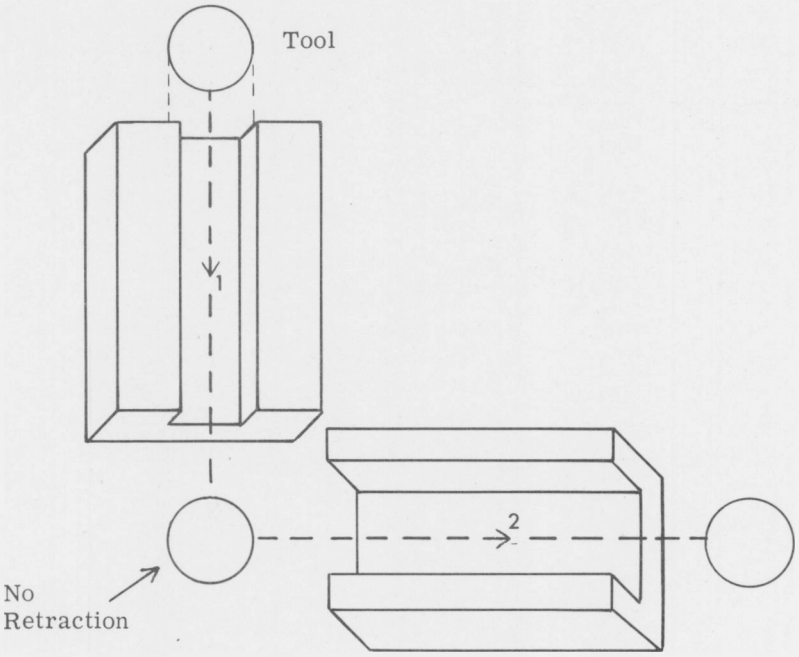
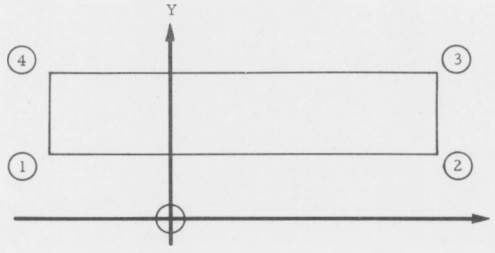


Figure 26: Staying at Working Depth Between Operations

Figure 27: Left and Right Offsets



Corner numbers to be used in optional Entry column in face milling etc.

Figure 28: Entry Points for Milling

8 Machining Operations 4: Contouring

Some control units for numerically-controlled machining centres and machine tools have built-in interpolation units and when so equipped, it is possible to order contouring motions in any two of the three axes. Tools can be directed along sloping lines (slopes) and around arcs of circles (arcs). When the tool is in the plane of an arc (that is, the XZ and YZ planes) the possible arc is less than a semicircle.

In MILMAP, a contouring sequence must be given a start and an end instruction, and between these, any number of slopes and/or arcs can be included that make up a continuous path for the tool. If a single arc or slope is required, the start and the end of the contouring sequence must be given. Start and end instructions use operation codes between 90 and 100.

Each slope must be defined by two points on the slope; each arc must be defined by two points on the arc together with the arc radius. If an arc or a slope is the first contour of a contouring sequence, then the first point, Point A, must be the actual start point. If the arc or slope is the last contour of a sequence, the last point, Point B, must be the actual finish point. If arcs and slopes are defined by their end-points, the end-points are also change points between operations and Point A of one contour equals Point B of the previous contour on the path. The rules are:

1 Point A of the first contour must be the actual start point.

2 Point B of the last contour must be the actual finish point.

3 Otherwise, slopes and arcs are defined by any two points on the particular contour, Point A always preceding Point B around the path. In defining an arc, Point B must be on the eventual cut, Point A need not be. In defining a slope, neither Point A nor Point B need be on the eventual cut. If an intersection takes place between an arc and another arc or slope, there are two possible intersections. The program will always take the intersection that is nearer Point B.

Two methods of co-ordinate representation are allowed. The part-programmer may write down all his Point A and Point B entries as distances from the same datum point. Alternatively, he can write down all Point B entries as distances from the corresponding Point A entries and all Point A entries, except the first, as distances from the corresponding previous Point B entries. The first Point A entry must be measured from the previously-defined datum or be defined itself as a datum. In this alternative method when Point A is the previous Point B, the Point A entry, which would have been X = 00.0000, Y = 00.0000, may be left blank.

Which alternative is chosen is signalled by the part-programmer choosing between two sets of sequence starts. If he wants to measure all co-ordinates from the same datum position, he will use sequence starts with the operation codes of 96 to 98. If he wants to measure all co-ordinates from the previous entry, he will use sequence starts with the operation codes of 93 to 95.

The same method of representation must be used throughout a contouring sequence, but different sequences within a part-program may be differently represented.

Except for performing this choice of co-ordinate representation, operation codes 93, 94, 95 are identical to 96, 97, 98 respectively.

SEQUENCE STARTS

The three sequence starts, for each of which there are now two different operation codes, provide information regarding the direction of the tool offset to be applied.

They are:

Operation Code

96 or 93 : Contour Left Offset

97 or 94 : Contour Right Offset

98 or 95 : Contour Without Offset

There is only one sequence end

Operation Code

99 : Contour End

The left and right offset refer to the direction of the tool offset looking along the path the tool is to take and applies for the whole sequence of operations which follow until a 99 operation code is reached.

As this continuous path assumes the same tool throughout, the tool is specified with operation codes 93, 94, 95, 96, 97, 98 to apply for the whole sequence. Nothing else is entered into these sequence start and end P.P.S. lines.

When there is more than one operation in the sequence, the tool will stay at working depth until the last slope or arc in the sequence is complete. The working depth may be varied from operation to operation.

OFFSETS

Tool offset is given a directive by the contour start used and is applied automatically. In addition, a slope can be extended back along its line if it is the first of a sequence, by a distance given on the P.P.S. as 'offset'. Similarly, a slope can be extended forward if it is the last of a sequence, by an entry under 'offset'. If the sequence consists of one slope only, the one entry under 'offset' is applied in opposite directions at each end of the line. No similar extension can be given to arcs.

OPERATION CODES FOR ARCS AND SLOPES

The individual arcs and slopes are given operation codes in the ranges 40 to 47, 50 to 52. The eight different arc operations are necessary to resolve the uncertainty of deciding to which circle the specified arc belongs:

Operation Code	Arc called for	
40	Short, CW, XY	CW = Clockwise
41	Short, ACW, XY	ACW = Anticlockwise
42	Long, CW, XY	Short = Less than or equal to a semi-circle
43	Long, ACW, XY	Long = More than a semi-circle
44	Short, CW, XZ	XY, XZ, YZ are the three possible contouring planes
45	Short, ACW, XZ	
46	Short, CW, YZ	
47	Short, ACW, YZ	

The rest of the P.P.S. line is completed as follows:

Operation Code	40 to 43	44, 45	46, 47
Radius	Radius of the circle to which the arc belongs		
Working Depth	Z	Y	X
Point A (Starting Point)	X_1Y_1	X_1Z_1	Z_1Y_1
Point B (Finishing Point)	X_2Y_2	X_2Z_2	Z_2Y_2
Variations to Speeds and Feeds	?	?	?

A CONTOURING EXAMPLE

The following two sequences are equivalent and are plotted in Figure 29.

Operation Code	Point A X		Point A Y	Point B X		Point B Y
96 (start)						
50	10.0000	A_1	15.0000	15.0000	B_1/A_2	15.0000
41	15.0000	B/A	15.0000	16.0000	B_2	15.2679
50	14.2679	A_3	14.2679	17.7321	B_3	16.2679
99 (end)						
93 (start)						
50	10.0000	A_1	15.0000	5.0000	B_1/A_2	0.0000
41				1.0000	B_2	0.2679
50	-1.7321	A_3	-1.0000	3.4642	B_3	2.0000
99 (end)						

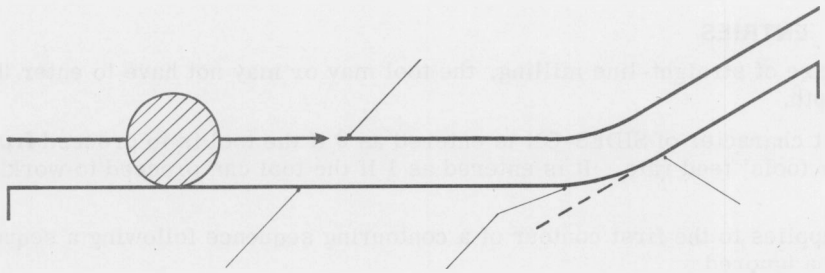


Figure 29: A Contouring Example

Because arcs (or slopes) are defined by two points, the Point A (X, Y) and Point B (X, Y) on the P.P.S. must be used for these points even when it is not an operation in the XY plane.

Only three operation codes are necessary for slopes to decide on the plane of operation:

Operation Code	Slope
50	In XY plane
51	In XZ plane
52	In YZ plane

The rest of the P.P.S. is completed as follows:

Operation Code	50	51	52
Working Depth	Z	Y	X
Point A	X_1Y_1	X_1Z_1	Z_1Y_1
Point B	X_2Y_2	X_2Z_2	Z_2Y_2
Offset	Distance along line, D.D. inches		
Variations to Speeds and Feeds	?	?	?

SIDES-ON ENTRIES

As in the case of straight-line milling, the tool may or may not have to enter the work on its way to working depth.

A, the first character of SIDES-ON is entered as 0 if the tool is to proceed from clearance to working depth at the tools' feed rate. It is entered as 1 if the tool can proceed to working depth at the rapid rate.

This only applies to the first contour of a contouring sequence following a sequence start. Any other entry will be ignored.

B, the second character of SIDES-ON is entered as 0 if the tool is to retract to clearance and entered as 1, if the tool is to remain at working depth at the end of the sequence. This only applies to the last contour of a contouring sequence preceding a sequence end. Any other entry will be ignored.

9 Sequencing

The program will sequence operations to minimize the time taken by the machining centre or machine tool. Milling and contouring operations are given the highest priority by the program and will be performed first. Single-point operations, to which the part-programmer has given a priority number on the P.P.S. (a number between 1 and 98, inclusive) are performed next, priority 01 preceding priority 02, etc. Lastly, the non-priority single-point operations are done.

If a single-point operation with an operation code in the range 20 to 29 is given a priority number, then it will be done completely at priority time, that is, the preceding tools will do their job before the main tool does its job at priority time.

In milling, contouring and in non-priority single-point operations, tools are selected in a certain order and within that order by diameter, sometimes in an increasing direction, sometimes in a decreasing direction. The following table gives the rules:

Order	Tool	Diameters First
1	Milling Cutters	Largest
2	Spot and Centre Drills	Largest
3	Drills	Smallest
4	Taps	Largest
5	Boring Bars	Smallest
6	Reamers	Largest
7	Countersinks	Smallest

The following additional rules apply:

1 A given tool will complete all its operations before it is changed, except if the tool is doing a priority operation, that is, most tools will only make one appearance.

2 All operations with the one tool on one face will be completed before indexing to another face takes place.

3 All milling and contouring operations with the same tool on the same face will be performed in P.P.S. Line Number order; that is, the part-programmer decides on his own milling strategy.

4 All single-point non-priority operations are done in a computer-selected, near-minimum tool path across the face.

10 Run Description System

GENERAL DESCRIPTION

MILMAP information is processed sequentially and there are a number of different points at which the program may be entered, depending on the type of data to be input and the processing required. Control of the sequence of processing is achieved by 'Run Description' parameter cards which must be used with each job submitted for MILMAP processing.

The use of these parameter cards:

1 increases computer efficiency,

2 reduces computer time and cost for each job,

3 makes a security cross-check that the correct magnetic tapes and card packs are being used,

4 greatly reduces the operating instructions required,

5 determines the amount of output from the run.

Intelligent use of these 'run description' cards will enable a part-programmer to exercise some control over the running of his jobs on the computer.

Before describing the Run Description system in detail, certain features of MILMAP computer runs will be explained.

THE STORE MAGNETIC TAPE

This tape holds a Tool Store file and a Material Store file with the Tool Store preceding. Once the use of MILMAP is established in a production unit, the Tool and Material stores will tend to change infrequently and when a change is to be made, it will probably be made to either one, not both. Most runs will use an existing STORE tape.

A new Store tape can be written from either Tool Store and Material Store card packs or Tool Store or Material Store card pack and a previous STORE tape.

THE PPSDATA MAGNETIC TAPE

This tape holds the part-program after the P.P.S. cards have been input and its content is printed. If the part-programmer is uncertain, he can stop further processing at this point when he has checked his printout and if no correction is needed, he can proceed with processing from the point he had reached. Now the PPSDATA tape holds the part-program, the STORE tape holds the tool and material data and no re-entry of the cards is needed.

ORDER OF CARD PACKS

The order of the card packs is always as follows:

RUN DESCRIPTION	Cards - always
TOOL STORE	Cards - if required
MATERIAL STORE	Cards - if required
P.P.S.	Cards - if required

RUN DESCRIPTION CARDS

Column 1 2 3	16	25
NEW	TOOLS	AAA

Action: The program expects Tool Store cards to be input. A Tool Store file coded 'AAA' is created (AAA is any alphanumeric combination of three characters) and the Tool Store is printed.

Column 1 2 3 16 25

N E W MATERIAL BBB

Action: The program expects Material Store cards to be input. A Material Store file coded 'BBB' is created (BBB is another alphanumeric combination of three characters) and the Material Store is printed.

If both these NEW cards were used, the new STORE tape is created with a 12-character name 'STORE AAABBB'

Column 1 2 3 16 25

U S E STORE AAABBB

Action: An existing STORE tape is used whose Tool and Material Store files are coded AAA and BBB respectively.

Column 1 2 3 4 16 25

C O P Y TOOLS XXX (another alphanumeric combination)

Action: This card must be preceded by a 'USE' card for a 'STORE' tape containing Tool File XXX (e.g. USE STORE XXXYYY). The program opens the existing STORE tape and copies the Tool file XXX only to the new tape, which will be named 'STORE XXXBBB' if new Material Store cards are input to produce a Material File BBB on the new tape.

Column 1 2 3 4 16 25

C O P Y MATERIAL YYY (another alphanumeric combination)

Action: Similar to Copy Tools except that in this case, the new tape 'STORE AAAYYY' is opened first and the Tool File AAA, described by a preceding 'New Tools AAA', is written to the new tape. Then an existing tape (e.g. STORE XXXYYY) is opened and the Material File 'YYY' is copied to the new tape.

Column 1 2 3 4 16 25

L I S T TOOLS XXX

Action: This directs the program to printout Tool Store file 'XXX'. As printing is automatic when 'New Tools XXX' is used, 'LIST Tools XXX' would only be used with 'Use Store XXXYYY' or 'Use Store XXXYYY', 'Copy Tools XXX' cards.

Column 1 2 3 4 16 25

L I S T MATERIAL YYY

Action: Similar to List Tools

Column 1 2 3 4 16 25

D A T A NNNNNNNN LLLLLL

Action: The program expects the input of a P.P.S. card pack whose HEADER card contains the Part Number NNNNNNNN - an alphanumeric combination of eight characters. A check will be made between DATA card and HEADER card that the eight characters are identical. The six character combination LLLLLL is for a short description (for example, 'MWK. E.' to indicate that the job will be run on a Milwaukee-Matic Model E). No check is made on this.

Column 1 2 3 16 25

R U N NNNNNNNN LLLLLL

Action: The program is directed to continue processing P.P.S. data through to the production of a control paper tape. The codes are the same as for the DATA card.

Column 1 2← →80

Available for Part Programmers written comments

Action: Columns 2 to 80 may contain any alphanumeric characters within the I.C.T. 64-character set and will be printed like other Run Description cards on the Run Description Print. They may be used to describe the job or to describe special features of the data. Any number of # cards may be interspersed with Run cards at any position prior to the '****' card.

Column 1 2 3 4

* * * *

Action: This indicates that the Run Description cards have all been received. The card reader stops ready to start on the next pack of cards (Tools, Material or P.P.S.). This card must be followed by a blank card and this pair of cards must always be present at the end of a 'Run Description'.

Order of Run Description Cards

NEW	TOOLS MATERIAL	T01 M02	if required
#			Comments in any position before ****
USE	STORE	T01 M01	if required
COPY	TOOLS MATERIAL	T01 M01	if required
#			
LIST	TOOLS MATERIAL		if required
DATA	12345678		if required
RUN	12345678		if required
****	Always used		
Blank	Always last two cards		

IMPERMISSABLE RUN CARD COMBINATIONS

The following examples point out some of the errors that can be made:

1 A NEW Tools or Material card should not be followed by another NEW card, or by a COPY card, or by a LIST card, if all of these call for the same item.

2 If both Tools and Material has been specified as new with NEW cards, a USE store card by itself or with a COPY card should not be used.

3 If either a NEW Tools or NEW Material card is used, not both, then it must be followed by a USE STORE card and a COPY card of the missing item. If either card is missing or they are reversed in order, they will not be accepted.

4 A RUN card followed by a four-asterisks card and a blank card will not be accepted. The minimum acceptable input for the complete MILMAP action is:

USE	STORE	AAABBB
RUN	12345678	MMMMMM
****		
Blank card		

In this case, Tools, Material and P.P.S. Data will be taken from magnetic tape.

5 More than one USE, DATA or RUN card is not allowed

6 Mis-spelling may result in rejection.

It is important to note that if the various alphanumeric codes are not used, then there is no cross-check that the correct cards and magnetic tapes are being used. All part-programming sections using MILMAP are strongly advised to adopt this checking system.

EXAMPLES

A few examples of correct run descriptions are given below:

1

NEW	TOOLS	AAA
NEW	MATERIAL	BBB
#	CREATION OF NEW STORE TAPE ONLY	

```
****
Blank
```

Tool and Material cards are input and tape 'STORE AAABBB' is created. The run then terminates.

```
2  NEW      TOOLS      AAA
   NEW      MATERIAL   BBB
   #  CHECKING P.P.S. BEFORE CONTINUING
   DATA     12345678
   ****
   Blank
```

Tool Store, Material Store and P.P.S. cards are to be read. The Header card in the P.P.S. card pack is to be checked for a PART NUMBER of 12345678. A Store magnetic tape and a P.P.S. DATA magnetic tape are to be written. The run then terminates.

```
3  NEW      TOOLS      AAA
   NEW      MATERIAL   BBB
   #  COMPLETE RUN AFTER P.P.S. CORRECTIONS
   DATA     12345678
   RUN      12345678
   ****
   Blank
```

This example is as example 2 except that this time the run continues to completion producing a control tape.

```
4  USE      STORE      AAABBB
   #  USE EXISTING STORE TAPE
   DATA     12345678
   RUN      12345678
   ****
   Blank
```

As example 3, except that the STORE tape is to be used. Tool and Material Store files will not be printed.

```
5  NEW      MATERIAL   BBB
   #  MORE MATERIALS ADDED AND SOME RATIOS CHANGED
   USE      STORE      XXXYYY
   COPY     TOOLS      XXX
   #  FULL TOOL STORE FOR MODEL 'E'
   LIST     TOOLS      XXX
   DATA     12345678   MWKE
   RUN      12345678
   ****
   Blank
```

11 Example Job

GENERAL DESCRIPTION

In this chapter, a complete example is given. The component is shown in Figure 30, with operation locations numbered as described in Chapter 4. Four datum points have been used, denoted D1, D2, D3 and D4. Temporary axes have been drawn in the Figure and the beginner is recommended to follow this practice. Figure 31, shows the clamping arrangement. Figure 32 is the completed P.P.S.

COMPUTER OUTPUT

The various computer printouts are shown in Figures 33 (a), (b), (c), (d), (e), (f), (g), (h).

(a) Tool Store

If new tools are entered or a Tool Store print is requested, the complete current Tool Store will be printed.

(b) Material Store

If new materials are added or a Material Store print is requested, the complete Material Store will be printed.

(c) Copy of P.P.S.

For checking purposes.

(d) Presentation Positions

These lists give the co-ordinates of all operation points referred to the table centre when each of the points is in its operating position.

(e) Conversion Ratios to Standard Speeds and Feeds for This Job

This is an extract from the Material Store for the selected material.

(f) Tools Required

All tools to be used are printed in this list in the order of use, together with the tool parameters and the time each tool will be cutting. The total time of machine tool operation is given for the benefit of estimators.

(g) Tape Image

This is a printout of the information on the paper tape. It will always resemble the Process Planning Sheet for the machine tool when part-programming is not computer-assisted. This printout and the previous one are useful to the machine operator when the work is performed.

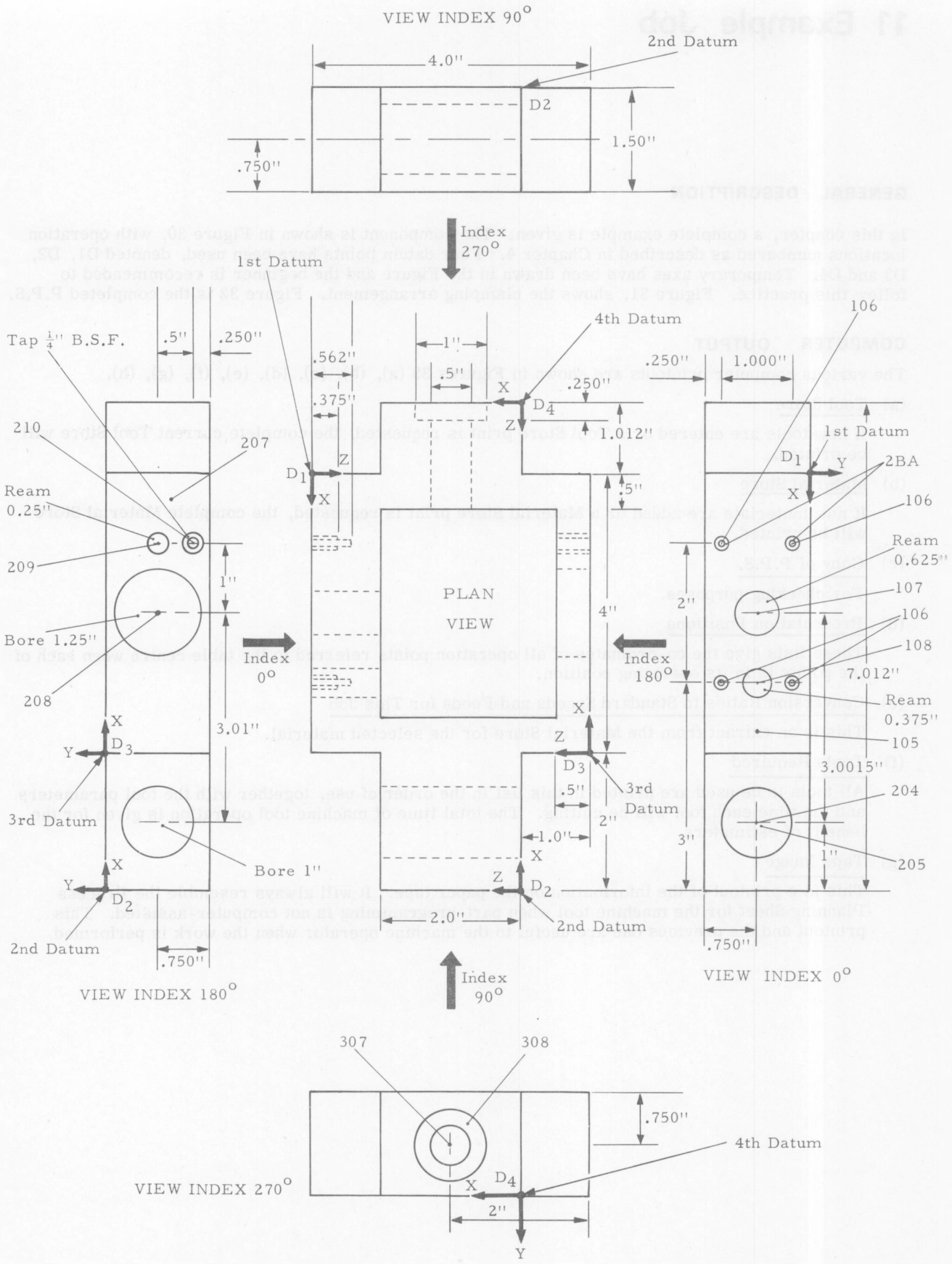


Figure 30: Example Job - Component Drawing

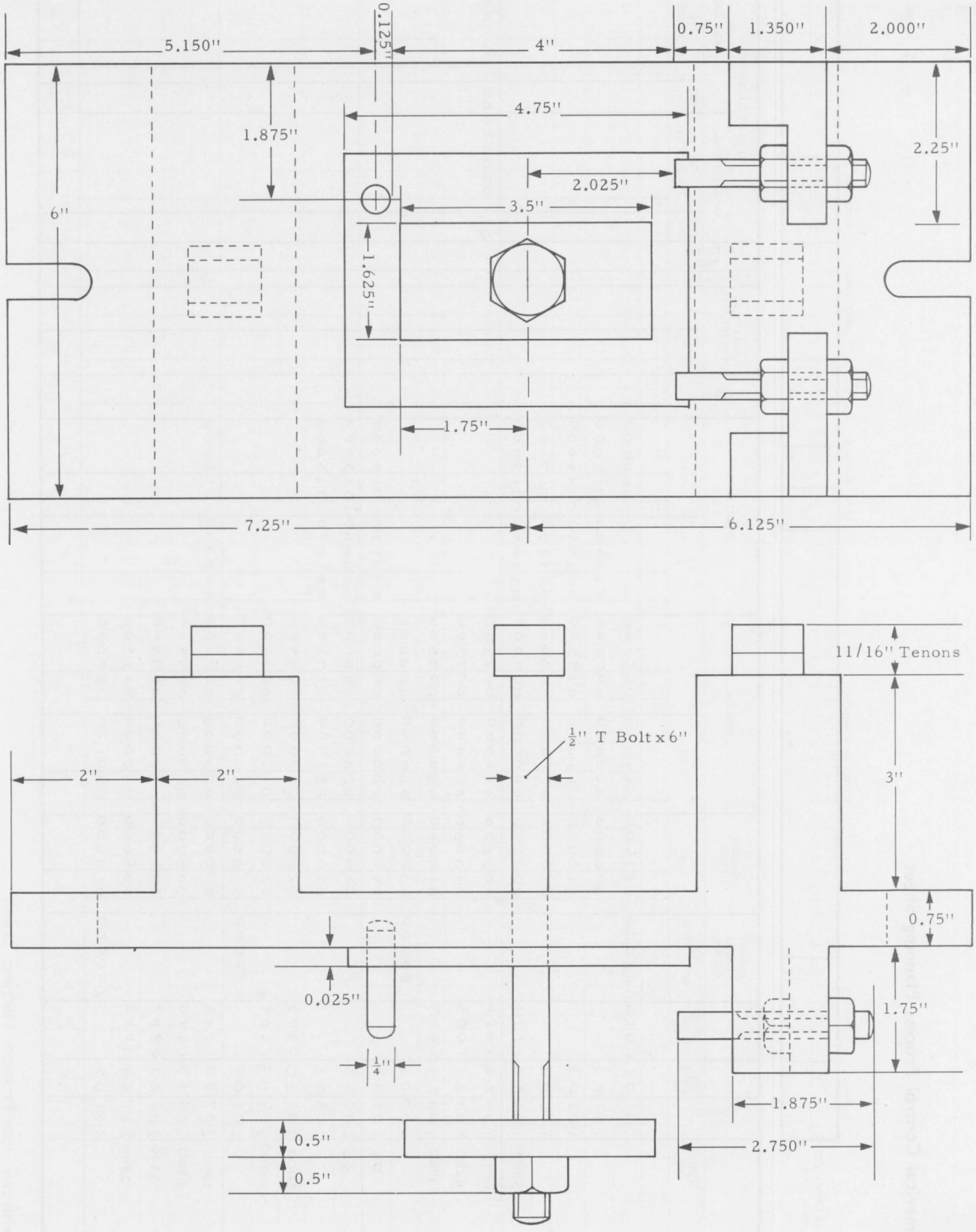


Figure 31: Example Job - Fixture Drawing

I·C·T Numerical Control Process Planning Sheet

SHEET 1 OF 2 SHEETS

HEADER CARD (Sheet 1 only)	MODE1	PART No.	PART DESCRIPTION	OPN.	PROG.	DATE	MATERIAL	TAPE No.	
									H
	1 -5	6 -12	13 -42	43 -45	46 -48	49 -54	55 -62	63 -68	80

OPERATION	TOOL DIA.	LINE NUMBER	OP. CODE No.	TOOL CODE No.	(INDEX) SIDES	(INDEX) RADIUS	WORKING DEPTH Z (x y)	POINT A X (y)	POINT A Y (z)	POINT B X (y)	POINT B Y (z)	OFFSET	VARIATIONS TO STANDARDS SPD%	VARIATIONS TO STANDARDS FD%	ENTRY POINT	SEQ. PRIORITY	MULTIPLE LOCATION LONGITUDINAL TOT. No.	MULTIPLE LOCATION LONGITUDINAL (X) INCREMENT	MULTIPLE LOCATION VERTICAL TOT. No.	MULTIPLE LOCATION VERTICAL (Y) INCREMENT
					ON	FINE	±	±	±	±	±	±	±	±				±		±
FIX ALUMINIUM		001	01	0010	000000		187500	099750	045000											
GUARD		102	03				000000	000000	000000	040000	-015000									
GUARD		103	03				010000	-041000	-017500	092750	-044000									
GUARD		104	03				010000	-021000	000000	-007500	-017500									
MILL FACE	·3000	105	30	1113			000000	000000	000000	040000	-015000				3					
TAP C	·1875	106	24	3016			005620	010000	-002500								02	02 00000	02	-01 00000
REAM	·6250	107	21	1005			010000	020000	-007500											
REAM	3750	108	21	1007			010000	030000	-007500											
RELOCATE		200	02		180000		030000	060000	000000											
GUARD	04	201	03				000000	000000	000000	070120	-015000									
GUARD	04	202	03				010000	020000	000000	060000	-015000									
GUARD		203	03				020000	-032750	-017500	081000	-044000									
DRILL	·5000	204	20	0406			020000	010000	-007500											
BORE ONLY	1·0000	205	13	1409			020000	010000	-007500											
RELOCATE		206	02		180000		-010000	020000	000000											
MILL FACE	·3000	207	30	1113			000000	000000	000000	040000	-015000				4					
BORE ONLY	1·2500	208	13	1410			005000	020000	-007500											
REAM	·2500	209	21	0902			005000	030000	-007500											
TAP C	·2500	210	24	3012			005000	030000	-012500											
RELOCATE		301	02		270000		010000	050120	000000											
		1 -3	4 5	6 -7	8 -9	10 -12	13 -15	16 -18	19 -22	23 -25	26 -29	30 -32	33 -36	37 -39	40 -43	44 -46	47 -50	51 -53	54 -56	57 -59	60 -62	63 -64	65 -67	68 -71	72 -73	74 -76	77 -80

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Figure 32: Example Job-Process Planning Sheet

I·C·T Numerical Control Process Planning Sheet

SHEET 2 OF 2 SHEETS

	MODEL	PART No.	PART DESCRIPTION	OPN.	PROG.	DATE	MATERIAL	TAPE No.	
HEADER CARD (Sheet 1 only)	1 -5	6 -12	13 -42	43 -45	46 -48	49 -54	55 -62	63 -68	H 80

OPERATION	TOOL DIA.	LINE NUMBER	OP. CODE No.	TOOL CODE No.	(INDEX) SIDES RADIUS ON	(INDEX) SIDES RADIUS FINE	WORKING DEPTH Z (x y)	POINT A X (y)	POINT A Y (z)	POINT B X (y)	POINT B Y (z)	OFFSET	VARIATIONS TO STANDARDS SPD'G	VARIATIONS TO STANDARDS FD'G	ENTRY POINT	SEQ. PRIORITY	MULTIPLE LOCATION LONGITUDINAL TOT. No.	MULTIPLE LOCATION LONGITUDINAL (X) INCREMENT	MULTIPLE LOCATION VERTICAL TOT. No.	MULTIPLE LOCATION VERTICAL (Y) INCREMENT
		±					±	±	±	±	±	±	±	±				±		±
GUARD		302	04				000000	000000	000000	020000	-015000									
GUARD		304	03				001088	-020000	000000	002500	-017500									
GUARD		305	03				001088	040000	000000	017500	-017500									
GUARD		307	03				003088	040000	-017500	-020000	-015000									
DRILL	·5000	308	20	0406			001512	010000	-007500							01				
DRILL	1·000	309	20	2105			000250	010000	-007500											
		1 -3	4 5	6 -7	8 -9	10 -12	13 -15	16 -18	19 -22	23 -25	26 -29	30 -32	33 -36	37 -39	40 -43	44 -46	47 -50	51 -53	54 -56	57 -59	60 -62	63 -64	65 -67	68 -71	72 -73	74 -76	77 -80

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Figure 32 cont...

CONTINUATION

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DESCRIPTION	TOOL CODE	ZONE 1 DIA.	ZONE 1 SETTING	AC	TPI	ZONE 2 D	ZONE 2 S	ZONE 3 D	ZONE 3 S	ZONE 4 D	ZONE 4 S	SP	FD	PREC TOOL
TAP 6 BA	30 01	0.1100	6.0000	80	48	05	053	17	028			15	510	0303
TAP 4 BA	30 02	0.1420	6.0000	80	39	05	053	17	028			13	510	0513
TAP 2 BA	30 03	0.1850	6.0000	80	31	05	048	17	028			11	510	0216
TAP 5/16 BSF	30 07	0.3125	6.0000	80	22	06	048	17	028			16	447	0524
TAP 1/4 BSF	30 08	0.2500	4.1250	80	26	17	028					08	481	0503
TAP 3/8 BSF	30 09	0.3750	7.5000	80	20	06	061	17	028			07	495	0429
TAP 5/16 BSF	30 10	0.3125	4.3750	80	22	17	028					16	447	0312
TAP 1/2 BSF	30 11	0.5000	7.0000	80	16	17	028					08	481	0524
TAP 3/16 WHIT	30 16	0.1875	6.0000	80	24	05	059	17	028			08	488	0529
TAP 4-4 OUNC	30 17	0.1120	6.0000	80	40	05	053	17	028			14	487	0303
TAP 4-4 OUNC	30 22	0.1120	7.5000	80	40	05	068	17	028			14	487	0303
TAP 5-4 OUNC	30 27	0.1250	7.5000	80	40	07	067	17	028			14	487	0413

Figure 33 (a): Tool Store Print - Example

CONTINUATION

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DATE 18/04/67

SEQ NO.	CODE	MATERIAL		FOR TOOL GROUPS 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
	10	ALUMINIUM		
046		SPEED		28 20 20 20 20 20 20 20 20 20 00 17 17 17 28 00 28 23 00 00 23 23 23 20 20 28 23 28 00
047		FEED	0.1D	10 10 10 10 10 10 10 10 10 10 00 10 10 10 10 00 10 10 00 00 10 10 10 10 10 10 10 10 00
048			0.5D	14 06 06 06 06 10 10 06 10 10 00 10 10 10 14 00 14 13 00 00 13 13 13 10 06 14 13 14 00
049			1.0D	10 07 07 07 07 10 10 07 10 10 00 10 10 10 10 00 10 09 00 00 09 09 09 10 07 10 09 10 00
050			1+ D	10 06 06 06 06 10 10 06 10 10 00 10 10 10 10 00 10 10 00 00 10 10 10 10 06 10 10 10 00
	11	BRASS		
051		SPEED		20 15 15 15 15 35 35 15 28 28 00 15 15 15 38 00 38 43 00 00 43 43 43 35 15 38 43 38 00
052		FEED	0.1D	10 10 10 10 10 25 25 10 13 13 00 10 10 10 10 00 10 10 00 00 10 10 10 25 10 10 10 10 00
053			0.5D	10 10 10 10 10 25 25 10 13 13 00 10 10 10 10 00 10 11 00 00 11 11 11 25 10 10 11 10 00
054			1.0D	10 10 10 10 10 25 25 10 16 16 00 10 10 10 10 00 10 11 00 00 11 11 11 25 10 10 11 10 00
055			1+ D	10 10 10 10 10 25 25 10 16 16 00 10 10 10 10 00 10 11 00 00 11 11 11 25 10 10 11 10 00
	12	COPPER SOFT		
056		SPEED		20 10 10 10 10 20 20 10 13 13 00 10 10 10 10 00 10 10 00 00 10 10 10 20 10 10 10 10 00
057		FEED	0.1D	16 10 10 10 10 15 15 10 13 13 00 10 10 10 10 00 10 10 00 00 10 10 10 15 10 10 10 10 00
058			0.5D	16 10 10 10 10 15 15 10 13 13 00 10 10 10 10 00 10 11 00 00 11 11 11 15 10 10 11 10 00
059			1.0D	16 10 10 10 10 15 15 10 16 16 00 10 10 10 10 00 10 11 00 00 11 11 11 15 10 10 11 10 00
060			1+ D	16 10 10 10 10 15 15 10 16 16 00 10 10 10 10 00 10 11 00 00 11 11 11 15 10 10 11 10 00
	13	COPPER HARD		
061		SPEED		10 07 07 07 07 10 10 07 06 06 00 07 07 07 04 00 04 04 00 00 04 04 04 10 07 04 04 04 00
062		FEED	0.1D	07 04 04 04 04 10 10 04 06 06 00 04 04 04 10 00 10 10 00 00 10 10 10 10 04 10 10 10 00
063			0.5D	07 03 03 03 03 10 10 03 05 05 00 03 03 03 10 00 10 08 00 00 08 08 08 10 03 10 08 10 00
064			1.0D	07 03 03 03 03 10 10 03 05 05 00 03 03 03 10 00 10 07 00 00 07 07 07 10 03 10 07 10 00
065			1+ D	07 03 03 03 03 10 10 03 05 05 00 03 03 03 10 00 10 07 00 00 07 07 07 10 03 10 07 10 00
	14	PHOSPHOR BRONZE		
066		SPEED		10 20 20 20 20 19 19 20 24 24 00 20 20 20 10 00 10 10 00 00 10 10 10 19 20 10 10 10 00
067		FEED	0.1D	08 06 06 06 06 20 20 06 10 10 00 06 06 06 10 00 10 10 00 00 10 10 10 20 06 10 10 10 00
068			0.5D	08 06 06 06 06 20 20 06 10 10 00 06 06 06 10 00 10 10 00 00 10 10 10 20 06 10 10 10 00
069			1.0D	08 07 07 07 07 20 20 07 10 10 00 07 07 07 10 00 10 10 00 00 10 10 10 20 07 10 10 10 00
070			1+ D	08 06 06 06 06 20 20 06 10 10 00 06 06 06 10 00 10 10 00 00 10 10 10 20 06 10 10 10 00

Figure 33 (b): Material Store Print - Example

'MILMAP'

PROCESS PLANNING SHEET

TAPE PPSDATA

WRITTEN 07/05/67

PART NO. 7012345 TEST PIECE OPERATION 1

CONTROL TAPE NO. 012345 MATERIAL: AL ALLOY M/C MODEL: MWK 2

PROGRAMMER ABC DATE 05/05/67

PAGE 3/ 1

DATE 07/05/67

001 01 F I X MATL CODE - 10 FIRST DATUM Z - 18.7500 X - 9.9750 Y - 4.5000 HEIGHT - 6.5000

LINE NO	OPERATION	TOOL CODE	SIDES ON FINE	WORKING DEPTH	POINT A X	POINT A Y	POINT B X	POINT B Y	OFF	% VAR SP	% VAR FD	E P	E PR	TOT X	X-INC	TOT Y	Y-INC
102	04 GUARD			0.0000	0.0000	0.0000	4.0000	- 1.5000									
103	03 GUARD			1.0000	- 4.1000	- 1.7500	9.2750	- 4.4000									
104	03 GUARD			1.0000	- 2.1000	0.0000	- 0.7500	- 1.7500									
105	30 MILLFACE	1113		0.0000	0.0000	0.0000	4.0000	- 1.5000				3					
106	24 TAP C'WISE	3016		0.5620	1.0000	- 0.2500								02	2.0000	02	- 1.0000
107	21 REAM	1005		1.0000	2.0000	- 0.7500											
108	21 REAM	1007		1.0000	3.0000	- 0.7500											
200	02 RELOCATE	INDEX	-	180.000	SHIFT DATUM BY Z :	3.0000	X :	6.0000	Y :	0.0000	WRT PREVIOUS DATUM						
201	04 GUARD			0.0000	0.0000	0.0000	7.0120	- 1.5000									
202	04 GUARD			1.0000	2.0000	0.0000	6.0000	- 1.5000									

Figure 33 (c): Copy of P.P.S. Print - Example

'MILMAP'

PRESENTATION POSITIONS

PART NO. 7012345 TEST PIECE OPERATION 1

CONTROL TAPE NO. 012345 MATERIAL: AL ALLOY M/C MODEL: MWK 2

PROGRAMMER ABC DATE 05/05/67

PAGE 4/ 1

DATE 07/05/67

LINE NO	OP CODE	TYPE	POINT A X	POINT A Y	POINT A Z	POINT B X	POINT B Y
102	04		- 2.0250	5.5000	- 2.0000	1.9750	4.0000
103	03		- 6.1250	3.7500	- 2.0000	7.2500	1.1000
104	03		- 4.1250	5.5000	- 2.0000	- 2.7750	3.7500
105	30		- 2.0250	5.5000	- 2.0000	1.9750	4.0000
106	24		- 1.0250	5.2500	- 2.0000		
107	21		- 0.0250	4.7500	- 2.0000		
108	21		0.9750	4.7500	- 2.0000		
200	02		- 3.9750	5.5000	- 1.0000		
201	04		- 3.9750	5.5000	- 1.0000	3.0370	4.0000
202	04		- 1.9750	5.5000	- 1.0000	2.0250	4.0000
203	03		- 7.2500	3.7500	- 1.0000	4.1250	1.1000
204	20		- 2.9750	4.7500	- 1.0000		
205	13		- 2.9750	4.7500	- 1.0000		
206	02		- 1.9750	5.5000	- 2.0000		

Figure 33 (d): Presentation Positions Print - Example

'MILMAP'

CONVERSION RATIOS TO STANDARD SPEEDS AND FEEDS

FOR THIS JOB

PAGE 4/ 3

DATE 07/05/67

MATERIAL

CODE 10 ALUMINIUM

FOR TOOL GROUPS

		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
SPEED		28	20	20	20	20	20	20	20	20	20	00	17	17	17	28	00	28	23	00	00	23	23	23	20	20	28	23	28	00
FEED	0.1D	10	10	10	10	10	10	10	10	10	10	00	10	10	10	10	00	10	10	00	00	10	10	10	10	10	10	10	10	00
	0.5D	14	06	06	06	06	10	10	06	10	10	00	10	10	10	14	00	14	13	00	00	13	13	13	10	06	14	13	14	00
	1.0D	10	07	07	07	07	10	10	07	10	10	00	10	10	10	10	00	10	09	00	00	09	09	09	10	07	10	09	10	00
	1+ D	10	06	06	06	06	10	10	06	10	10	00	10	10	10	10	00	10	00	00	00	10	10	10	10	06	10	10	10	00

* NOTE: RATIOS AS SHOWN ARE 10 X(ACTUAL)-- EG: 10 = 1.0 ACTUAL

Figure 33 (e): Conversion Ratios to Standard Speeds and Feeds for this Job

'MILMAP'

TOOLS REQUIRED FOR THIS JOB

TAPE EXPPS5
WRITTEN 07/05/67

PART NO. 7012345 TEST PIECE OPERATION 1

CONTROL TAPE NO. 012345

MATERIAL: AL ALLOY M/C MODEL: MWK 2

PROGRAMMER ABC DATE 05/05/67

PAGE 5/ 1
DATE 07/05/67

LOADING SEQUENCE	TOOL CODE	TOTAL CUTTING TIME IN MINS	TOOL DIA	SETTING LENGTH
1	11 13	5.542	0.3000	7.5000
2	06 02	0.105	0.7500	7.5000
3	06 01	0.161	0.3750	6.0000
4	06 08	0.090	0.2500	6.0000
5	04 02	0.030	0.1440	6.0000
6	02 05	0.033	0.2130	7.5000
7	02 11	0.069	0.2402	7.5000
8	04 11	0.028	0.3600	7.5000
9	04 06	0.090	0.5000	7.5000
10	04 09	0.076	0.5950	6.5000
11	21 05	0.045	1.0000	7.5000
12	30 12	0.053	0.2500	7.2500
13	30 16	0.060	0.1875	6.0000
14	14 05	1.374	0.6100	7.5000
15	14 09	1.750	1.0000	7.5000
16	14 10	0.262	1.2500	7.5000
17	10 05	0.126	0.6250	7.5000
18	10 07	0.040	0.3750	7.0000
19	09 02	0.060	0.2500	6.5000

19 TOOLS REQUIRED

Figure 33 (f): Tools Required Print - Example

PAGE 6/ 5

DATE 07/05/67

LOC NO	SEQ NO	PREP COMM	X	Y	Z	FEED RATE	TABLE INDEX	SPINDLE SPEED	TOOL CODE	A/F	CFR	ARC CENTRE OFFSET X/X/Y Y/Z/Z	
106	0013				0	800			0601				Select tool 0601
106	0014									06			
106	0015	00	109750	042500	0	800		2500					
106	0016				126480								Spot drill 1st hole of pattern 106
106	0017				127940	012							
106	0018				126480	500							
108	0019			037500									Spot drill for 108
108	0020				128600	012							
108	0021				126400	500							
106	0022			032500									Spot drill 2nd hole of pattern 106
106	0023				127940	012							
106	0024				126480	500							
107	0025		119750	037500									Spot drill for 107
107	0026				128590	012							
107	0027				126480	500							
106	0028		129750	032500									Spot drill 3rd hole of pattern 106
106	0029				127940	012							
106	0030				126480	500							
106	0031			042500									Spot drill 4th hole of pattern 106
106	0032				127940	012							
106	0033				126480	500							
106	0034				0	800							Index 180°
204	0035						4						
204	0036		090250	037500									

Figure 33 (g): Tape Image Print - Example

Appendix A A Complete List of Operation Code Numbers

01	Fix
02	Relocate
03	Guard
04	Guard
10	Drill to Depth only
11	Drill only
12	Ream only
13	Bore (through) only
14	Tap Clockwise only
15	Tap Anticlockwise only
19	Bore (blind) only
20	Drill
21	Ream
23	Bore (through)
24	Tap Clockwise (through)
25	Drill to Depth
26	Tap Anticlockwise (through)
27	Tap Clockwise (blind)
28	Tap Anticlockwise (blind)
29	Bore (blind)
30	Mill Face
31	Mill Slide
32	Mill Line
33	Mill Step
34	Mill External
35	Mill Internal
36	Mill Recess
37	Mill Fine
40	Contour Arc Short, CW, XY
41	Contour Arc Short, ACW, XY
42	Contour Arc Long, CW, XY
43	Contour Arc Long, ACW, XY
44	Contour Arc Short, CW, XZ
45	Contour Arc Short, ACW, XZ
46	Contour Arc Short, CW, YZ

47	Contour Arc Short, ACW, YZ	
50	Contour Slope XY	
51	Contour Slope XZ	
52	Contour Slope YZ	
93	Contour Start Left Offset	All co-ordinates measured from the same datum position.
94	Contour Start Right Offset	
95	Contour Start Without Offset	
96	Contour Start Left Offset	All co-ordinates measured from the previous entry.
97	Contour Start Right Offset	
98	Contour Start Without Offset	
99	Contour End	

AMENDMENT RECORD

List Number	*Item Numbers*
	to
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	to
	to
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Should any additions or amendments to this Manual be necessary, they will be issued in the form of Amendment Lists.
When such changes have been incorporated, an appropriate entry should be made in the table on the left and the pink instruction sheet(s) should be filed behind this page.

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1900 Series

Operator's Reference Manual of Peripherals

First Edition March 1967

Amendment list 11
incorporating User Notices numbers 3, 4, 5 and 6

Each amendment list contains one or more numbered instructions to replace one or more existing pages or to add one or more new pages.

When a page is amended, significant technical changes on the re-issued page will be indicated by a vertical line in the margin against the changed passages. Any lines on the re-issued page which remain from a previous amendment, will be removed. New chapters or completely revised chapters will not be marked with amendment lines.

The date of issue appears at the foot of all new pages and re-issued pages in the form (month, year).

1	Contents	Remove and destroy pages v and vi. Insert new pages v and vi.
2	Contents Part B	Remove and destroy pages xv to xxi. Insert new pages xv to xxiii.
3	Chapter 2 Part B	Remove and destroy pages B-2-7 to B-2-11. Insert new pages B-2-7 to B-2-11.
4	Chapter 3 Part B	Remove and destroy pages B-3-3 and B-3-4. Insert new pages B-3-3 and B-3-4.
5	Chapter 9.1 Part B	Insert new Chapter 9.1, Part B after Chapter 9, Part B.
6	Chapter 13 Part B	Remove and destroy pages B-13-3 and B-13-4. Insert new pages B-13-3 and B-13-4.
7	Chapter 14 Part B	Insert new Chapter 14, Part B after Chapter 13, Part B.
8	Contents Part C	Remove and destroy pages xxiii to xxvii. Insert new pages xxv to xxix.
9	Contents Part D	Remove and destroy pages xxix to xxxiv. Insert new pages xxxi to xxxviii.
10	Chapter 5 Part D	Insert new Chapter 5, Part D after Chapter 4, Part D.
11	Contents Part E	Remove and destroy pages xxxiii to xxxv. Insert new pages xxxix to xli.
12	Contents Part F	Remove and destroy pages xxxvi.a and xxxvi.b. Insert new pages xliii and xliv.
13	Chapter 2 Part F	Remove and destroy pages F-2-3 and F-2-4. Insert new pages F-2-3 and F-2-4.
14	Chapter 3 Part F	Remove and destroy pages F-3-1 to F-3-6. Insert new pages F-3-1 to F-3-6.
15	Contents Appendixes	Remove and destroy pages xxxvii to xxxix. Insert new pages xlv to xlvii.
16	Appendix 3	Remove and destroy pages App 3-1 to App 3-4. Insert new pages App 3-1 to App 3-4.
17	Appendix 4	Remove and destroy pages App 4-17 and App 4-18. Insert new pages App 4-17 and App 4-18.
18		This amendment cancels User Notices numbers (3), (4), (5) and (6) to the Operators Reference Manual of Peripherals.
19		Update the amendment record and file this list at the back of the manual.

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Amendment list 12

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1	Part D	Remove and destroy pages xxxv to xxxviii. Insert new pages xxxv to xxxviii.
2	Part D	Insert new Chapter 6 (pages D-6-1 to D-6-10) after existing Chapter 5.
3		Update the amendment record and file this list at the back of the manual.

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Amendment list 13
incorporating User Notices numbers 7 and 8

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1	Contents	Remove and destroy pages v and vi. Insert new pages v and vi.
2	Part B Contents	Remove and destroy pages xi to xiv. Insert new pages xi to xiv.
3	Part B Contents	Remove and destroy pages xxi and xxii. Insert new pages xxi and xxii.
4	Part B Chapter 3.1	Remove and destroy the page facing page B-3.1-1, and pages B-3.1-1 to B-3.1-9. Insert new Chapter B-3.1.
5	Part B Chapter 4	Remove and destroy pages B-4-1 and B-4-2. Insert new pages B-4-1 and B-4-2.
6	Part B Chapter 4	Remove and destroy pages B-4-5 to B-4-8. Insert new pages B-4-5 to B-4-8.
7	Part D Contents	Remove and destroy pages xxxv and xxxvi. Insert new pages xxxv and xxxvi.
8	Part D Chapter 1	Remove and destroy pages D-1-3 to D-1-12. Insert new pages D-1-3 to D-1-13.
9	Part F Chapter 3	Remove and destroy pages F-3-1 and F-3-2. Insert new pages F-3-1 and F-3-2.
10	Appendixes Contents	Remove and destroy pages xlv to xlvii. Insert new pages xlv to xlvii.
11	Appendix 1	Remove and destroy pages 1-1 and 1-2. Insert new pages 1-1 and 1-2.
12	Appendix 4	Remove and destroy pages 4-17 to 4-21. Insert new pages 4-17 to 4-25.
13	Remove and destroy User Notices 7 and 8.	
14	Update the amendment record and file this list at the back of the manual.	

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1	Contents	Remove and destroy pages v and vi. Insert new pages v and vi.
2	Part B Illustrations list	Remove and destroy pages xxi and xxii. Insert new pages xxi and xxii.
3	Part D Contents	Remove and destroy pages xxxi to xxxviii. Insert new pages xxxi to xxxviii.1.
4	Part D Chapter 1	Remove and destroy page D-1-3 and D-1-4. Insert new page D-1-3 and D-1-4.
5	Part D Chapter 1.1	Insert new page facing page D-1.1-1, and pages D-1.1-1 to D-1.1-13 after Chapter 1.
6	Part D Chapter 6	Remove and destroy pages facing page D-6-1, and pages D-6-1 to D-6-10. Insert new page facing page D-6-1, and pages D-6-1 to D-6-10.
7	Appendix 4	Remove and destroy pages 4.23 and 4.24. Insert new pages 4.23 and 4.24.
8		Update the amendment record and file this list at the back of the manual.
		User Notices 1 to 8 are obsolete.

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Amendment list 15

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1	Part B Chapter 3.1	Remove and destroy Part B Chapter 3.1 part divider sheet. Replace by new part divider sheet.
2	Part B Chapter 3.1	Remove and destroy pages B-3.1-7 and B-3.1-8. Replace by new pages B-3.1-7 and B-3.1-8.
3	Part C Contents list	Remove and destroy pages xxvii to xxix. Replace by new pages xxvii to xxx.
4	Part C Chapter 5	Remove and destroy pages C-5-1 to C-5-6. Replace by new pages C-5-1 to C-5-11.
5	Part D Contents list	Remove and destroy pages xxxi and xxxii. Replace by new pages xxxi to xxxvi.
6	Part D Illustrations list	Remove and destroy pages xxxvii and xxxviii. Replace by new pages xxxvii to xxxviii.1.
7	Part D Chapter 1	Remove and destroy pages D-1-1 and D-1-2. Replace by new pages D-1-1 and D-1-2.
8	Part D Chapter 1	Remove and destroy pages D-1-9 to D-1-13. Replace by new pages D-1-9 to D-1-15.
9	Part D Chapter 1.1	Remove and destroy pages D-1.1-11 and D-1.1-12. Replace by new pages D-1.1-11 and D-1.1-12.
10	Part D Chapter 1.2	Insert new part divider sheet after page D-1.1-13.
11	Part D Chapter 1.2	Insert new Chapter 1.2 after Part D Chapter 1.2 part divider sheet.
12	Part D Chapter 6	Remove and destroy pages D-6-1 and D-6-2. Replace by new pages D-6-1 and D-6-2.
13	Part D Chapter 6	Remove and destroy pages D-6-9 and D-6-10. Replace by new pages D-6-9 and D-6-10.
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