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LUBRICATION NOTICE

- 1 MAKE SURE YOU FOLLOW THE MACHINE TOOLS RECOMMENDED INSTRUCTIONS.
- 2 USE THE RECOMMENDED GREASE FOR THE HEADSTOCK AND OIL FOR THE BALLSCREWS.
- 3 OIL THE BALLSCREWS WEEKLY.
- 4 DO NOT OPERATE UNTIL LUBE INSTRUCTIONS HAVE BEEN FOLLOWED.

SECTION 1

STARTURN (BBC)

INTRODUCTION

STARTURN is a bench turning centre driven by direct numerical control (D.N.C.) from an external microcomputer.

STARTURN is programmed using the I.S.O. format with G & M codes. This, plus the facility to incorporate a milling and drilling attachment, (Starturn 4 only) provides a powerful and versatile system for use within a training environment.

The software used to control STARTURN is an easy-to-use, menu-driven package, offering all the facilities required to simulate a full C.N.C. turning centre, with a function to prove out programs by Graphical Simulation before the actual turning of the workpiece.

Programs can be easily edited, saved and, as the system will support a printer, hard copies of the Program and Graphical Simulation can be made.

This manual has been written on the assumption that the user has no prior knowledge of CNC terms.

SECTION 2

CONTROL SYSTEMS

Since the industrial revolution engineers have striven to produce automatic machines. The initial need was to speed up operations and to produce long production runs of the same components economically also taking the drudgery out of repetitive work. This type of machine has been with us for a long time from simple cam auto's to sequence control machines using a plugboard or dial setting to achieve the operational sequence and desired dimensions.

The sequence control machines were the forerunner of the present NC (numerical control) and C.N.C. (computer numerical control) machines. However, the sequence control machines required quite lengthy setting up which restricted their use to long production runs to recoup the down time spent in setting.

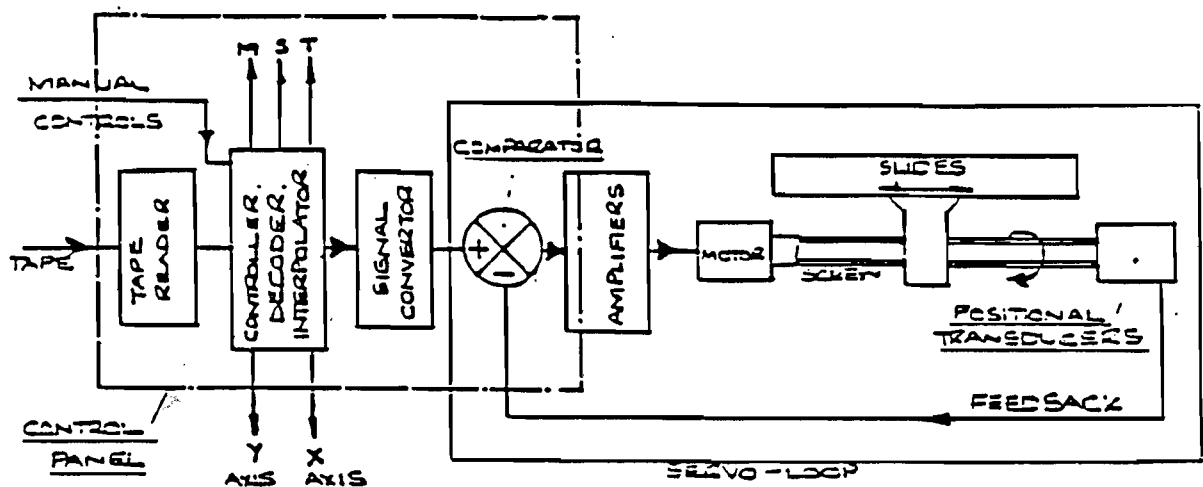
This was one of the reasons for developing NC machines which could be utilized for a simple operation, such as drilling a series of holes in a fixed position at pre-set centre distances, to a much more sophisticated set up which involved a multi-control sequence of operations.

The first NC machines were drilling machines which allowed no carriage movement whilst the tool was cutting. Once this type of operation had been successfully achieved by NC then the need arose to produce machines to allow the travel of the slides during cutting operations, i.e. milling, turning and profiling and also tool changes built into the program. This type of NC machine was usually controlled by a punched tape which was read by a tape reader on the machine. This transferred the information on the tape by a series of electrical impulses to the control system, which in turn moved the slides and tools to the program supplied.

Two types of systems are used to control the NC function:

- (1) Closes loop control
- (2) Open loop control

Fig. 1. Block diagram (simplified) of an NC CLOSED LOOP CONTROL

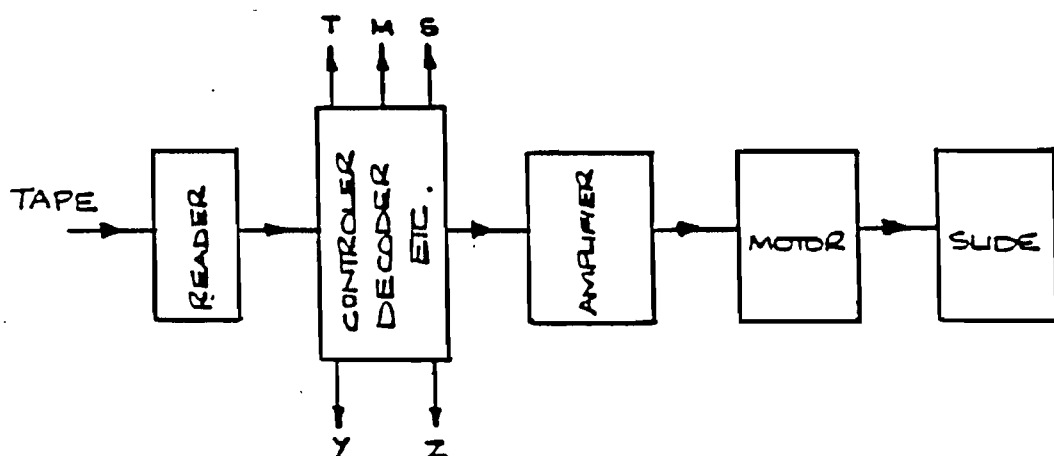


This is a very complex control which is used where a very high degree of accuracy is required i.e. in such machines as jig borers, machining centres, etc.

Fig. 2. NC System using OPEN LOOP CONTROL

Since no feedback is used this eliminates the need for a zero system. This system uses stepping motors which require pulses to rotate i.e. a fixed number of pulses per rev means 1 pulse rotates the motor a fixed number of degrees (a step) and which moves the slides a fixed increment using an accurately pitched screw.

Fig. 2. OPEN LOOP CONTROL



This is a much simpler system and is used on the STARTURN DNC Lathe.

CNC (COMPUTER NUMERICAL CONTROL)

With the advent of the silicon chip, computers no longer need to be huge expensive installations. This has brought them into the field of machine control where space and ease of operation are at a premium.

A mini-computer using the silicon chip and magnetic tape, instead of paper tape, has instigated a new generation of control systems.

DNC (DIRECT NUMERICAL CONTROL)

DNC allows a machine to be run from a host computer, thus eliminating the need for a specialised dedicated computer control system. The computer can be programmed remote from the machine and only connected when the program is to be executed. DNC therefore allows for a more flexible approach to computerised part programming. The STARTURN lathe utilises the latest in DNC technology.

SECTION 3

TECHNICAL SPECIFICATION

MECHANICAL

	<u>Starturn 4</u>	<u>Starturn 8</u>
Swing Over Bed	140 mm (5½")	200 mm (8")
Swing Over Cross-slide	38 mm (1½")	115 mm (4½")
Distance between Centres	250 mm (10")	400 mm (15¾")
Spindle Speed (Stepless)	0-2000 r.p.m.	
Spindle Bore	10 mm (3/8")	20 mm (13/16")
Spindle Taper	No. 1	No. 3
Tailstock Taper	No. 1	No. 2
Ground Bed		
X Axis Ballscrew	8mm Ø 2.5mm p	8mm Ø 2.5mm p
Z Axis Ballscrew	10mm Ø 4mm p	16mm Ø 5mm p
Quick Change Toolpost		
Mechanical Resolution	0.01 mm (0.0004")	

MACHINE DIMENSIONS

	<u>Starturn 4</u>	<u>Starturn 8</u>
Length	660 mm (26")	910 mm (36")
Width	425 mm (16¾")	550 mm (22")
Height	430 mm (17")	550 mm (22")
Weight	70 kg. (155 lbs.)	95 kg (210 lbs)

ELECTRICAL

50/60 Hz - 1 phase 220/240 Volts.

Spindle Motor

½ H.P. D.C. Permanent Magnet.

Axes Motors

Stepper Motors - 200 Steps/REV. D.C. 2.9 V 3.8 A.

STANDARD EQUIPMENT

SOFTWARE DISC.

SOFTWARE PROTECTION DEVICE (DONGLE).

COMPUTER LINK CABLE.

QUICK CHANGE TOOLPOST AND HOLDER.

SELF CENTRING 3 JAW CHUCK.

SET OF OUTSIDE JAWS.

SAFETY GUARDS. (INTERLOCKED).

INSTRUCTION MANUAL AND PARTS LIST.

FLUORESCENT MACHINE LIGHT.

LATHE MAINTENANCE TOOLS.

FUSES.

MACHINE PLUG.

SOCKET FOR 8 STATION INDEXABLE TOOLPOST. (STARTURN 8).

SOCKET FOR 6 STATION INDEXABLE TOOLPOST. (STARTURN 4).

SECTION 4

INSTALLATION & LUBRICATION

4.1 LIFTING

Starturn can be lifted by 2 people.(STARTURN 4)

Weight: 36 Kilos, Length: 600mm, Height: 250mm, Width: 300mm.

STARTURN 8 will need 4 people to lift due to the increased weight of 95 Kilos.

4.2 MACHINE SITING

Starturn can be mounted on a suitably strong desk top, and does not require bolting down.

4.3 CLEANING

Before wiring the machine to the mains supply, first remove all anti-corrosive coatings from the slideways and working parts, including all bright surfaces, using a kerosene-based cleaner. After cleaning, oil all bright surfaces with a light machine oil. Regular cleaning and oiling will ensure a long life for the machine, with a minimum of maintenance.

4.4 ELECTRICAL SUPPLY

The regular electrical mains power supply to the machine is single phase/240v/50Hz. Three phase is not suitable for this product and cannot be supplied.

Connect the mains supply to the supplied adaptor.

4.5 LUBRICATION

All oiling and greasing points have been fitted prior to despatch. Before the machine is switched on, oil the ballscrews with the recommended lubricant.

The ballscrews must be oiled weekly to avoid seizure.

Add grease sparingly to the headstock bearings, through the grease nipples at the back of the headstock.

All slideways should be lightly oiled daily before movement of the saddle and the tailstock.

	SHELL	CASTROL
OIL	VITREA 60	PERFECTO NN
GREASE	ALVANIA No.3	SPHEEROL AP3

Equivalents of all lubricants are available from other manufacturers.

SECTION 5

MAINTENANCE

Routine inspection and maintenance of the machine should be carried out to the following schedule:-

<u>PERIOD</u>	<u>MAINTENANCE REQUIRED</u>
DAILY	Lubricate oil nipples. Wipe slides and ways and coat with a thin film of oil. Clean out swarf.
WEEKLY	Clean machine thoroughly. Check nuts and bolts for slackness. LUBRICATE BOTH BALLSCREWS.
SIX MONTHLY	Check adjustment of saddle and side strips. Grease Headstock bearings.
ANNUALLY	Check machine allignments and accuracy. Check headstock bearing adjustments.

TOP SLIDE STRIP ADJUSTMENT

Take up for wear on the top slide gib strip by loosening the 3 lock nuts and adjust the screws to give slight drag, then tighten the lock nuts.

CROSS SLIDE - STRIP ADJUSTMENT

Take up for wear on the cross slide gib strip by loosening the 3 lock nuts on the side of the cross slide and slowly tighten up the screws. Once tight release half a turn and tighten up the lock nuts.

TAILSTOCK AND CHUCK MOUNTING

CHUCK MOUNTING

STARTURN is set up prior to despatch with the chuck already in position.

For remounting the chuck, first ensure that the spindle nose and the back mounting plate of the chuck is clean and free from dust or protective covering.

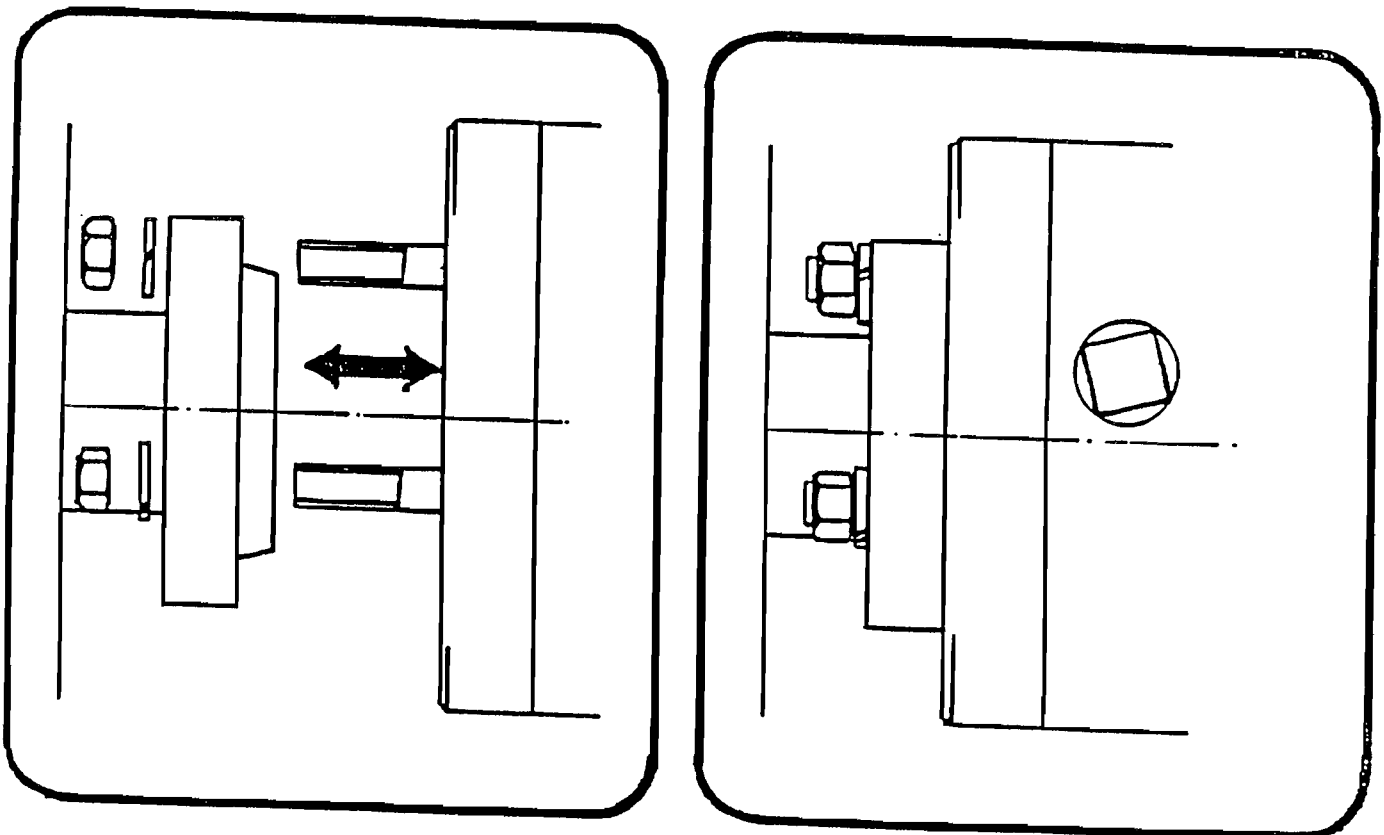
Locate the three studs through the holes in the spindle nose and fix a spring washer and M8 Nut to each of the studs and tighten accordingly. (SEE FIG.3)

TAILSTOCK

The tailstock barrel has a Morse Taper bore and may be locked in position by turning the locking handle (A) on the top of the tailstock in a clockwise direction.

The tailstock is locked by means of a bed clamp B, operated by tightening the nut in the centre of the tailstock base. (SEE FIG.4)

FIG.3



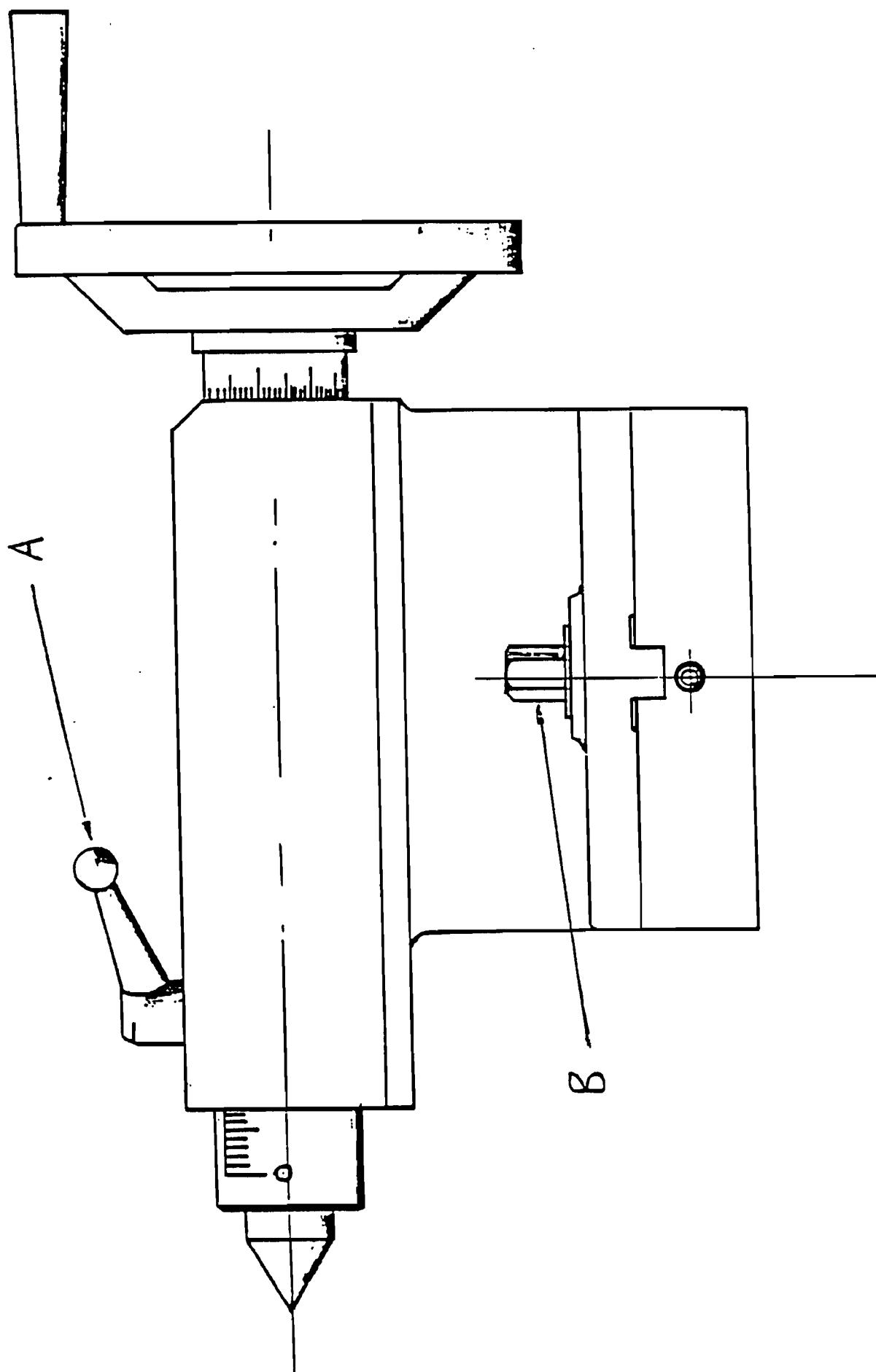


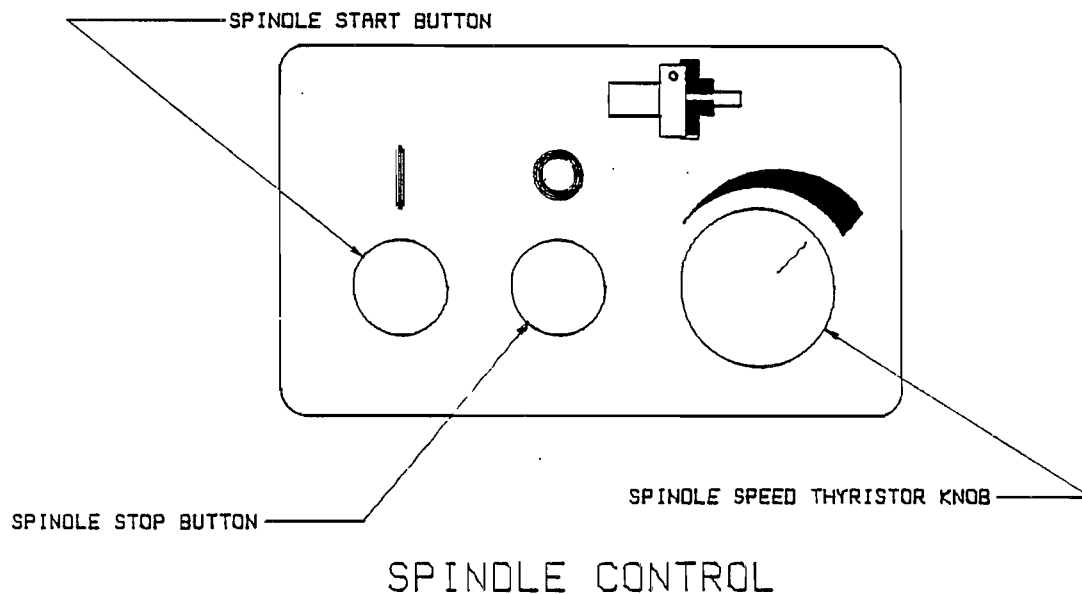
FIG.4

SECTION 6

OPERATION OF SPINDLE CONTROLS

The spindle is operated by pressing the green spindle start button, located on the left hand side of the front of the cabinet. The spindle speed is increased by turning the large thyristor knob. During program execution, the spindle speed will be displayed on the computer screen, and will be updated as the knob is turned.

To stop the spindle press the red button, under the spindle control section on the cabinet.

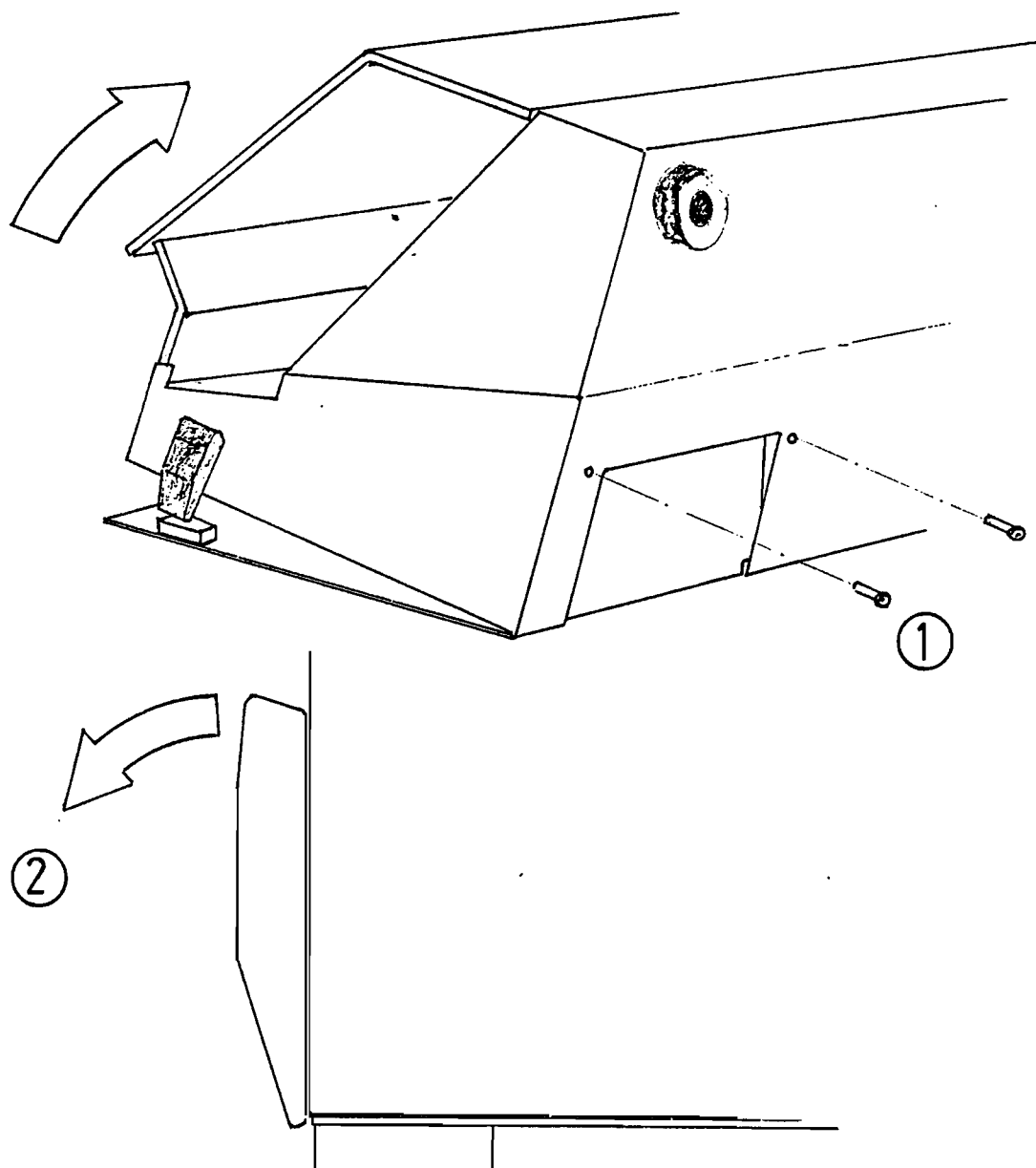


SECTION 7A

GAINING ACCESS TO THE ELECTRICAL COMPARTMENT (STARIURN 4 ONLY)

Should problems occur with the machine it may be necessary to gain access to the machine's electrical components. The method of achieving this is described below.

1. Ensure all work is done on a flat firm base. Although the machine is equipped with an internal safety micro switch to cut off the mains, it is still desirable to disconnect the mains supply.
2. Remove the two M4 button head screws above the rear fuse panel.
3. Unclip the two side catches and lift the body of the machine (hinged at the rear) up and over the chassis base, to reveal the electrics.



SECTION 7

THE QUICK CHANGE TOOLPOST

STARTTURN will accept a maximum of 9 pairs of tool offsets in its memory with a 0 (zero) tool offset cancelling all previous offsets; therefore the maximum number of tools that can be used in the quick change toolpost in any one programme is 9 with tool 0 being used as a reference tool.

To change tools in the toolpost either pull or push the clamping lever to the central position and lift out the tool holder. Insert the new tool holder ensuring the height adjusting screw is firmly down on the base body, and clamp the holder by either pulling or pushing the clamping lever to the locked position.

To set the centre height of the lathe tool slacken off the clamping handle, and loosen the locking nut - then either screw the height adjusting screw clockwise to raise the tool holder or vice-versa. The manufacturers repeatable accuracy on clamping is 0.01 mm.

SECTION 8

SYSTEM OPERATION

8.1 CONNECTING THE SYSTEM

Ensure all electrical supply is turned off.

The STARTURN software has been designed to run on any version of the BBC computer, and comprises a disc, cable and security ROM chip, which must be placed in the correct position in the computer depending on the version of BBC being used.

The guidelines for inserting the security chip are given below.

BBC Model 'B' Version

The computer cover must first be removed by means of the four screws, two located under the front of the BBC and two on the back of the computer. Next unscrew the keyboard, this is done by removing the two screws, one at either end. On the bottom right of the main circuit board there are five 28 pin ROM sockets and the security ROM can be inserted into any free socket. When inserting the ROM ensure that the small notch at one end is pointing away towards the back of the computer, insert with care, making sure that all the legs on the chip are correctly located. When fitted put the keyboard and outer cover back before switching on the mains power.

BBC Model 'B+' Version

The computer cover must be removed as previously described in the BBC Model 'B' section. In the model 'B+' version of the computer however the keyboard does not need removing.

When the cover is taken off 8 ROM slots can be seen at the top left of the main printed circuit board, some of these slots may already have chips in them. The STARTURN security ROM can be positioned in any of the free slots, again the notch in the ROM should face towards the back of the computer. Take extreme care not to bend the legs on the chip during insertion. Replace the cover before applying mains power to the computer.

BBC Master Version

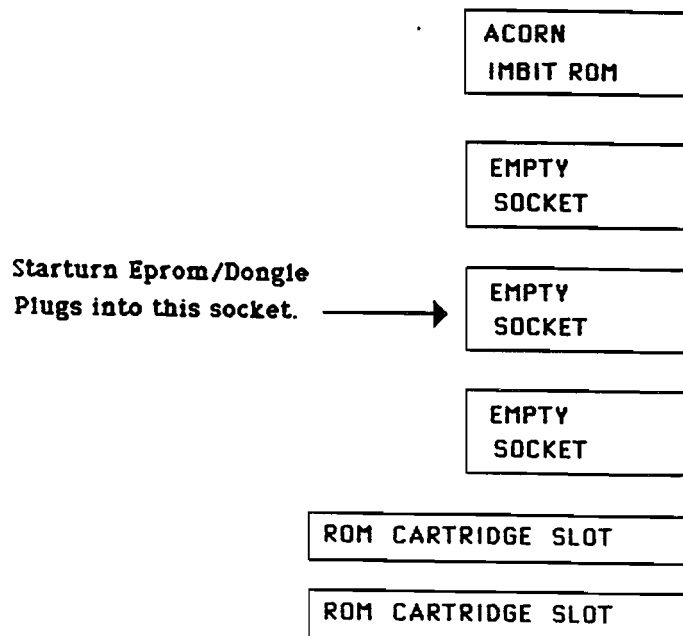
The simplest method of fitting the security chip to the master is to use the ROM cartridge method, where the chip is placed in ROM cartridge holder and slotted into one of the two available cartridge slots. If this method is used the ROM can be positioned in any slot on the cartridge and in any slot on the computer.

Should no ROM cartridge be available then there is one slot inside the computer into which the ROM may be fitted.

Again the computer cover must be removed, this can be done by removing the four screws on the underside of the computer, marked 'FIX'.

With the cover removed the ROM slots can be seen down the right-hand side of the main printed circuit board. The EPROM must be fitted to the slot shown in the diagram below.

RUNNING STARTURN ON MASTER 128



Once the EPROM has been inserted replace the cover before applying power to the computer.

Now the ROM is correctly inserted in the computer the link between the BBC and the machine can be accomplished by means of the cable supplied.

One end of the cable connects to the 'Computer link' socket on the machine whilst the other end goes to the 'RS 423' plug on the rear of the BBC computer.

The power can now be applied to all equipment to make the system ready for use.

8.2 OPERATION

Insert the STARTURN disc supplied as part of the package, into the disc drive, and boot up the system by presing the shift and break keys at the same time, the software will load and display the main menu displayed below.

EDITOR	PROGRAM	TEMP	MAIN MENU
			EDIT PROGRAM DISC UTILS NEW PROGRAM PRINTOUT MANUAL SIMULATION SETTINGS HELP SCREEN EXIT SYSTEM
ARROW KEYS MOVE BAR			
RETURN SELECTS OPTION			

When the main menu appears for the first time the 'EDIT PROGRAM' option, the top option on the menu, is automatically highlighted in blue. The other options when required can be selected by pressing the UP and DOWN arrow keys until the correct function is selected and press the RETURN key, to confirm the selection.

Each of the STARTURN's functions will be explained in more detail under their individual sections.

SECTION 9

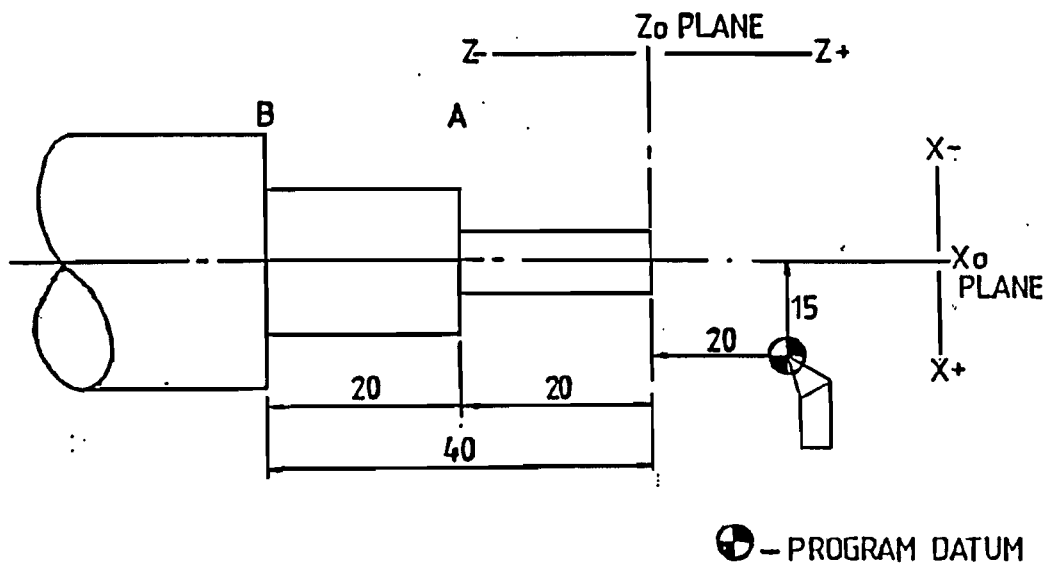
PROGRAMMING

PROGRAMMING STARTUP

New programs are entered into the computer by selecting the 'NEW PROGRAM' function from the main menu.

All of the programming functions of the machine are explained in the following pages along with the method of entering the information into the computer.

BASIC PRINCIPLES



The above diagram illustrates the terms X0; Z0; Program Datum; Absolute and Incremental, as used in the writing of programs for CNC Machines.

Z0 is taken as the end of the workpiece.

X0 is taken as the centre line of the spindle.

The Program Datum is shown 20mm from the Z0 plane and 15mm from the X0 plane. Its position is expressed as Z20; X15.

When programming in absolute units and using the program datum for reference, then the face "A" is positioned at Z,-20; the face "B" is positioned at Z,-40.

continued overleaf/

NOTE: All Absolute Z measurements to the left of Z0 are -VE.
All Absolute Z measurements to the right of Z0 are +VE.
Similarly for dimensions on either side of X0 plane, as shown.

When Incremental programming is used, the co-ordinates are as follows
(still working from the program datum):-

Face "A" is positioned at Z,-40.

Face "B" is positioned at Z,-60.

All Incremental Z measurements towards the chuck are -VE

All Incremental Z measurements away from the chuck are +VE.

All Incremental X measurements towards the centre line are -VE.

All Incremental X measurements away from the centre line are +VE.

MACHINE AXIS FORMAT

The diagrams below illustrate the plan view of STARTURN. The Z axis runs along the length of the bed, and the X axis along the cross slide at 90° to the bed. The plus and minus signs indicate the direction of the tool.

Fig. A. Absolute

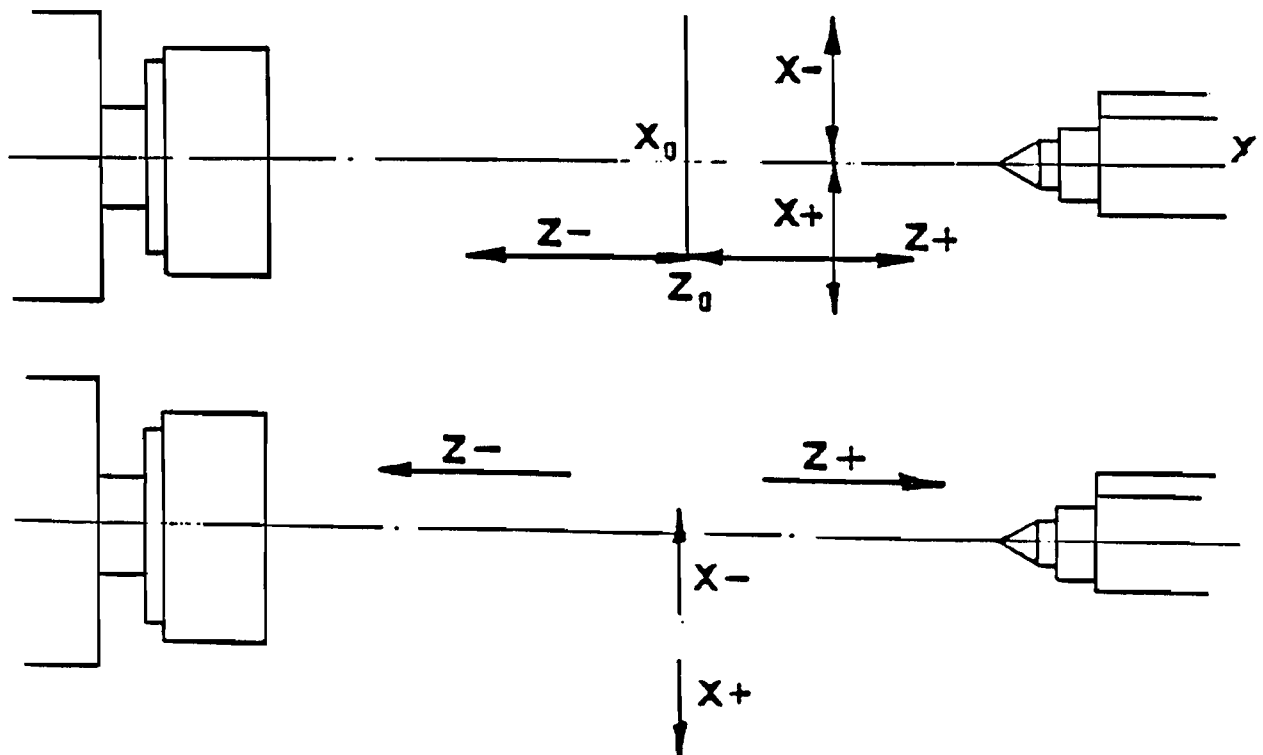
Z Axis: to the left hand side of Z0 towards the chuck is negative.
to the right hand side of Z0 away from the chuck is positive.

X Axis: X0 is on the centre line of the spindle.
Away from X0 towards the guard the movement is negative and towards the operator from X0 is positive.

Fig. B. Incremental

Z Axis: towards the chuck is negative.
away from the chuck is positive.

X Axis: away from the operator is negative.
towards the operator is positive.



STARTURN utilises the International Standards Organisation (I.S.O.) Method of part programming coding. The system uses G codes and M codes to control the machines operation. The relevant codes for the STARTURN are automatically displayed on the screen whilst a new program is being entered on the computer, or an existing program is being edited.

All of the G and M codes will be explained fully in the following pages, along with examples where appropriate.

Absolute (G90) and incremental (G91) methods of programming

There are two basic methods of programming the STARTURN, the first is 'Absolute' Programming. When programming the X0 and Z0 positions are where all the dimensions for the component are taken, i.e. at the centre line and at the end of the component being programmed. In absolute mode this rule stays true for the whole of the program, so all 'Z' dimensions are taken from the end of the component, and X from the centre line.

In incremental programming the co-ordinates for the various tool movements are taken from the previous position i.e. the X0 and Z0 position changes with each movement of the tool.

The above explanation is shown on the diagram on the previous page.

There are certain instances where incremental programming has to be used, i.e. repeat loops, subroutines, but this will be explained under the relevant sections in the manual.

RAPID TRAVERSE (G00)

The code G00 is used to move the tool from point to point at maximum feedrate of 1200mm/min. The only information that the computer requires to execute the block of program is the X and Z values of the new position of the tool.

Should values be entered for both X and Z then both the axes will move simultaneously to ensure that the tool moves to the new position in a straight line.

Should only one of the axes require to be moved, then only one value need be entered, i.e. if the Z axis (along the bed) is to be moved at rapid traverse for a distance of 20mm towards the chuck then simply input Z-20 and do not enter a vlaue for X. The same rule applies to the X axis.

The rapid traverse (G00) is used to position the tool prior to a cutting movement and should not be used for cutting operation.

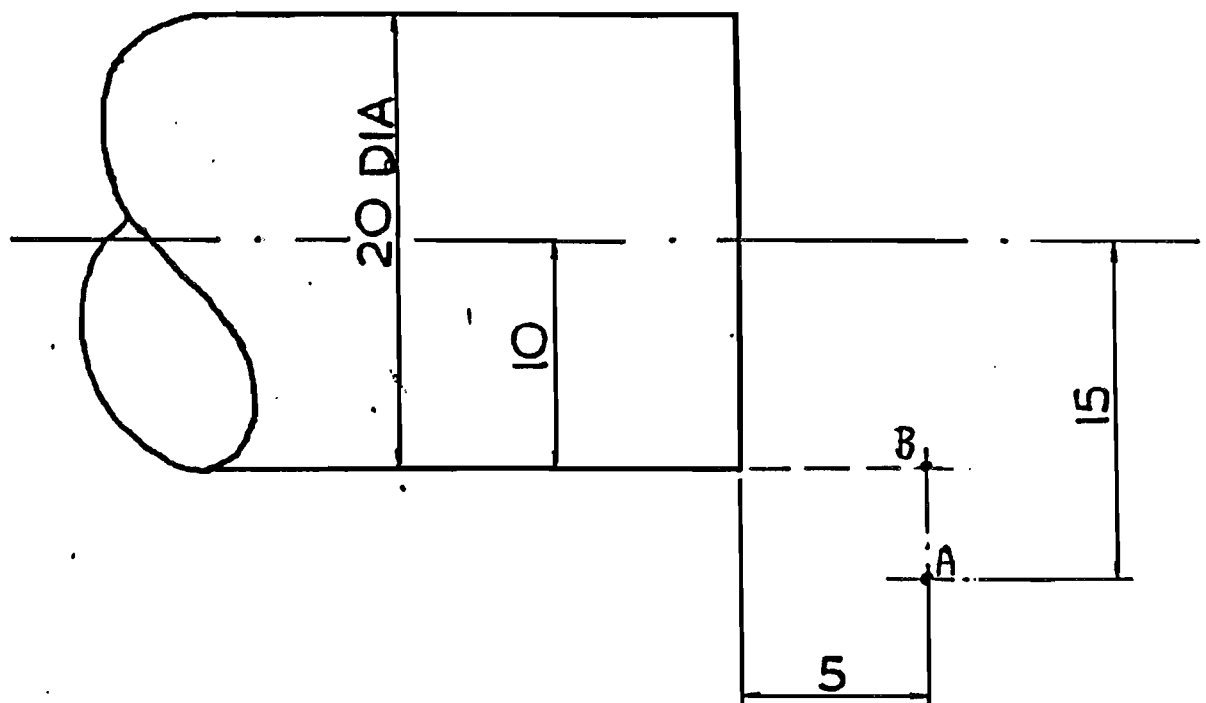
An example of absolute and incremental input for G00 rapid and G01 linear is shown overleaf.

LINEAR (G01)

The code G01 is used as a cutting movement and acts in the same way as rapid traverse (G00) the only difference is that a feedrate must be entered to tell the STARTURN at what rate to move the slides.

Once a feedrate has been input the computer retains the figure and executes all G01 linear moves at that feedrate, unless a new feedrate value is entered. This system means that as the computer will remember and, retain X Z and F (Feedrate) values, they are called 'MODAL' and need not be input each time a G00 or G01 block of program is input.

POINT TO POINT GOO, GO1



From point A: X15 Z5

Point B incremental X-5 Z0

Point B absolute X 10 Z5

CIRCULAR INTERPOLATION (CLOCKWISE G02 AND COUNTER-CLOCKWISE G03)

Circular Interpolation movements are used to produce radii. Two possible arcs are available i.e. clockwise and counter-clockwise (cw/ccw). The direction of the arc can be determined by taking a plan view of the machine and looking in which direction the tool will be moving during the execution of the block. It can be seen, therefore, that a clockwise (G02) arc will produce a convex radius, whereas a counter-clockwise arc will produce a concave form. These are shown in the diagram on the following page.

To program an arc adopt the following procedure:-

Before an arc can be produced, the tool must first be positioned at the start point for the curve, this is done by means of the previous block, i.e. if a radius is to be produced at Block 30 in the program then Block 29 would take the tool to the start position.

Four items of information are required to be input to complete the circular block.

Enter either G02 or G03 to select the correct sense for the arc being machined.

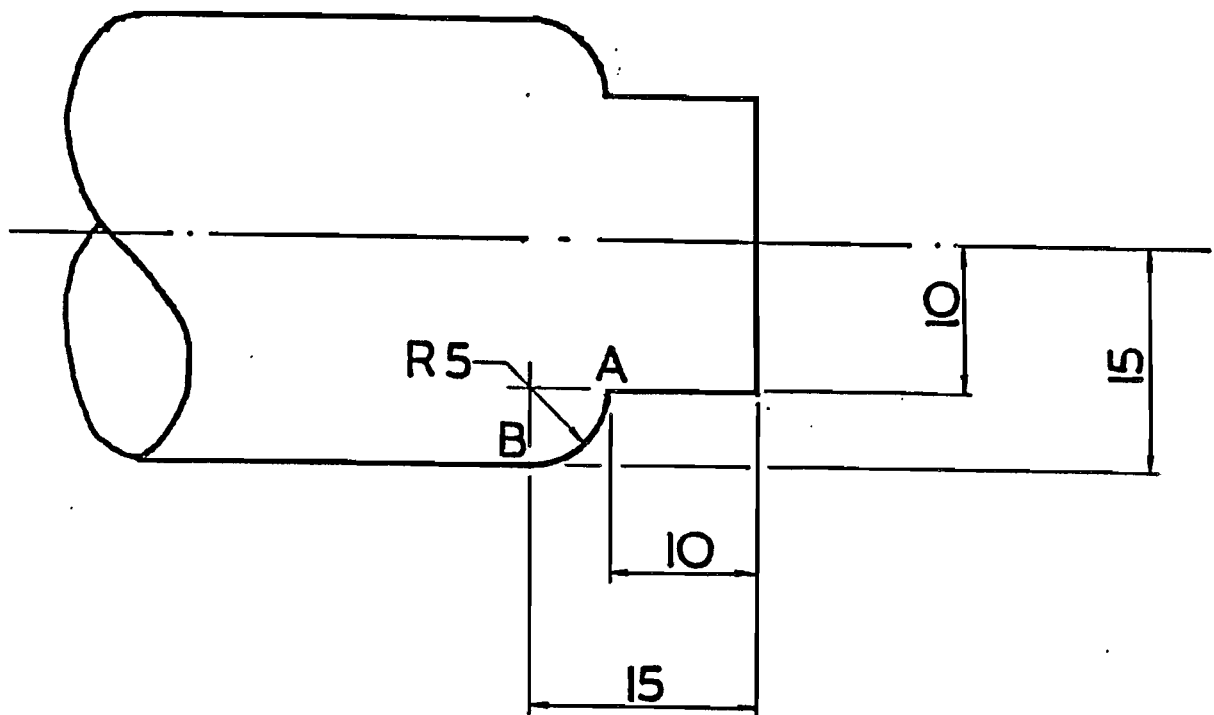
Next input the X destination point and Z destination point. These are the positions in X and Z where the tool will end at the completion of the arc.

Input the 'R' value, this represents the radius of the curve being produced.

Finally if required a 'F' feedrate figure may be input, if this should be left blank then the previous feedrate will be selected.

STARTURN will allow for a radius of an arc whose centre point is outside the limits of the machine - providing the start and end points are within those limits.

CIRCULAR INTERPOLATION

ABSOLUTE

With tool at pos. A
 X=10,00 Z=10,00
 circular coordinates
 X 15,0 Z-15,0
 RAD (I)=5,0 'G02' CW

INCREMENTAL

With tool at pos. A
 circular coordinates
 X 5,0 Z-5,0
 RAD (I)=5,0 'G02' CW

DWELL (G04)

The DWELL facility halts the movement of the tool for a specific number of seconds, the value of which can be between 1 and 99 seconds.

The function may be used for example when the tool may be left in position at the bottom of a recess or groove, to improve the surface finish.

The only information required to complete the block is the time duration in seconds, this value is prompted by the computer at the time the block is input.

NOTE:

The DWELL facility must NOT be used for tool changing purposes. Tool changes are actioned with an M06 code (see page 37)

If a tool change is made during a G04 DWELL block the correct tool offsets will not be taken up by the computer, and a tool to workpiece collision may result.

DO-LOOP (REPEAT LOOP) G73, G06

Should the operator require the same operation to be performed a number of times, then the DO-LOOP facility is of prime importance. The function need only be performed once, and the computer told how many times to repeat the operation. To specify a DO-LOOP, adopt the following procedure:-

As DO-LOOPS should be programmed in incremental format, the first block of the repeat procedure will be G91 to change the format to incremental. Secondly, the code G73 START DO LOOP is entered. The only data to be input is the X value, which represents the number of times the loop is to be repeated. The next lines of program represent the operation to be performed, this could be, for example, a roughing down operation, or facing operation. When these blocks of program have been entered, input a G06 END DO to specify the end of the loop procedure. Finally, if the format for the rest of the program is absolute, change the format back by entering a G90.

The way in which the function works is that the computer reads the START DO LOOP block and executes the operation to be repeated. When the computer reaches the END DO command, it will return to the start of the loop again. It does this until the correct number of loops has been executed.

In the following example, a bar of 20mm diameter requires turning to a finished diameter of 10mm by 25mm long. The program shown will accomplish the procedure.

In this DO-LOOP the tool moves towards the centre line of the billet, a distance of 1mm, and a cut is taken for a length of 25mm. The tool is then retracted by 0.5mm to avoid leaving trail lines on the work surface. The tool now returns to the Z start position, followed by an X movement of 0.5mm towards the centre line. This operation is then repeated 5 times, leaving the bar at the correct diameter of 10mm.

The time savings are obvious; rather than having to define each individual tool movement for the 5 passes, which would take 20 blocks of program, the whole procedure is programmed in only 8 blocks.

In the above example it can now be seen why DO-LOOPS are programmed incrementally - an absolute DO-LOOP would simply execute each cut at the same position.

NOTE: A DO-LOOP may not be contained within another loop
i.e. NESTED, one loop must be finished before a second loop can be started.

SUBROUTINES G28, G05, G65

The Subroutines function allows for a group of operations to be re-executed more than once within a program, and as many times as required. The Subroutine function must not be confused with the Do Loop facility. The example in Fig.IV highlights the differences.

A Subroutine must always be defined at the end of the program, after the M02 End of Program statement. It can then be called into use at any point in the program, by use of the G65 Subroutine Call command.

To define a Subroutine, adopt the following procedure:-

The code G28 is used to declare the start of a Subroutine. When input, you will be required to enter a label - this represents the Subroutine identity number, which can be any number of your choice. e.g. label 2

The next blocks of the program are those to perform the operation required.

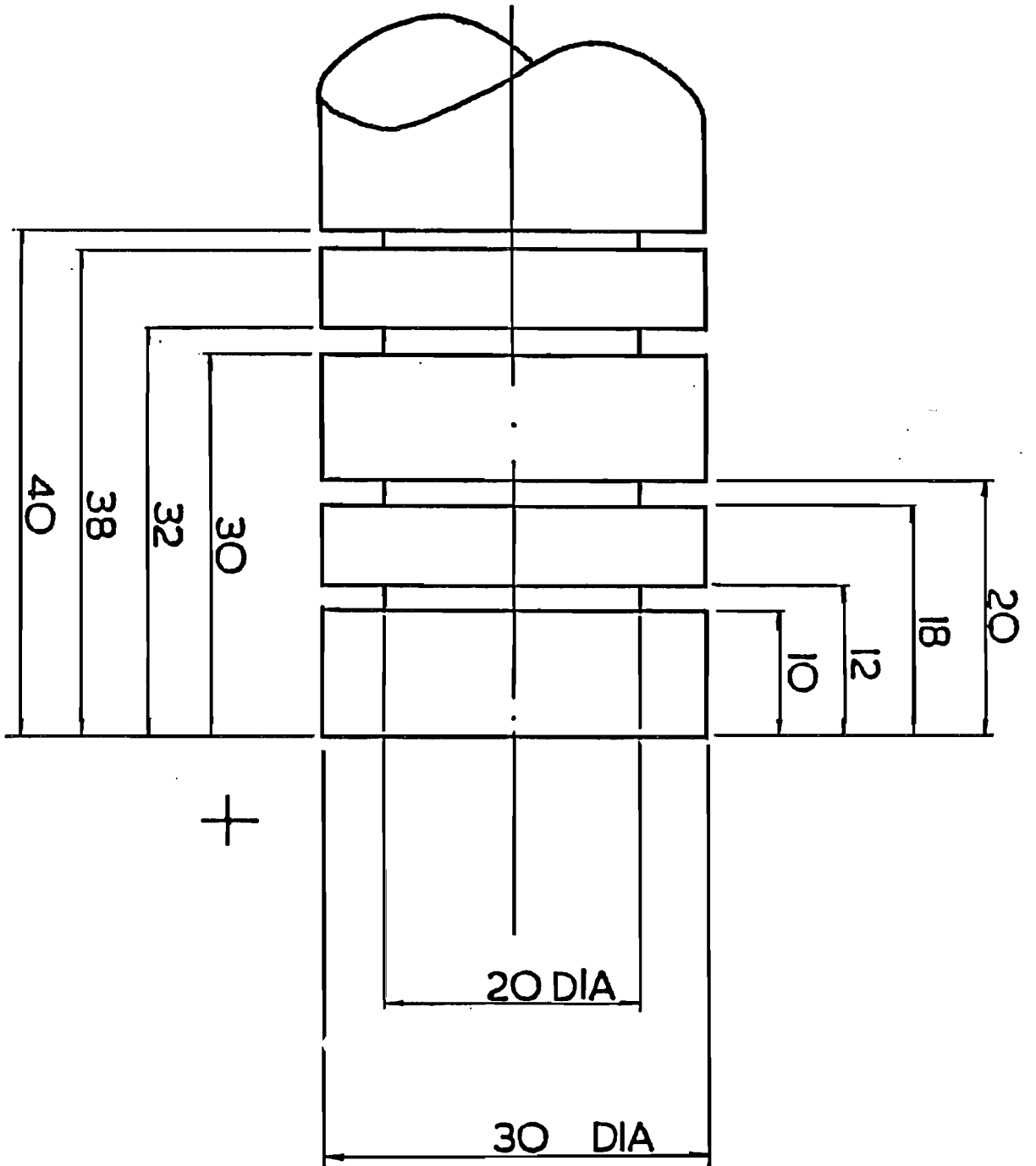
NOTE: A Subroutine should be programmed incrementally - when defined in absolute mode it would be executed at the same place each time. Therefore, the first block of program after the G28 should be an incremental block (G91). A code of G05 End Subroutine will signify the end of a Subroutine. The block before this code should contain a G90 to return to the format being used in the rest of the program (if incremental format is being used throughout the program, then this is not necessary).

The Subroutine, now it is defined, can be called into use at any time within the program, by use of the G65 Subroutine call function, which will require the Subroutine label number to be entered. The same Subroutine can be used any number of times, when required.

In the example the Subroutine, when called, will produce two grooves, four grooves are turned by calling up the Subroutine and re-executing it at a different position.

[illegible]

SUBROUTINE



PROGRAM SCALE (G20)

The program scale facility allows for a program whose physical dimensions are too large for the STARTURN machine to execute, to be scaled down to within those limits. It can also be used to scale up a program to a larger size.

Programs can therefore be directly transferrable from STARTURN8 to STARTURN4 by entering the appropriate scale value at the beginning of the program.

When inputting a G20 program scale block in a program, the computer will prompt for a scale value in the range of 0.01 to 10 times.

This value represents the number of times the numeric values in the program will be scaled i.e. if 0.5 is entered all the program will be executed at half size.

To increase the size of the program enter a scale figure larger than 1.

Should two scales be used in a program then the one entered last will be active and the first will be overwritten.

It must be noted that if a component is scaled down, the size of the blank billet must be scaled down accordingly.

A program scale will not affect the operation of the graphic simulation as this has its own scaling factor (see page 44).

THREADING CYCLE (G33)

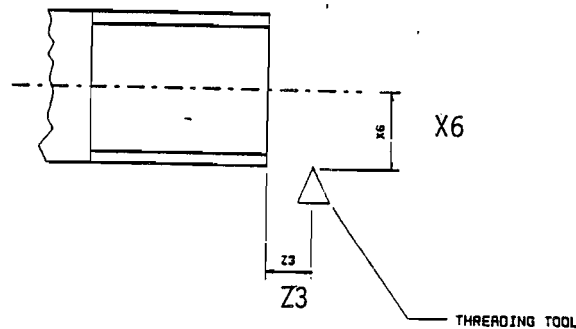
The G33 THREADING CYCLE allows for screw threads of any pitch and depth to be cut on components.

The cycle is known as a 'CANNED CYCLE'. This means that when all the information about the screw thread is input into the computer, the machine will cut the screw thread to those specifications.

The procedure for executing a screw thread is as follows:-

The thread to be cut is a M12 x 1.75 x 20 mm long.

The tool must first be positioned at the radius of the thread and approx 3mm away from the start. This is to give the tool time to get to the correct feed for the pitch.



The next block is the G33 which prompts for the depth of the thread. The root dia for the thread is 9.8530 therefore the depth is $\frac{12-9.8530}{2} - 1.0735$

The X value to be input into computer = root radius = $\frac{9.853}{2}$
= 4.926

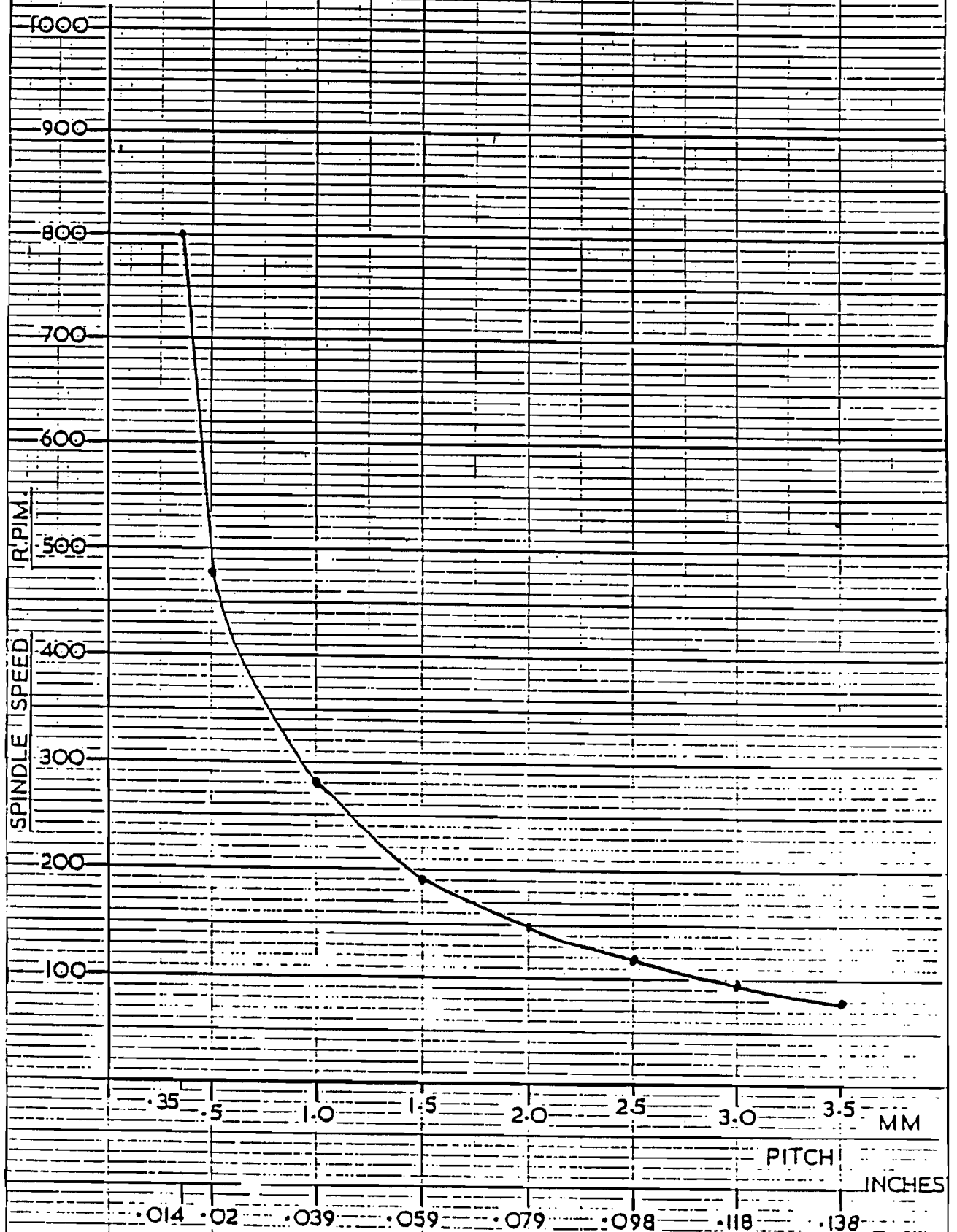
The Z value to be input into the computer represents the length of the thread. This is absolute from the starting position. In this case the length entered = 20 + 3 so a Z length of -23 mm.

The P value to be input is the pitch, in this example 1.75.

The C value is the number of cuts for the thread, this will be 35. This value varies with the depth of the thread.

The total information for the G33 is X 4.926 Z-23
P29 C35.

SPINDLE SPEEDS FOR SCREWCUTTING



PROGRAM OFFSET (G54)

The G54 program offset facility allows for the whole or part of a program to be offset or shifted to a new position.

The effect of the offset is to add the offset figure entered to the dimensions in the program.

e.g. if a G54 of X12.3 is input. The X dimensions for the rest of the program will all be increased by 12.3 mm.

The G54 could be used to provide a dry run facility away from the billet. By inputting A Z offset, the offset value is incremental, so a further offset of 12.3 will add 24.6 to the programmed dimensions.

The G54 could also be used in conjunction with a repeat loop to repeat parts of a component in a different position.

e.g. the same radii may be turned on a component with a displacement of 15 mm by entering the relevant offset figure in X or Z and repeating the move.

IMPERIAL UNITS (G70) and METRIC UNITS (G71)

As STARTURN can think in both imperial and metric units it needs to be told which are to be used in the program.

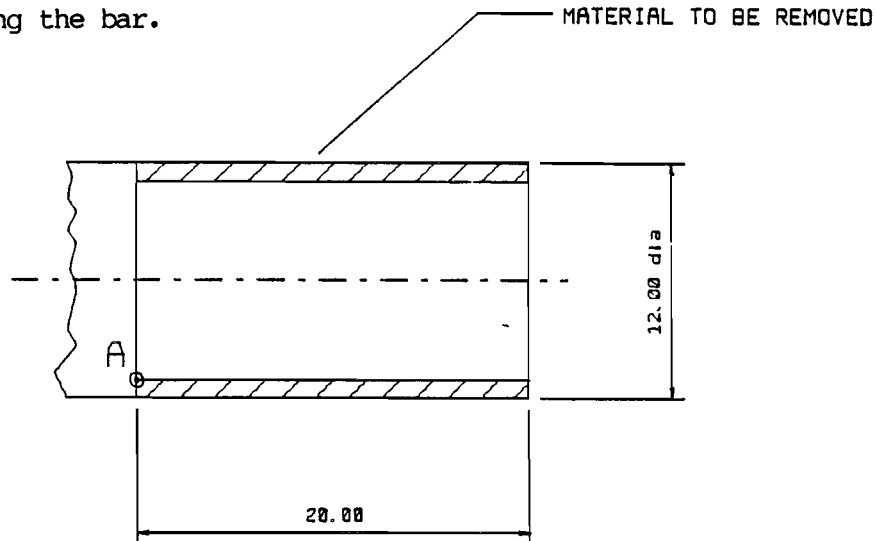
Should a G70 code be input in a program then the units from that point onwards will be imperial. The same for metric will be true for G71.

The units of a program can be changed during a program by inserting the relevant code. Should a program be required to be input in metric then the G71 at the beginning of the program need not be entered as this is the unit of measurement on which the machine defaults.

CANNED TURNING CYCLE (G84)

The canned turning cycle (G84) facility enables a complete turning operation to be accomplished in one block simply by stating the depth of cut and length in the G84 block.

e.g. in the following example a cut of 1 mm deep and length of 20 mm is to be taken along the bar.



To execute the turning cycle the tool must be positioned on the diameter and approx 2-3 mm away (to give the tool time to build up to the correct feedrate) in this case it will be 2 mm.

The X and Z positions prior to the canned cycle are X6 Z2.

The canned turning cycle block is now input. This requires the X and Z positions at the end of the cut (position A), i.e. in this case x 5 Z-20. The tool will remove the material and return to the start position of X6 Z2.

The program would be as follows

```
N10 G00 RAPID TRAV X6 Z2 (rapid to start posn)
N11 G84 CANNED CYCLE X5 Z-20 F100 (canned cycle execution)
```

CANNED TURNING CYCLE (cont.)

The previous example was executed in absolute mode. In incremental all the values would be taken from the starting tool position (X6 X2) the resulting program in incremental would be

```
N10 G00 RAPID TRAV X6 Z2 (start position)
M11 G84 CANNED CYCLE X-1 Z-22 (incremental values)
```

As it can be seen from the above examples the canned turning is a valuable time and block saver. To do the same operation without using the canned cycle would have taken 5 blocks whereas with the cycle the program was done in 2 blocks of program.

M CODES (MISCELLANEOUS FUNCTIONS)

The M functions are used to control the spindle, tool changes and program stops. They operate as follows:

MO3 SPINDLE FWD

On entry of MO3 the computer will prompt for a spindle speed value, the range of which is displayed on the screen.

When the MO3 block is encountered in the program the operator will be prompted to set the spindle speed on the machine to the one programmed. This is done by pressing the green spindle start button and adjusting the speed using the thyristor knob.

MO5 SPINDLE STOP

The code MO5 will prompt that the spindle be stopped. This code is used at the end of the program and prior to a tool change.

MO6 TOOL CHANGE

On an entry of MO6 the operator will be prompted for a tool number in the range of 1 - 9. Once the program is running and a tool change is detected the operator will be prompted to fit the correct tool in the toolpost. The tool offsets for that tool will then be taken up on the machine as instructed by the computer.

MO2 END OF PROGRAM

This code must be entered as the last command in the program.

NOTE: Any subroutines must be programmed after the MO2 end of program statement.

SECTION 10

ENTERING YOUR PROGRAM INTO THE COMPUTER

Once written the program can be entered into the computer ready for simulation, execution or printing.

To, input the program first select the 'NEW PROGRAM' option to clear the memory of any existing program. The selection can be made by highlighting the option using the cursor up and down keys and pressing RETURN.

Next take option 'EDIT PROGRAM' by adopting the same procedure.

The screen will display the G codes in the right hand window of the screen, along with the editing options at the bottom left, as shown below.

EDITOR	PROGRAM	TEMP	CODES
			G00 FAST TRAVERSE
			G01 LINEAR
			G02 CIRCULAR CW
			G03 CIRCULAR CCW
			G04 DWELL
			G05 SUB END
			G06 END LOOP
			G20 PROGRAM SCALE
			G28 SUB START
			G33 THREAD CYCLE
			N001
SCROLL WITH ARROW KEYS			
I INSERT D DELETE			
E EDIT S SEARCH H HELP			
G CODES ESC EXIT			

The functions of the options displayed at the bottom of the screen is as follows.

SCROLL WITH ARROW KEYS

UP and DOWN arrow keys on the keyboard allow a program to be scrolled on the screen. This allows the program to be listed on the screen at the speed the operator desires.

A program block which requires editing can be moved into position by use of these arrow keys, these are located on the right hand side of the computer keyboard.

INSERT

Pressing the I key takes the computer into insert mode, it is this mode which allows for a program to be input.

On Pressing I the following message will be displayed.

```
ENTER G OR M CODE  
FOR COMMENTS TYPE (  
ESC TO QUIT INSERTING
```

It is now possible to input the CNC part program by entering a G or M code.

To make the program easier to understand during future inspection the facility has been built into the system to allow comments to be typed into the program as a reminder as to what the functions of the program are doing. The comment facility can also be used at the beginning of the program to state the length, dia and type of material being cut etc.

To enter the comment into the program, in place of typing G or M, enter '(' bracket, this will allow for the text to be input, end the text by pressing return to accept.

Pressing the Escape key when prompted by the above message, will take the operator back to the editing options menu.

When inputting the G and M codes into the computer to build up a program the screen prompts for the information it requires to complete the block, e.g. if G00 rapid traverse is entered by typing G00 followed by return, then the computer prompts for the X and Z values. These values can be input in any order. When complete type 'E' to end the block and go onto the next block. The screen input for G00 rapid traverse will look like this:-

EDITOR	PROGRAM	TEMP	CODES
			G00 FAST TRAVERSE
			G01 LINEAR
			G02 CIRCULAR CW
			G03 CIRCULAR CCW
			G04 DWELL
			G05 SUB END
			G06 END LOOP
			G20 PROGRAM SCALE
			G28 SUB START
			G33 THREAD CYCLE
			G54 OFFSET
N001	G00 FAST TRAVERSE		
	X Z		
PRESS ONE OF XZ			
E ENDS EDIT			

With all the G and M codes prompts will appear on the screen to assist in programming. The codes along with their respective prompts are listed below.

PROMPT

G00	RAPID TRAVERSE	X CO-ORDINATE	Z CO-ORDINATE		
G01	LINEAR	X CO-ORDINATE	Z CO-ORDINATE	F FEEDRATE	
G02	CIRCULAR CW	X CO-ORDINATE	Z CO-ORDINATE	F FEEDRATE	R RADIUS
G03	CIRCULAR CCW	X CO-ORDINATE	Z CO-ORDINATE	F FEEDRATE	R RADIUS
G04	DWELL	SECONDS (1 - 99 RANGE)			
G05	END SUB	NO INPUT REQUIRED			
G06	END DO-LOOP	NO INPUT REQUIRED			
G20	PROGRAM SCALE	SCALE (0.01 TO 10 VALUE RANGE)			
G28	SUBROUTINE START	LABEL NUMBER			
G33	THREADING	X CORE RADIUS	Z LENGTH	P PITCH	C NUMBER OF CUTS
G54	OFFSET	X OFFSET	Z OFFSET		
G65	CALL SUB	LABEL NUMBER			
G70	IMPERIAL UNITS	NO INPUT REQUIRED			
G71	METRIC UNITS	NO INPUT REQUIRED			
G73	START DO-LOOP	NUMBER OF TIMES (COUNT 1-99 RANGE)			
G84	CANNED TURNING CYCLE	X FINISH RADIUS	Z LENGTH	F FEEDRATE	
G90	ABSOLUTE FORMAT	NO INPUT REQUIRED			
G91	INCREMENTAL FORMAT	NO INPUT REQUIRED			
M02	END OF PROGRAM	NO INPUT REQUIRED			
M03	SPINDLE START	SPINDLE SPEED			
M05	SPINDLE STOP	NO INPUT REQUIRED			
M06	TOOL CHANGE	TOOL NUMBER			

D DELETE

The delete function allows blocks of program to be erased from the program. To remove a block it must first be positioned at the bottom of the screen by use of the UP and DOWN cursor keys.

Once in position pressing the 'D' key will erase the block. The rest of the program however will be renumbered automatically from that point onwards by the computer.

NOTE:

Use this function carefully as once a program block has been deleted it is not possible to retrieve it, and the whole block will have to be re-input.

E EDIT:

Pressing the E key at the program editing stage allows for individual values within program blocks to be amended e.g. should the Z value in block 20 of a program require changing, it must first be positioned at the bottom of the screen by means of the cursor up and down arrow keys or by use of the search facility (see below).

Once in position at the bottom of the screen, pressing the 'E' key will prompt for the new value to be changed, once Z has been amended press E again to accept the new data.

S SEARCH

The 'S' SEARCH function allows a particular block of program to be found and displayed at the bottom of the screen ready for amendment or deletion.

On entry of 'S' the operator will be prompted to input the desired block number of program to be found, when found it will be displayed at the bottom of the program listing section of the screen.

G CODES

Due to the limitation of the BBC the full list of G and M codes cannot be displayed at the same time. Pressing the G key will allow for the rest of the codes to be shown in the right hand window of the screen, successive presses of G will toggle between the two lists.

HELP

Pressing 'H' will display the G and M codes on the screen along with an explanation of each. Successive codes can be displayed by pressing the space bar. Once the desired code explanation has been found pressing 'ESCAPE' will return to program editing.

'ESC' EXIT

Pressing the escape key quits the program editing function and returns to the STARTURN main menu.

SECTION 11

GRAPHIC SIMULATION

When the program has been typed into the computer or loaded into memory from disc (see disk utils section) it can be simulated on the screen by means of the graphical simulation option.

To run the simulation adopt the following procedure from the STARTURN main menu take the 'SETTINGS' option by highlighting it using the UP and DOWN cursor control keys and pressing return to accept.

The screen will now look like the one displayed below.

EDITOR	PROGRAM	TEST	SETTINGS
			LENGTH
			00.000
			DIAMETER
			00.000
			BORE DIAM
			0.000
			SCALE
			1.0
			UNITS
			METRIC
			SOUND
			NO
			HELP
N001			

The various simulation options available to the operator are shown down the right hand side of the screen.

The values displayed may differ from the one shown above, this is because the computer stores the settings along with the program, when it is stored on disc (see disc util section) and these settings will be loaded back, into memory each time. When the 'NEW PROGRAM' option is taken the simulation settings are not cleared and are remembered from the previous program.

The functions along with an explanation of each is given below.

LENGTH

The length option allows for the length of the billet to be used for the simulation. The length entered represents the amount of material protruding from the chuck.

When the length has been input press return to accept.

DIAMETER

The diameter option, selected by using the cursor UP and DOWN keys to highlight, and return to accept, allows for the diameter of the bar being used to be input, once entered. Press return to accept the value.

BORE DIAMETER

The bore diameter option when selected allows for the billet or bar to be pre-drilled prior to the simulation, to allow for boring operations to be done. Once the bore diameter is successfully input the billet will appear drilled when the simulation is started, the bore is for the full length of the component.

SCALE

The scale option when selected allows for the simulation scale to be increased or decreased, depending on the figure input into the field. Once run the simulation scale may be changed to give a more acceptable figure. Should too big a value be input then the simulation will be scaled outside the limits of the physical creen and the result will not be seen.

UNITS

The units function allows for the simulation to be changed from metric to imperial and vice versa.

The conversion does not affect the program in the memory of the computer.

SOUND

The facility has been built into the system to allow the cutting action in the simulation to produce sound from the computer speaker, a sound will also be produced should the Z axis be programmed to be in collision with the chuck jaws. Successive presses of the return key during the sound selection process will turn the sound on and off.

HELP

The HELP option displays on the screen the meaning of all the simulation settings options. To list through them press the space bar and to return to normal operation press 'ESCAPE'.

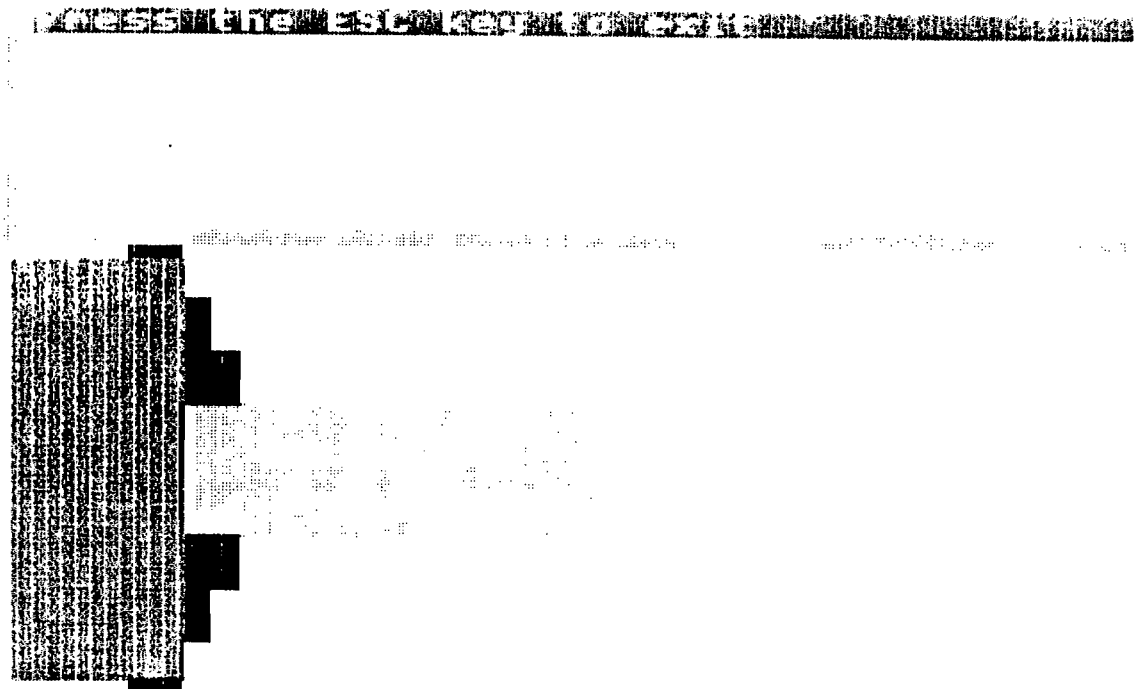
EXECUTING THE SIMULATION

To run the toolpath simulation on the computer monitor, first ensure that the 'SIMULATION SETTINGS' procedure has been done, and then select the 'SIMULATION' option from the STARTURN main menu.

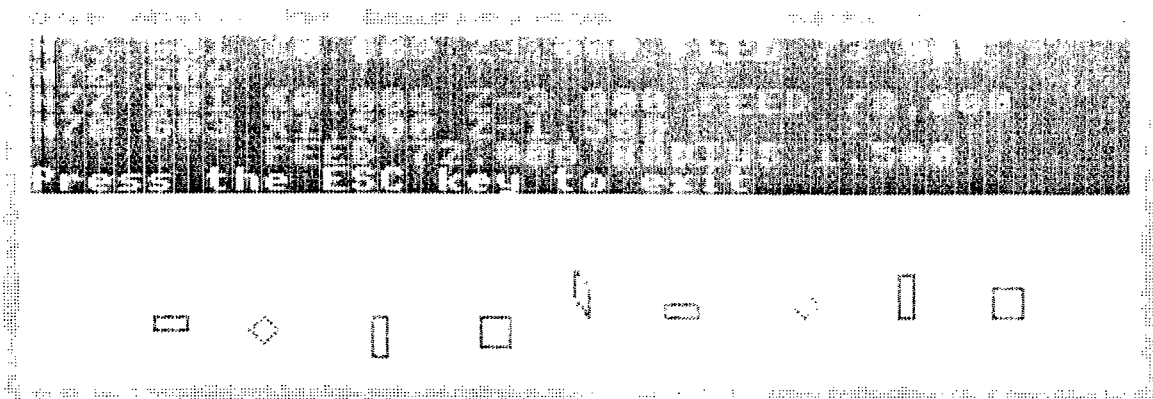
The chuck and billet will be drawn in the bottom half of the screen. The program listing will be shown at the top, with the tools in between the two.

As the simulation is running the program will prompt for the tool it will use depending on the tool number programmed. The simulation tools are numbered 1 to 10 from the left. Thus if a threading tool is to be used in the program it must be designated as tool number 3. This is to ensure the simulation chooses the correct tool.

The initial simulation screen will look like the one shown below.



As the simulation process progresses the screen will display the following:-





SECTION 12

DISK UTILITIES

The Disk utilities option allows for programs to be saved to and loaded from disc. Also programs can be re-named and deleted from the disc. The full list of utilities is explained in detail below.

To enter into the disc utilities, highlight the option on the main menu, by use of the cursor UP and DOWN arrow keys on the computer keyboard, and press 'RETURN'. The screen will display the following:-

EDITOR	PROGRAM	PROG 1	DISC UTILS
			CATALOG LOAD PROG SAVE PROG RENAME PROG DELETE PROG SELECT DRIVE HELP

ARROW KEYS MOVE BAR
RETURN SELECTS OPTION

CATALOG

The Catalog function allows for a list to be displayed on the right hand section of the screen showing all of the part programs present on the disc.

LOAD PROGRAM

The LOAD program option will allow for a previously saved program to be loaded back into the memory of the computer. When the option is selected by highlighting with the cursor, the programs will be displayed in the right hand window of the screen. To load a program it must first be highlighted by use of the cursor UP and DOWN keys, a press of the 'RETURN' key will then load the program. The program name will then be displayed at the top of the screen.

SAVE PROG

The SAVE program option allows for a program in the memory of the computer, which may be a newly typed program, or one previously loaded from disk, to be stored onto the disc.

The option must be selected by highlighting the option by using the cursor UP or DOWN keys. When the RETURN key is pressed the operator will be prompted to input the program name. This must be any name up to a maximum of seven characters. The program will be saved once the 'RETURN' key is pressed.

RENAME PROG

This option allows for programs already existing on the disc to have their names changed.

To change a program name, once the option has been selected the programs residing on the disc will be displayed down the right hand side of the screen. Select the program to be changed. The computer will then prompt for the new program to be input. When the 'Return' key is pressed the program will be stored to itself under the new name i.e. it will be over written.

DELETE PROG

The delete program option allows for programs to be removed from the disc to allow space for new ones. To delete a program select the 'DELETE PROG' option from the 'DISC UTILS' menu. The programs will be displayed down the right hand section of the screen. Select the program to be deleted by using the UP and DOWN cursor keys on the computer keyboard. When the 'RETURN' key is pressed the program will be deleted from the disc. Executing a disc 'CATALOG' will prove that the program has been removed.

NOTE: Use the delete option with care, as once a program is deleted it cannot be retrieved.

SELECT DRIVE

The select drive option is only used when a twin disk drive system is used. The way it works is to use Drive 0 as the operating drive, thus the STARTURN master disc is placed in this drive. Drive 1 can hold a data disc onto which can be stored the programs. This allows more flexibility as discs do not require swapping in Drive 0 should a data disc be needed.

HELP

The Help function lists all the disc utilities available along with an explanation of their meaning, the list can be advanced on the screen by pressing 'SPACE' normal operation will resume by pressing the 'ESCAPE' key.

SECTION 13

PRINTOUT

The Printout option selected from the 'STARTURN' main menu by use of the cursor UP and DOWN keys and pressing 'RETURN' allows for a computer part program listing to be obtained on an Epson Printer connected to the centronics parallel printer port. The program print produced looks like the one should below.

DENFORD MACHINE TOOLS LTD.
STARTURN PROGRAM DMTTEST

```
(STARTURN TEST PROGRAM
(This program should
(be run on arrival of
(your new Starturn
(lathe.
(Please ensure that
(you have everything
(connected correctly.
(This includes a cable
(from BEC to Starturn
(and a security device
N001 G90 ABSOLUTE
N002 G71 METRIC
N003 G20 PROGRAM SCALE
      SCALE 1.0
N004 G00 FAST TRAV'SE
      X 11.000 Z 0.000
(call cycle twice.
(use tool 1 in simul.
N005 M03 SPINDLE FWD
      650 RPM
N006 M06 TOOL CHANGE
      TOOL 1
N007 G65 SUB CALL
      LABEL 2
N008 G00 FAST TRAV'SE
      X 0.000 Z-0.500
N009 G65 SUB CALL
      LABEL 2
(canned turning cycle.
N010 G90 ABSOLUTE
N011 G00 FAST TRAV'SE
      X 10.000 Z 0.000
N012 G73 REPEAT LOOP
      3 TIMES
N013 G91 INCR'TAL
N014 G84 CANNED CYCLE
      X-0.500 Z-25.000
      F 78.00
N015 G00 FAST TRAV'SE
      X-0.500 Z
N016 G06 END LOOP
N017 G90 ABSOLUTE
N018 G00 FAST TRAV'SE
      X 11.000 Z-26.000
N019 G65 SUB CALL
      LABEL 4
N020 G90 ABSOLUTE
N021 G00 FAST TRAV'SE
      X 13.000 Z-5.000
(imperial subroutine
N022 G65 SUB CALL
      LABEL 3
N023 G90 ABSOLUTE
(3mm radii subroutine
N024 G00 FAST TRAV'SE
      X 10.000 Z 1.000
```

SECTION 14

HELP SCREEN

The HELP SCREEN option, accessed by highlighting, using the cursor UP and DOWN keys and pressing 'RETURN' is designed as an aid to programming.

When entered into the option will display all the available 'G' and 'M' codes and an explanation of each. This gives an indication as to what function each code may be put. To scroll, the 'G' and 'M' codes press the 'SPACE BAR', and to quit the option press the 'ESCAPE' key.

During the listing the screen will display the following:-

EDITOR	PROGRAM	PROG 1	MAIN MENU
<u>G00 FAST TRAVERSE</u>			
MODAL			EDIT program
e.g.			DISC UTILS
G00			NEW PROGRAM
X2.220 Z1.330			PRINTOUT
			MANUAL
			SIMULATION
Moves the tool to the programmed			SETTINGS
X and Z position at 400mm/min			HELP SCREEN
			EXIT SYSTEM
Press SPACE to continue			

SECTION 15

MANUAL CONTROL & PROGRAM EXECUTION

The manual control option which can be selected from the STARTURN main menu, by moving the brackets by means of the ↑ up and ↓ down arrow keys on the computer keyboard and pressing ENTER .

In this option the computer controls the machine, and the operator is able to set the tool length offsets, and execute the program.

When selected the following menu will be displayed.

BBC	STARTURN	PROGRAM	PROG1
MANUAL CONTROL			
X	Z	SPINDLE SPEED	
9.000	2.000	0	
FEED RATE = 40MM/MIN TOOL 0 MM/MIN TOOL 0			
METRIC UNITS		CONTINUOUS JOG	
F0 = JOG MODE		F1 = METRIC/IMPERIAL	
F2 = FEED		F3 = FEED	
F4 = EXIT MANUAL		F5 = EXECUTE PROGRAM	
F6 = TOOL OFFSETS		F7 = TOOL CHANGE	
F8 = DATUM X		F9 = DATUM Z	

The screen displays the X and Z position of the slides. Until the tool offsets have been correctly set the figures are meaningless. The spindle speed is also displayed. This will show the correct spindle speed as the speed is adjusted by use of the spindle thyristor knob.

The feedrate value is also displayed, the initial value is set to 400mm/min. The method of changing the feedrate is explained in the following section.

The current tool is shown, this automatically registers as tool 0.

Finally the units of measurement are displayed. The default value is 'METRIC', and the mode of JOG is shown, this defaults to CONTINOUS - explained in the next section.

THE NUMERIC KEYS

In the bottom half of the screen are displayed the functions represented by the red function keys at the top of the computer keyboard. Their usage within the STARTURN software is described below.

'F0' JOG MODE

The '0' key changes the JOG mode of the machine. When first turned on the job mode is displayed on the screen as 'CONTINOUS'. This means that when the cursor keys on the keyboard are pressed the tool will move in that direction until the key is released.

By changing the feed to JOG mode by pressing the '0' key the tool will only jog by 0.01 mm on each press of the arrow key.

This is to allow the tool to be moved slowly to the component to avoid a tool collision, when setting the tool offsets the mode can be changed back to continous by pressing 'F0' again.

'F1' METRIC/IMPERIAL

When the manual control function is taken the machine units default to metric. The units can however be changed by pressing 'F1'. When pressed the screen will display imperial units, and the X and Z figures on the screen will be converted.

The units must be set to inch or metric according to the units programmed, to enable the display of the X and Z dimensions to be shown correctly.

'F2' FEED <

The F2 key changes the manual feedrate by decreasing it. When pressed the feedrate value displayed on the screen will be reduced. This is to allow for a slower rate of feed to be used when turning the diameter of facing the billet during the toolsetting procedure.

When first selected the feedrate defaults to 400mm/min.

'F3' FEED >

The 'F3' function key acts in the opposite manner to F2 by increasing the manual feedrate. The maximum the feed can be increased to is 1200 mm/min.

The maximum feed on the X axis is however 400mm/min and any higher feed will automatically be overridden to 400mm/min should the 'X' axis cursor keys be pressed.

'F4' EXIT MANUAL

The finished manual control function quits manual control and returns the operator to the main menu.

'F5' EXECUTE PROGRAM

Upon pressing the '5' function key the program will be executed on the machine. The computer will request that the correct tool be placed in the toolpost at the appropriate time, when a M06 tool change command is detected in the program.

The same procedure will occur for a M03 spindle forward command, in this case the computer will prompt for the spindle speed on the machine to be set to the same value as programmed.

In both the above cases i.e. when the tool has been changed or, spindle speed set the computer requests that the 'RETURN' key be pressed, to enable the rest of the program to be executed.

NOTE: Before the program is executed the tool offsets must be set to enable the program to run correctly. (see Tool Offsets section). Should any problem occur during the program, a tool breakage for example, and the execution of the program needs to be stopped immediately. Then press the red emergency, stop button on the right hand front of the machine.

If pressed the emergency stop button can be unlocked using the key.

NOTE: Pressing emergency stop will effectively counteract the tool offsets. Tool zero needs to be reset, to continue with the program with the correct settings. (see Tool Offsets page 60).

'F6' TOOL OFFSETS

The tool offsets function allows for the amendment of the tools that have been set. A component may have the length and diameter slightly altered to allow for tool wear compensation, or to make length and diameter changes without affecting the actual CNC Part Program. The method of tool adjustment is described in the 'SECOND OFF' section of the manual.

'F7' TOOL CHANGE

The 'F7' set tool number function allows for the different tools to be used in the program to be selected for setting. This procedure is described in detail under the 'OFFSETS' section of the manual.

'F8' DATUM Z

The 'F8' DATUM Z function allows the Z zero (the face of the billet) to be logged for each of the tools used in the program. When the tool is touched onto the end of the billet and the 'F8' key pressed the screen will display Z0 for that tool.

The full procedure is explained under the 'OFFSETS' section of the manual.

The final message displayed shows the direction the tool will move when the appropriate arrow keys on the keyboard are pressed.

'F9' DATUM Z

The DATUM Z function allows the diameter of the tool to be input as each of the tools to be used are touched onto the workpiece, when the tool tip is touched onto the diameter and 'F9' pressed the screen will register the radius. The full procedure is explained under the 'OFFSETS' section of the manual.

SECTION 16

OFFSETS

TOOL OFFSETS

Before the program can be run, each tool to be used in the program, must be set for its own X and Z zero. This is because each tool varies in the length and position when placed in the toolpost.

The first tool to be set is always Tool 0. This acts as a reference tool as all other tool offsets will be taken from this tool. Theoretically the zero reference tool should not be used for turning as it may get broken and the other offsets for other tools set will become redundant.

In a one tool program the same tool however can be used as Tool 0 and Tool 1 as both carry the same offset. Therefore if Tool 0 is to be used as Tool 1 it is only necessary to set the offsets for tool zero.

SETTING THE OFFSETS

To set the tool offsets the following procedure must be adopted.

Ensure the billet is secure in the chuck and that the tools are secure in their tool holders.

Select the first tool to be set - "TOOL 0" - by pressing the F7 "TOOL CHANGE" option from the menu, a prompt will inform that Tool 0 must be inserted and 'RETURN' pressed.

The Z zero plane (end of billet) now needs to be set by moving the tool up to the end of the bar using the arrow keys. In the 'CONTINUOUS MODE' this can be carried out at a fast feedrate.

As the tool nears the billet, the feedrate will need to be reduced to avoid tool collision. As the tool is almost in contact with the work the 'JOG MODE' can be changed to 'SINGLE STEP' by pressing the 'F0' key.

It is recommended that a pass is taken across the face of the billet. This process ensures a square reference face. Press the F9 'DATUM' Z key to set the plane as zero. At this point the Z dimension on the screen will display 0.00.

EXECUTING THE PROGRAM

After all the tools have been set the program can be executed on the machine by pressing the 'F5 EXECUTE PROGRAM' function skey.

During the running of the program should a 'M06' tool change or 'M03' spindle start code be detected by the program then in the case of 'M06' the operation will stop and the computer will prompt for the tool to be changed, when the correct tool is in postion, pressing the 'RETURN' key will continue with the operation.

In the case of 'M03' spindle speed, the operation of the program will again be suspended until the spindle speed is adjusted by means of the spindle speed thyristor knob to the speed requested by the computer. When 'RETURN' is pressed after the correct speed is attained, the operation of executing the program will continue.

When the program is executing 4 options will appear on the screen to enable the operator to manipulate the running of the program. These functions are displayed at the bottom of the screen, and they are explained below.

F0 - SINGLE STEP

F1 - NORMAL

F2 - FEED DOWN

F3 - FEED UP

F0 - SINGLE STEP

The single step function, as it suggests allows a program to be run one block at a time. After the completion of the current block the 'SPACE BAR' must be pressed to continue the operation.

It is possible to enter into the single step option halfway through a program, execute a few blocks and then return to continuous running by pressing the F1 - normal function key (explained below).

The single step function is useful for the first proof running of a program.

F1 - NORMAL

The F1 - normal option will return the operation of the program execution to a continuous mode. The function is used to return back to normal operation after F0 - SINGLE STEP.

F2 - FEED UP

The F2 - FEED UP option allows for the feed as the program is running to be overridden and increased. Each press of the F2 key will increase the feed by 10mm/min. The feed will stay overridden until a new rate is detected in the program.

F3 - FEED DOWN

The F3 - FEED DOWN option acts in the opposite way to the F2 function described above i.e. it decreases the programmed feed.

TOOL OFFSETS/EXECUTING THE SECOND OFF

After the first component has been produced and inspected, any dimensional errors can be compensated for by adjusting the tool offsets.

To inspect the offsets that were initially set prior to running the program, press the 'F6 TOOL OFFSETS' key when the computer is in the manual mode.

The following screen will be displayed.

BBC STARTURN		PROGRAM TEMP
TOOL OFFSETS (MM)		
TOOL	X OFFSET	Z OFFSET
0	0.000	0.000
1	0.100	-2.350
2	-20.750	10.150
3	0.100	1.000
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
9	0.000	0.000

RETURN EDITS HIGHLIGHTED OFFSET

FO LOAD OFFSETS F1 SAVE OFFSETS

ARROW KEYS SELECT OFFSET TO EDIT

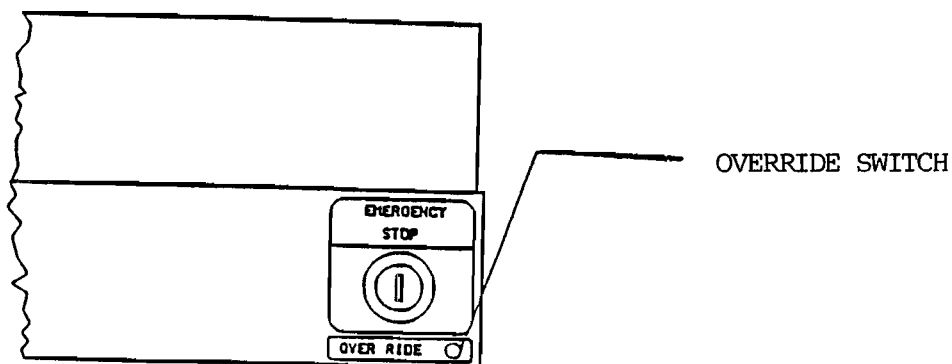
The next process is to take a skim along the outside diameter of the billet, again by using the computers' arrow keys. At this stage press F8 DATUM X key, whereupon the computer will request the diameter of the newly turned section of the billet. An accurate measurement of the turned section must be taken, either with a micrometer or verniers. Enter the measured diameter into the computer. The

X dimension on the screen will display half the value entered, as STARTURN operates on a radial system of measurement.

To set the new tool, press the F7 "TOOL CHANGE" function key on the computer keyboard. Again the computer will request that the tool be inserted in the toolpost and 'RETURN' pressed to acknowledge the tool has been inserted. The above

tool setting procedure can be repeated for all the tools to be set in the program.

NOTE: Should the slides hit the axis overtravel limit switch in the Z axis (the stop is adjustable along the bed) then simultaneously press the small reset button located under the emergency stop button and move the slide away under manual control.



AXIS LIMIT SWITCH OVERRIDE

The function keys F0 and F1 have the following function within the tool offset display.

F0 - LOAD OFFSETS

The load offsets function allows for previously saved offsets to be brought back off disc. When the option is taken all the saved offset files will be listed on the screen, the desired file can be highlighted by use of the cursor up and down keys and brought back into memory by pressing return.

When the offsets are in memory setting tool zero on the machine actions the other tools as tool zero is the reference tool and the others are set around it.

F1 - SAVE OFFSETS

When a program has been successfully executed the tools set can be saved to the disc to be retrieved and used at a later date, this eleviates the need to set all the tools again. When the option is taken the computer will prompt for a filename to be input, this filename must be a maximum of 7 characters and may be the same filename as the program.

EDIT TOOL OFFSETS

If after producing several components a diameter or length is becoming incorrect due to tool wear, a tool offset can be amended to compensate for the tool wear.

e.g. if Tool 2 is used to finish turn an outside profile and it is found to be 1mm oversize then the offset value for X must be increased by 0.5 mm giving a new value of 10.65 mm. To change the value, the offset must be highlighted by means of the cursor control keys (UP and DOWN and LEFT and RIGHT arrows are used). Once highlighted the computer will prompt for the new offset value will be prompted. When all offset changes have been done the 'ESCAPE' key will return control to the manual menu.

During the amendment procedure the screen will look like the following:-

BBC STARTURN PROGRAM TEMP

TOOL OFFSETS (MM)

TOOL	X OFFSET	Z OFFSET
0	0.000	0.000
1	0.100	-2.350
2	-20.750	10.150
3	0.100	1.000
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
9	0.000	0.000

NEW TOOL 1 X OFFSET

RETURN EDITS HIGHLIGHTED OFFSET

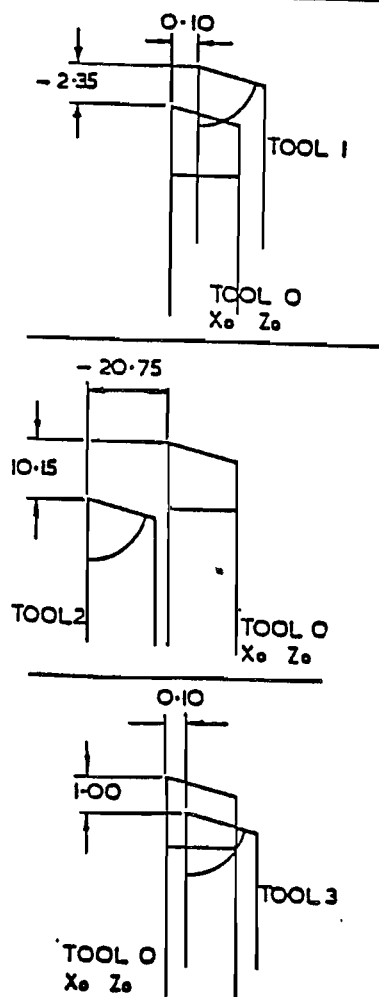
FO LOAD OFFSETS F1 SAVE OFFSETS

ARROW KEYS SELECT OFFSET TO EDIT

IN THE ABOVE CASE THE TOOL 1 X OFFSET WILL BE HIGHLIGHTED

RELATION OF TOOL OFFSETS FOR PREVIOUSLY DESCRIBED EXAMPLE

TOOL OFFSET REPRESENTATION



SECTION 17

EXIT SYSTEM

When the operation of the STARTURN lathe and software is complete. The system must be closed down logically by using the 'EXIT SYSTEM' function accessed by using the cursor UP and DOWN arrow keys and pressing 'RETURN'.

This function ensures that all the files are correctly closed. Should the computer be turned off without the exit being executed information may be lost or corrupted and the simulation settings will not be saved.

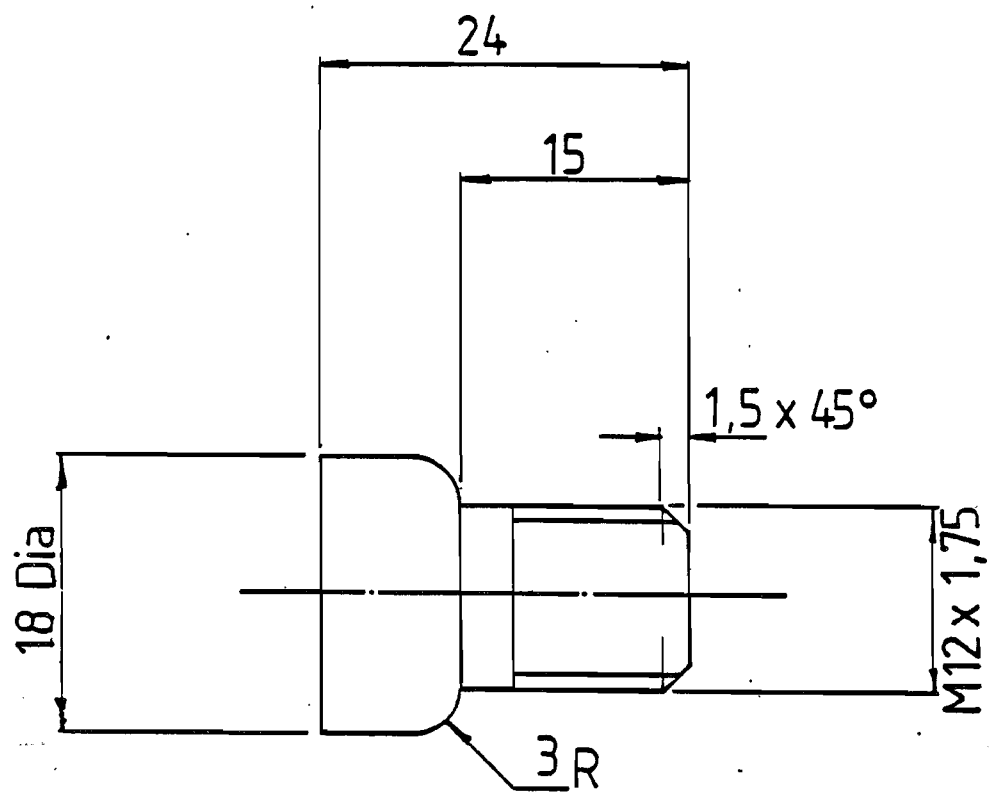
On completion of the command the computer will return to basic command level.

G & M CODE LISTINGS

G00 POSITIONING (RAPID TRAVERSE)
G01 LINEAR INTERPOLATION
G02 CIRCULAR INTERPOLATION C'WISE
G03 CIRCULAR INTERPOLATION C C'WISE
G04 DWELL
G05 END SUBROUTINE
G06 END REPEAT LOOP
G20 PROGRAM SCALE
G28 SUBROUTINE
G33 THREADING
G54 PROGRAM OFFSET
G65 SUBROUTINE CALL
G70 IMPERIAL UNITS
G71 METRIC UNITS
G73 REPEAT LOOP
G84 CANNED TURNING CYCLE
G90 ABSOLUTE
G91 INCREMENTAL
M02 END OF PROGRAM
M03 SPINDLE FWD
M05 SPINDLE STOP
M06 TOOL CHANGE

SECTION 18

PROGRAM EXAMPLES



DRAWING No.	TEST 1
DESCRIPTION	PROGRAM 1
PROGRAMME No.	1
MATERIAL	BRASS
PROGRAMME BY	T QUARMBY
DATE	06/03/85

TOOLING & SETTING DATA

Starturn

TOOL 1 R.H. KNIFE TOOL
TOOL 2 THREADING TOOL
TOOL 3 PARTING TOOL

BILLET LENGTH 40mm
BILLET DIA 19mm

N	G	X/I	Z	F	S	T	M	REMARKS
1	00	15	5					RAPID TRAVERSE
2						1	06	TOOL CHANGE (TOOL 1)
3					500		03	SPINDLE FWD
4	00	9.2	0.2					RAPID TRAVERSE
5	91							INCREMENTAL
6	73	3						DO-LOOP (3 TIMES)
7	00	-1						INCREMENTAL CUT DEPTH
8	01		-15.2	40				INCREMENTAL CUT LENGTH
9	00		15.2					RAPID RETURN
10	06							END DO-LOOP
11	90							ABSOLUTE FORMAT
12	00	5	0.2					RAPID TRAVERSE
13	01	6.2	-1	40				LINEAR
14	00	5	0.2					RAPID TRAVERSE
15	01	4.5	0.2					LINEAR
16	01	6	-1.5					LINEAR
17	01	6	-15					LINEAR
18	02	9	-18					CIRCULAR CW RAD.3
		3						
19	01	9	-20					LINEAR
20	00	10	-20					RAPID TRAVERSE
21	00	15	5					RAPID TRAVERSE
22							05	SPINDLE STOP
23						2	06	TOOL CHANGE (TOOL 2)
24					180		03	SPINDLE FWD
25	00	6	3					RAPID TRAVERSE
26	33	5.4	-10	PITCH 1.75 CUTS 3.5				THREADING
27	00	15	5					RAPID TRAVERSE
28							05	TOOL CHANGE (TOOL 3)
29							06	TOOL CHANGE (TOOL 3)
30					500		03	SPINDLE FWD
31	00	9.5	-22					RAPID TRAVERSE
32	01	-0.2						LINEAR
33	00	12						RAPID TRAVERSE
34	00	15	5					RAPID TRAVERSE
35							02	END OF PROGRAM

DRAWING No.	TEST 2
DESCRIPTION	PROGRAM 2
PROGRAMME No.	2
MATERIAL	MILD STEEL
PROGRAMME BY	S CROWTHER
DATE	15/09/85

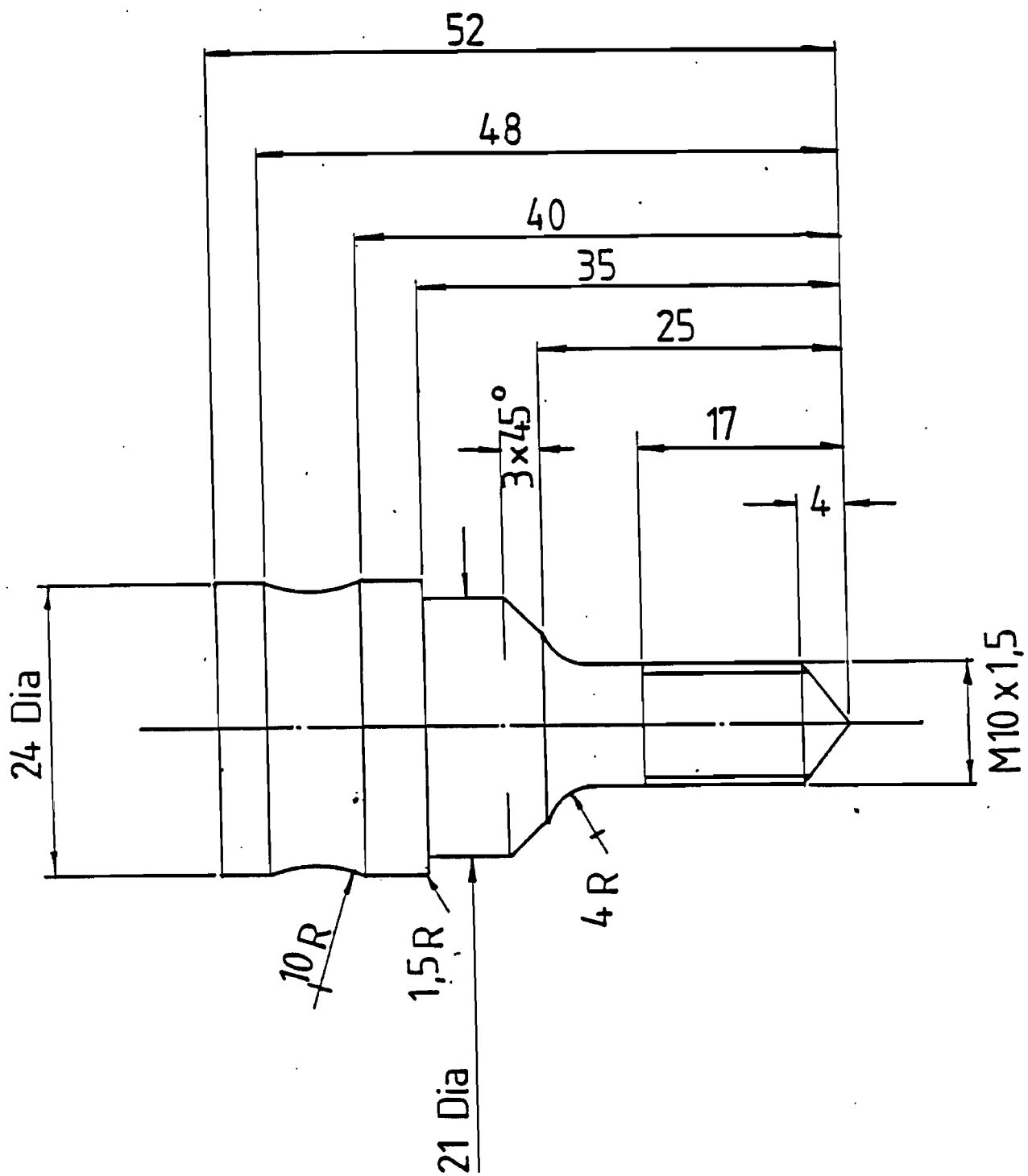
TOOLING & SETTING DATA

TOOL 1 R.H. KNIFE TOOL
TOOL 2 THREADING TOOL
TOOL 3 PARING TOOL

Starturn

BILLET LENGTH 80mm
BILLET DIA 25mm

N	G	X/I	Z	F	S	T	M	REMARKS
1	00	15	5					RAPID TRAVERSE
2						1	06	TOOL CHANGE (TOOL 1)
3					1000		03	SPINDLE FWD
4	00	12.2	2					RAPID TRAVERSE
5	01		-55	80				LINEAR
6	00		2					RAPID TRAVERSE
7	00	11.5						RAPID TRAVERSE
8	01		-349					LINEAR
9	00		2					RAPID TRAVERSE
10	00	10.7						RAPID TRAVERSE
11	01		-34.9					LINEAR
12	00		2					RAPID TRAVERSE
13	73	3						START DO-LOOP
14	91							INCREMENTAL
15	00	-0.88						INCREMENTAL CUT DEPTH
16	01		-22.9					INCREMENTAL CUT LENGTH
17	00		22.9					RAPID RETURN
18	06							END DO-LOOP
19	90							ABSOLUTE
20	00	0	2					RAPID TRAVERSE
21	01	0	0					LINEAR
22	01	5.4	-1.5		50			LINEAR
23	00	0	0					RAPID TRAVERSE
24	01	5.4	-3					LINEAR
25	00	9	-20					RAPID TRAVERSE
26	01	11	-25		80			LINEAR
27	00	9	-20					RAPID TRAVERSE
28	00	5.4	-20.5					RAPID TRAVERSE
29	01	11	-22					LINEAR
30	01	5.4	-20					LINEAR
31	01	11	-24					LINEAR
32	00	11	-20					RAPID TRAVERSE
33	01	6	-20	80				LINEAR
34	03	9	-23					CIRCULAR CCW RAD 3
		3						
35	00	9	-20					RAPID TRAVERSE



DRAWING NO.	TEST PROGRAM 3
PROGRAMME No.	3
MATERIAL	MILD STEEL
PROGRAMME BY	T QUARMBY
DATE	25/02/86

TOOLING & SETTING DATA

TOOL 1 R.H. KNIFE TOOL
TOOL 2 THREADING TOOL
TOOL 3 PARTING TOOL

Starturn

BILLET LENGTH 80
BILLET DIA 25

N	G	X/I	Z	F	S	T	M	REMARKS
1	00	15	5					RAPID TRAVERSE
2						1	06	TOOL CHANGE (Tool 1)
3					1000		03	SPINDLE FWD
4	00	12	1		1200			RAPID TRAVERSE
5	01	12	-35	130				LINEAR
6	00	12	1					RAPID TRAVERSE
7	00	10	1					RAPID TRAVERSE
8	01	10	-35					LINEAR
9	00	10	1					RAPID TRAVERSE
10	00	8	1					RAPID TRAVERSE
11	01		-32	130				LINEAR
12	01	10.2	-35					LINEAR
13	00		1					RAPID TRAVERSE
14	00	6.5	1					RAPID TRAVERSE
15	01	6.5	-30	130				LINEAR
16	01	8.2	-32					LINEAR
17	00		1					RAPID TRAVERSE
18	00	3						RAPID TRAVERSE
19	01	7	-3	100				LINEAR
20	00		1					RAPID TRAVERSE
21	00	1	1					RAPID TRAVERSE
22	01	7	-5	100				LINEAR
23	00		-12					RAPID TRAVERSE
24	03	7	-26					CIRCULAR CCW RAD 30
		30						
25	00	8	-26					RAPID TRAVERSE
26	00		1					RAPID TRAVERSE
27	00	0	1					RAPID TRAVERSE
28	01	0	0	100	1800			LINEAR
29	01	6	-6	80				LINEAR
30	01		-12					LINEAR
31	03	6	-26					CIRCULAR CCW RAD 30
		30						
32	01	6	-30					LINEAR
33	01	10	-35	80				LINEAR
34	02	12.5	-37.5					CIRCULAR CW RAD 2.5
		2.5						

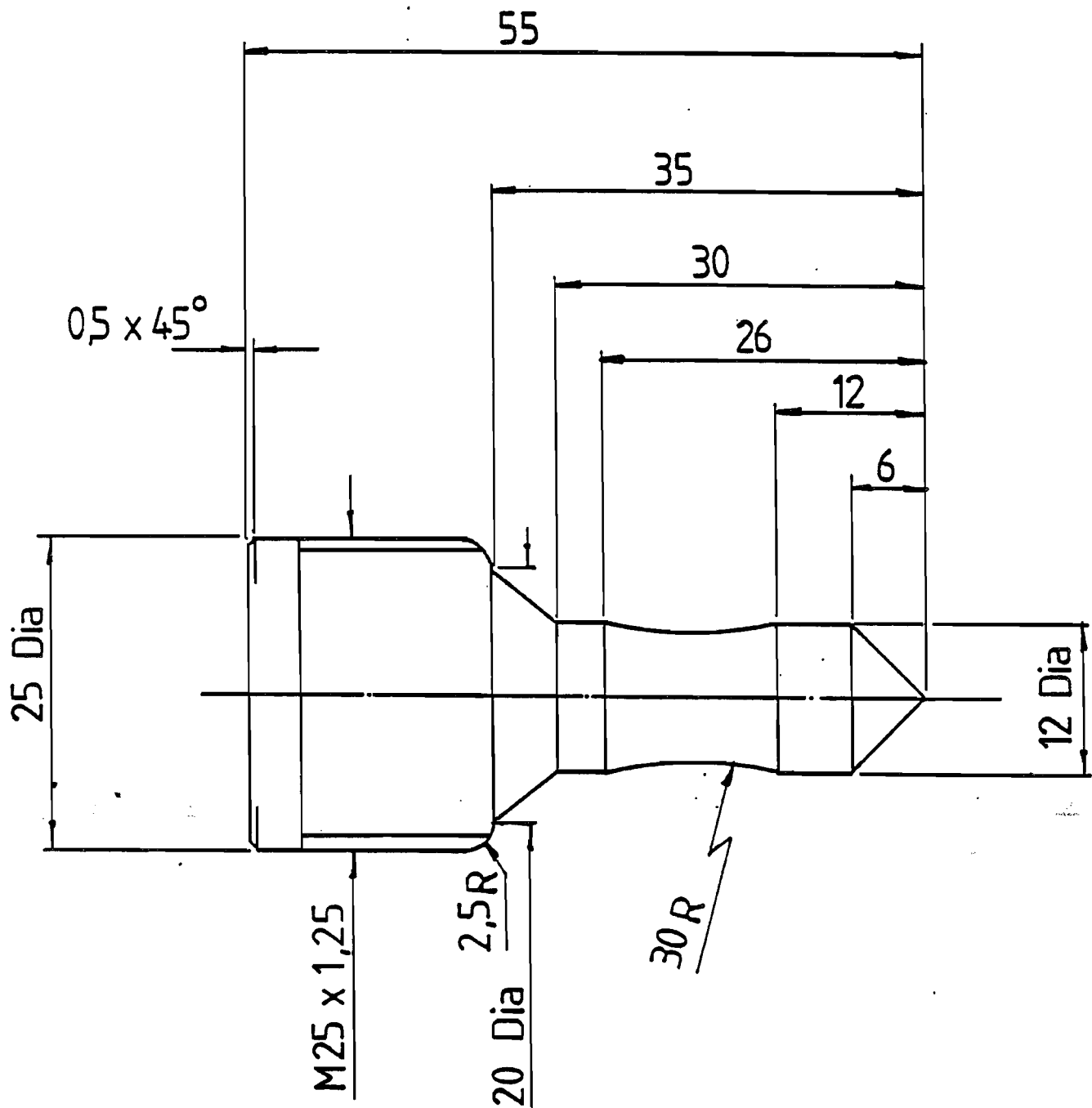
DRAWING NO.	TEST 2
DESCRIPTION	
PROGRAMME No.	
MATERIAL	
PROGRAMME BY	
DATE	PAGE 2

TOOLING & SETTING DATA

Starturn

N	G	X/I	Z	F	S	T	M	REMARKS
36	00	6	-20					RAPID TRAVERSE
37	03	10	-24					CIRCULAR CCW RAD 4
		4						
38	00	10	-20.5					RAPID TRAVERSE
39	00	5.4	-20.5					RAPID TRAVERSE
40	03	9.4	-24.5					CIRCULAR CCW RAD 4
		4						
41	01	10.7	-25	80				LINEAR
42	01	10.7	-34					LINEAR
43	02	12.4	-37					CIRCULAR CW RAD 3
		3						
44	00		2					RAPID TRAVERSE
45	00	0	2		1200			INCREASE SPINDLE SPEED
46	00	0	0					RAPID TRAVERSE
47	01	5	-4	80				LINEAR
48	01		-21					LINEAR
49	03	9	-25					CIRCULAR CCW RAD 4
		4						
50	01	10.5	-28					LINEAR
51	01		-35					LINEAR
52	02	12	-36.5					CIRCULAR CW RAD 1.5
		1.5						
53	01		-40					LINEAR
54	03	12	-48					CIRCULAR CCW RAD 10
		10						
55	01		-55					LINEAR
56	00	15	5					RAPID TRAV
57							05	SPINDLE STOP
58						2	06	TOOL CHANGE (TOOL 2)
59					220		03	SPINDLE FWD
60	00	5	3					RAPID TRAV
61	33	4.097	-17	PITCH	1.5	CUTS 35		THREADING
62	00	15	5					RAPID TRAV
63							05	SPINDLE STOP
64						3	06	TOOL CHANGE (TOOL 3)
65					1000		03	SPINDLE FWD
66	00	13	-54					RAPID TRAV

Starturn



GLOSSARY OF TERMS

A

A AXIS - The axis of rotary motion of a machine tool member or slide about the X axis.

ABSOLUTE ACCURACY - Accuracy as measured from a reference which must be specified.

ABSOLUTE DIMENSION - A dimension expressed with respect to the initial zero point of a co-ordinate axis.

ABSOLUTE POINT (Robots) - Equivalent to absolute co-ordinates in NC machines. The co-ordinates of a data point are defined in relation to an absolute zero.

ABSOLUTE PROGRAMMING - Programming using words indicating absolute dimensions.

ABSOLUTE READOUT - A display of the true slide position as derived from the position commands within the control system.

ABSOLUTE SYSTEM - NC system in which all positional dimensions, both input and feedback, are measured from a fixed point of origin.

ACCANDEC - (Acceleration and deceleration) Acceleration and deceleration in feedrate; it provides smooth starts and stops when operating under NC and when changing from one feedrate value to another.

ACCEPTANCE TEST - A series of tests which evaluate the performance and capabilities of both software and hardware.

ACCESS TIME - The time interval between the instant at which information is:
1. called for from storage and the instant at which delivery is completed, i.e., the read time. 2. Ready for storage and the instant at which storage is completed, i.e., the write time.

ACCUMULATOR - A part of the logical-arithmetic unit of a computer. It may be used for intermediate storage to form algebraic sums, or for other intermediate operations.

ACCURACY - 1. Measured by the difference between the actual position of the machine slide and the position demanded. 2. Conformity of an indicated value of a true value, i.e., an actual or an accepted standard value. The accuracy of a control system is expressed as the deviation or difference between the ultimately controlled variable and its ideal value, usually in the steady state or at sampled instants.

ACTIVE STORAGE - That part of the control logic which holds the information while it is being transformed into motion.

ADAPTIVE CONTROL - A technique of automatically adjusting feeds and/or speeds to an optimum by sensing cutting conditions and acting upon them.

ADDRESS - A character or group of characters at the beginning of a word what identifies the data of allowing in the word.

ADDRESS BLOCK FORMAT - A block format in which each word contains an address.

ALGOL - (Algorithmic Language) Language used to develop computer programmes by algorithm.

ALGORITHM - A rule or procedure for solving a mathematical problem that frequently involves repetition of an operation.

ALPHANUMERIC OR ALPHAMERIC - A system in which the characters used are letters A through Z, and numerals 0 to 9.

ALPHANUMERIC DISPLAY - Equipment, such as a CRT, which is capable of displaying only letters, digits and special characters.

AMPLIFIER - A signal gain device whose output is a function of its input.

AMPLITUDE - Term used to describe the magnitude of a simple wave or simple part of a complex. The largest or crest value measured from zero.

ANALOG - In NC the term applies to a system which utilizes electrical voltage magnitudes or ratios to represent physical axis positions.

ANALOG DATA - The information content of an analog signal as conveyed by the value of magnitude of some characteristics of the signal such as the amplitude, phase, or frequency of a voltage, the amplitude or duration of a pulse, the angular position of a shaft, or the pressure of a fluid.

ANALOG-TO-DIGITAL (A/D) CONVERTER - A device that changes physical motion or electrical voltage into digital factors.

ANALOG SIGNALS - Physical variables (e.g., distance, rotation) represented by electrical signals.

AND - A logical operator which has the property such that if X and Y are two logic variables, then the function 'X and Y' is defined by the following table:

X	Y	X AND Y
0	0	0
0	1	0
1	0	0
1	1	1

The AND operator is usually represented in electrical notation by a centred dot '.', and in FORTRAN programming notation by an asterisk '*' within a Boolean expression.

AND-GATE - A signal circuit with two or more inputs. The output produces a signal only if all inputs received coincident signals.

APT - (Automatically Programmed Tools) A universal computer-assisted programme system for multi-axis contouring programming. APT III - Provides for five axes of machine tool motion.

APPLICATION PROGRAMMES - Computer programmes designed and written to solve a specific problem.

ARC CLOCKWISE - An arc generated by the co-ordinated motion of two axes in which curvature of the path of the tool with respect to the workpiece is clockwise, when viewing the plane of motion from the positive direction of the perpendicular axis.

ARC COUNTERCLOCKWISE - (Substitute 'Counterclockwise' for 'Clockwise' in 'Arc Clockwise' definition.)

ARCHITECTURE - Operating characteristics of a control system, or control unit, or computer.

ASCII - (American Standard Code for Information Interchange) A data transmission code which has been established as an American Standard by the American Standards Association. It is a code in which 7 bits are used to represent each character. Also USASCII.)

ASSEMBLY - The fitting together of a number of parts to create a complete unit.

ASSEMBLY DRAWING - The drawing of a number of parts which shows how they fit together to construct a complete unit.

ASYNCHRONOUS TRANSMISSION - The transmission of information in irregular sections, with the time interval of each transmission varying and each section being identified by a stop and stop signal.

ASYNCHRONOUS - Without any regular time relationship.

ATTRIBUTE - A quality that is characteristic of a subject.

AUTOMATED ASSEMBLY - The application of automation to assembly.

AUTOMATION - The technique of making a process or system automatic. Automatically controlled operation of an apparatus, process, or system, especially by electronic devices. In present day terminology, usually used in relation to a system whereby the electronic device controlling an apparatus or process also is interfaced to and communicates with a computer.

AUXILIARY FUNCTION - A function of a machine other than the control of the co-ordinates of a workpiece or cutter - usually on-off type operations.

AXIS - 1. A principle direction along which a movement of the tool or workpiece occurs. 2. One of the reference lines of a co-ordinate system.

AXIS (Robots) - A moving element of a robot or manipulator.

AXIS INHIBIT - Prevents movement of the selected slides with the power on.

AXIS INTERCHANGE - The capability of inputting the information concerning one axis into the storage of another axis.

AXIS INVERSION - The reversal of normal plus and minus values along an axis which makes possible the machining of a left-handed part from right-handed programming or vice-versa. Same as mirror image.

B

B AXIS - the axis of rotary motion of a machine tool member or slide about the Y axis.

BACKGROUND - In computing the execution of low priority work when higher priority work is not using the computer.

BACKGROUND PROCESSING - The automatic execution of computer programmes in background.

BACKLASH - A relative movement between interacting mechanical parts, resulting from looseness.

BAND - The range of frequencies between two defined limits.

BASE - A number base. A quantity used implicitly to define some system of representing numbers by positional notation. Radix.

BATCH - A number of items being dealt with as a group.

BATCH PROCESSING - A manufacturing operation in which a specified quantity of material is subject to a series of treatment steps. Also, a mode of computer operations in which each programme is completed before the next is started.

BAUD - A unit of signalling speed equal the number of discrete conditions or signal events per second; 1 bit per second in a train of binary signals, and 3 bits per second in an octal train of signals.

BEHIND THE TAPE READER - A means of inputting data directly into a machine tool control unit from an external source connected behind the tape reader.

BENCHMARK - A standard example against which measurements may be made.

BINARY - A numbering system based on 2. Only the digits 0 and 1 are used when written.

BINARY CIRCUIT - A circuit which operates in the manner of a switch, that is, it is either 'on' or 'off'.

BINARY CODED DECIMAL (BCD) - A number code in which individual decimal digits are each represented by a group of binary digits; in the 8-4-2-1 BCD notation, each decimal digit is represented by a four-place binary number, weighted in sequence as 8, 4, 2 and 1.

BINARY DIGIT (BIT) - A character used to represent one of the two digits in the binary number system, and the basic unit of information or data storage in a two-state device.

BILL OF MATERIALS - A listing of all the parts that constitute an assembled product.

BLOCK - A set of words, characters, digits, or other elements handled as a unit. On a punched tape, it consists of one or more characters or rows across the tape that collectively provide enough information for an operation. A 'word' or group of words considered as a unit separated from other such units by an 'end of block' character (EOB).

BLOCK DELETE - Permits selected blocks of tape to be ignored by the control system at discretion of the operator with permission of the programmer.

BLOCK DIAGRAM - A chart setting forth the particular sequence of operations to be performed for handling a particular application.

BLOCK FORMAT - The arrangement of the words, characters and data in a block.

BODE DIAGRAM - A plot of log amplitude ratio and phase angle as functions of log frequency, representing a transfer function.

BOOLEAN ALGEBRA - An algebra named for George Boole. This algebra is similar in form to ordinary algebra, but with classes, propositions, yes/no criteria, etc., for variables rather than numeric quantities, it includes the operator's AND, OR, NOT, EXCEPT, IF THEN.

BOOTSTRAP - A short sequence of instructions, which when entered into the computer's programmable memory will operate a device to load the programmable memory with a larger, more sophisticated programme - usually a loader programme.

BUFFER STORAGE - 1. A place for storing information in a control for anticipated transference to active storage. It enables control system to act immediately on stored information without waiting on tape reader. 2. A register used for intermediate storage for information in the transfer sequence between the computer's accumulators and a peripheral device.

BULK MEMORY - A high capacity auxiliary data storage device such as a disc or drum.

BUG - An error or mistake.

BUS - A conductor used for transmitting signals or power between elements.

BYTE - A sequence of adjacent bits, usually less than a word, operated on as a unit.

C

C AXIS - The axis of rotary motion of a machine tool member or slide about the Z axis.

CALIBRATION - Adjustment of a device, such that the output is within a specified tolerance for particular values of the input.

CANCEL - A command which will discontinue any canned cycles or sequence commands.

CANNED CYCLE - A preset sequence of events initiated by a single NC command, e.g., G84 for NC tap cycle. Also fixed cycle.

CANONICAL FORM - A standard numerical representation of data.

CARD PUNCH - Device for punching holes in a card in accordance with a standard code.

CARD READER - Equipment for sensing and transmitting recorded instructions from a pattern of holes on a punched card.

CARD TO TAPE CONVERTER - A device which converts information directly from punched cards to punched or magnetic tape.

CARTESIAN CO-ORDINATES - Means whereby the position of a point can be defined with reference to a set of axes at right angles to each other.

CATHODE RAY TUBE (CRT) - A display device in which controlled electron beams are used to present alphanumeric or graphical data on a luminescent screen.

CENTRAL PROCESSING UNIT (CPU) - The portion of a computer system consisting of the arithmetic and control units and the working memory.

CHAD - Pieces of material removed in card or tape punching operation.

CHAD DETECTOR - A circuit built into a numerical control system to check for Chad in the holes of punched tape.

CHANNEL - A communication path.

CHARACTER - One of a set of symbols. The general term to include all symbols such as alphabetic letters, numerals, punctuation marks, mathematic operators, etc. Also, the coded representation of such symbols.

CHIP - A single piece of silicon which has been cut from a slice by scribing and breaking. It can contain one or more circuits but is packaged as a unit.

CIRCULAR INTERPOLATION - 1. Capability of generating up to 90 degrees of arc using one block of information as defined by EIA. 2. A mode of contouring control which uses the information contained in a single block to produce an arc of a circle.

CLDATA - Cutter location data.

CLEAR - To erase the contents of a storage device by replacing the contents with blanks or zeros.

CLEARANCE DISTANCE - The distance between the tool and the workpiece when the change is made from rapid approach to feed movement to avoid tool breakage.

CLFILE - Cutter location file (see CLDATA).

CLOCK - A device which generates periodic synchronization signals.

CLOSED LOOP - A signal path in which outputs are fed back for comparison with desired values to regulate system behaviour.

CNC - Computer (Computerized) Numerical Control - A numerical control system wherein a dedicated, stored programme computer is used to perform some or all of the basic numerical control functions.

COMMAND - An operative order which initiates a movement or a function.

COMPATIBILITY - The interchangeability of items.

COMPILER - A programme which translates from high-level problem-oriented computer languages to machine-oriented instructions.

COMPONENT - One of the parts of which an entity is composed.

COMPUTER - A device capable of accepting information in the form of signals or symbols, performing prescribed operations on the information, and providing results as outputs.

COMPUTER AIDED ENGINEERING (CAE) - The use of computing facilities in the integration of all aspects of design and manufacture to create an integrated engineering facility.

COMPUTER AIDED DESIGN (CAD) - A process which uses a computer in the creation or modification of a design.

COMPUTER AIDED MANUFACTURE (CAM) - A process which uses a computer in the management, control or operation of a manufacturing facility.

COMPUTER AIDED DESIGN/COMPUTER AIDED MANUFACTURE (CAD/CAM) - The integration of computer aided design with computer aided manufacture.

COMPUTER PART PROGRAMMING - The preparation of a part programme to obtain a machine programme using a computer and appropriate processor and part processor.

CONFIGURATION - The manner in which items are arranged.

CONTINUOUS PATH OPERATION - An operation in which rate and direction of relative movement of machine members is under continuous numerical control. There is no pause for data reading.

CONTOURING - An operation in which simultaneous control of more than one axis is accomplished.

CONTOURING CONTROL SYSTEM - An NC system for controlling a machine (milling, drafting, etc.) in a path resulting from the co-ordinated, simultaneous motion of 2 or more axes.

CONTROLLED PATH (Robots) - The straight line motion of a defined offset tool point between programmed points. All robot axes are interpolated through the programmed span.

CONTROL TAPE - A tape on which a machine programme is recorded.

CO-ORDINATE DIMENSIONING - A system of dimensioning based on a common starting point.

CO-ORDINATE DIMENSIONING WORD - 1. A word in a block of machining information that provides instruction for one of the machine's axes. 2. A word defining an absolute dimension.

CORE MEMORY - A high speed random access data storage device utilizing arrays of magnetic ferrite cores, usually employed as a working computer memory.

CORE RESIDENT - Pivotal programmes permanently stored in core memory for frequent execution.

COUNTER - A device or memory location whose value or contents can be incremented or decremented in response to an input signal.

CURSOR - Visual movable pointer used on a CRT by an operator to indicate where corrections or additions are to be made.

CUTTER DIAMETER COMPENSATION - A system in which the programmed path may be altered to allow for the difference between actual and programmed cutter diameters.

CUTTER OFFSET - 1. The distance from the part surface to the axial centre of a cutter. 2. An NC feature which allows an operator to use an oversized or undersized cutter.

CUTTER PATH - The path described by the centre of a cutter.

CYCLE - 1. A sequence of operations that is repeated regularly. 2. The time it takes for one such sequence to occur.

CYCLE TIME - The period required for a complete action. In particular, the interval required for a read and a write operation in working memory, usually taken as a measure of computer speed.

CYCLING CONTROL - A fundamental level machine control which programmes the machine through dial or plugboard input.

D

DAMPING - A characteristic built into electrical circuits and mechanical systems to prevent rapid or excessive corrections which might lead to instability or oscillatory conditions.

DATA - Facts or information prepared for processing by, or issued by, a computer.

DATA BASE - Comprehensive files of information having a specific structure such that they are suitable for communication, interpretation and processing by both human and automatic means.

DATA POINT - A programmed point which contains tool plant co-ordinate data and functional information.

DEAD BAND - The range through which an input can be varied without initiating response, usually expressed in percent of span.

DEAD TIME - The interval between initiation of a stimulus change and the start of the resulting response.

DEAD ZONE - A range of inputs for which no change in output occurs.

DEBUG - To detect, locate, and remove mistakes from computer software or hardware.

DECADE - A group of assembly of ten units.

DECADE SWITCHING - Use of a series of switches each with ten positions with values of 0 to 9, in which adjacent switches have a ratio of value of 10:1.

DECIMAL CODE - A code in which each allowable position has one of 10 possible states. (The conventional decimal number system is a decimal code.)

DECODER - A circuit arrangement which receives and converts digital information from one form to another.

DEDICATED - Devoted to a particular function or purpose.

DEVIATION - The error or difference between the instantaneous value of the controlled variable and the setpoint.

DIAGNOSTIC ROUTINE - A programme which locates malfunctions in hardware or software.

DIGITAL - Representation of data in discrete or numerical form.

DIGITAL COMPUTER - A computer that operates on symbols representing data, by performing arithmetic and logic operations.

DIGITAL-TO-ANALOG (D-A) CONVERSION - Production of an analog signal, whose instantaneous magnitude is proportional to the value of a digital input.

DIGITIZE - To obtain the digital representation of a measured quantity or continuous signal.

DIRECTOR - A term used to designate an NC control unit.

DESCRETE - State of being separate or distinct, as opposed to a continuously varying state or condition.

DISCRETE COMPONENT CIRCUIT - An electrical circuit, implemented with individual transistors, resistors, diodes, capacitors, or other components.

DISK - A device on which information is stored.

DISK MEMORY - A non-programmable, bulk storage, random access memory consisting of a magnetizable coating on one or both sides of a rotating thin circular plate.

DISPLAY - Lights, annunciators, numerical indicators, or other operator output devices at consoles or remote stations.

DISTRIBUTED COMPUTER NETWORK - A collection of computers which can communicate with each other.

DISTRIBUTED PROCESSING - The processing of information on a distributed computer network in such a manner as to improve the overall efficiency of the task.

DITHER - An electrical oscillatory signal of low amplitude and of a predetermined frequency imparted to a servo valve to keep the spool from sticking.

DNC - (Direct Numerical Control) Numerical control of machining or processing by a computer.

DOCUMENTATION - The group of techniques necessarily used to organize, present, and communicate recorded specialized knowledge.

DOUBLE PRECISION - The use of two computer words to represent a number.

DOWNTIME - The interval during which a device is inoperative.

DRIFT - An undesired change in output over a period of time, which is unrelated to input, operating conditions, or load.

DRIVER - A programme or routine that controls external peripheral devices or executes other programmes.

DUMP - To copy the present contents of a memory onto a printout or auxiliary storage.

DWELL - A timed delay of programmed or established duration, not cyclic or sequential, i.e., not an interlock or hold.

DYNAMIC GAIN - The magnitude ratio of a steady state output to a sinusoidal input signal.

E

EBCDIC - Extended binary coded decimal interchange code.

EDIT - To modify a programme, or alter stored data prior to output.

EDITOR - A computer programme which provides the ability to edit.

EIA STANDARD CODE - Any one of the Electronics Industries Association standard codes for positioning, straight-cut, and contouring control systems.

ELECTROMAGNETIC INTERFERENCE (EMI) - Unwanted electrical energy or noise induced in the circuits of a device, due to the presence of electromagnetic fields.

EMULATOR - A device or programme which behaves like another system, and produces identical results.

ENCODER - An electromechanical transducer which produces a serial or parallel digital indication of mechanical angle or displacement.

END EFFECTOR (Robots) - The general term used to describe a gripper or other tool used on a robot.

END OF BLOCK CHARACTER - 1. A character indicating the end of a block of tape information. Used to stop the tape reader after a block has been read. 2. The typewriter function of the carriage return when preparing machine control tapes.

END OF PROGRAMME - A miscellaneous function (m02) indicating completion of a workpiece. (Stops spindle, coolant and feed after completion of all commands in the block. Used to reset control and/or machine.)

END OF TAPE - A miscellaneous function (m30) which stops spindle, coolant and feed after completion of all commands in the block. (Used to reset control and/or machine.)

END POINT - An extremity of a span.

ERROR - The difference between the indicated and desired values of a measured signal.

ERROR DETECTING - A data code in which each acceptable term conforms to certain rules, such that if transmission or processing errors occur, false results can be detected.

ERROR SIGNAL - Difference between the output and input signals in a servo system.

EXCLUSIVE OR - A logical operator, which has the property such that if X and Y are two logic variables, then the function is defined by the following table:

X	Y	Function
0	0	0
0	1	1
1	0	1
1	1	0

The logical operator is usually represented in electrical notation by an encircled plus sign '+'. There is no equivalent FORTRAN symbol.

EXECUTE - To carry out an instruction or to run a programme.

EXECUTIVE - Software which controls the execution of programmes in the computer, based on established priorities and real-time or demand requirements.

EXTENDED ARITHMETIC ELEMENT - A CPU logic element, which provides hardware implemented multiply, divide, and normalize functions.

F

FEEDBACK - The signal or data fed back to a commanding unit from a controlled machine or process to denote its response to the command signal. The signal representing the difference between actual response and desired response that is used by the commanding unit to improve performance of the controlled machine or process.

FEEDBACK CONTROL - Action in which a measured variable is compared to its desired value, with a function of the resulting error signal used as a corrective command.

FEEDBACK DEVICE - An element of a control system which converts linear or rotary motion to an electrical signal for comparison to the input signal. E.g., resolver, encoder, inductosyn.

FEEDBACK LOOP - A closed signal path, in which outputs are compared with desired values to obtain corrective commands.

FEEDBACK RESOLUTION - The smallest increment of dimension that the feedback device can distinguish and reproduce as an electrical output.

FEEDBACK SIGNAL - The measurement signal indicating the value of a directly controlled variable, which is compared with a setpoint to generate a correction command.

FEED ENGAGE POINT - The point where the motion of the Z axis changes from rapid traverse to a programmed feed (usually referred to as the 'R' dimension).

FEEDFORWARD (ANTICIPATORY) CONTROL - Action in which information concerning upstream conditions is converted into corrective commands to minimize the effect of the disturbances.

FEED FUNCTION - The relative motion between the tool or instrument and the work due to motion of the programmed axis or axes.

FEEDRATE BY-PASS - A function directing the control system to ignore programmed feedrate and substitute selected operational rate.

FEEDRATE NUMBER - A coded number read from the tape which described the feedrate function. Usually denoted as the 'F' word.

FEEDRATE OVERRIDE - A variable manual control function directing the control system to reduce or increase the programmed feedrate.

FINAL CONTROL ELEMENT - A valve, motor, or other device which directly changes the value of the manipulated variable.

FIRMWARE - Programmes or instructions stored in read only memories.

FIRST GENERATION - 1. In the NC industry, the period of technology associated with vacuum tubes and stepping switches. 2. The period of technology in computer design utilizing vacuum tubes, electronics, off-line storage on drum or disc, and programming in machine language.

FIXED BLOCK FORMAT - A format in which the number and sequence of **words** and **characters** appearing in successive **blocks** is constant.

FIXED HEADS - Rigidly mounted reading and writing transducers on bulk memory devices.

FIXED SEQUENCE FORMAT - A means of identifying a word by its location in a block of information. Words must be presented in a specific order and all possible words preceding the last desired word must be present in the block.

FLIP FLOP - A bi-stable device. A device capable of assuming two stable states. A bi-stable device which may assume a given stable state depending upon the pulse history of one or more input points and having one or more output points. The device is capable of storing a bit of information; controlling gates; etc. A toggle.

FLOPPY DISK - A flexible disk used for storing information.

FLOW CHART - A graphical representation of a problem or system in which interconnected symbols are used to represent operations, data, flow, and equipment.

FLUIDICS - The technique of control that uses only a fluid as the controlling medium. All control is performed without moving elements.

FOREGROUND PROCESSING - Execution of real-time or high priority programmes, which can pre-empt the use of computing facilities.

FORMAT - The arrangement of data.

FORMAT CLASSIFICATION - A means, usually in an abbreviated notation, by which the motions, dimensional data, type of control system, number of digits, **auxiliary functions**, etc. for a particular system can be denoted.

FORMAT DETAIL - Describes specifically which words of what length are used by a specific system in the **format classification**.

FORTRAN - Acronym for Formula Translator, an algebraic procedure oriented computer language designed to solve arithmetic and logic programmes.

FOURTH GENERATION - In the NC industry, the change in technology of control logic to include computer architecture.

FREQUENCY RESPONSE ANALYSIS - A method of analyzing systems based on introducing cyclic inputs and measuring the resulting output at various frequencies.

FREQUENCY RESPONSE CHARACTERISTIC - The amplitude and phase relation between steady state sinusoidal inputs and the resulting sinusoidal outputs.

FULL DUPLEX - Allows the simultaneous transmission of information in both directions.

FULL PROPORTIONAL SERVO - A system with complete proportionality between output and input.

FULL RANGE FLOATING ZERO - A characteristic of a numerical machine tool control permitting the zero point on an axis to be shifted readily over a specified range. The control retains information on the location of 'permanent' zero.

G

G CODE - A word addressed by the letter G and followed by a numerical code defining preparatory functions or cycle types in a numerical control system.

GAIN - The ratio of the magnitude of the output of a system with respect to that of the input (the conditions of operation and measurements must be specified, e.g., voltage, current or power).

GATE - A device which blocks or passes a signal depending on the presence or absence of specified input signals.

GAUGE HEIGHT - A predetermined partial retraction point along the Z axis to which the cutter retreats from time to time to allow safe X-Y table travel.

GENERAL PURPOSE COMPUTER - A computer designed and capable of carrying out a wide range of tasks.

GENERAL PURPOSE PROCESSOR - A computer programme which carries out computations on the part programme and prepares the author location data for a particular part without reference to machines on which it might be made.

GRAPHICS - The use of a computer to interactively create a drawing displayed on a terminal.

GRAY CODE - A binary code, in which successive values differ in one place only.

GROUP TECHNOLOGY - The grouping of machines and of parts based on similarities in production requirements such that the parts may be produced more efficiently.

H

HALF DUPLEX - Allows the transmission of information one way at a time.

HARD COPY - Any form of computer produced printed document. Also, sometimes punched cards or paper tape.

HARDWARE - Physical equipment.

HEAD - A device, usually a small electromagnet on a storage medium such as magnetic tape or a magnetic drum, that reads, records, or erases information on that medium. The block assembly and perforating or reading fingers used for punching or reading holes in paper tape.

HOLLERITH - A 12 bit code used for recording characters in punched paper cards.

HOUSEKEEPING - The general organisation of programmes stored to ensure efficient system response.

HYSTERESIS - The difference between the response of a system to increasing and decreasing signals.

I

IEEE - Institute of Electrical and Electronic Engineers.

IC - Integrated circuit.

INCREMENTAL DIMENSION - A dimension expressed with respect to the preceding point in a sequence of points.

INCREMENTAL FEED - A manual or automatic input of preset motion command for a machine axis.

INCREMENTAL PROGRAMMING - Programming using words indicating incremental dimensions.

INCREMENTAL SYSTEM - Control system in which each co-ordinate or positional dimension is taken from the last position.

INDEXING - Movement of one axis at a time to a precise point from numeric commands.

INDUCTOSYN SCALE - A precision data element for the accurate measurement and control of angles or linear distances, utilizing the inductive coupling between conductors separated by a small air gap.

INHIBIT - To prevent an action or acceptance of data by applying an appropriate signal to the appropriate input.

INITIALIZE - To cause a programme or hardware circuit to return a programme, a system, or a hardware device to an original state or to selected points with a computer programme.

INPUT - A dependent variable applied to a control unit or system.

INPUT RESOLUTION - The smallest increment of dimension that can be programmed as input to the system.

INSTABILITY - The state of property of a system where there is an output for which there is not corresponding input.

INSTRUCTION - A statement that specifies an operation and the values or locations of its operands.

INSTRUCTION SET - The list of machine language instructions which a computer can perform.

INTEGRATED CIRCUIT (IC) - A combination of interconnected passive and active circuit elements incorporated on a continuous substrate.

INTEGRATOR - A device which integrates an input signal, usually with respect to time.

INTELLIGENT TERMINAL - A terminal which has its own local processing power.

INTERACTIVE GRAPHICS - Ability to carry out graphics tasks with immediate response from the computer.

INTERFACE - 1. A hardware component or circuit for linking two pieces of electrical equipment having separate functions. E.g., tape reader to data processor or control system to machine. 2. A hardware component or circuit for linking the computer to external I/O device.

INTERFEROMETER - An instrument that uses light interference phenomena for determination of wavelength, spectral fine structure, indices of refraction, and very small linear displacements.

INTERLOCK - To arrange the control of machines or devices so that their operation is interdependent in order to assure their proper co-ordination.

INTERLOCK BY-PASS - A command to temporarily circumvent a normally provided interlock.

INTERPOLATION - 1. The insertion of intermediate information based on assumed order or computation. 2. A function of a control whereby data points are generated between given co-ordinate positions to allow simultaneous movement of two or more axes of motion in a defined geometric pattern. E.g., linear, circular and parabolic.

INTERPOLATOR - A device which is part of a numerical control system and performs interpolation.

INTERRUPT - A break in the execution of a sequential programme or routine, to permit processing of high priority data.

I/O - (Input/Output) Input or output or both.

ITERATION - A set of repetitive computations, in which the output of each step is the input to the next step.

J

JCL - Job control programme.

JOB - An amount of work to be completed.

JOG - A control function which provides for the momentary operation of a drive for the purpose of accomplishing a small movement of the driven machine.

K

KEYBOARD - The keys of a teletype-writer which have the capability of transmitting information to a computer but not receiving information.

L

LAG - Delay caused by conditions such as capacitance, inertia, resistance or dead time.

LANGUAGE - A set of representations and rules used to convey information.

LAYOUT - A visual representation of a complete physical entity usually to scale.

LEVEL - 1. Formerly a channel of punched tape. 2. The average amplitude of a variable quantity applying particularly to sound or electronic signals expressed in decibels, volts, amperes, or watts. 3. The degree of subordination in a hierarchy.

LIGHT PEN - A photo sensing device similar to an ordinary fountain pen which is used to instruct CRT displays by means of light sensing optics.

LINEAR INTERPOLATION - A function of a control whereby data points are generated between given co-ordinate positions to allow simultaneous movement of two or more axes of motion in a linear (straight line) path.

LINE PRINTER - A printing device that can print an entire line of characters all at once.

LINKAGE - A means of communicating information from one routine to another.

LOCKOUT SWITCH - A switch provided with a memory, which protects the contents of designated segments from alteration.

LOG - A detailed record of actions for a period of time.

LOG OFF - The completion of a terminal session.

LOG ON - The beginning of a terminal session.

LOGIC - 1. Electronic devices used to govern a particular sequence of operations in a given system. 2. Interrelation or sequence of facts or events when seen as inevitable or predictable.

LOGIC LEVEL - The voltage magnitude associated with signal pulses representing ONES and ZEROS in binary computation.

LOOP TAPE - A short piece of tape, containing a complete programme of operation, with the ends joined.

LSI - Large Scale Integration - A large number of interconnected integrated circuits manufactured simultaneously on a single slice of semi-conductor material (usually over 100 gates or basic circuits, with at least 500 circuit elements).

M

MACHINE LANGUAGE - A language written in a series of bits which are understandable by, and therefore instruct, a computer. The 'first level' computer language, as compared to a 'second level' assembly language or a 'third level' compiler language.

MACHINE PROGRAMME - an ordered set of instructions in automatic control language and format recorded on appropriate input media and sufficiently complete to effect the direct operation of an automatic control system.

MACHINING CENTRE - A machine tool, usually numerically controlled, capable of automatically drilling, reaming, tapping, milling and boring multiple faces of a part and often equipped with a system for automatically changing cutting tools.

MACRO - A source language instruction from which many machine language instructions can be generated (see compiler language).

MAGNETIC CORE - An element for switching or storing information on magnetic memory elements for later use by a computer.

MAGNETIC CORE STORAGE - The process of storing information on magnet memory elements for later use by a computer.

MAGNETIC DISK STORAGE - a storage device or system consisting of magnetically coated metal disks.

MAIN FRAME - See central processing unit.

MANUAL DATA INPUT (MDI) - A means of inserting data manually into the control system.

MANUAL FEEDRATE OVERRIDE - Device enabling operator to reduce or increase the feedrate.

MANUAL PART PROGRAMMING - The manual preparation of a manuscript in machine control language and format to define a sequence of commands for use on an NC machine.

MANUSCRIPT - Form used by a part programmer for listing detailed manual or computer part programming instructions.

MEMORY - A device or media used to store information in a form that can be understood by the computer hardware.

MEMORY BULK - Any non-programmable large memory, i.e., drum, disk.

MEMORY CYCLE TIME - The minimum time between two successive data accesses from a memory.

MEMORY PROTECT - A technique of protecting stored data from alteration, using a guard bit to inhibit the execution of any modification instruction.

MANAGEMENT INFORMATION SERVICE (MIS) - An information feedback system from the machine to management and implemented by a computer.

MICROPROCESSOR - A single integrated circuit which forms the basic element of a computer.

MICROPROGRAMMING - A programming technique in which multiple instruction operations can be combined for greater speed and more efficient memory use.

MICROSECOND - One millionth of a second.

MILLISECOND - One thousandth of a second.

MISCELLANEOUS FUNCTION - An off-on function of a machine such as Clamp or Coolant on. (See Auxiliary Function.)

MINEMONIC - An alphanumeric designation, designed to aid in remembering a memory location or computer operation.

MODEM - A contraction of modulator demodulator. The term may be used with two different meanings: 1. The modulator and the demodulator of a modem are associated at the same end of a circuit. 2. The modulator and the demodulator of a modem are associated at the opposite ends of a circuit to form a channel.

MODULE - An independent unit which may be used on its own or in conjunction with other units to form a complete entity.

MONITOR - A device used for observing or testing the operations of a system.

MOVABLE HEADS - Reading and writing transducers on bulk memory devices which can be positioned over the data locations.

MSI - Medium Scale Integration. (See LSI.) Smaller than LSI, but having at least 12 gates or basic circuits with at least 100 circuit elements.

MULTIPLEXER - A hardware device which handles multiple signals over a single channel.

N

NAND - A combination of the Boolean logic functions NOT and AND.

NAND GATE - A component which implements the NAND function.

NANOSECOND - One thousandth of one microsecond.

NEGATIVE LOGIC - Logic in which the more negative voltage represents the one (1) state; the less negative voltage represents the zero (0) state.

NIXIE LIGHT OR TUBE - A glow lamp which converts a combination of electrical impulses into a visible number.

NOISE - An extraneous signal in an electrical circuit capable of interfering with the desired signal. Loosely, any disturbance tending to interfere with the normal operation of a device or system.

NOR GATE - A component which implements the NOR function.

NOT - a logic operator having property that if P is a logic quantity then quantity 'NOT P' assumes values as defined in the following table:

P	NOT P
0	1
1	0

The NOT operator is represented in electrical notation by an overline, e.g. \overline{P} and in FORTRAN by a minus sign '-' in a Boolean expression.

NUMERICAL CONTROL (NC) - A technique of operating machine tools or similar equipment, in which motion is developed in response to numerically coded commands.

NUMERICAL DATA - Data in which information is expressed by a set of numbers that can only assume discrete values.

O

OBJECT PROGRAMME - The coded output of an assembler or compiler.

OCTAL - A characteristic of a system in which there are eight elements, such as a numbering system with a radix of eight.

OFF-LINE - Operating software or hardware not under the direct control of a central processor, or operations performed while a computer is not monitoring or controlling processes or equipment.

OFFSET - The steady state deviation of the controlled variable from a fixed setpoint.

ON-LINE - A condition in which equipment or programmes are under direct control of a central processor.

ONE - One of the two symbols normally employed in binary arithmetic and logic, indicating binary one and the true condition, respectively.

OPEN LOOP - A signal path without feedback.

OPEN LOOP SYSTEM - A control system that has no means of comparing the output with the input for control purposes (no feedback).

OPERATING SYSTEM - Software which controls the execution of computer programmes and the movement of information between peripheral devices.

OPTIMIZATION - A process whose object is to make one or more variables, assume in the best possible manner, the value best suited to the operation in hand dependent on the values of certain other variables which may be either predetermined or sensed during the operation.

OPTIMIZE - To establish control parameters which maximize or minimize the value of performance.

OPTIONAL STOP - A **Miscellaneous Function** command similar to 'Program Stop' except that the control ignores the command unless the operator has previously pushed a button to validate the command. (m01).

OR - A logic operator having the property that if P and Q are logic quantities then the quantity 'P or Q' assumes values as defined by the following table:

P	Q	P OR Q
0	0	0
0	1	1
1	0	1
1	1	1

The OR operator is represented in both electrical and FORTRAN terminology by a '+', i.e., $P + Q$.

OR GATE - A device which implements the OR function.

ORIENTATION (Robots) - The angular position of the wrist axes.

OUTPUT - Dependent variable signal produced by a transmitter, control unit or other device.

OUTPUT IMPEDANCE - The impedance presented by a device to the load.

OUTPUT SIGNAL - A signal delivered by a device, element, or system.

OVERLAY - A technique of repeatedly using the same area of computer store when actioning different stages of a problem.

OVERSHOOT - The amount that a controlled variable exceeds its desired value after a change of input.

P

PARABOLA - A plane curve generated by a point moving so that its distance from a fixed second point is equal to its distance from a fixed line.

PARABOLIC INTERPOLATION - Control of cutter path by interpolation between three (3) fixed points by assuming the intermediate points are on a parabola.

PARALLEL - The simultaneous transfer and processing of all bits in a unit of information.

PARAMETER - A characteristic of a system or device, the value of which serves to distinguish various specific states.

PARITY CHECK - A test of whether the number of ONES or ZEROS in an array of binary digits is odd or even to detect errors in a group of bits.

PART PROGRAMME - An ordered set of instructions in a language and in a format required to cause operations to be effected under automatic control, which is either written in the form of a machine programme on an input media or prepared as input data for processing in a computer to obtain a machine programme.

PART PROGRAMMER - A person who prepares the planned sequence of events for the operation of a numerically controlled machine tool.

PASSWORD - A word the operator must supply in order to meet the security requirements and gain access to the computer.

PATCH - Temporary coding used to correct or alter a routine.

PERIPHERAL - Auxiliary equipment used for entering data into or receiving data from a computer.

PERIPHERAL EQUIPMENT - The auxiliary machines and storage devices which may be placed under control of the central computer and may be used on-line or off-line. E.g., card reader and punches, magnetic tape feeds, high speed printers, CRTs and magnetic drums or discs.

PICOSECOND - One millionth of one microsecond.

PITCH (Robots) - A rotation of the payload or tool about a horizontal axis on the end of a robot arm which is perpendicular to the longitudinal axis of the arm.

PLANNING SHEET - A list of operations for the manufacture of a part, prepared before the part programme.

PLOTTER - A device used to make a drawing of a display.

POINT-TO-POINT CONTROL SYSTEM - An NC system which controls motion only to reach a given end point but exercises no path control during the transition from one end point to the next.

POLAR AXES - The fixed lines from which the angles made by radius vectors are measured in a polar co-ordinates system.

POLAR CO-ORDINATES - A mathematical system for locating a point in a plane by the length of its radius vector and the angle this vector makes with a fixed line.

POSITION SENSOR - A device for measuring a position, and converting this measurement into a form convenient for transmission.

POSITION STORAGE - The storage media in an NC system containing the co-ordinate positions read from tape.

POSITION READOUT - A display of absolute slide position as derived from a position feedback device (transducer usually) normally attached to the lead screw of the machine. (See Command Readout.)

POSITIVE LOGIC - Logic in which the more positive voltage represents the one (1) state.

POST-PROCESSOR - A computer programme which adapts the output of a processor into a machine programme for the production of a part on a particular combination of machine tool and controller.

PRECISION - The degree of discrimination with which a quantity is stated, e.g., a three-digit numeral discriminates among 1000 possibilities. Precision is contrasted with accuracy, i.e., a quantity expressed with 10 decimal digits of precision may only have one digit of accuracy.

PREPARATORY FUNCTION - An NC command on the input tape changing the mode of operation of the control. (Generally noted at the beginning of a block by 'G' plus two digits.)

PREPROCESSOR - A computer programme which prepares information for processing.

PREVENTATIVE MAINTENANCE - Maintenance specifically designed to identify potential faults before they occur.

PRINTED CIRCUIT - A circuit for electronic components made by depositing conductive material in continuous paths from terminal to terminal on an insulating surface.

PROCESSOR - A computer programme which processes information.

PROGRAMME - A plan for the solution of a problem. A complete programme includes plans for the transcription of data, coding for the computer, and plans for the absorption of the results into the system. The list of coded instructions is called a routine. To plan a computation or process from the asking of a question to the delivery of the results, including the integration of the operation into an existing system. Thus, programming consists of planning and coding, including numerical analysis, systems analysis, specification of printing formats, and any other functions necessary to the integration of a computer in a system.

PROGRAMMABLE - Capable of being set to operate in a specified manner, or of accepting remote setpoint or other commands.

PROGRAMMED ACCELERATION - A controlled velocity increase to the programmed feedrate of an NC machine.

PROGRAMMED DWELL - The capability of commanding delays in programme execution for a programmable length of time.

PROGRAMME STOP - A Miscellaneous Function (m00) command to stop the spindle coolant and feed after completion of the dimensional move commanded in the block. To continue with the remainder of the programme, the operator must initiate a restart.

PROTOCOL - Set of rules governing message exchange between two devices.

PUNCHED CARD - A piece of lightweight cardboard on which information is represented by holes punched in specific positions.

PUNCHED PAPER TAPE - A strip of paper on which characters are represented by combinations of holes.

PULSE - A short duration change in the level of a variable.

Q

QUADRANT - Any of the four parts into which a plane is divided by rectangular co-ordinant axes lying in that plane.

QUADRATURE - Displaced 90 degrees in phase angle.

R

R DIMENSION - (See Feed Engage Point.)

RANDOM ACCESS MEMORY (RAM) - A storage unit in which direct access is provided to information, independent of memory location.

RASTER DISPLAY - A display in which the entire display surface is scanned at a constant refresh rate.

RASTER SCAN - Line-by-line sweep across the entire display surface to generate elements of a display image.

READ - to acquire data from a source. To copy, usually from one form of storage to another, particularly from external or secondary storage to internal storage. To sense the meaning of arrangements of hardware. To sense the presence of information on a recording medium.

READER - A device capable of sensing information stored in an off-line memory media (cards, paper tape, magnetic tape) and generating equivalent information in an on-line memory device (register, memory locations).

READ ONLY MEMORY (ROM) - A storage device generally used for control programme, whose content is not alterable by normal operating procedures.

REAL TIME CLOCK - The circuitry which maintains time for use in programme execution and event initiation.

REAL TIME OPERATION - Computer monitoring, control or processing functions performed at a rate compatible with the operation of physical equipment or processes.

REFERENCE BLOCK - A block within an NC programme identified by an 'O' or 'H' in place of the word address 'N' and containing sufficient data to enable resumption of the programme following an interruption. (This block should be located at a convenient point in the programme which enables the operator to reset and resume operation.)

REFRESH - CRT display technology which requires continuous restroking of the display image.

RELOCATABLE POINT/SEQUENCE OF POINT (Robots) - A point or sequence in a robot which can be relocated in space.

REPAINT - Redraws a display on a CRT to reflect its current status.

REPEATABILITY - The closeness of agreement among multiple measurements of an output, for the same value of the measured signal under the same operating conditions, approaching from same direction, for full range traverses.

REPRODUCIBILITY - The closeness of agreement among repeated measurements of the output for the same value of input, made under the same operating conditions over a period of time, approaching from either direction.

RESOLUTION - 1. The smallest distinguishable increment into which a signal or picture, etc. is divided in a device or system. 2. The minimum positioning motion which can be specified.

RESOLVER - 1. A mechanical to electrical transducer (see Transducer) whose input is a vector quantity and whose outputs are components of the vector. 2. A transformer whose coupling may be varied by rotating one set of windings relative to another. It consists of a stator and rotor, each having two distributed windings 90 electrical degrees apart.

RETROFIT - Work done to an existing machine tool from simply adding special jigs or fixtures to the complete re-engineering and manufacturing, and often involving the addition of a numerical control system.

ROBOT - An automatic device which performs functions ordinarily ascribed to human beings.

ROLL (Robots) - A rotation of the payload or tool about the longitudinal axis of the wrist.

ROUTINE - A series of computer instructions which performs a specified task.

RUN - The execution of a programme on a computer.

S

SAMPLE AND HOLD - A circuit used to increase the interval during which a sampled signal is available, by maintaining an output equal to the most recent input sample.

SAMPLES DATA - Data in which the information content can be, or is, ascertained only at discrete intervals of time. (Can be analog or digital.)

SAMPLING PERIOD - The interval between observations in a periodic sampling control system.

SCALE - To change a quantity by a given factor, to bring its range within prescribed limits.

SCALE FACTOR - A coefficient used to multiply or divide quantities in order to convert them to a given magnitude.

SCANNER - The equipment used to digitize co-ordinate information from a master and convert it to punched tape for later recreation of the master shape on an NC machine.

SCHEDULE - A programme or timetable of planned events or of work.

SECOND GENERATION - 1. In the NC industry, the period of technology associated with transistors (solid state). 2. The period of technology in computer design utilizing solid state circuits, off-line storage, and significant development in software, the assembler.

SECURITY - Prevention of unauthorized access to information or programmes.

SENSITIVITY - The ratio of a change in steady state output to the corresponding change of input, often measured in percent of span.

SENSOR - A unit which is actuated by a physical quantity and which gives a signal representing the value of what physical quantity.

SEQUENCE (Robots) - Part of a robot programme which consists of a point or series of points the performance of which will be dependent on defined input/flag conditions existing.

SEQUENCE CONTROL - A system of control in which a series of machine movements occurs in a devised order, the completion of one movement initiating the next, and in which the extent of the movements is not specified by numeric data.

SEQUENCE NUMBER - A number identifying the relative location of blocks or groups of blocks on a tape.

SEQUENCE READOUT - A display of the number of the block of tape being read by the tape reader.

SERIAL - The transfer and processing of each bit in a unit of information, one at a time.

SERVO AMPLIFIER - The part of the servo system which increases the error signal and provides the power to drive the machine slides or the servo valve controlling a hydraulic drive.

SETPOINT - The position established by an operator as the starting point for the programme on an NC machine.

SIGN - The symbol or bit which distinguishes positive from negative numbers.

SIGNAL - Information conveyed between points in a transmission or control system, usually as a continuous variable.

SIGNIFICANT DIGIT - A digit than contributes to the precision of a numeral. The number of significant digits is counted beginning with the digit contributing the most value, called the most significant digit, and ending with the one contributing the least value, called the least significant digit.

SIMULATOR - A device or computer programme that performs simulation.

SKEWING - Refers to time delay or offset between any two signals in relation to each other.

SOFTWARE - The collection of programmes, routines, and documents associated with a computer.

SOURCE IMPEDANCE - The impedance presented to the input of a device by the source.

SOURCE LANGUAGE - The symbolic language comprising statements and formulas used to specify computer processing. It is translated into object language by an assembler or compiler, and is more powerful than an assembly language in that it translates one statement into many items (see macro).

STABILITY - Freedom from undesirable deviation, used as a measure of process controllability.

STANDBY POWER SUPPLY - An energy generation or storage system, that can permit equipment to operate temporarily or shut down in an orderly manner.

STATIC GAIN - The ratio of steady state output to input change.

STEADY STATE - A characteristic or condition exhibiting only negligible change over an arbitrarily long period of time.

STEPPING MOTOR - A bi-directional permanent magnet motor which turns in finite steps.

STEP RESPONSE - The time response of an instrument subjected to an instantaneous change in input.

STEP RESPONSE TIME - The time required for an element output to change from an initial value to a specified percentage of a steady state, either before or in the absence of overshoot, after an input step change.

STORAGE - A memory device in which data can be entered and held, and from which it can be retrieved.

STORAGE TUBE - A CRT which retains an image for a considerable period of time without redrawing.

STRAIGHT CUT SYSTEM - A system which has feedrate control only along the axes and can control cutting action only along a path parallel to the linear (or circular) machine ways.

STYLUS - A hand-held device by which co-ordinate information may be input to a display unit.

SUB PROGRAMME - A segment of a machine programme which can be called into effect by the appropriate machine control command.

SUBROUTINE - A series of computer instructions to perform a specific task for many other routines. It is distinguishable from a main routine in that it requires, as one of its parameters, a location specifying where to return to the main programme after its function has been accomplished.

SUMMING POINT - A point at which signals are added algebraically.

SYNCHRO - A transformer having a polyphase primary winding and single phase secondary winding which can be rotated. The voltage induced into the secondary may be controlled in phase by turning the secondary coil.

SYNCHRONUS - A fixed rate transmission of information synchronised by a clock for both receiver and sender.

SYNTAX - The rules which govern the structure of words and expressions in a language.

T

TABLET - An input device which allows digitized co-ordinates to be indicated by stylus position.

TACHOMETER - A speed measuring instrument generally used to determine revolutions per minute. In NC it is used as a velocity feedback device.

TAPE - A magnetic or perforated paper medium for storing information.

TAPE TRAILER - The trailing end portion of a tape.

TAPE LEADER - The front or lead portion of a tape.

TAPE PREPARATION - The act of translating command information into punched or magnetic tape.

TASK - A unit of work.

TEACH (Robots) - The mode by which a robot is driven to required points in space for programming.

TERMINAL - A device by which information may be entered or extracted from a system or communication network.

THIRD GENERATION - 1. In the NC industry, the period of technology associated with integrated circuits. 2. The period of technology in computer design utilizing integrated circuits, core memory, advanced subroutines, time sharing, and fast core access.

THRESHOLD - The minimum value of a signal required for detection.

TIME CONSTANT - For a first order system, the time required for the output of complete 63.2% of the total rise or decay as a result of a step change of the input.

TIME SHARING - The interleaved use of a sequential device, to provide apparently simultaneous service to a number of users.

TOGGLE - A flip-flop or two-position switch.

TOOL CENTRE POINT (Robots) - The real or imaginary offset point defined in relation to the tool mounting plate of a robot which moves in a straight line between programmed points and at the programmed velocity in controlled path machines.

TOOL FUNCTION - A tape command identifying a tool and calling for its selection. The address is normally a 'T' word.

TOOL LENGTH COMPENSATION - A manual input means which eliminates the need for preset tooling and allows programmer to programme all tools as if they are of equal length.

TOOL OFFSET - 1. A correction for tool position parallel to a controlled axis. 2. The ability to reset tool position manually to compensate for tool wear, finish cuts and tool exchange.

TOOLPATH FEEDRATE - The velocity, relative to the workpiece, if the tool reference point along the author path, usually expressed in units of length per minute or per revolution.

TOOLPATH - The geometry of the path a tool will follow to machine a component.

TRACK - The portion of a moving storage medium, such as the drum, tape or disc, that is accessible to a given reading head position.

TRANSFER FUNCTION - An expression relating the output of a linear system to the input.

TRUNCATE - To terminate a computational process in accordance with some rule, e.g., to end the evaluation of a power series at a specified term.

TRUTH TABLE - A matrix that describes a logic function by listing all possible combinations of inputs, and indicating the outputs for each combination.

TUNING - The adjustment of coefficients governing the various modes of control.

TURNING CENTRE - A lathe type numerically controlled machine tool capable of automatically boring, turning outer and inner diameters, threading, facing multiple diameters and faces of a part and often equipped with a system for automatically changing or indexing cutting tools.

TURN KEY SYSTEM - A term applied to an agreement whereby a supplier will install an NC or computer system so that he has total responsibility for building, installing, and testing the system.

V

VARIABLE (Robots) - An ability to count events.

VARIABLE BLOCK FORMAT - Tape format which allows the number of words in successive blocks to vary.

VECTOR - A quantity that has magnitude, direction and sense and that is commonly represented by a directed line segment whose length represents the magnitude and whose orientation in space represents the direction.

VECTOR FEEDRATE - The resultant feedrate which a cutter or tool moves with respect to the work surface. The individual slides may move slower or faster than the programmed rate; but the resultant movement is equal to the programmed rate.

VOLATILE STORAGE - A memory in which data can only be retained while power is being applied.

W

WINDUP - Lost motion in a mechanical system which is proportional to the force or torque applied.

WIRE-FRAME - A 3-dimensional drawing created by the projection of the points of intersection of the geometry.

WORD ADDRESS FORMAT - Addressing each word in a block by one or more characters which identify the meaning of the word.

WORD LENGTH - The number of bits or characters in a word.

WORLD CO-ORDINATES (Robots) - The co-ordinate system by which a point in space is defined in three cartesian co-ordinates and three orientation or polar co-ordinates.

WRIST (Robots) - The element of a robot which applies orientation to a tool.

X

X AXIS - Axis of motion that is always horizontal and parallel to the work-holding surface.

Y

Y AXIS - Axis of motion that is perpendicular to both the X and Z axes.

YAW (Robots) - A rotation of a payload or tool about a vertical axis that is perpendicular to the pitch axis of the wrist.

Z

Z AXIS - Axis of motion that is always parallel to the principle spindle of the machine.

ZERO - One of the two symbols normally employed in binary arithmetic and logic, indicating the value zero and the false condition, respectively.

ZERO OFFSET - A characteristic of a numerical machine tool control permitting the zero point on an axis to be shifted readily over a specified range. (The control retains information on the location of the 'permanent' zero.)

ZERO SHIFT - A characteristic of a numerical machine tool control permitting the zero point on an axis to be shifted readily over a specified range. (The control does **not** retain information on the location of the 'permanent' zero.)

ZERO SUPPRESSION - The elimination of non-significant zeros to the left of significant digits usually before printing.

ZERO SYNCHRONIZATION - Z technique which permits automatic recovery of a precise position after the machine axis has been approximately positioned by manual control.