
ORAC
ORAC
'G' CODES
G 00 POINT TO POINT
G 01 LINEAR INTERPOLATION
G 02 CIRCULAR INTERPOLATION C.W.
G 03 CIRCULAR INTERPOLATION C.C.W.
G 04 DWELL
G 06 INTERMEDIATE COMMAND
G 29 RETURN TO ZERO
G 33 THREAD CUTTING
G 45 TOOL OFFSET
G 73 REPEAT FACILITY
G 90 ABSOLUTE PROGRAMMING
G 91 INCREMENTAL PROGRAMMING
DENFORD
SHARP
DATA INPUT
FUNCTION
MANUAL
SPINDLE CONTROL
DATA CASSETTE
START
STOP
DENFORD
EMERGENCY STOP
RESET
RESET

ORAC

Computer Numerically Controlled (CNC) British built Bench Training Lathe.

ORAC manufactured by Denford Machine Tools is a CNC Lathe designed specifically for technical training. ORAC incorporates the latest micro-processor using a visual display unit **allowing for verification of programs using Tool Path Graphics,** with an audio cassette deck instructing step by step programming. An RS232C link will interface ORAC to printers, paper tape punch units and computers.

GENERAL SPECIFICATIONS

CNC CONTROL SYSTEM

1. Self contained Console.
2. Green on Black 5″ V.D.U. with outlets to external T.V. and Monitor with facility for Tool Path Graphics.
3. Touch Tone Alpha Numeric Keyboard allowing full manual data input.
4. Mini Magnetic Cassette Unit for multi-program and tool offset storage.
5. RS232C Interface, for connection with computers, paper tape punch units and printers, etc.
6. Axis Jog on both axes with fast, slow and 0.01 mm increments.
7. Programmable Feedrate 0-1200 mm/min (48 inch/min).
8. Programmable Spindle Speed 0-2000 rpm.
9. Feedrate and Spindle Speed Override.
10. Linear Interpolation with vectorially correcting Feedrates.
11. Circular Interpolation.
12. Absolute/Incremental, Inch/mm programming throughout program.
13. Manual Program Stop.
14. Do-Loop facility allowing canned cycles for turning, facing, pecking and grooving.
15. Sub-routine facility.
16. Screwcutting from .35-3.5 mm Pitch 8-70 TPI.
17. Floating Program Datum.
18. 160 Block Memory.
19. Tool Offsets for up to 10 tools with tool wear compensation.
20. Edit with search facility.
21. Single step execution.
22. Programmable Dwell 0-99 secs.
23. 4 Auxiliary Outputs.
24. 4 Programmable Inputs.
25. System Resolution 0.01 mm (0.0004″).

SAFETY FEATURES

Key Operated Isolator Switch, Membrane Keyboard, Chuck Guard, Axes Limit Switches - (adjustable on Z Axis), Electronic Shear Key built into Spindle Controller, Diagnostic Fault Finder.

EXTRA EQUIPMENT

A Full Range of Optional Equipment and Accessories are available including: Printers, Plotters, Computers, Software for Apple II, BBC Acorn, Epson HX20, Commodore, Pet, Paper Tape Punch Units and Porta Progs.

MECHANICAL

Swing Over Bed	200 mm (8″)
Swing Over Cross-slide	115 mm (4½″)
Distance between Centres	400 mm (15¾″)
Spindle Speed (Stepless)	0-2000 rpm
Spindle Bore	20 mm (13/16″)
Spindle Taper	No. 3
Tailstock Taper	No. 2
Tapers	20 : 1 - 1 : 20
Radii	2 mm to 3000 mm
Bed	Hardened and Ground Ways
X Axis Ballscrew	8 mm dia. 2.5 mm Pitch
Z Axis Ballscrew	16 mm dia. 5 mm Pitch

Toolpost - Quick Change with repeatability 0.0001″, 40 different locations.

Mechanical Resolution ..... 0.01 mm (0.0004″)

Machine Dimensions:-

Length 920 mm (36″) Width 560 mm (22″)
Height 540 mm (21″) Weight 140 Kilos (310 lbs)

ELECTRICAL

50 Hz - 1 phase 240 volts
60 Hz - 1 phase 220 volts

Spindle Motor

½ H.P. A.C. 0.37 kw 380-420 V 1.3 A incorporating A.C. Frequency Changer.

Axes Motors

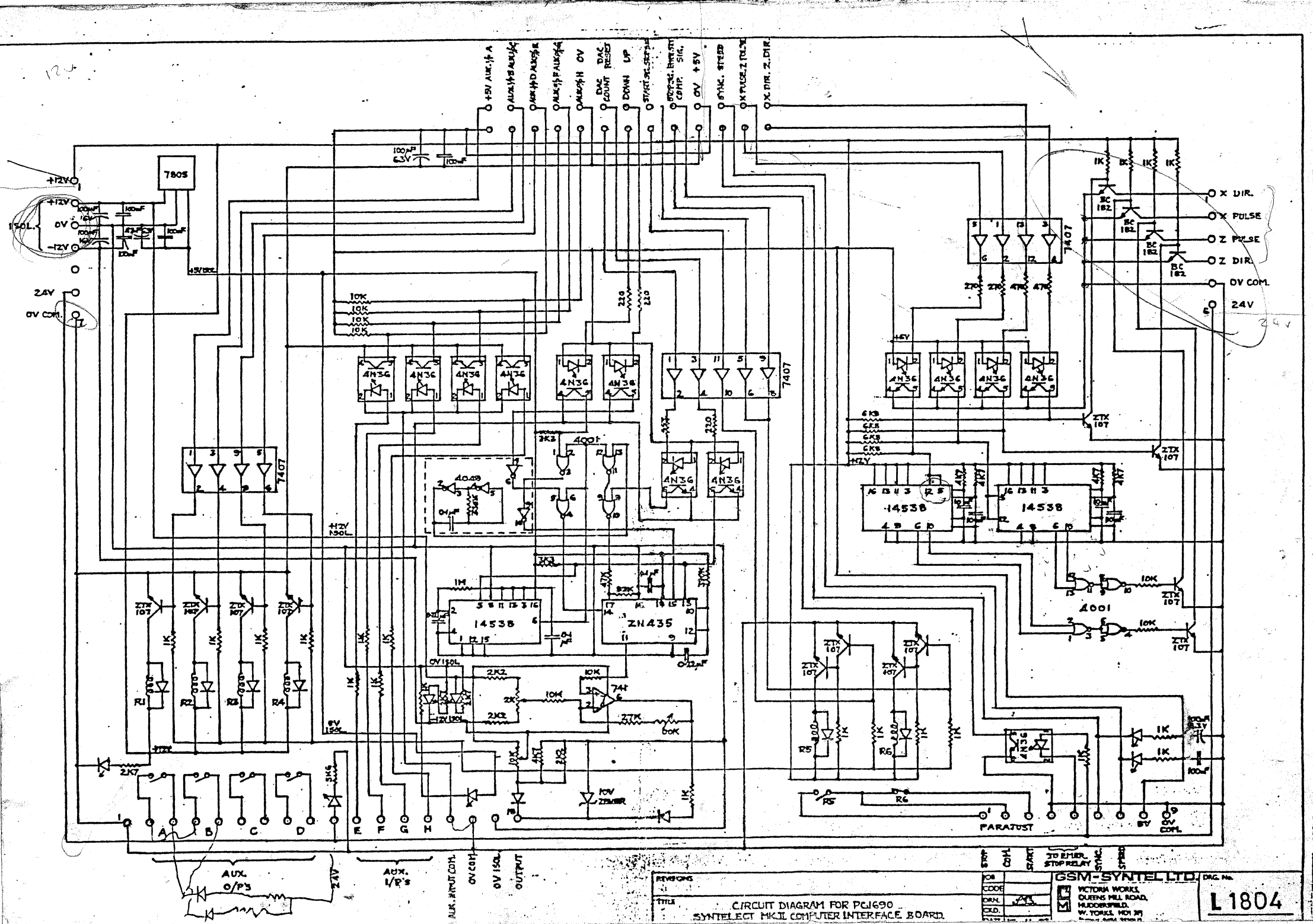
Stepper Motors - 200 Steps/Rev D.C. 2.9 V 3.1 A.

STANDARD EQUIPMENT

RS232C Link, Quick Change Toolpost and Holder, Self Centring 3 Jaw Chuck, Set of Outside Jaws, Installation, Maintenance and Instruction Manual, Spare Parts List, Map Light, Audio Cassette Deck and Headphone Outlet, Audio Instruction Tape, Video Instruction Film, Co-Axial T.V. Socket for V.D.U., Lathe Maintenance Tools, Mini Magnetic Cassette for Program Storage, Test Program with Component, Operator Training.

DENFORD MACHINE TOOLS

DENFORD MACHINE TOOLS LIMITED, BIRDS ROYD, BRIGHOUSE, WEST YORKSHIRE Phone: 0484 712264 Telex: 517478


+12V
0V
-12V
ISOL.
7805
24V
0V COM.
+5V AUX. I/P A
AUX. I/P B
AUX. I/P C
AUX. I/P D
0V
DAC COUNT RESET
DOWN UP
START SEQUENCE
STOP SEQ. INTERRUPT SIG.
+5V
STROBE
X PULSE, Z PULSE
X. DIR. Z. DIR.
4N36
7407
14538
ZN435
4001
ZTX 107
X DIR.
X PULSE
Z PULSE
Z DIR.
0V COM.
24V
PARA JUST
AUX. O/P's
AUX. I/P's
OUTPUT
REVISIONS
TITLE
CIRCUIT DIAGRAM FOR PCI690
SYNTELECT MKII COMPUTER INTERFACE BOARD
GSM-SYNTEL LTD.
VICTORIA WORKS
QUEENS MILL ROAD
HUDDERSFIELD
W. YORKS. HD1 3EJ
DRG. No.
L1804

INDEX

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

INTRODUCTION

The ORAC you have purchased utilizes the latest advances in microprocessor technology. These advances combined with Denfords programming aids and computer technology give you, the user, the very latest in CNC training. You will find the keyboard is simple to understand, simple to utilize and simple for editing purposes.

The keyboard itself provides switches which are completely sealed, combining the best of touchtone with pressure techniques thereby ensuring that no erroneous information is entered into the system. All programming may be accomplished at the machine by the operator or at a Desk Top Computer, transferring the completed programs to ORAC through the RS 232 C link.

As with any CNC machine, the programmer should know how to use good machining practice and be familiar with shop orientated terms. The manual has been written under these assumptions.

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 repetetive 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

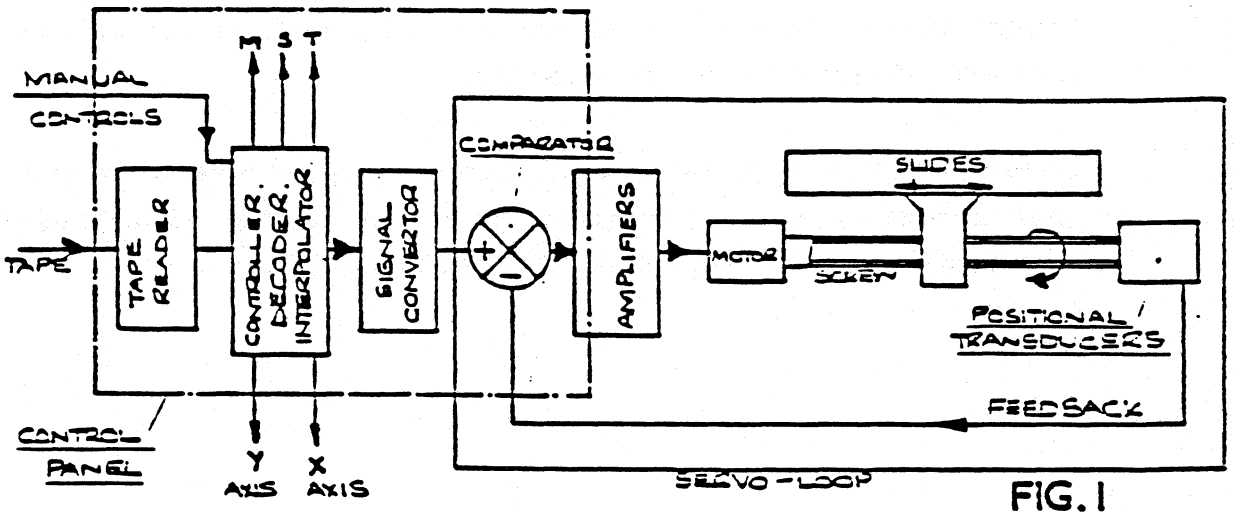


FIG. 1

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

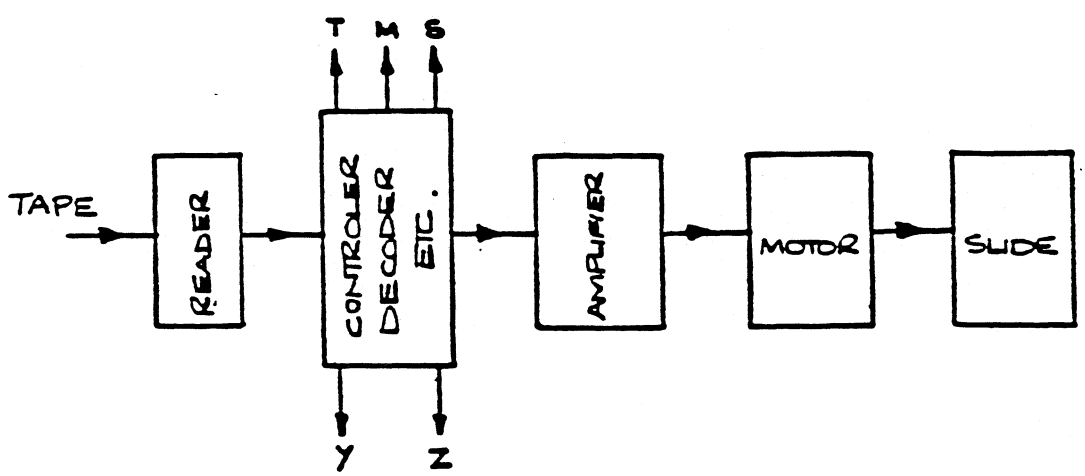


FIG. 2

This is a much simpler system and is used on the ORAC CNC 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 with advantages which are included in the new ORAC CNC BENCH TRAINING LATHE.

SECTION 3

TECHNICAL SPECIFICATION

CAPACITIES:

SWING OVER BED	200 mm	8"
SWING OVER	115 mm	4½"
DISTANCE BETWEEN CENTRES	400 mm	15¾"

HEADSTOCK:

SPINDLE BORE	20 mm	25/32"
SPINDLE NOSE INTERNAL TAPER	No.3	
SPINDLE BEARINGS	TAPER ROLLER	
SPINDLE SPEEDS	STEPLESS	0-2000 RPM

THREADS AND FEEDS:

SCREWCUTTING PITCHES	.35-3.5mm	8-70 TPI
X AND Z AXIS SCREWS	BALLSCREWS	
RAPID TRAVERSE	1200 mm/min	47"/min
FEEDRATES	INFINATELY VARIABLE UP TO 1200 mm/min	47"/min

LINEAR AND CIRCULAR INTERPOLATION:

TAPERS	20:1	1:20
RADII	2 mm TO	3000 mm

CARRIAGE AND BED:

BED LENGTH	660 mm	26"
BED WIDTH	116 mm	4¾"
GROUND AND HARDENED	2 VEES-2 FLATS	
CROSS SLIDE MOVEMENT	95 mm	
TOP SLIDE TO SPINDLE CENTRE LINE	19 mm	¾"

TAILSTOCK:

BARREL TAPER	No.2
BARREL MOVEMENT	50 mm
BARREL GRADUATIONS	MILLIMETRES

MOTORS:

MAIN DRIVE MOTOR	0.37 KW 380-420 V 1.3A AC
STEPPER MOTOR X	200 STEPS/REV DC 2.9 V 3.1A
STEPPER MOTOR Z	200 STEPS/REV DC 2.9 V 3.1A

MACHINE DIMENSIONS (OVERALL):

LENGTH	920 mm	36"
HEIGHT	540 mm	21"
WIDTH	560 mm	22"
WEIGHT	140 kg	310 lbs

CNC CONSOL:

RESOLUTION	-	0.01 mm 0.0005"
FEEDRATE INFINATELY VARIABLE UP TO		1200 mm/min 47"/min
RAPID TRAVERSE		1200 mm/min 47"/min
SPINDLE SPEEDS		50-2000 R.P.M. INFINATELY VARIABLE
TOOL OFFSETS UP TO 10 PAIRS		
PROGRAM LENGTH UP TO 160 BLOCKS		
PROGRAMMING USING I.S.O. FORMAT	-	18 'G' CODES
PROGRAMMABLE SPINDLE START AND STOP		
FACILITY FOR PROVING PROGRAMS USING TOOLPATH GRAPHICS		
PROGRAM AND TOOL OFFSET STORAGE ON MINI CASSETTE		
PROGRAM DISPLAY	-	7" V.D.U.
KEYBOARD	-	TOUCH TONE
CONTROL SYSTEM	-	SYNTELECT
AUXILIARY OUTPUTS	-	4
AUXILIARY INPUTS	-	4
DATA INPUT	-	ALPHA/NUMERIC KEYBOARD
DO LOOP AND SUB-ROUTINE FACILITY		
COMPUTER DATA LINK	-	RS 232 C
TOOL COMPENSATION VIA TOOL OFFSET EDIT FACILITY		
SINGLE PHASE INPUT		220/250V/50 HZ
		110/115V/60 HZ

SAFETY FEATURES

KEY OPERATED ISOLATOR SWITCH
DIAGNOSTIC FAULT FINDER
TOTALLY ENCLOSED CHUCK GUARD
AXIS LIMIT SWITCHES

STANDARD EQUIPMENT

RS 232 LINK FOR COMPUTER OR PRINTER.

QUICK CHANGE TOOLPOST AND HOLDER.

SELF CENTRING 3 JAW CHUCK.

SET OF OUTSIDE JAWS.

SAFETY GUARDS.

INSTRUCTION MANUAL AND PARTS LIST.

MAP LIGHT.

STEREO CASSETTE DECK.

2 HI-FREQUENCY SPEAKERS AND HEADPHONE OUTLET.

AUDIO INSTRUCTION TAPE.

VIDEO INSTRUCTION FILM.

CO AXIAL T.V. SOCKET FOR V.D.U.

LATHE MAINTENANCE TOOLS.

MINI MAGNETIC CASSETTE FOR PROGRAM STORAGE.

2 FUSES.

MACHINE PLUG.

TEST PROGRAM WITH COMPONENT.

SOCKET FOR 8 STATION PROGRAMMABLE TOOLPOST.

SECTION 4

INSTALLATION AND LUBRICATION

INSTALLATION

LIFTING

Although ORAC can be lifted by up to 3 to 4 persons, it is advisable to use some recommended lifting apparatus.

If using a lifting device, slide steel bars through the two channels underneath the machine about 50" in length and secure a rope around the 4 ends of the bar.

Recommended cross section of Bar:- $1\frac{1}{4}$" x $\frac{5}{8}$"

ERECTION ON SITE

ORAC can be mounted at any desk top situation. It is unnecessary to bolt ORAC to a base, however, if this is so required push a bar through each of the channels underneath the machine and secure through either end of the bars.

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 the minimum of maintenance.

ELECTRICAL SUPPLY CONNECTION

The regular electrical mains power supply to the machine is single phase 240 V 50 HZ. Three Phase is NOT suitable for this product and cannot be supplied.

Connect the mains supply to the supplied adaptor.

N.B. The machine should only be commissioned by a qualified electrical Engineer.

LUBRICATION

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

To oil the X-slide screw, remove the grommit in the cross slide cover and apply oil. To oil the Z axis screw, pull back both spiral spring covers at the a[illegible]n ends, and apply oil. Also lubricate through the point on the top of the apron.

OIL BOTH BALLSCREWS WEEKLY. FAILURE TO DO THIS COULD RESULT IN SEIZURE.

Add grease sparingly to the Headstock bearings through Grease Nipples at back of Headstock.

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

	SHELL	CASTROL
OIL	VITREA 68	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:-

PERIOD	MAINTENANCE REQUIRED
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.

SECTION 6

TAILSTOCK AND CHUCK MOUNTING

CHUCK MOUNTING

ORAC 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 No.2 MT 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)

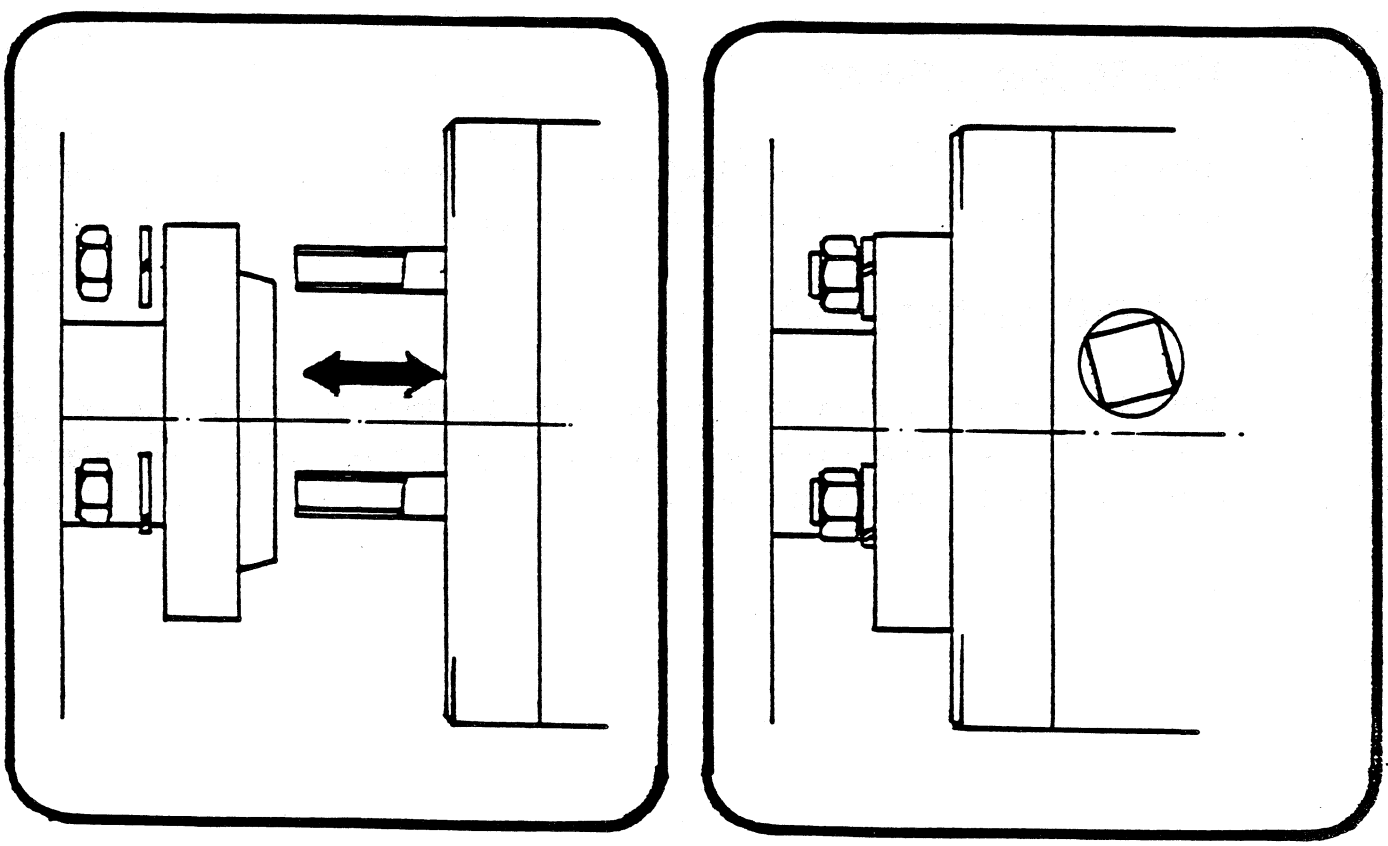


FIG.3

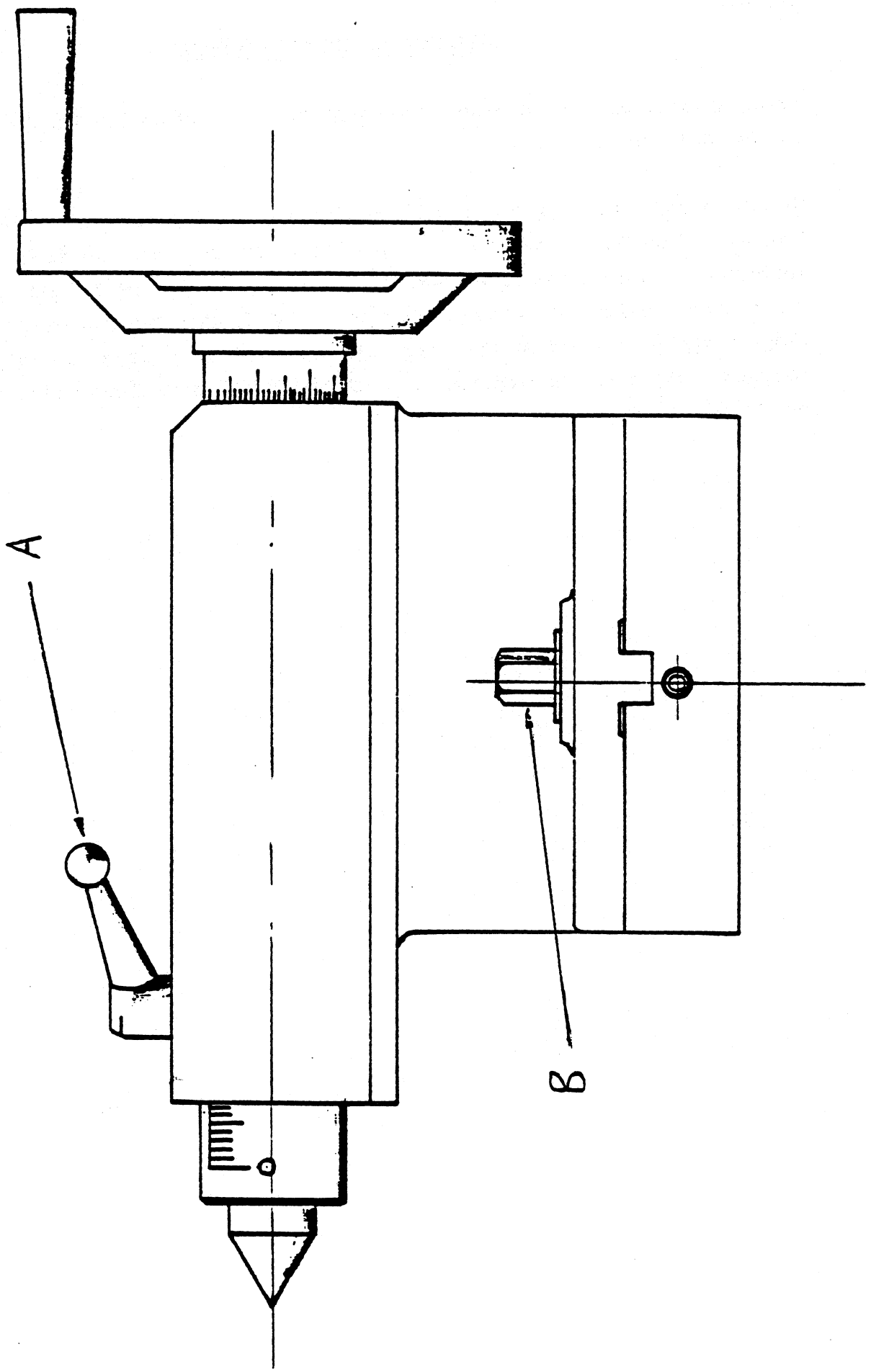


FIG.4

SECTION 7

OPERATION OF SPINDLE CONTROLS

Having carried out the necessary procedure for the installation of the machine it is now ready for operation.

Switch on the mains supply and wait for the menu to appear on the V.D.U. If the Emergency Stop Button is locked in position, the axis and spindle controls are inoperative. Unlock the button and switch on the spindle by depressing the round green Button under the spindle controls. The initial spindle speed will be a cogging effect. Increase the speed by pressing the + under the spindle speed controls. First run the spindle at a low speed to ensure lubrication and freedom of all running parts.

SECTION 8

THE QUICK CHANGE TOOLPOST

ORAC 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 vise-versa. The manufacturers repeatable accuracy on clamping is 0.01 mm.

SECTION 9

MACHINE AXIS FORMAT

FIG.5 illustrates the plan view of ORAC. 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.5A 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 splash guard the movement is negative and towards the operator from X0 is positive.

FIG.5B 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.

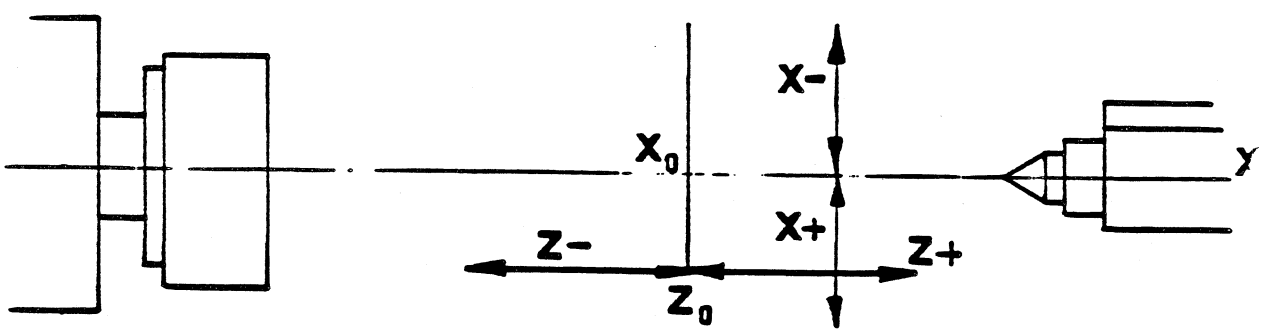


FIG.5A

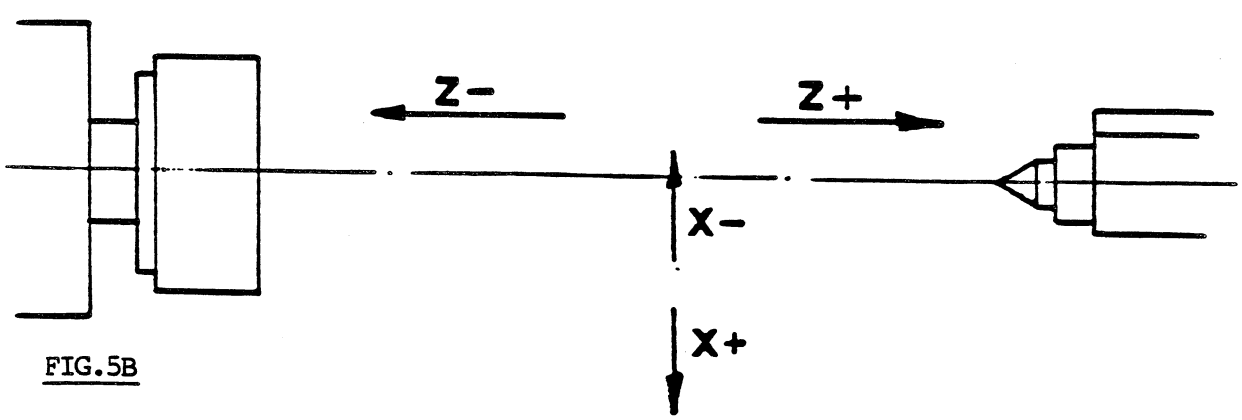
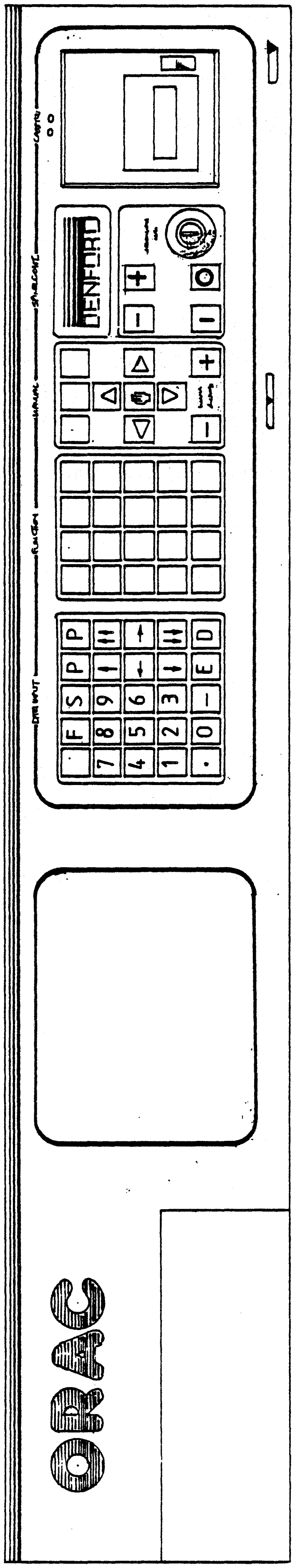


FIG.5B



THE ALPHA NUMERIC KEYBOARD

SECTION 10

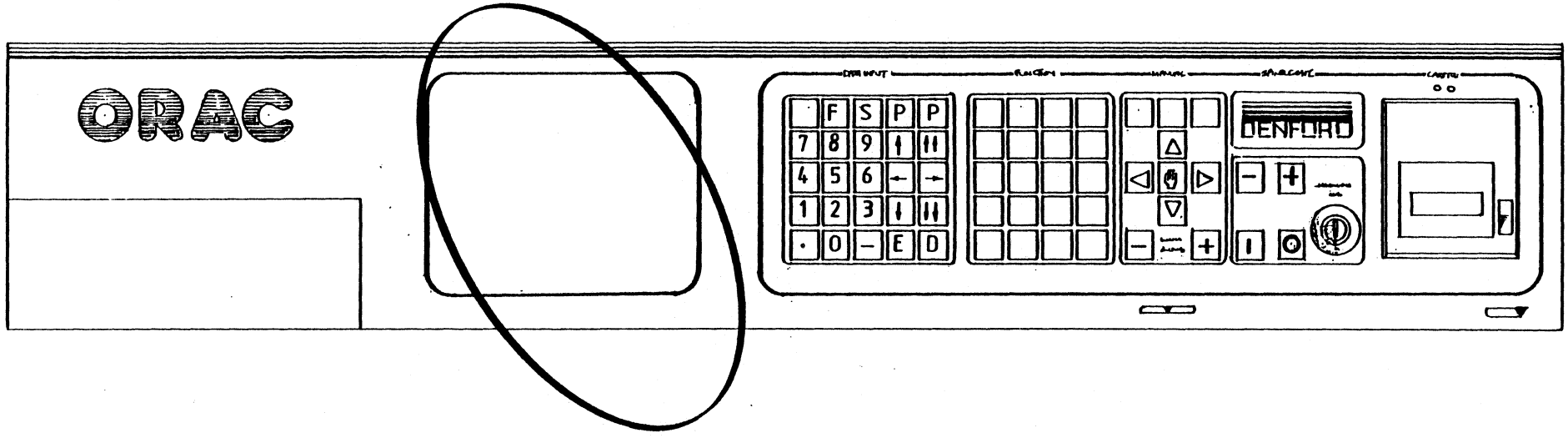
THE VISUAL DISPLAY UNIT (V.D.U.)

The Visual Display Unit (referred to as the screen) assists the operator in programming by giving a visual display of all information entered, and guiding you through the program.

The screen will also display the block which is actually being executed at that particular time.

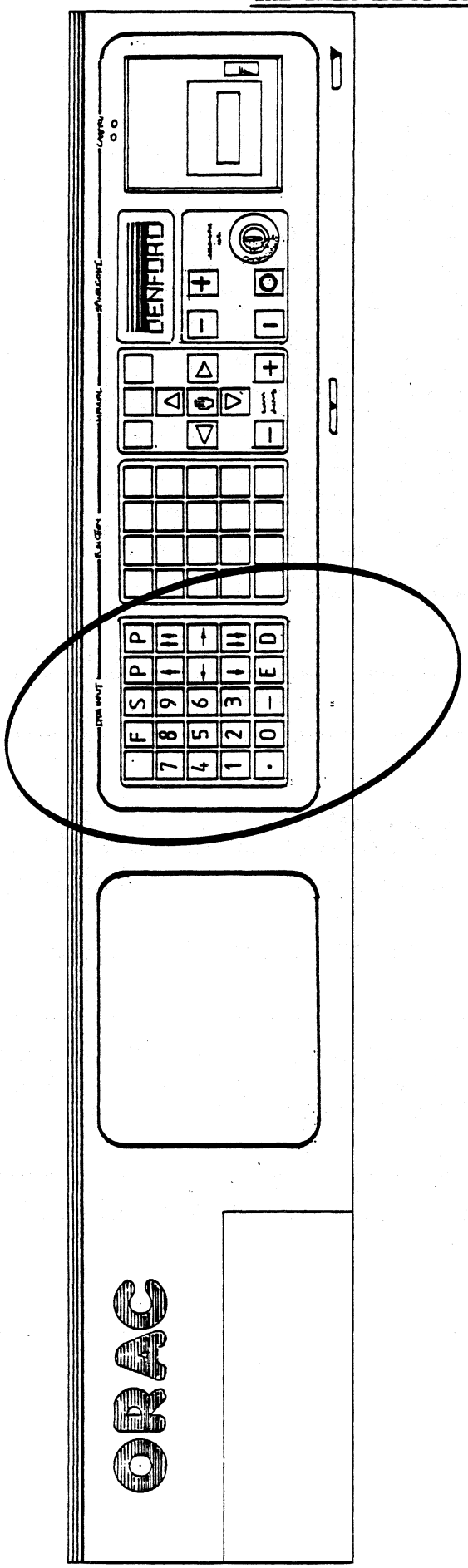
The information on the screen can be displayed on a larger screen by connecting up a T.V. monitor to ORAC via the coaxial link at the rear of the machine.

ORAC's screen is also used for proving the program using the toolpath graphics facility.

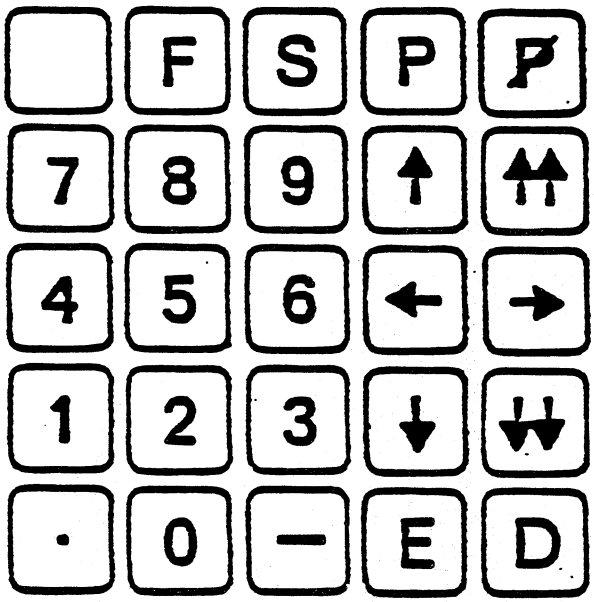


VISUAL DISPLAY UNIT [V.D.U.]

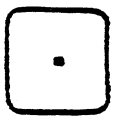
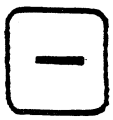
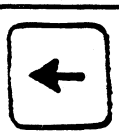
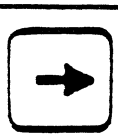
THE DATA INPUT SECTION



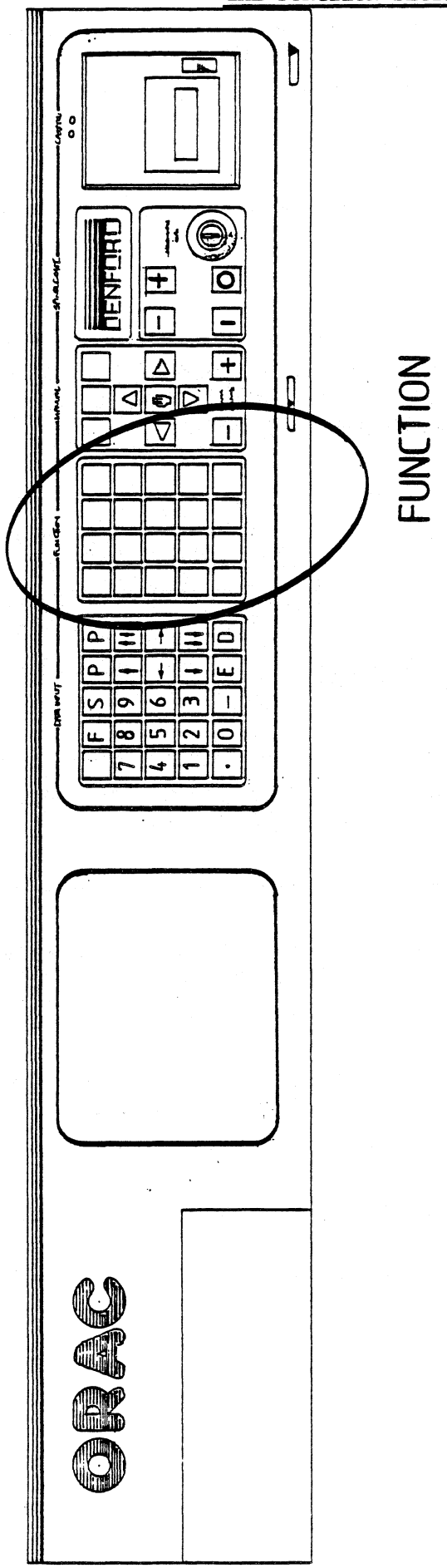
DATA INPUT SECTION



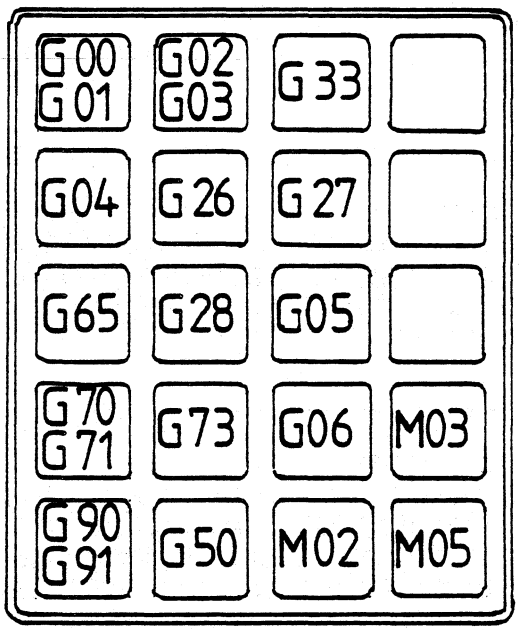
KEY	FUNCTION
0 TO 9	a) NUMERICAL DATA KEYS. b) INSTRUCTION SELECTION KEYS USED DURING PROGRAMMING.
F	FUNCTION KEY: USED AS INSTRUCTED ON VDU.
S	SPACE KEY: USED DURING PROGRAM ENTERING AND EDITING TO DELETE A CHARACTER. WITH THE CURSOR UNDER THE APPROPRIATE NUMBER OR LETTER PRESS S.
P	PAGE INSERT KEY: USED DURING PROGRAM EDITING TO INSERT A NEW PAGE. (SEE SECTION 23 PAGE 64)
P	PAGE DELETE KEY: USED DURING PROGRAM EDITING TO DELETE A PAGE. (SEE SECTION 23 PAGE 64)

KEY	FUNCTION
	DECIMAL POINT KEY.
	MINUS SIGN KEY.
	ENTER KEY: USED IN CONJUNCTION WITH ALMOST ALL PROGRAMMING AND IS USED TO CONFIRM AND TRANSFER INFORMATION INTO THE MEMORY.
	DELETE KEY: A) USED TO DELETE SELECTED DATA. (SEE SECTION 23 PAGE 63) B) USED TO SELECT DRILL SIZE IN GRAPHICAL SIMULATION. (SEE SECTION 24 PAGE 65)
	PAGE FORWARD KEY: USED DURING PROGRAMMING AND EDITING TO MOVE ON TO NEXT PAGE.
	PAGE REVERSE KEY: USED DURING PROGRAMMING AND EDITING TO MOVE BACK TO PREVIOUS PAGE.
	CURSOR KEY: A) MOVES FLASHING CURSOR UPWARDS. B) INCREASES BILLET SIZE IN GRAPHICAL SIMULATION.
	CURSOR KEY: A) MOVES FLASHING CURSOR DOWNWARDS. B) DECREASES BILLET SIZE IN GRAPHICAL SIMULATION.
	CURSOR KEY: MOVES FLASHING CURSOR TO LEFT.
	CURSOR KEY: MOVES FLASHING CURSOR TO RIGHT.

THE FUNCTION SECTION



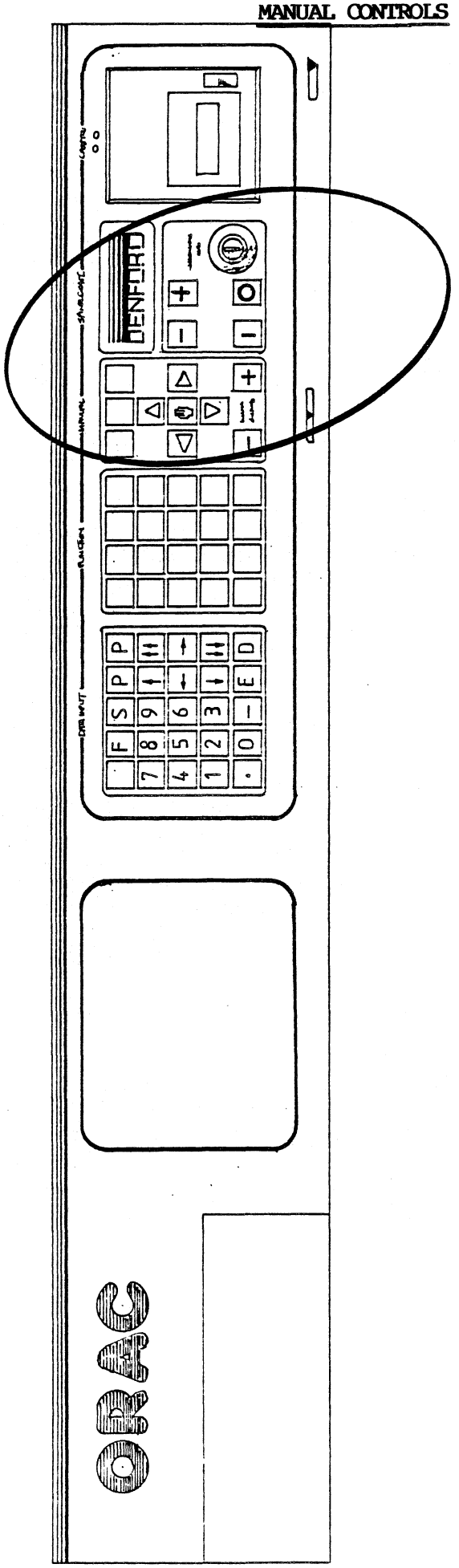
FUNCTION



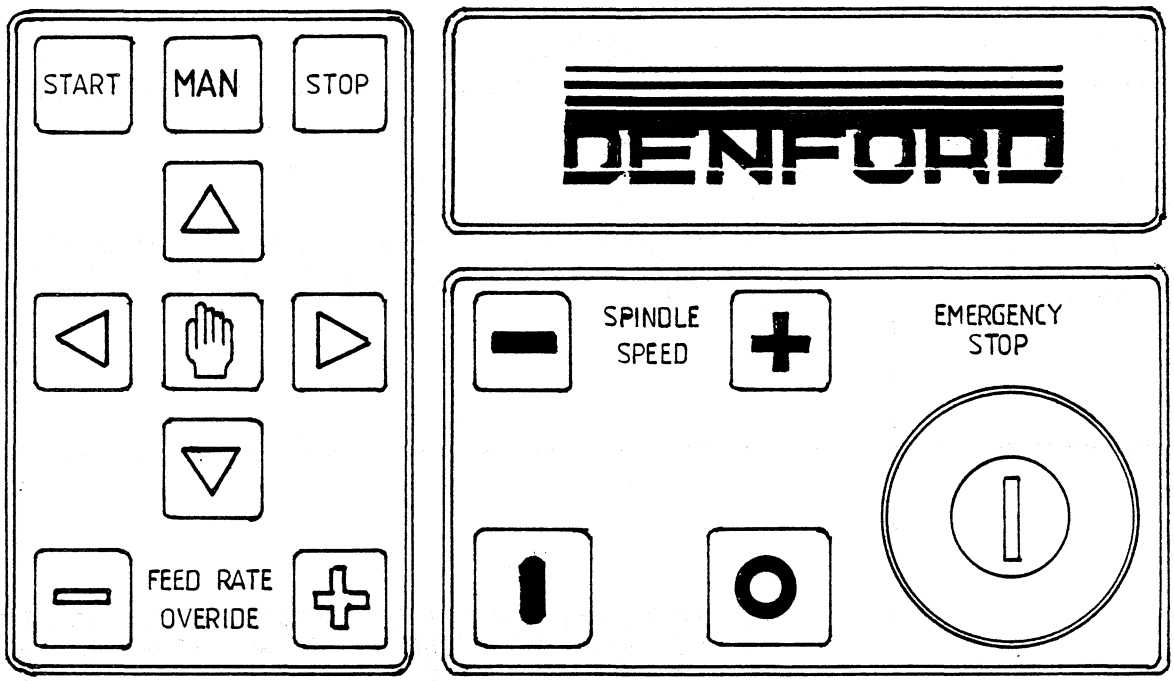
KEY	FUNCTION
G00 G01	LINEAR INTERPOLATION. POINT TO POINT OPERATION: THIS INSTRUCTION MOVES THE TOOL IN EITHER THE X (FACING) OR Z (TURNING) DIRECTIONS INDIVIDUALLY. OR X AND Z DIRECTIONS SIMULTANEOUSLY (TAPER TURNING) i.e. LINEAR INTERPOLATION. (SEE SECTION 18.2 PAGE 40 FOR DETAILED INSTRUCTION)
G02 G03	CIRCULAR INTERPOLATION. THIS INSTRUCTION ENABLES ORAC TO CUT IN A CIRCULAR MOTION. (SEE SECTION 18.3 PAGE 41 FOR DETAILED INSTRUCTION)

KEY	FUNCTION
G 33	THREAD CUTTING: THIS INSTRUCTION PROVIDES A THREADING CYCLE FOR EXTERNAL AND INTERNAL THREADS. (SEE SECTION 18.4 PAGE 44 FOR DETAILED INSTRUCTION)
G 04	DWELL PERIOD: THIS INSTRUCTION ALLOWS A TIMED DWELL PERIOD TO BE PROGRAMMED BETWEEN MACHINING OPERATIONS, AND THE MACHINE WILL REMAIN STATIONARY AT ITS PRESENT POSITION. (SEE SECTION 18.5 PAGE 48)
G 26	AUXILLIARY INPUTS: THIS INSTRUCTION ALLOWS THE PROGRAM TO BE HALTED BETWEEN MACHINING OPERATIONS. THE EXECUTE PROGRAM WILL ONLY PROCEED BEYOND THIS POINT IF ANY OF THE 4 AUXILLIARY INPUTS PROGRAMMED TO RECEIVE AN INPUT SIGNAL ARE ACTIVATED. (SEE SECTION 18.6 PAGE 49 FOR DETAILED INSTRUCTION)
G 27	AUXILLIARY OUTPUTS: THIS INSTRUCTION ALLOWS ANY OF THE 4 AUXILLIARY OUTPUT RELAYS TO BE OPERATED TO CONTROL EXTERNAL FUNCTIONS. (SEE SECTION 18.7 PAGE 50 FOR DETAILED INSTRUCTION)
G 65	CALL SUBROUTINE: THIS INSTRUCTION ALLOWS A SUBROUTINE TO BE CALLED FOR EXECUTION. (SEE SECTION 18.8 PAGE 51 FOR PROGRAM FORMAT)
G 28	SUBROUTINE START: THIS INSTRUCTION ALLOWS A SUBROUTINE TO BE CONSTRUCTED AND ALLOCATED AN IDENTITY NUMBER. THE SUBROUTINE FORMAT IS EXPLAINED IN SECTION 18.8 PAGE 51.
G 05	END SUBROUTINE PROGRAM: THIS INSTRUCTION ENDS THE SUBROUTINE. ALL FUNCTIONS ENTERED BETWEEN 'SUB' AND 'END SUB' CONSTITUTE THE SUBROUTINE. (SEE SECTION 18.8 PAGE 52)
G 73	START DO LOOP: THIS INSTRUCTION IS USED FOR STARTING A REPETITIVE SEQUENCE. (SEE SECTION 18.9 PAGE 55 FOR PROGRAM FORMAT)

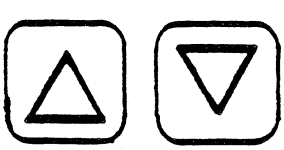
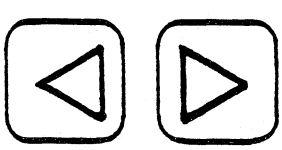
KEY	FUNCTION
G 06	END DO LOOP: THIS INSTRUCTION ENDS THE DO LOOP SEQUENCE. ALL FUNCTIONS ENTERED BETWEEN 'DO' AND 'END DO' CONSTITUTE THE SEQUENCE TO BE EXECUTED THE REQUIRED NUMBER OF TIMES (COUNT).
M 02	END PROGRAM: THIS INSTRUCTION DEFINES THE END OF THE MAIN PROGRAM. (SEE SECTION 18.10 PAGE 58)
G 70 G 71	UNITS SELECTION: INCH OR MILLIMETRES. THIS INSTRUCTION SELECTS THE UNITS FOR SUBSEQUENCE PROGRAM PAGES. ALTERNATIVE DEPRESSION OF THE KEY CHANGES THE UNITS FROM INCH TO MILLIMETRES TO INCH etc. (THIS FEATURE OF ORAC ENABLES US TO PROGRAM EITHER IN INCH OR MILLIMETRES WITHIN THE SAME PROGRAM.) ENSURE THAT THE UNITS FOR THE PROGRAM ARE SELECTED AT EITHER BLOCK 1 OR 2. (SEE SECTION 26 PAGE 68 FOR UNITS FOR TOOL OFFSETS)
G 90 G 91	INCREMENTAL/ABSOLUTE FORMAT: THIS INSTRUCTION SELECTS THE PROGRAM FORMAT FOR SUBSEQUENT PROGRAM PAGES. ALTERNATE DEPRESSION OF THE KEY CHANGES THE FORMAT FROM INC. TO ABS. TO INC. etc. THIS FEATURE OF ORAC ENABLES US TO PROGRAM IN EITHER ABSOLUTE OR INCREMENTAL WITHIN THE SAME PROGRAM. IT IS EXTREMELY HELPFUL WHEN DRAWINGS ARE DIMENSIONED WITH A COMBINATION OF INCREMENTAL AND ABSOLUTE CO-ORDINATES. ENSURE THAT THE FORMAT FOR THE PROGRAM IS SELECTED AT EITHER BLOCK 1 OR 2.
G 50	PROGRAM DATUM: THIS INSTRUCTION ALLOWS THE CO-ORDINATES OF THE PROGRAM DATUM TO BE ENTERED AND THESE VALUES ARE ALWAYS TAKEN FROM THE CENTRE LINE OF THE SPINDLE ON X AND FROM THE END OF THE WORKPIECE ON Z. EVEN THOUGH INCREMENTAL MAY HAVE BEEN SELECTED FOR THE FORMAT THE PROGRAM DATUM SHOULD ALWAYS BE ENTERED IN BLOCK No.3 AND ENTERED IN THE UNITS PREVIOUSLY SELECTED IN BLOCK 1 OR 2.
M 03	SPINDLE START: THIS INSTRUCTION WILL START THE SPINDLE IN A FORWARD DIRECTION DURING A PROGRAM.
M 05	SPINDLE STOP: THIS INSTRUCTION IS USED TO STOP THE SPINDLE ROTATION WITHIN THE PROGRAM, E.G. FOR A TOOL CHANGE.

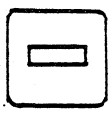
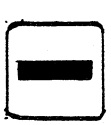
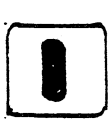
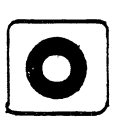


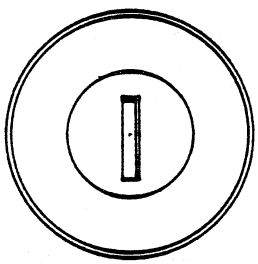
MANUAL CONTROL



KEY	FUNCTION
START	a) STARTS AND RESTARTS THE OPERATING SEQUENCE WHEN EXECUTING A PROGRAM. ENSURE BEFORE STARTING OR RESTARTING A PROGRAM THAT THE SPINDLE IS RUNNING. b) STARTS THE TOOLPATH SIMULATION.
STOP	a) STOPS THE OPERATING SEQUENCE WHEN EXECUTING A PROGRAM. TO RESTART THE PROGRAM PRESS THE SQUARE GREEN START BUTTON. b) INPUTS POSITIONAL INFORMATION FOR 'Zo PLANE' AND 'X DIA.' WHEN USED AS INSTRUCTED IN THE 'TOOL OFFSET' SETTING UP MODE. (SEE SECTION 26 PAGE 68) c) STOPS MANUAL OPERATING SEQUENCE AND RETURNS TO EITHER THE MAIN MENU OR THE TOOL OFFSET MENU. d) STOPS TOOLPATH SIMULATION AT ANY TIME. TO RESTART PRESS THE SQUARE GREEN START BUTTON. AFTER COMPLETION OF THE SIMULATION, THIS KEY IS USED TO RETURN TO THE MAIN MENU.

KEY	FUNCTION
MAN	ALLOWS SELECTION OF MANUAL AXIS CONTROL ONCE AUTOMATIC EXECUTION OF A PROGRAM HAS BEEN STOPPED USING THE SQUARE RED STOP KEY.
	ONCE OPERATING UNDER MANUAL OPERATION YOU MUST DECIDE WHAT YOU WISH TO DO IN MANUAL. YOU HAVE THREE OPTIONS. THE FIRST FEED INDICATED UNDER MANUAL OPERATION IS FAST FEED. THIS IS INDICATED IN THE BOTTOM RIGHT HAND CORNER OF THE SCREEN. THE FAST FEEDRATE IS A RAPID MOVE AT 47 INCHES/MIN OR 1200 MM/MIN. IF YOU DEPRESS THIS KEY THE FEEDRATE WILL CHANGE FROM FAST TO SLOW. THE SLOW FEEDRATE IS 6 INCHES/MIN OR 150 MM/MIN. A FURTHER DEPRESSION OF THE KEY WILL CHANGE THE FEEDRATE TO STEP. THIS IS A JOG OF 0.01 MM OR 0.0004 INCHES. EACH TIME YOU DEPRESS THE KEY THE FEEDRATE WILL CHANGE FROM FAST TO SLOW TO STEP. CONSTANT DEPRESSION OF THE KEY WILL CONTINUALLY CHANGE THE INDICATED FEEDRATE. (SEE SECTION 26 PAGE 68 FOR TOOL OFFSET FEEDRATES)
	X TRAVERSE: IN AND OUT.
	Z TRAVERSE: LEFT AND RIGHT. PRESS THE KEY POINTING TO THE LEFT TO MOVE THE TOOL TOWARDS THE CHUCK AND TO THE RIGHT TO MOVE AWAY FROM THE CHUCK. SIMILARLY PRESS THE KEY POINTING UPWARDS TO MOVE THE TOOL TOWARDS THE CENTRE LINE OF THE SPINDLE AND DOWNWARDS TO MOVE THE TOOL AWAY FROM THE CENTRE LINE. WHEN IN MANUAL FAST OR SLOW MOVEMENT WILL OCCUR ONLY AS LONG AS YOU KEEP CONSTANT DEPRESSION ON THE APPROPRIATE ARROW BUTTONS. CARE SHOULD BE TAKEN WHEN APPROACHING AN OBSTRUCTION, SUCH AS A WORKPIECE, BECAUSE THE MACHINE NEEDS A SHORT DISTANCE TO DECELERATE.

KEY	FUNCTION
	a) WHEN OPERATED DURING EXECUTION OF A PROGRAM, REDUCES THE AXIS FEED IN OPERATION AT THAT TIME FROM ITS PROGRAMMED VALUE TO SOME LOWER VALUE. b) WHEN OPERATED IN GRAPHICAL SIMULATION, CHANGES THE SIMULATED FEEDRATE OF THE TOOL TO SLOW.
	a) WHEN OPERATED DURING EXECUTION OF A PROGRAM, INCREASES THE AXIS FEED IN OPERATION AT THAT TIME FROM ITS PROGRAMMED VALUE TO SOME HIGHER VALUE. b) WHEN OPERATED IN GRAPHICAL SIMULATION, CHANGES THE SIMULATED FEEDRATE OF THE TOOL TO FAST.
	WITH BOTH THE ABOVE OVERRIDE FACILITIES, THE PROGRAMMED AND OVERIDE FEEDRATES ARE DISPLAYED ON THE SCREEN DURING EXECUTION. AFTER THE COMPLETED EXECUTION OF THE BLOCK, WITH THE OVERRIDDEN FEEDRATE, THERE WILL BE A RETURN TO THE PROGRAMMED VALUE. THE OVERRIDE RANGE IS FROM 0% TO 110%. THE DISPLAY ONLY INDICATES THE FEEDRATE IN UNITS OF TEN. HENCE A FEEDRATE OF 50 MM/MIN WITH MAXIMUM POSITIVE OVERRIDE OF 10% WILL STILL ONLY INDICATE 50 MM/MIN EVEN THOUGH THE ACTUAL VALUE WILL BE 55 MM/MIN.
	WHEN OPERATED DURING THE EXECUTION OF A PROGRAM, REDUCES THE SPINDLE SPEED FROM THE PROGRAMMED VALUE. KEY HELD DOWN UNTIL REQUIRED SPEED IS ACHIEVED, THEN RELEASED, AND SPEED REMAINS AT THAT SET LEVEL UNTIL A CHANGE IN A SUBSEQUENT BLOCK.
	WHEN OPERATED DURING THE EXECUTION OF A PROGRAM, INCREASES THE SPINDLE SPEED FROM THE PROGRAMMED VALUE. KEY HELD DOWN UNTIL REQUIRED SPEED IS ACHIEVED, THEN RELEASED, AND SPEED REMAINS AT THE SET LEVEL UNTIL A CHANGE IN A SUBSEQUENT BLOCK. UNLIKE FEEDRATE OVERRIDE THE NEW SPINDLE SPEED IS NOT INDICATED ON THE V.D.U.
	GREEN BUTTON STARTS SPINDLE.
	RED BUTTON STOPS SPINDLE. WARNING: THE DEPRESSION OF SPINDLE STOP IN MID PROGRAM STOPS THE SPINDLE, HOWEVER, THE AXIS WILL CONTINUE TO RUN.

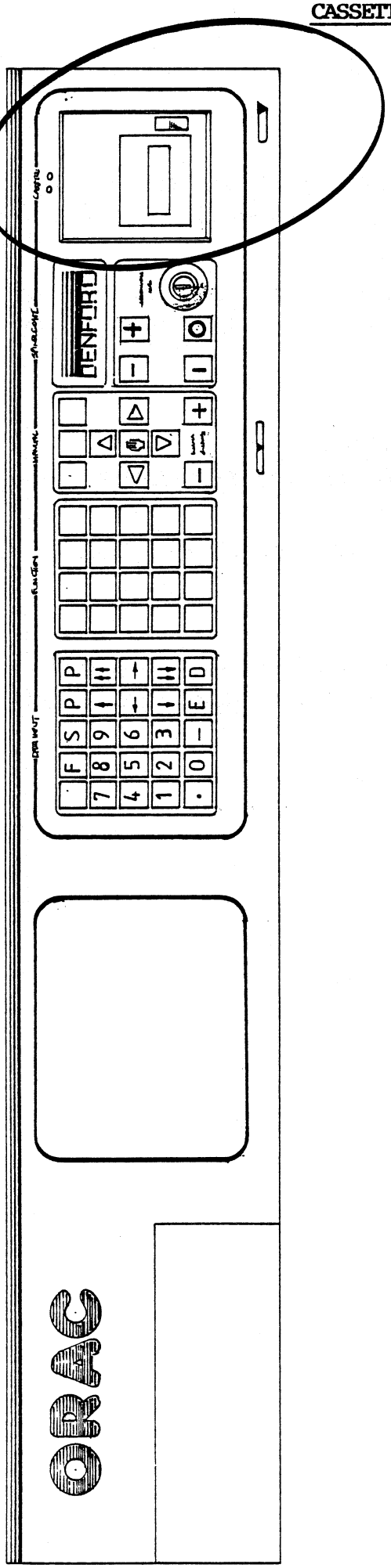
KEY	FUNCTION
	EMERGENCY STOP. STOPS BOTH SPINDLE AND AXIS DRIVES. BUTTON LOCKS DOWN WHEN OPERATED AND CAN ONLY BE RESET WITH KEY.

DEPRESSION OF THE EMERGENCY STOP BUTTON, WITH THE KEY IN THE VERTICAL POSITION, WILL LOCK THE BUTTON DOWN, AND THE V.D.U. WILL DISPLAY MANUAL OPERATION WITH THE APPROPRIATE X AND Z CO-ORDINATES. TO OPERATE THE MACHINE IN MANUAL MODE WAIT A MINIMUM OF 3 SECONDS AND UNLOCK THE BUTTON BY TURNING THE KEY TO THE RIGHT.

IF THE KEY IS TURNED TO THE RIGHT ON DEPRESSION IT WILL NOT LOCK DOWN, BUT WILL RETURN TO ITS ORIGINAL POSITION AND THE V.D.U. WILL DISPLAY: MANUAL OPERATION WITH THE APPROPRIATE X AND Z CO-ORDINATES. HOWEVER, THE MACHINE MAY BE INOPERATIVE DUE TO THE RELAYS NOT HAVING TIME TO RESET. TO OPERATE THE MACHINE, LOCK IN THE BUTTON AND HOLD FOR 3 SECONDS BEFORE RELEASE.

WHEN THE EMERGENCY STOP IS OPERATED, POSITIONAL INFORMATION WILL BE LOST AND RE-EXECUTION MUST COMMENCE FORM PAGE 01 OF THE PROGRAM.

TO RETURN TO THE MAIN MENU PRESS THE SQUARE RED STOP KEY UNDER THE MANUAL SECTION OF THE CONTROL PANEL.



DATA CASSETTE

OPERATION OF THE DATA CASSETTE IS ENTIRELY AUTOMATIC DURING BOTH THE "LOAD" AND "SAVE" MODES OF OPERATION.

THE ONLY OPERATOR REQUIREMENT IS TO ENSURE THAT WHEN PROMPTED VIA THE V.D.U. TO CHECK "CASSETTE LOADED" - THAT A TAPE CASSETTE IS ACTUALLY LOADED INTO THE MACHINE.

TO LOAD A CASSETTE, PUSH UPWARDS ON THE BUTTON AT THE RIGHT OF THE CASSETTE HOLDER WHEN THE DOOR OPENS, INSERT THE TAPE WITH THE EXPOSED TAPE SURFACE DOWNWARDS. WHEN FULLY INSERTED CLOSE THE DOOR.

THE CASSETTE CARRIES 2 FUNCTIONS:

1. IT IS USED TO STORE PROGRAMMES AND OFFSETS BY TRANSFERRING THE INFORMATION FROM THE MEMORY TO THE CASSETTE.
2. IT IS USED TO LOAD PROGRAMMES AND OFFSETS BY TRANSFERRING INFORMATION FROM THE CASSETTE TO THE MEMORY.

FOR DETAILED OPERATION SEE SECTIONS 21 AND 22 PAGES 61 AND 62 FOR PROGRAM TRANSFERS. AND SECTIONS 26.3 AND 26.4 PAGES 73 AND 74 FOR OFFSET TRANSFERS.

SECTION 15

CLEARING THE MEMORY

Once ORAC has been switched on at the mains the memory will be clear.

There are 3 ways to clear ORAC'S memory if there is a program already loaded:

1. Return to the menu, and then depress 5 to enter a new program into memory and then E. ORAC will assume a new program is going to be entered into memory, and so will clear the existing program.

2. Return to the menu and load a program from cassette by depressing 1 on the keyboard and then E, place a cassette into the holder and press E to acknowledge that you have indeed loaded a cassette. Once the screen displays PROGRAM TRANSFER COMPLETE, the existing program in ORAC'S memory will be replaced with the new program taken from the cassette.

   NOTE In both of the above cases, only ORAC'S program memory is cleared. The tool offsets stored in memory will remain until replaced.

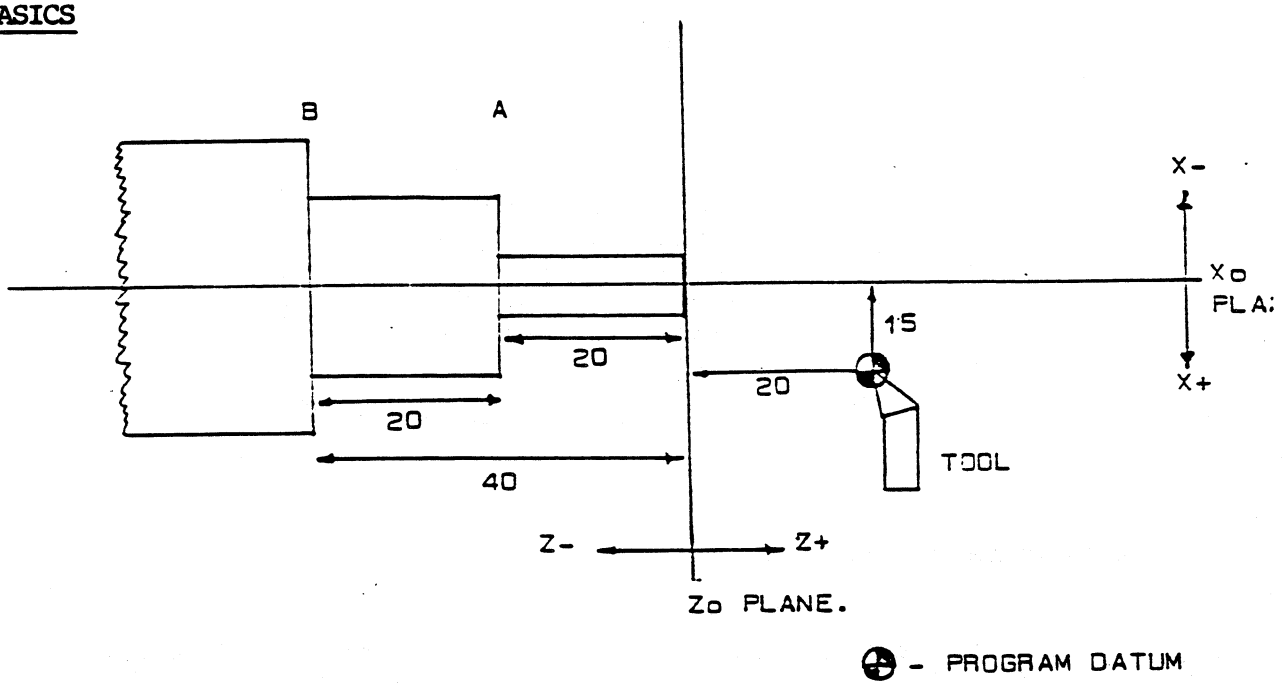
3. Memory is also lost when the mains supply to the machine is turned off, however, this should not be used as a method of clearing memory.

SECTION 16

BASIC PRINCIPLES

PROGRAMMING:

BASICS



THE ABOVE DIAGRAM ILLUSTRATES THE TERMS Zo; Xo; PROGRAM DATUM; ABSOLUTE AND INCREMENTAL AS USED IN THE WRITING OF PROGRAMS FOR CNC MACHINES.

Zo IS TAKEN AS THE END OF THE WORKPIECE.

Xo IS TAKEN AS THE CENTRE LINE OF THE SPINDLE.

THE PROGRAM DATUM IS SHOWN 20 MM FROM THE Zo PLANE AND 15 MM FROM THE Xo 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:

NOTE ALL ABSOLUTE Z MEASUREMENTS TO THE LEFT OF Zo ARE -VE.

ALL ABSOLUTE Z MEASUREMENTS TO THE RIGHT OF Zo ARE +VE.

SIMILARLY FOR DIMENSIONS ON EITHER SIDE OF THE Xo PLANE AS SHOWN.

WHEN INCREMENTAL PROGRAMMING IS USED, THE (STILL WORKING FROM THE PROGRAM DATUM);

THE FACE "A" IS POSITIONED AT Z,-40:

THE 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.

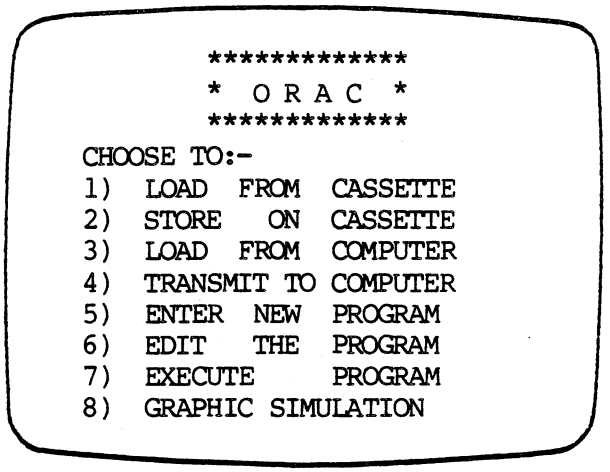
ALL INCREMENTAL X MEASUREMENTS TOWARDS THE CENTRE LINE ARE -VE.

ALL INCREMENTAL X MEASUREMENTS AWAY FOR THE CENTRE LINE ARE +VE.

SECTION 17

THE MAIN MENU

Once the mains have been switched on the screen displays:



This is the program menu for ORAC.

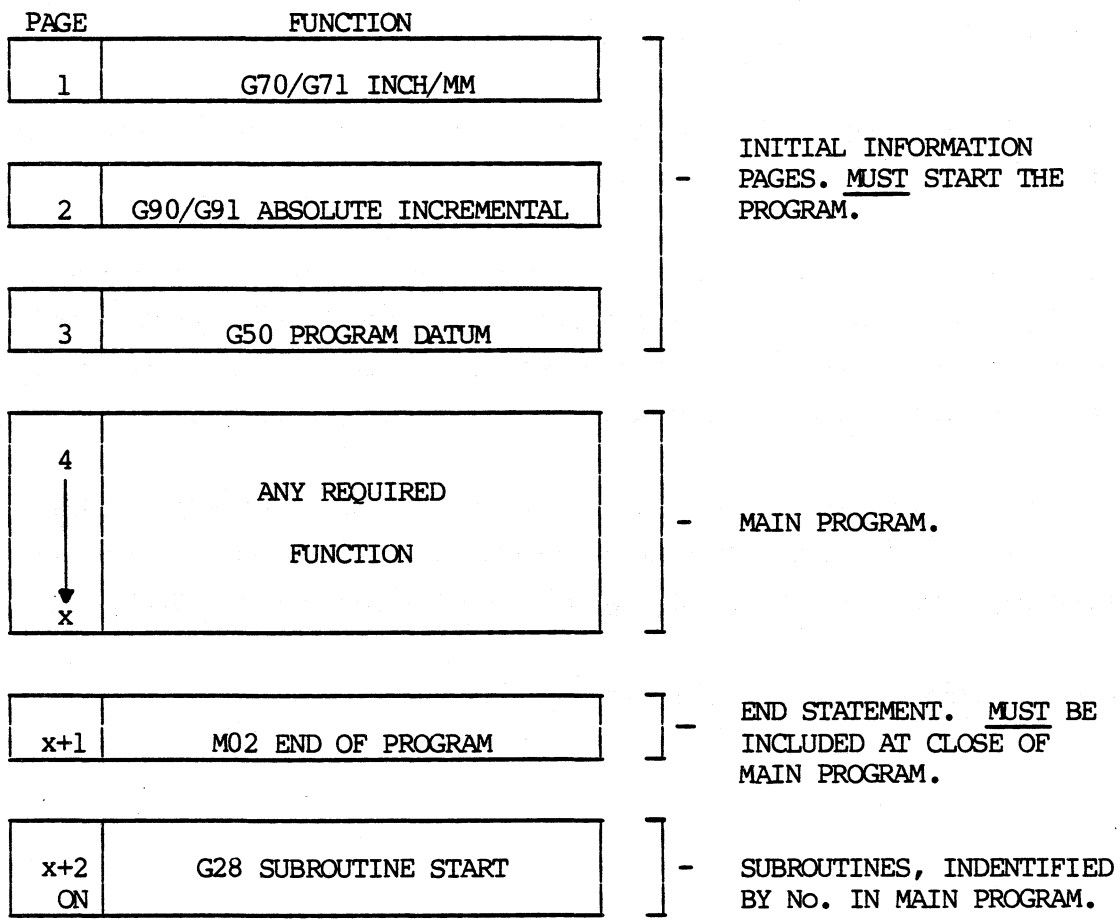
1. This choice is explained in full detail in Section 21 Page 61.
2. This choice is explained in full detail in Section 22 Page 62.
3. Loading from a Computer - this is explained in full detail in Section 32 Page 104.
4. Transmitting to a Computer - this is explained in full detail in Section 33 Page 105.
5. To Enter a new program see Section 18 Page 37.
6. To Edit a program in memory see Section 23 Page 63.
7. To Execute a program see Section 25 Page 67.
8. To prove a program using the graphical simulation, see Section 24 Page 65.

SECTION 18

ENTERING A NEW PROGRAM

To Enter a new program into ORACS memory depress key 5 on the Data input section of the keyboard, followed by E. This will bring you to Page 01 on the screen.

The Program structure should now be as follows:



The first 2 pages of any program must contain either INCH or MILLIMETRE units and INCREMENTAL or ABSOLUTE format. The 3rd Page of any program should ALWAYS be t PROGRAM DATUM.

Subsequent pages of Program can then be chosen in any sequence to suit the tool movements required to produce the finished workpiece.

Once a page of information is complete, advance to the following page by pressing the key with the 2 arrows pointing in a downward direction.

To view pages previously entered, press the key with the 2 arrows pointing in the upward direction.

As a function on each new page is chosen, the flashing cursor shows the next piece of data which requires to be entered. When the data is entered and confirmed by pressing the 'E' key, the cursor moves to the next line. This sequence continues until all data is entered for that page. You must then advance to the next page.

The program is terminated with depression of the M02 key. This will end the program at that point. If subroutines are to be programmed, this will be built up starting after the END OF PROGRAM Command (See Section 18.8 Page 51).

N.B. A program can contain up to 160 blocks.

EXAMPLES OF PAGES USING EACH FUNCTION

1.

```
PAGE 01    MM-UNITS          G71




F1 - QUIT
F2 - SELECT PAGE
```

Selected by pressing the 

key.

For INCH units the page is the same.
(Substitute INCH for MM.)

```
PAGE 02    INCREMENTAL-FORMAT G91




F1 - QUIT
F2 - SELECT PAGE
```

Selected by pressing the 

Key.

For ABSOLUTE format the page appears the same.
(Substitute ABSOLUTE for INCREMENTAL.)

```
PAGE 03    PROGRAM-DATUM     G50




F1 - QUIT
F2 - SELECT PAGE
```

Selected by pressing the 

key.

The PROGRAM DATUM values are taken from the centre line of the spindle on X and from the end of the workpiece on Z.
The PROGRAM DATUM must always be entered at page 3.

2.

```
PAGE 04   POINT-TO-POINT.G00,G01
   X
   Z
 FEEDRATE
 TOOL-NO
SPINDLE-SPEED
F1 - QUIT
F2 - SELECT PAGE
```

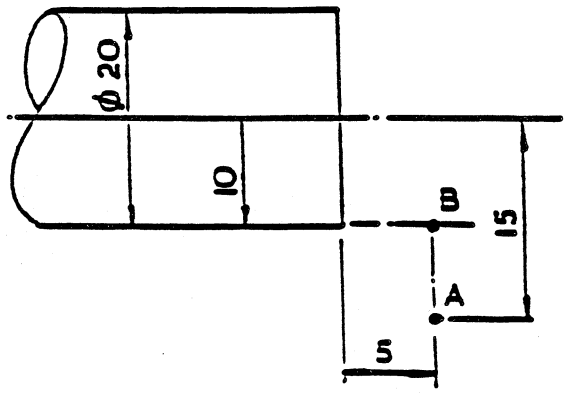
Selected by pressing the G00 G01 key.

Key in the required X and Z values using the Data Input Section of the keyboard.

If working in incremental and only X axis movement is required enter in a Z value of 0.

If working in Absolute format and only X axis movement is required key in the Z value the same as the previous page.

e.g.



FROM POINT A TO POINT B

POINT A X15 Z5

POINT B INCREMENTAL
X-5 Z 0

POINT B ABSOLUTE
X10 Z5

The above also applies when only Z axis movement is required.

For programming LINEAR INTERPOLATION (i.e. X and Z axis moving simultaneously) simply enter in the different X and Z co-ordinates.

Once the appropriate X and Z co-ordinates have been entered you must give the particular movement a FEEDRATE. This can be taken as any value from 0-1200 mm/min in increments of 10 or from 0-47 INCHES/MIN in increments of 1.

NOTE: DO NOT OVERRIDE THE FAST FEEDRATE.

A TOOL NUMBER must now be entered. Use any tool number from 1-9. NOTE: TOOL 0 should always be programmed as the last tool number in a program, as this tool has no offsets on X or Z.

Finally enter a SPINDLE SPEED. This can be entered as any value from 0-2000 in increments of 10.

NOTE The feedrate tool number and spindle speed are modal. IE, it is not necessary to enter any of the values if they are repeated in the previous blocks - this also applies for G02 and G03.

3.

```
PAGE 05   CIRCULAR-INT..G02,G03
   X
   Z
 RADIUS
 SENSE  CW  CCW
 TOOL-NO
SPINDLE-SPEED
F1 - QUIT
F2 - SELECT PAGE
```

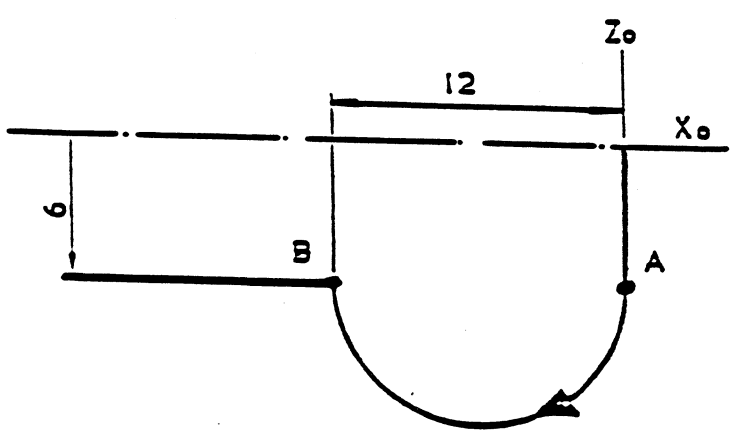
Selected by pressing the G02 G03 key.

The X and Z values being requested, are for the END co-ordinates of the arc. The tool has already been positioned at the start of the arc in the previous page. The X and Z values can be entered in either Absolute or Incremental.

You must now enter a RADIUS. This can be entered as a value between 2 mm and 3000 mm/0.075" and 120".

ORAC will allow for the RADIUS to give circle centre point outside the machine axis limits so long as the end point is inside the limits. By only having to program a Radius ORAC eliminates the time consuming process of calculating the exact circle centres. This is done by the computer. It is, however, important that a RADIUS is not programmed which is less than half the distance between the start and the end point of the circular motion.

e.g.



PT. A

X6 Z0

PT. B

X6 Z-12

The straight line distance between point A and B is 12.

Therefore the smallest radius which can be programmed is 6.00 mm. A CIRCULAR INTERPOLATION page, as follows, would produce semi-circular form.

X 6.0 Z-12.0 RAD 6.0 CW

Once a radius has been programmed it is now required to give the tool movement a SENSE OF DIRECTION. In the above example a clockwise direction of rotation has to be programmed. This is achieved by deleting the letters CCW (abbreviation for counter clockwise). Do this by moving the flashing cursor using the single arrowed key pointing to the right under one of the letters CCW and then depress the 'D' key.

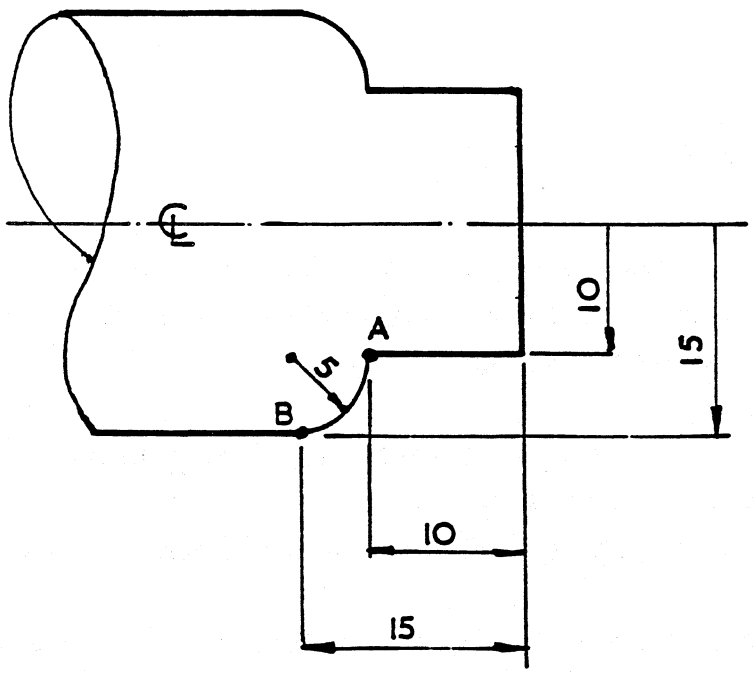
This deletes CCW and you are left with the letters CW. If on further studying the page, an error has been made and the program required CCW tool movement, simply press the G02/G03 key and enter the full page again this time pressing the 'D' key with the flashing cursor under the letters CW.

You must now enter a FEEDRATE for the tool movement, and this should not be less that 40 mm/min or 1.5 inches/min.

Complete the page by entering the appropriate TOOL NUMBER and SPINDLE SPEED.

NOTE Any minor are being programmed i.e. between 0° and 180° either CW or CCW can be entered in one page of information. Any major arcs, i.e. greater than 180° should be constructed using 2 minor arcs in 2 separate pages.

EXAMPLES



ABSOLUTE PROGRAMMING

With the tool already at the position A

X 10.0 Z-10.0

The page for circular interpolation is as follows:

X 15.0 Z-15.0

RAD 5.0 SENSE CW

INCREMENTAL PROGRAMMING

With the tool position at A the page for circular interpolation is as follows:

X 5.0 Z-5.0

RAD 5.0 SENSE CW

4. THREADING

```
PAGE 08   THREADING..G33
 IN/OUT-SIDE.DIAM
 ROOT-DIAMETER
 CUT.(INCR)..X
 LENGTH..Z
PITCH
STARTS
TOOL-NO
SPINDLE-SPEED

F1 - QUIT
F2 - SELECT PAGE
```

Selected by pressing the G33 key.

The page before SCREWCUTTING should take the tool level with the diameter to be screwcut and contain a spindle speed ready for the appropriate thread to be cut. (See GRAPH for spindle speeds for screwcutting page 47.)

Press the G33 key and key in the IN OR OUT-SIDE DIAMETER e.g. for a 12 mm I.S.O. METRIC COARSE EXTERNAL THREAD key in diameter of 12.0.
e.g. for a 12 mm I.S.O. metric coarse INTERNAL thread key in a diameter of 9.85.

Press the E key and key in the ROOT DIAMETER. The ROOT DIAMETER will, of course, determine whether the thread is internal or external.
i.e. A smaller root diameter will therefore produce an EXTERNAL thread.
A larger root diameter will produce an INTERNAL thread.

Press the E key to enter this information. The size of the cuts necessary to take the tool to the root diameter is now entered (i.e. CUT (INCR)...X). This can be any value smaller than the depth of thread and is an INCREMENTAL VALUE.

E.G. 12 mm External thread

12 mm OUTSIDE DIAMETHER
9.85 ROOT DIAMETER

therefore total depth of cut is $\frac{12-9.85}{2} = 1.075$

say 1.07

So any CUT size taken as an incremental value on the 'X' axis can now be entered less than 1.07.

This value is obviously dependant on the material. A value of 0.03 mm, for example, would be appropriate if cutting mild steel.

If the CUT SIZE is not divisible exactly into the total depth of cut ORAC will do the necessary calculations to round up the last cut.
E.G.

1.07 ≡ 35 cuts of 0.03 and a final cut 0.02.

Once the root diameter has been reached ORAC is programmed to take two further cuts at the final depth to clean up the thread.

Press the E key to enter the cut size.
Now a LENGTH must be entered.
This is also an INCREMENTAL value always taken towards the chuck whether a -ve or +ve value is programmed.

Press the E key to enter the LENGTH OF THREAD. Now key in the PITCH size. This value has programming limits.

The minimum PITCH is 0.35 mm/.014"
The maximum PITCH is 3.50 mm/0.138"

The value for the PITCH in both Metric and Imperial is entered as a decimal to a maximum of 2 and 3 decimal places respectively. Any size of pitch programmed above the maximum value and below the minimum value will result in stoppage of execution of the program and return to the manual operation page will result.
Press the E key to enter the PITCH.
The number of STARTS used in a program is always 1.
Key in a TOOL NUMBER and press E.
A SPINDLE speed is finally entered.

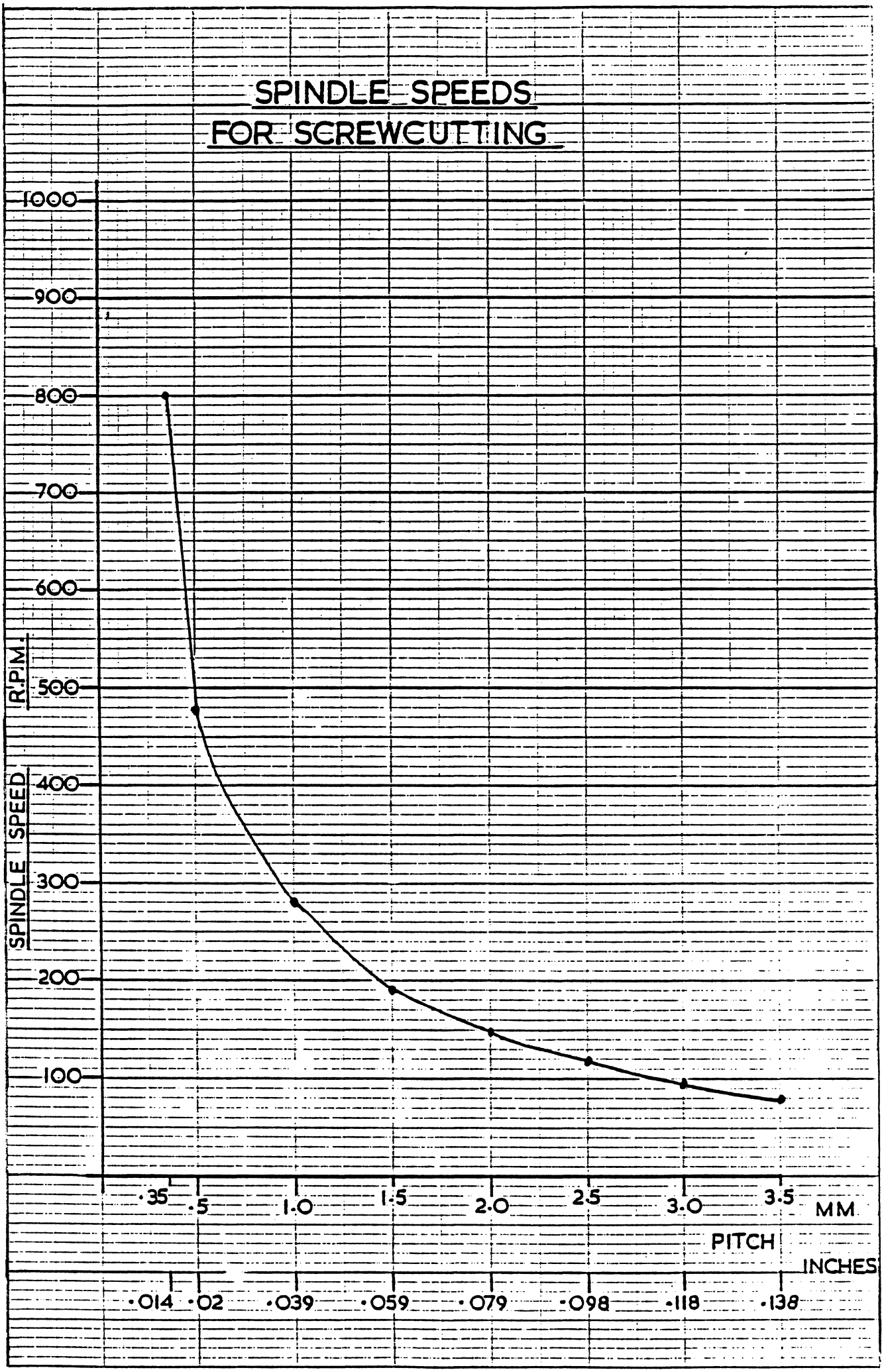
The value for the spindle speed depends on the pitch entered. The smaller the pitch, the faster the spindle speed.

A general ratio of pitch to spindle speed is shown on the Graph of SPINDLE SPEED AGAINST PITCH (see page 47).

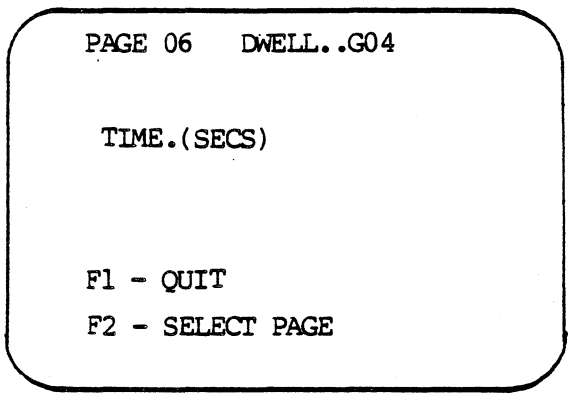
NOTE: The feedrate override will have no effect during execution of the screwcutting cycle.
Spindle speed override will affect the traverse of the cycle.
i.e. Increase of spindle speed will increase the feedrate and visa versa.

It is bad practice to effect a spindle speed override whilst in the screwcut cycle because too high an increase could result in a return to the "MANUAL OPERATION" page. The red stop button under the manual section of the keyboard will have no effect whilst taking a pass along the material, however, it will stop execution on the return pass. To restart the execution press the square green start button under the manual section of the control panel and the tool will drop in at the correct point on the thread.

If on execution, the cut size on the X axis is too large, you must return to the menu by stopping the execution as explained above, and depressing the reset key underneath the right hand side of the machine. You are then in a position to edit the program.


SPINDLE SPEEDS
FOR SCREWCUTTING
1000
900
800
700
600
500
400
300
200
100
R.P.M.
SPINDLE SPEED
·35
·5
1·0
1·5
2·0
2·5
3·0
3·5
MM
PITCH
INCHES
·014
·02
·039
·059
·079
·098
·118
·138

5. DWELL

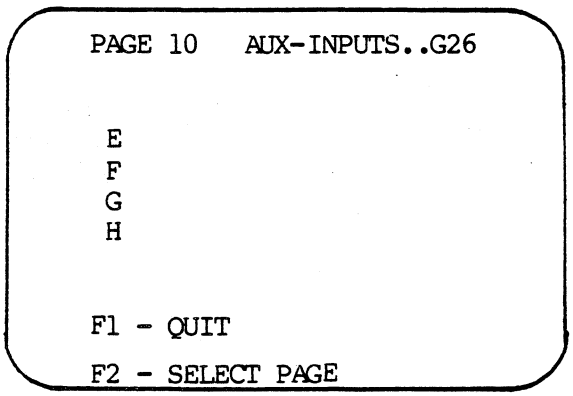


Selected by pressing the G04 key.

A DWELL can be entered at any stage in the program to stop the tool movement at a certain point, maybe in a recess or a spot face. This value is entered in seconds up to a maximum of 99. During the execution of a DWELL the seconds will be shown counting down on the screen. Once at zero the execution of the program will continue.

NOTE: DO NOT program a DWELL for a tool change.
See SECTION 26 PAGE 75 for tool changing.

6. AUXILLIARY INPUTS

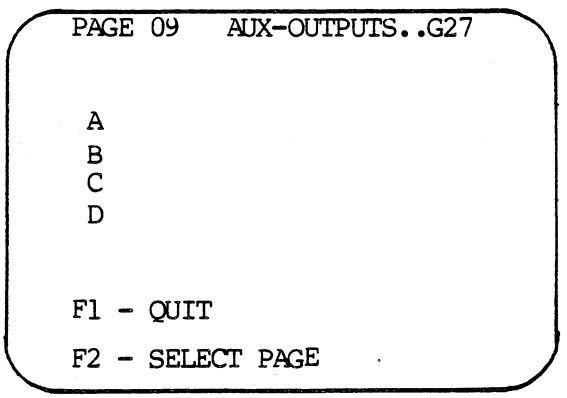


Selected by pressing the G26 key.

The 4 AUXILLIARY INPUTS, E F G H, can be programmed as a 'wait' or a 'hold' function by entering a control symbol in the program adjacent to the input letter. Entering a '0' (zero) causes the program to hold awaiting an input signal to that input terminal.
Entering a '1' (one) causes the program to hold awaiting the removal of an input signal to that input terminal.
Leaving a space means that any signal present should be ignored.

EXAMPLE A microswitch could be positioned in some way as to be activated by the guard, and wired into one of the input terminals, say E. (See section 33)
Program '0' into input E.
When the program reaches this page it will stop awaiting an input signal. i.e. The closure of the guard. Once it has received it the execution of the program will continue. If a '1' is programmed into input E the program will stop, awaiting the guard to be taken off the microswitch for execution of the program to continue.

7. AUXILLIARY OUTPUTS



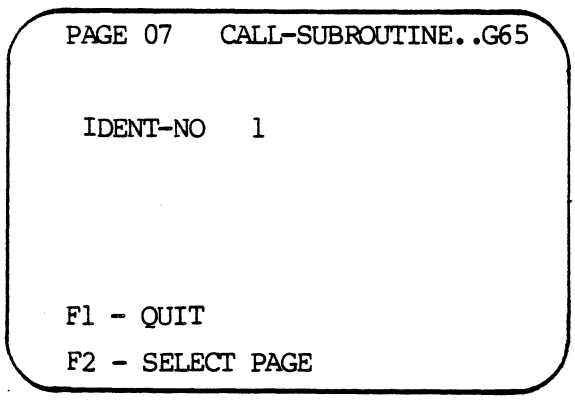
Selected by pressing the G27 key.

The 4 output relays, A B C D, can be used to control auxiliary equipment by enter either a '1' (one) or '0' (zero) adjacent to the relay letter.
Entering a '1' (one) causes the relay to switch on.
Entering a '0' (zero) causes the relay to switch off.
Leaving a space means no change in state.

EXAMPLE It is possible to control spray mist coolant through the AUXILLIARY OUTPUT due to the fact that it is controlled electrically. Connect up to any output terminal, say 'B' and program a '1' opposite B at the output page. Once this page is reached in the program the coolant will turn on. To turn the coolant off at a later stage in the program, call up the auxiliary output page and program a '0' opposite B.

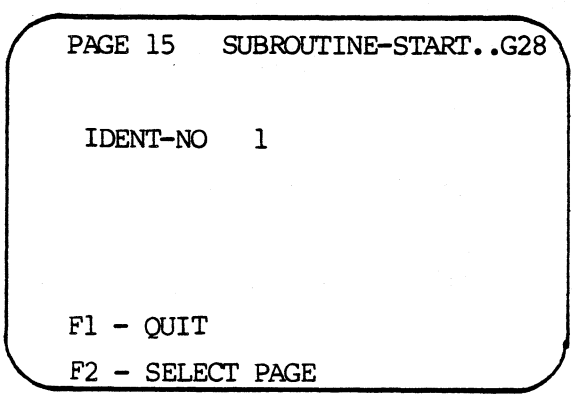
8. SUBROUTINES

A SUBROUTINE must be put into memory after the end of the main program and then called to be utilized as needed by the program. A SUBROUTINE is like a canned cycle that is put in memory with an identifying number and then can be called at several locations.



Selected by pressing the G65 key.

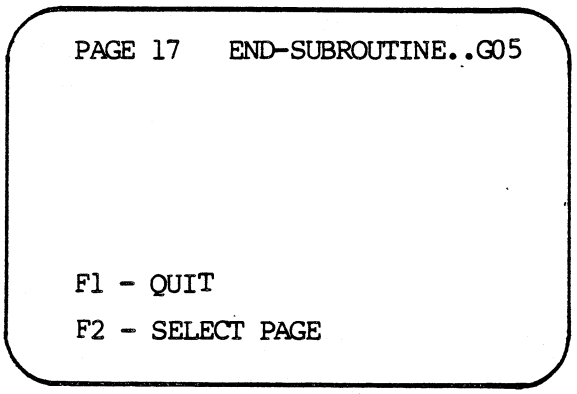
This function is used to CALL up a SUBROUTINE in a program. The numbers entered opposite the IDENT-NO should correspond to the number given to the SUBROUTINE outside the main program. A SUBROUTINE can be called as many times as is necessary up to a maximum of 99.



Selected by pressing the G28 key.

This function signifies the START of a SUBROUTINE and should only be programmed after the main program has been completed.
i.e. If the main program is 10 pages long the subroutine should start at page 11 or any subsequent page.

The identity number is given to the subroutine so more than one subroutine can be called up using the G65 key. The identity number for a subroutine should be a maximum of 2 digits. Three or more digits would register as a program error. The page after G28 SUBROUTINE START should be incremental - a subroutine in absolute would be executed in the same place each time.



Selected by pressing the G05 key.

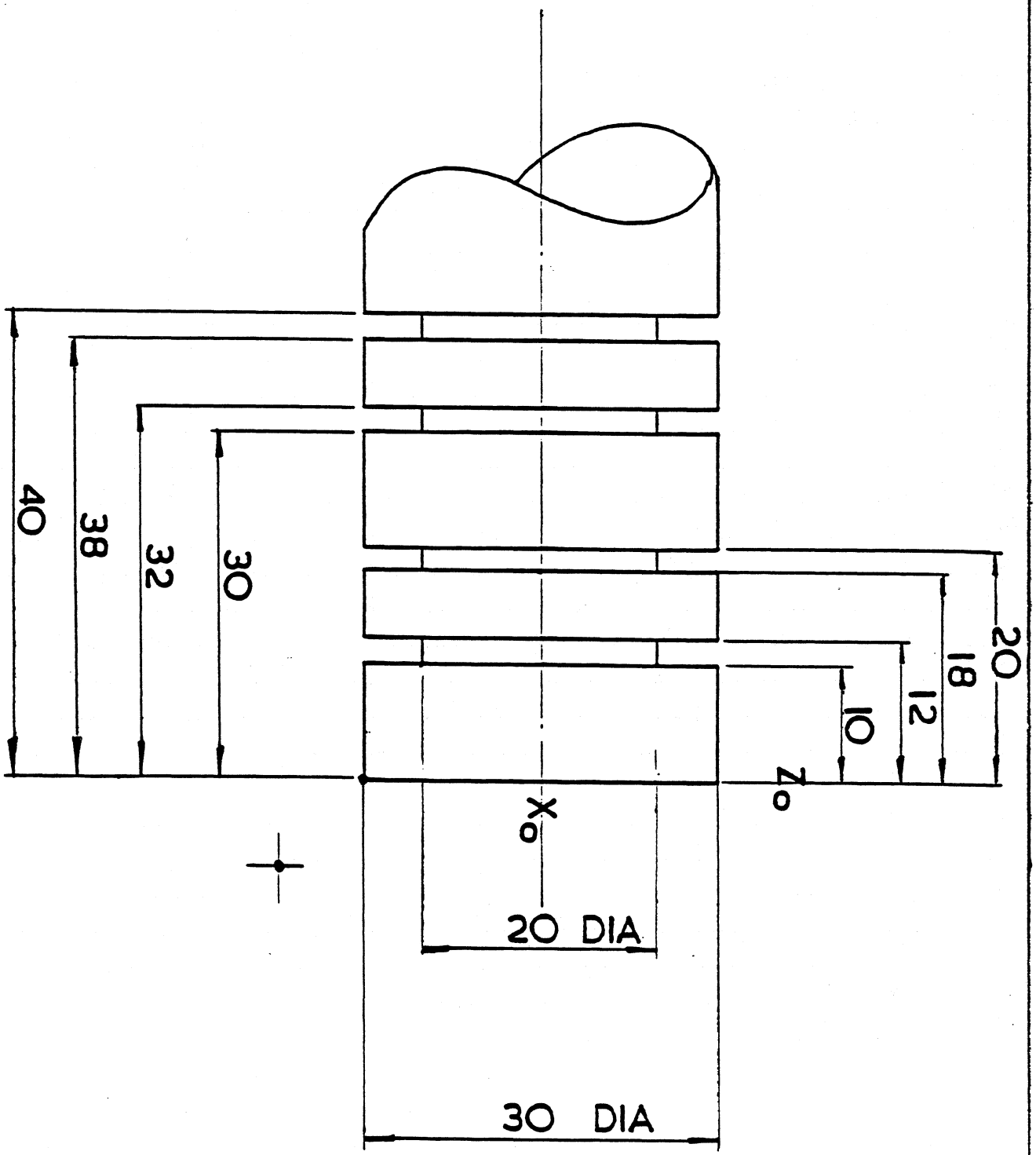
This function will END THE SUBROUTINE. The page before END OF SUBROUTINE should always carry the necessary format for the continuation of the program.

e.g. If the page in the program after the call of a subroutine has been programmed as an absolute dimension, it will only be executed as such if absolute is programmed at the end of the subroutine.

N.B. ALWAYS start the programming of a subroutine in INCREMENTAL.

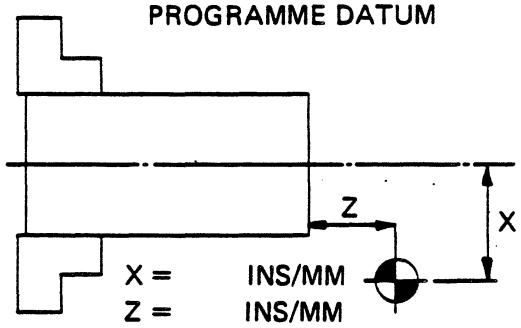
Always end the programming of a subroutine in the format used for the rest of the program.

e.g. of a subroutine build up.


40
38
32
30
20
18
12
10
Zo
Xo
20 DIA
30 DIA

DRAWING No.	SUBROUTINE
DESCRIPTION	
CASSETTE I/D	
MATERIAL	
PROGRAMME BY	AMD
DATE	18-4-85

PROGRAMME DATUM



ORAC

TOOLING:

No. 0 - TOOL REF	
" 1	RECESS TOOL
" 2	
" 3	
" 4	
" 5	
" 6	
" 7	
" 8	
" 9	

BELOW IS AN EXAMPLE OF A THREAD CUTTING PAGE

PAGE_____	THREAD DIA_____ ROOT DIA_____ CUT. INCR...X_____ LENGTH.Z (INCR)_____ PITCH_____
..	STARTS_____ TOOL No_____ SPINDLE SPEED_____

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
01	G71									
02	G90									
03	G50	20	15							
04	M03									
05	G00	16	-12					1200	1	600
06	G65									
07	G00	16	-32					1200		
08	G65									
09	G00	20	15					1200		
10	M05									
11	M02									
12										
13	G28									
14	G91									
15	G01			-6	0			40		
16	G00			6	0			1200		
17	G00			0	-8					
18	G01			-6	0			40		
19	G00			6	0			1200		
20	G90									
21	G05									

9. DO-LOOPS

When the operator desires the same operation or series of operations to be done several times the DO-LOOP is of great importance. The operator need only program the first complete sequence, he may then repeat this as many times as he desires up to a maximum of 99.

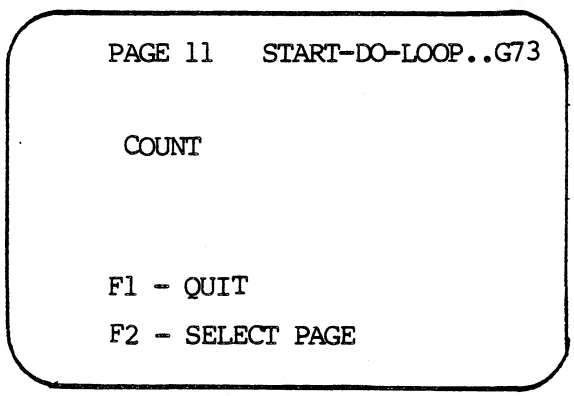
The manner in which this is accomplished is as follows:
Depress G73 (START DO-LOOP) 'N' where N is the count or the number of times the routine is to be repeated. Advance to the next page. The information now programmed will be repeated the desired number of times. After entering this information end the DO-LOOP by depressing the G06 (END DO-LOOP) key.
Example: Suppose a bar of diameter 20 mm requires turning down to a finish diameter of 10 mm, 25 mm long, this can be accomplished using a DO-LOOP.

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
01	G71									
02	G90									
03	G50	10	5							
04	M03									
05	G00	10	0.5					1200	1	1000
06	G73	5								
07	G91									
08	G00			-1.0	0			1200		
09	G01			0	-25.5			100		
10	G00			0.5	0			1200		
11	G00			0	25.5					
12	G00			-0.5	0					
13	G06									

In this DO-LOOP the tool moves towards the centre line 1 mm. A cut is then turned towards the chuck 25.5 mm, giving a turned length of 25 mm. The tool then retr .s 0.5 mm to avoid leaving trail lines, and returns to its Z start position. The tool then returns to its X start position.

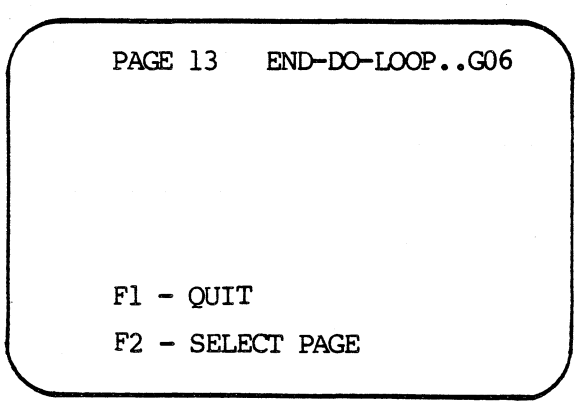
This operation is repeated 5 times leaving the bar the desired 10 mm diameter. Please note the time savings involved: Rather than having to program each individual pass and tool retraction etc. by using point to point commands which would have taken a total of 20 pages, the same was done in a DO-LOOP using only 8 pages.

Instructions in a DO-LOOP are usually INCREMENTAL.



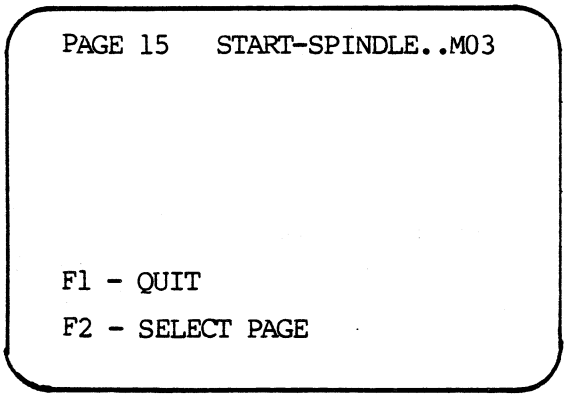
Selected by pressing the G73 key.

This function signifies the start of a DO-LOOP. The Count is the number of times the series of operations is to be repeated. Any value from 1-99 can be entered. Any value above 99 would register as a program error.



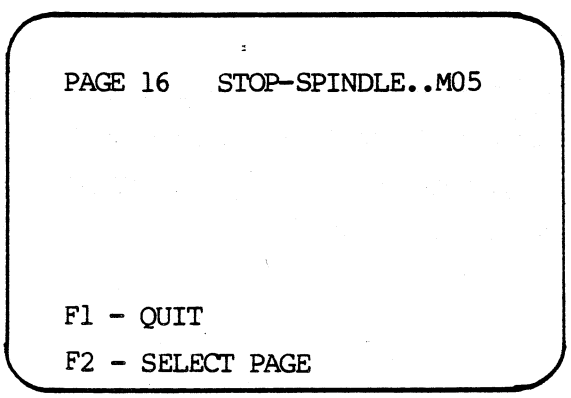
Selected by pressing the G06 key.

This function signifies the END of DO-LOOP. It is worthwhile remembering at this stage that unless altered, the format is still in incremental.



Selected by pressing the M03 key.

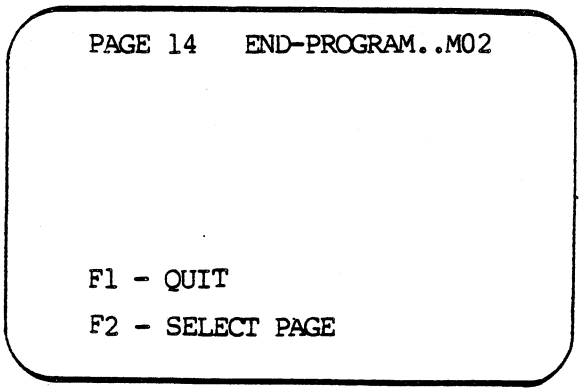
This function will start the spindle at any point in the program, and will reach the programmed value in any subsequent block.



Selected by pressing the M05 key.

This function will stop the rotation of the spindle at any point in the program. This should generally be used before a manual tool change or before the M02 end of program command.

10.



Selected by pressing the M02 key.

This function signifies the end of the program. However, subroutines can still be programmed after the main program has been completed.

If the completion of a program has now been made it will be necessary to return to menu. (See SECTION 19 PAGE 59.)

NOTE: Before the end of a program ensure that TOOL 0 is programmed in the last point to point page along with the program Datum X and Z positions. This is necessary because any other tool programmed will carry an offset and thus re-execution will start from a different position.

SECTION 19

RETURNING TO MAIN MENU

There are 3 different ways in which the operator can return to menu.

1. If midway through entering a program or at the end of a program you can return to the main menu by pressing keys F and I. This will list the program errors and show the total at the bottom of the screen. Depress the E key and this will return you to the main menu.

2. If at any stage in the build up or execution of a program you can return to the main menu be pressing the reset key under the right hand side of the control panel. This WILL NOT cancel the program.

3. On depression of the emergency stop button the control automatically drops into the MANUAL OPERATION mode. Once in this mode you can return to the main menu by depressing the square red stop key under the manual section of the keyboard.

SECTION 20

PROGRAM ERRORS

On quitting a program either midway through or at the end by pressing F and I, a list of program errors is given, and the screen displays the pages at which these errors occur and the total at the bottom of the screen.

A program error refers to an omission of a value in the build up of a program. It does not refer for example, to an oversized dimension or a high feedrate.

On the displaying of the program errors make a note of the pages and edit the program accordingly. Press E and this will return you to the main menu. If program errors are still present, on Execution the program the number of errors and the pages will again be displayed after the depression of keys 7 and E. The operator cannot, however, proceed with the execution of the program because on t... depression of the E key, the screen will return to the main menu. It is therefore necessary to correct all the errors via the edit mode before execution can take place.

If no program errors are present after selecting F and 1, the screen will automatically return to the main menu.

SECTION 21

TO LOAD A PROGRAM FROM CASSETTE

With the main menu being displayed on the screen press keys 1 and E. The screen will now display

CASSETTE LOADED?

Place the cassette with the required program on into the holder and close the holder. Acknowledge that the cassette has now been loaded by pressing E.

It is now required to select the position on the cassette, where the program is to be stored - select either 1 or 2. The cassette will now automatically rewind and then take the data off the cassette at the desired position.

NOTE: Ensure that the side of the cassette holding the required program is facing out once placed in the holder.

If the holder is not closed, or a cassette is not placed in the holder, and the E key is depressed, the process will be 'ABORTED' and return to the main menu again.

To stop a transfer of a program from cassette once the cassette has started to rewind, depress the RESET button under the right hand side of the control panel. This will return you to the main menu.

When a program has been taken off the cassette, the screen will display

CASSETTE LOADED? OK
CASSETTE I.D. NO. ....
CHECKSUM .. OK?

The I.D. number will be the number given to the program when previously stored on cassette. This could range from a single to a 4 digit number.

The Checksum number will be a 1 to 3 digit number. This refers to the number of characters in the program. Check that this is the same as the checksum number displayed on the screen when the program was first stored on the cassette. If this is so confirm that all is OK by pressing E. The screen will now display

PROGRAM TRANSFER COMPLETE for 2 seconds and return to the main menu.

If a cassette is damaged and the program is being taken off cassette, some information may be lost during the transfer. ORAC will inform you of this error by displaying 'CHECKSUM ERROR' or 'INSUFFICIENT MEMORY'. If this occurs it is advisable to try another cassette.

SECTION 22

TO STORE A PROGRAM ON CASSETTE

If a program in memory requires storing on a cassette, firstly return to the main menu. Now press keys 2 then E. The screen then displays

CASSETTE LOADED?

Place the cassette into the holder with the side to be used for storing the program face out. Close the holder and depress the E key. The screen will now ask for the identity number of the new program.

To avoid complications the next time the cassette is used, enter a 1 to 4 digit number and press E. It is now required to enter the position on the cassette for storing the program. Press either 1 or 2. The cassette will now automatically rewind and store the program onto cassette.

If the program previously on cassette has been altered and is now being replaced on the same cassette, give it a different I.D. Number. The program previously on cassette will be erased by the storage of a new program even if they are of different lengths.

To Abort a storage of a program once the cassette has started to rewind depress the reset button under the right hand side of the control unit. This will result in a return to the main menu.

Once the program has been stored on the cassette the screen will display

"program transfer complete".

If you require to store a program indefinitely on cassette, remove the black pin located in the corner of the cassette, for which ever side is being used. Now write the identity number given to that program on the cassette for future reference.

SECTION 23

EDITING A PROGRAM

Once a program is in memory and requires EDITING firstly return to the main menu. Now select editing mode by depressing keys 6 then E. Page one will now be displayed on the screen. To advance through the pages of the program press the key with the 2 arrows in the downward direction. Each time the key is depressed the page will advance by one, keeping the key depressed will advance through the program page by page.

To search for the required page of information press F then 2. Enter the desired page number followed by E. The new page will now be displayed.

CHANGING DATA

Once at the page which requires altering take the cursor down to the required line. This can be done using either the E key or the single arrowed keys. With the cursor at the required line, take it under the value which is to be altered.

This value can now be altered in 3 different ways.

E.G.

1. If the current value of say 100 is to be changed to 250, take the cursor under the 1 in 100 and now key in the new value of 250. This will automatically be written over the top and the new value will now be displayed.
2. If the current value of say 250 is to be changed to 25, take the cursor under the 0 in 250 and press the 'S' key. This will put a 'SPACE' in place of the zero and 25 will currently be displayed.
3. If the current value of say 150 is to be changed to say 1900, this can be altered using either method 1 or by taking the cursor under any number value of 150 and pressing the 'D' key to delete the full value. Once deleted enter the new information of 1900.

TO CHANGE THE FUNCTION OF A PAGE

Select the required page and then depress the new function key. This will automatically delete the existing page and the new function will be displayed. Enter the data applicable to that page in the normal manner.

DELETING A PAGE

Select the required page and depress the 'P' key (PAGE DELETE). That information will automatically be cleared form memory. This will result in all the following pages having their page number decreased by one automatically.

E.G. If page 10 is to be deleted, carry out the instruction on the previous page. Page 11 will now become page 10, page 12 will now become page 11 and so on.

INSERTING A PAGE

Once you have completed a program it sometimes becomes necessary to add a page somewhere in the middle of the program. For example, if you had a 50 page program, and you found that in between pages 20 and 21 you wanted to insert another pag ORAC is equipped to handle this situation. In order to accomplish this select page 21 and the data present in that page will be displayed. At this point press the 'P' key (page insert key). Page 21 will still be displayed, however, there will be no data present. The information previously at page 21 will now have been moved forward to page 22. To enter the new information into page 21 depress the appropriate function key and enter the information in the normal manner.

When it is decided that the program is satisfactory, exit from the edit routine by depressing keys F followed by 1. Check no program errors are present and depress E. This will now return you to the main menu.

SECTION 24

GRAPHICAL SIMULATION

It is advisable to verify all programs in memory using the toolpath simulation facility. This will display immediately any dimensional program errors by displaying the bar stock being machined step by step on the VDU.

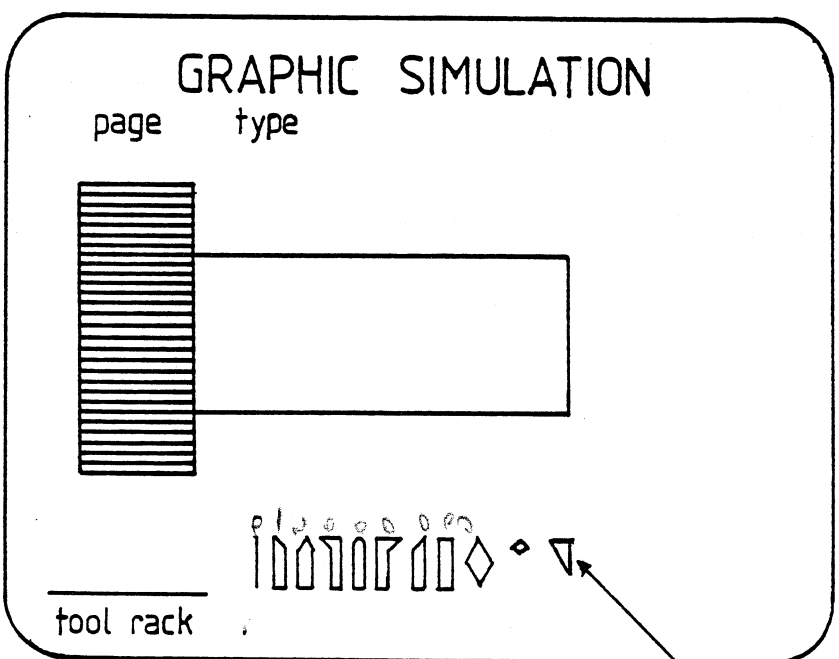
Proceed as follows:

Firstly depress 8 followed by E. A check will be made for any program errors. If no errors are present you must now enter the billet diameter. Enter this value in the units selected for the program and then press E. It is then required to enter the length of the billet, outside the chuck. Press E to enter into memory.

At this point in the routine the drill diameter is being requested. If a drill is being used enter the diameter by pressing D followed by the drill size, and enter. If there is no drill being used simply press E to enter.

The billet size, approximately to scale, will now be shown in the chuck. Increase the size using the ↑ key and decrease using the ↓ key. Once satisfied press enter.

The following page will now be displayed.



Only displayed if drill diameter is entered - allocate the tool number used in the program under this tool.

Allocate a tool number to each tool, eg, the tool on the left of the tool rack mu first be given a number. If this shape or any other tool shapes are not desired simply enter a 0 and the next tool will await a tool number.

If the tool shapes present on the VDU do not correspond to the tools to be used, it is possible to construct a further tool shape using the small diamond tool to the right of the rack. Enter a 0 under each tool shape not required, then enter the tool number for the diamond tool. The cursor will then flash below this tool.

The shape of this tool can now be increased or decreased in length using the ↓ ↑ keys and in width using the ← → keys. Once satisfied with the shape press E.

If an error has been made at this point the tool rack can be now re-entered in the same manner.

After correct selection of the tool shapes press Enter and the simulation can now be started by pressing the square green start button on the manual section of the control panel.

During the simulation, the feedrate can be decreased to a slow feed using the -ve key on the feedrate override and then increased to the fast speed using the +ve key.

The simulation can also be stopped by depressing the square red stop key and then restarted using the square green start key.

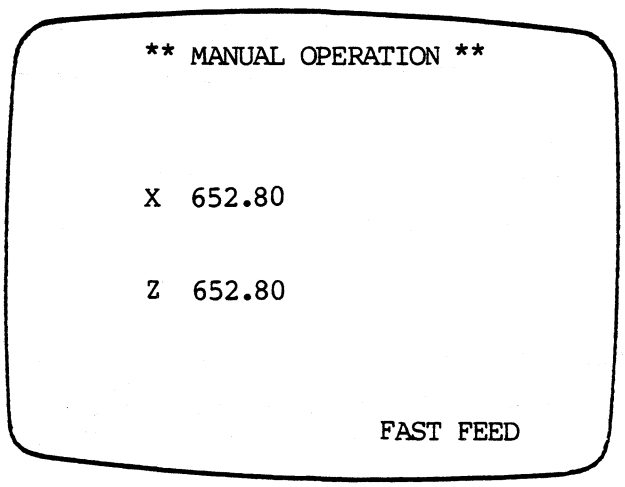
Once the simulation is complete you can return to the main menu by depressing t square red stop button.

SECTION 25

EXECUTING A PROGRAM

Once a program has been loaded into memory and all editing is complete you are now ready to machine the part. Unlock the emergency Stop Button and depress keys 7 and E.

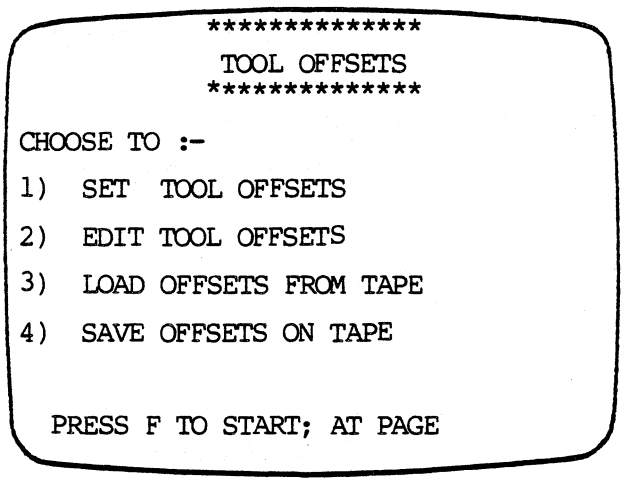
The total number of program errors are now displayed. With no errors in the program the screen will display:



The tool can now be moved under manual control on both axis using the axis job buttons located under the manual section of the keyboard. The initial feedrate for the jogs is indicated on the screen as FAST FEED. The feedrate can be changed by depressing the "HAND" key. See section 13 PAGE 26 for manual controls.

NOTE Until tool offsets have been set the actual values displayed for X and Z give no indication of actual tool position. Once in manual control after the setting of the tools is complete the display indicates the actual position in Both axis in absolute units, taken from X zero and Z zero.

To proceed with the execution of the program, press the square red 'STOP' key under the manual section of the keyboard. This stops manual operation and the TOOL OFFSET menu will be displayed.

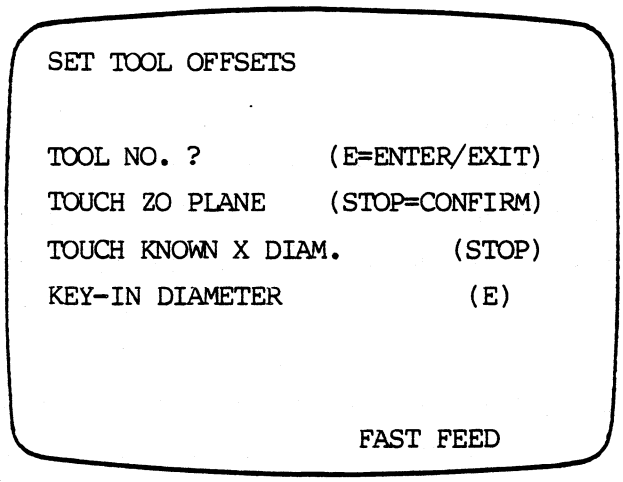


In order for the machine to produce an accurate part from the program the computer must know the difference in position of the cutting edges of each tool in both X and Z axis.

The control system can store up to 9 pairs of tool offsets. Tool 0 is designated as a reference tool. All other offsets are relative to this tool.

1. TO SET TOOL OFFSETS

For setting all the offsets for the program depress keys 1 then E. The page is displayed as shown.



Key in the tool number and press E for Enter. If it is required to return to the menu omit the number and simply press E for Exit.

The first tool number will be TOOL 0. Depress 0 then 'E'.

Touch on the Zo Plane with the tool. This is normally taken as the end of the workpiece. Do this using the axis jog buttons. The feedrate is indicated on the bottom right hand corner of the screen. The initial feedrate if FAST, however, it is advisable to approach the job on SLOW and the STEP feed. If necessary face up the work using the jog buttons. Once satisfied that the tool is set at the end of the workpiece press the square red 'STOP' key. The Z axis is now set at zero for this tool.

To set the X axis touch on a known X diameter, again using the axis jog buttons.

NOTE ONCE THE Z AXIS IS ZEROED THE FEED RETURNS TO FAST.
THE FEEDRATE INDICATED ON THE SCREEN MAY NOT BE THE ACTIVE FEEDRATE. PRESS THE 'HAND' KEY TO CHANGE THE FEEDRATE. THIS IS NOW THE ACTIVE FEEDRATE, AND IS INDICATED BY THE FLASHING CURSOR.

If the diameter is not true use the jog buttons to turn a diameter.

Once the diameter has been turned take the tool away from the work on the Z axis only, leaving the tool level with the diameter. To set the position of the tool on the X axis, press 'STOP'.

Stop the spindle and measure the diameter. Now key in the diameter in the SA' units as chosen for the Program Datum. If the wrong value is entered, take the cursor back under the numbers and overwrite as in the edit mode. When satisfied that the value is correct depress 'E'. The setting page will appear again for the setting of the next tool. Set the offsets for all the tools as explained and then return to the tool offset menu by pressing 'E' for Exit.

NOTE: Tool 0 is chosen as a reference tool and should not be used as a tool during a program. The reference tool is set so that a program using several tools can easily be re-executed for the following batch by taking the offsets off tape and then setting the reference tool, as ALL offsets are taken relative to this tool.

It is possible however, in a single tool program to use tool one as this referenc tool. I.E. Set tool 0 as previously explained using tool 1. It is then not necessary to set tool 1 as this is the same tool and therefore will have no difference in position to tool 0.

When satisfied with the offsets and with the tool offset menu on the screen, you can edit the offsets.

2. EDITING THE TOOL OFFSETS

Depress keys 2 then E. The offsets for each tool relative to tool 0 will now be shown as below.

```
** TOOL  OFFSET  EDIT  **
           X       Z
TOOL.0   000.00  000.00
TOOL.1  -002.35  000.10
TOOL.2   010.15 -020.75
TOOL.3   001.00  000.10
TOOL.4   000.00  000.00
TOOL.5   000.00  000.00
TOOL.6   000.00  000.00
TOOL.7   000.00  000.00
TOOL.8   000.00  000.00
TOOL.9   000.00  000.00

"F" TO QUIT
```

The offsets are displayed in the units selected for the program Datum.

The offsets shown in the example can be interpreted as overleaf:

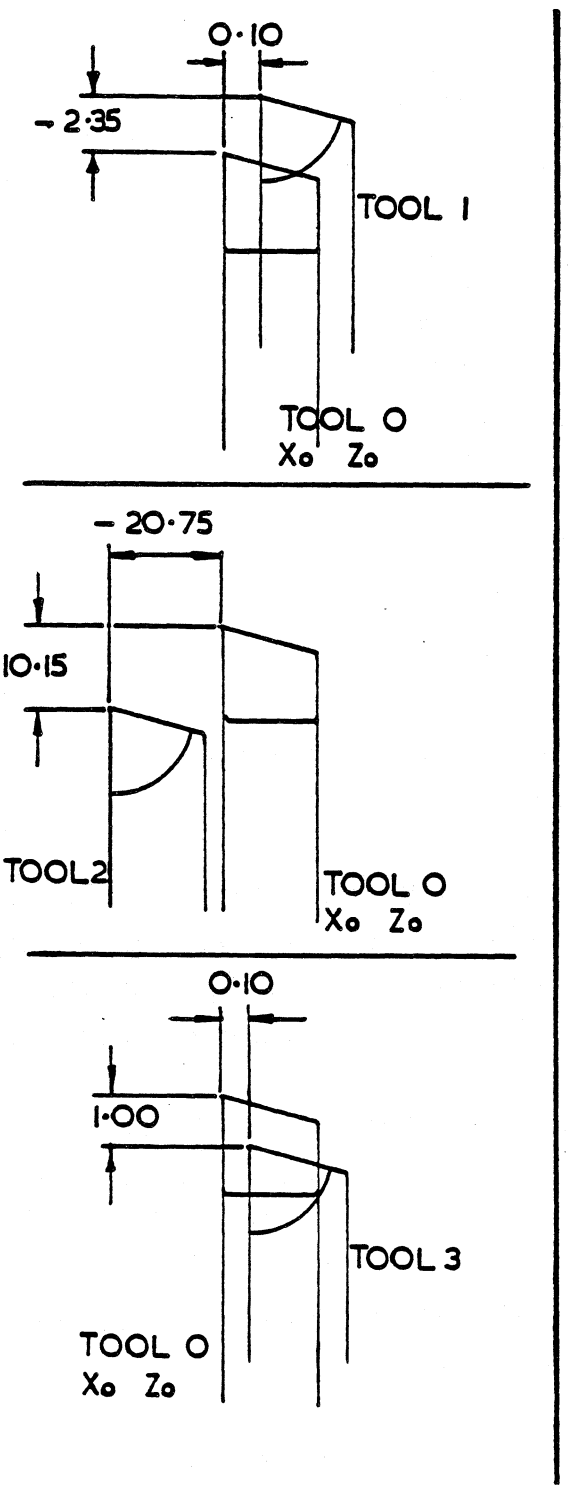
If after producing several components a diameter is oversize, a tool offset can be edited to compensate for the tool wear.

If say tool 2 was used to finish turn this diameter and it was found to be 1 mm oversize, the offset value on the X axis must be INCREASED by 0.5 mm giving a new value of 10.65 mm. Using the single arrowed keys take the cursor to the line for tool 2 and key in the new value 10.65 under the X axis column.

If say tool 1 was the tool being used and the diameter was 1 mm oversize, the offset value on the X axis would have 0.5 mm added to it giving a new value of -1.85 mm.

The editing procedure explained above should be applied in exactly the same way for altering the lengths of components.

Once it has been established that the offsets are satisfactory return to the TOOL OFFSET menu again by pressing 'F' to Quit, as instructed on the screen.


0·10
- 2·35
TOOL 1
TOOL 0
Xo Zo
- 20·75
10·15
TOOL2
TOOL 0
Xo Zo
0·10
1·00
TOOL 3
TOOL 0
Xo Zo

3. LOADING OFFSETS FROM TAPE

If a program to be executed, has offsets that have previously been stored on cassette, it can be re-executed by taking the offsets from tape and setting tool 0. (Providing, of course, that the tools have not been moved in the holders.)

With the tool offset menu current, depress keys 3 then E. The screen will display "CASSETTE LOADED?". Place the appropriate cassette in the holder and press E. The screen will now display "Tape position 1 or 2?". Select the desired position by pressing either 1 or 2. The cassette will now rewind to the beginning and load the offset data. When the tape stops, the Cassette I.D. Number is displayed, along with the Checksum. Check that the Identity number is the same as the one given to the offsets when stored on cassette. Confirm by depressing 'E' and the screen will display

"DATA TRANSFER COMPLETE"

If this does not occur, an error message will be observed such as

"INSUFFICIENT MEMORY"

"CHECKSUM ERROR"

"ABORTED"

(In both loading and saving functions, if error messages occur, then the operation should be repeated in case the malfunction was caused, for example, by a line transient or some other none repetitive interference. If continued error messages occur then the cassette has most probably been damaged.)

Once offset data has been transferred to memory the tool offset menu will be displayed.

4. TO SAVE THE OFFSETS ON TAPE

Once all the tool offsets have been set it may be necessary to store these offsets on tape to be used on another occasion. Depress keys 4 then E. The screen will display CASSETTE LOADED?
Place a cassette in the holder and depress the E key.

The screen will now display "Tape position 1 or 2?". Select the position by pressing either 1 or 2. (It makes sense to store the offsets at the same position as the program.) It is now necessary to enter an identity number.

Enter a number up to 4 digits and depress the E key. With the entering of the fourth digit the cassette will automatically rewind and store the offsets on cassette. The offsets can be stored on the same side of the cassette as th. program.

The Checksum Number will be displayed on the screen when the E key is depressed. This, as with the program storage, gives an indication of the memory used in storing the offsets and is displayed as a Hexadecimal number.

When the transfer of the offsets onto cassette is complete, the screen will display
"DATA TRANSFER COMPLETE"

Note that the tape transport mechanism starts automatically, first rewinding the tape back to the start, then operating in the forward direction and recording the offset Data. If for some reason that Data is not transferred onto the tape, this last message will be displayed as "TOOL OFFSETS NOT VALID" or "ABORTED". Repe.. the procedure and if the same occurs try a new cassette as the existing one is most likely damaged.

Once the information has been transferred the screen will return to the tool offset menu.

To continue with the execution of the program follow the instructions on the screen. "PRESS F to start at page ?".

Simply press the F key followed by the page at which execution is to commence. EG, To start from the beginning of the program press F then 1 and Enter.

It is important to note that before depressing 'F' to Quit the offset routine, remove the last tool set. Failure to do so could result in the axis moving to the program datum and colliding with the work.

The axis will now move to the program datum and this position will be displayed on the screen. If, however, on completion of the offsets, the axis happen to be positioned at the program Datum, then X and Z will be displayed with no positions, because no movement has occurred.

Page number 4 will be displaying these positions as well as the current feedrate, and the desired tool number. The spindle speed will be displayed once the program has started.

Pages 1, 2 and 3 have already been executed.

Before starting the execution of the program, ensure that the correct tool is fitted as indicated in the display. Now start the spindle with the round green key under the spindle controls, and then start the cycle by pressing the square green key under the manual section of the keyboard.

The machine will execute the program page by page, changing speeds and feeds as programmed, and only stopping for tool changes, a Dwell, or whilst waiting for a programmed input to occur.

When a tool change occurs the axis and spindle stop, and the next tool number is displayed on the screen indicated by the flashing cursor. To restart the program change the tool and start the spindle. With the spindle running depress the start button under the manual section of the keyboard. The tool offset is automatically set for the new tool before execution continues.

On the completion of the penultimate page, the machine will stop and request for a tool change to tool 0. Take out the current tool and continue with the execution back to program Datum. It is not necessary to place tool 0 in the holder as it has no particular function.

When the program is finally complete, the screen will display "LAST PAGE', and then return to the main menu.

SECTION 27

EXECUTING THE 2ND OFF

On completion of a program it may be necessary to repeat the same component several times. It is therefore necessary to have the same length of bar extended from the chuck jaws. Tool 0 can be used as a bar stop.

Therefore with the finished component still in the chuck program a tool change away from the work to Tool 0. The axis will stop and await confirmation. Insert Tool 0 and program this tool to travel to Xo Zo where a further tool change should be programmed, to say Tool 1. At this point tool 0 is at Zo with no offsets, and the spindle and axis will stop awaiting a tool change. At this point take out the finished component and insert the new blank, pulling it out to touch Tool 0 (the Bar Stop) and tighten the chuck. The new bar now has exactly the same Zo as the finished component. Take out tool 0 and start the rest of the cycle. Remember return to the program Datum with tool 0 in the last page.

To start the re-execution of the program depress 7 then E.
With no errors present the manual operations page will be displayed.
Depress the stop key to quit normal operation.

If all the sizes on the completed component were correct, and it is not necessary to edit the tool offsets, depress 'F' followed by the desired page number where the program is to be started - usually page one.

Start the spindle and then the cycle.

SECTION 28

TOOL BREAKAGE

During the execution of a program it is possible that the tool could break or cause a bad surface finish by shattering due to excessive tool wear.

To overcome this problem simply stop the execution by depressing the square red stop key under the manual section of the keyboard. It will now be necessary to take the tool away from the work in order to be able to change tip or to remove from the holder to regrind. This can be done using the axis jog buttons. Depress "MAN" under the manual section, and "MANUAL OPERATION" will be displayed, along with the current X and Z dimensions. Now by depressing the appropriate axis jog buttons the tool can be brought away from the work. Carry out whatever is necessary with the tool and stop manual operation be depressing the "STOP" key. The TOOL OFFSET MENU will now be displayed.

If a tool has been reground, it may be necessary to reset the tool offset. Carry out the procedure as explained in section 25 page 66. When satisfied with the tool, depress 'F' followed by the page number where execution needs to be re-continued.

The axis will now return to the start of the movement in which the tool was damaged and continue its execution.

SECTION 29

THE RESET BUTTONS

You will notice on the front panel there are 2 'RESET' labels. These are to indicate the buttons located below the front panel. The reset button on the right hand side of the control panel situated below the cassette unit can be depressed at any stage during a program build up or execution and will result in a return to the main menu, WITHOUT LOSS OF MEMORY. If depressed during the execution of the program it is advisable to reset tool 0 again.

The reset button located below the manual controls is used for resetting the limit switches on the axis of the machine. (Located at either end on the X axis and at the Headstock end on the Z axis.) If, during manual operation of the axis or during the exectuion of a program, the X axis (and Z axis on some systems) hits the limit switches then the screen will display "MANUAL OPERATION" and the axis a spindle are inoperative. To reset the switches depress the reset button and hold, while at the SAME TIME depressing the axis jog button to move the axis away from the limit switch. Once this has been accomplished the reset key can be released. If this occurs during the execution of a program, re-execution must commence from page 1.

SECTION 30

GUIDELINES

Following these guidelines will assist the operator, and reduce costly programming errors.

1. Start each program with the units or format in pages 1 and 2 and follow these with the Program Datum.

2. Do-loops and Subroutines should usually be programmed incrementally.

3. Remember to return to the format used for the rest of the program at the end of a Do-loop or Subroutine.

4. Subroutines must be entered after the end of the program.

5. Subroutines cannot be contained within subroutines or Do-loops. (I.E. Nested.)

6. Do-loops cannot be nested within Do-loops or Subroutines.

7. Do not override the maximum feedrate of 1200 mm/min 47"/min.

8. Ensure that the feedrate programmed is compatible with the units selected.

9. The minimum feedrate for circular interpolation should be 40 mm/min or 1.5 inches/min.

10. Any minor arc (less than 180°) either CW or CCW can be programmed in one page. Major arcs (greater than 180°) should be constructed using two minor arcs.

11. Do not program a radius which is less than the value to join the X Z points specified.

12. Units and/or format may be changed during the pages of a program.

13. Metric Ballscrews are used in ORAC, so therefore its prime units are MM.

14. If keywords on pages are accidently deleted (e.g. FEEDRATE) this will cause a program error to be displayed when the program is compiled. This can only be corrected by re-entering the page function and all the Data again.

15. Too high a spindle speed or too coarse a pitch in the threading cycle will cause automatic rejection during execution and a return to "MANUAL OPERATION" will result, and the program must be re-executed from the start.

16. To ensure accurate repetitive re-execution of a program, reference tool 0 should be programmed in the last point to point page as this carries no tool offsets on the X and Z axis.

17. No point to point pages should be programmed without a movement on X or Z.
e.g. If already at X15 Z10 the following page cannot contain both these values (above in absolute format - same applies for incremental format).

18. Taper turning on ORAC is done using the point to point function. The maximum ratio between the 2 axis is 35:1. I.E. 1 mm on X to 35 mm on Z and vice versa.

19. Write the program down and update the written copy as you are editing.

20. Program the tools in sequence, always starting at number 1. Keep the written program and record the tool descripion on it.

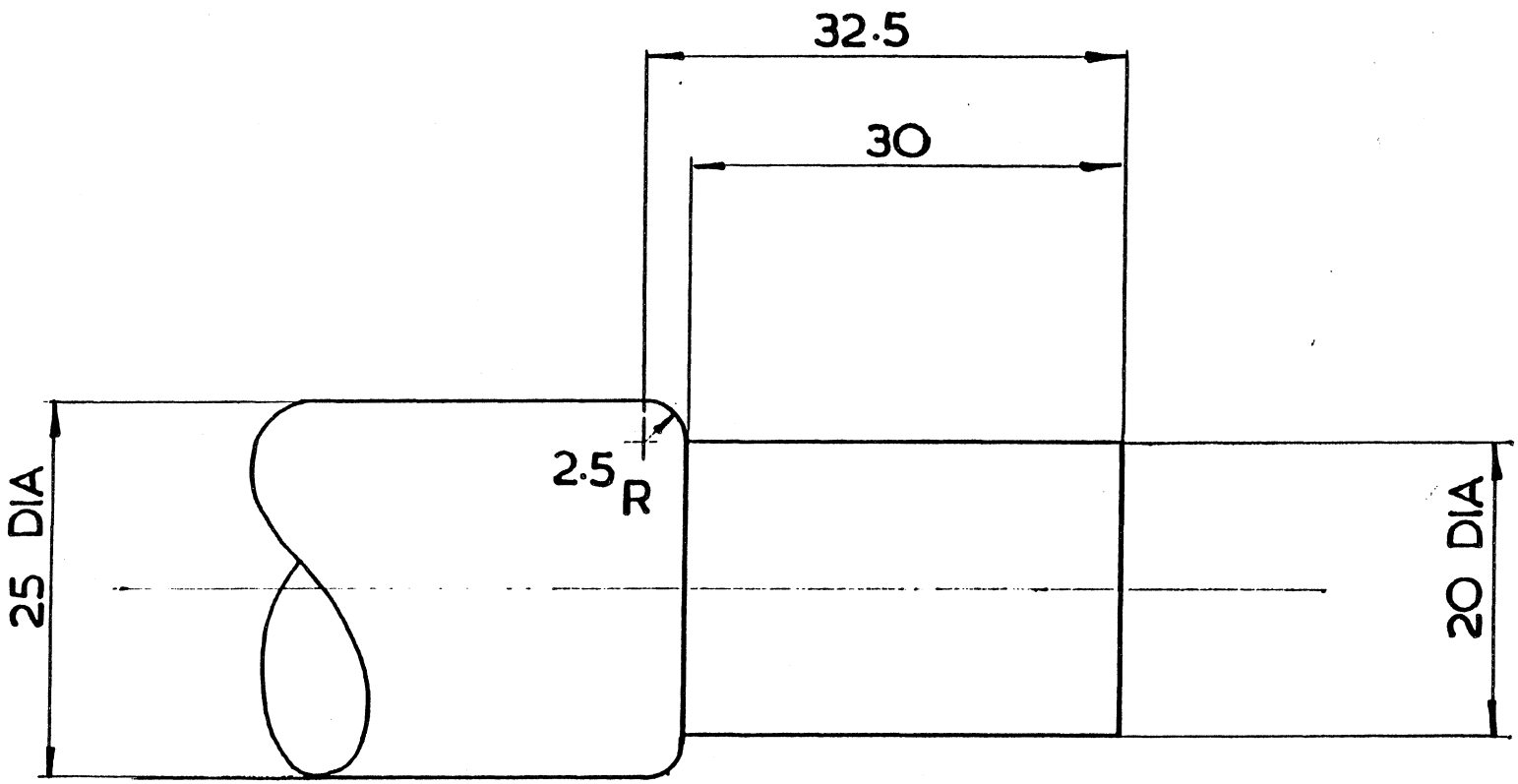
21. Ensure, before turning a diameter during the setting of the X axis offset, that the cursor is flashing below the feedrate. Any other feedrate displayed without the flashing cursor may not be the active feedrate.

22. Ensure the emergency stop button is unlocked before depressing the 'F' key to quit the offset routine.

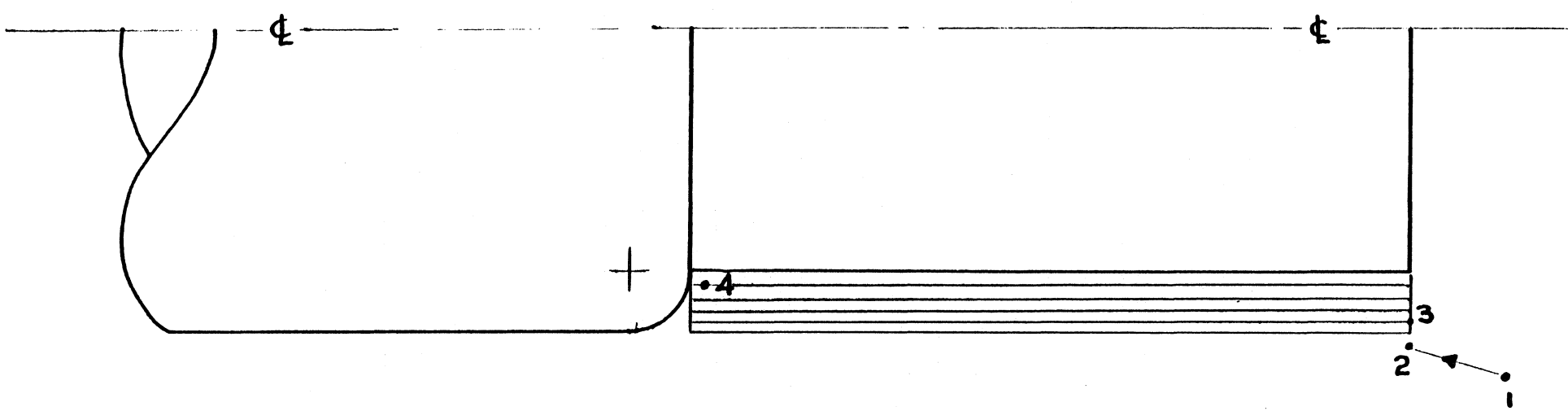
23. THINK!

SECTION 31

PROGRAMMING EXAMPLES



TEST PIECE Nº 1



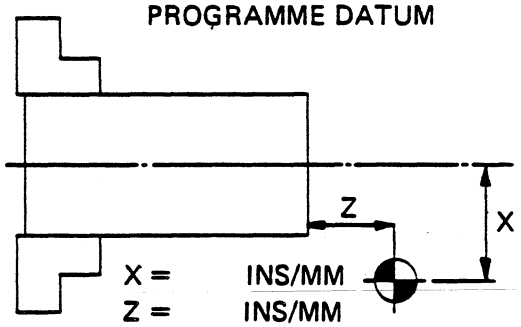
83

ENLARGEMENT OF TEST PIECE Nº 1

DRAWING No.	TEST PIECE 1
DESCRIPTION	
CASSETTE I/D	
MATERIAL	M/S AL
PROGRAMME BY	AMD
DATE	

BELOW IS AN EXAMPLE OF A THREAD CUTTING PAGE

PROGRAMME DATUM



ORAC

TOOLING:

No. 0 - TOOL REF	
" 1	R.H. KNIFE TOOL
" 2	
" 3	
" 4	
" 5	
" 6	
" 7	
" 8	
" 9	

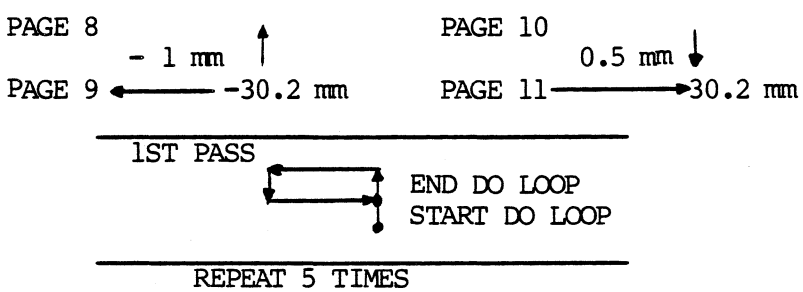
PAGE _____ THREAD DIA _____ ROOT DIA ____ CUT. INCR...X ____ LENGTH.Z (INCR) _____ PITCH ____

" STARTS _____ TOOL No _____ SPINDLE SPEED _____

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
01	G71									
02	G90									
03	G50	15	5							
04	M03									
05	G00	13	0.2					1200	1	800
06	G73	5								
07	G91									
08	G00			-1	0			1200		
09	G01			0	-30.2			80		
10	G00			0.5	0			1200		
11	G00			0	30.2			1200		
12	G06									
13	G90									
14	G00	10.1	-29.9					1200		10[illegible]
15	G01	10	-30					80		
16	G02	12.5	-32.5			2.5	CW	80		
17	G00	15	0					1200		
18	G00	15	5					1200	0	
19	M05									
20	M02									

TEST PIECE 1

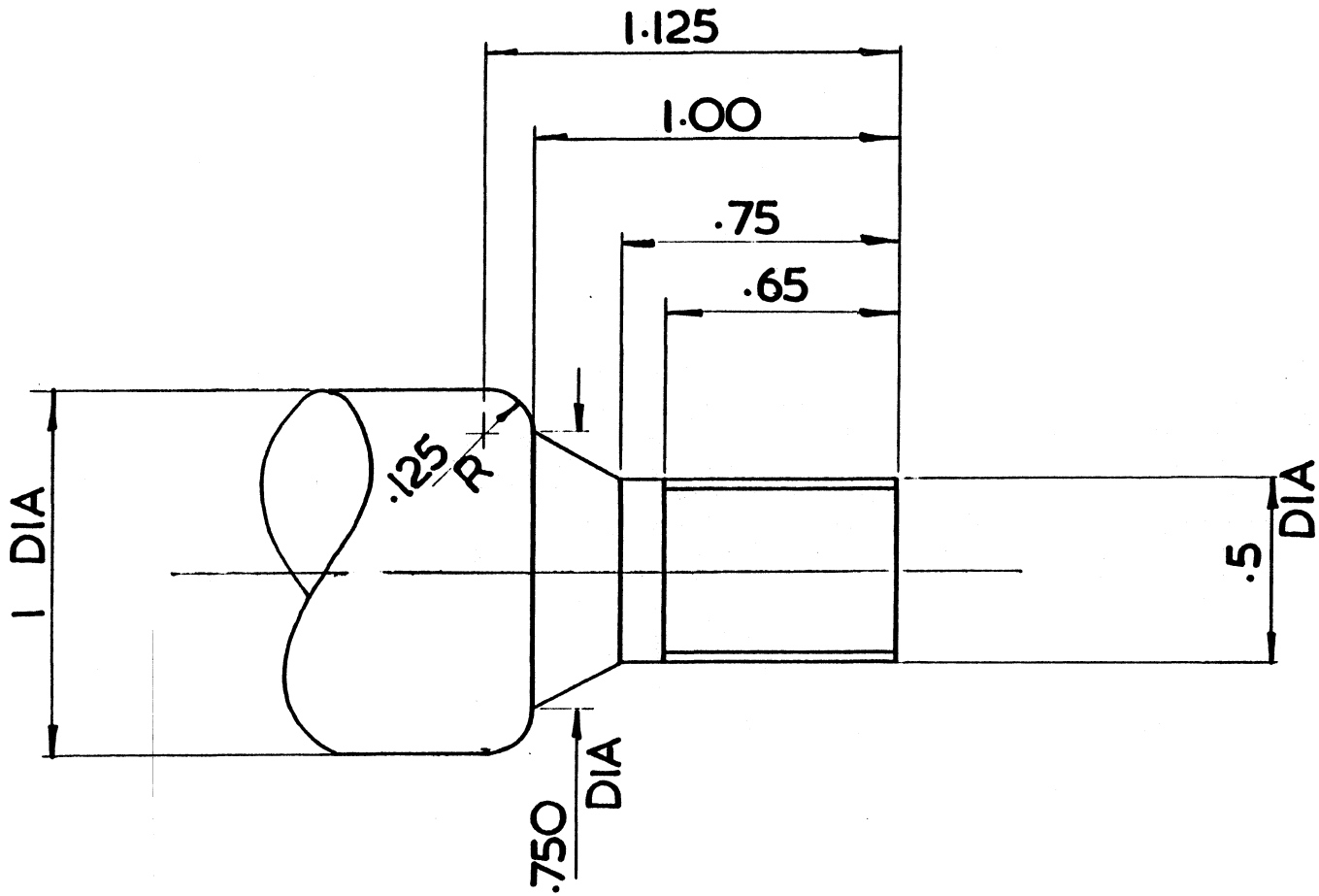
Page No.	G & M Function	
01	G71	METRIC UNITS HAVE BEEN SELECTED AND WILL EFFECT UNTIL CHANGED.
02	G90	ABSOLUTE FORMAT SELECTED AND WILL EFFECT UNTIL CHANGED.
03	G50	PROGRAM DATUM SHOULD NOW BE SET WITH THE 'X' VALUE TAKEN FROM THE CENTRE LINE OF THE SPINDLE AND THE 'Z' AXIS FROM THE END OF THE WORKPIECE. 'X' 15.0 MM 'Z' 5.0 MM (1).
04	M03	STARTS THE SPINDLE.
05	G00	POINT TO POINT SELECTED TO MOVE THE TOOL TO A POSITION NEARER THE WORKPIECE READY FOR TURNING - (2).
06	G73	THE START OF A DO LOOP IS NOT BEING CALLED. A COUNT IS ENTERED OF 5. EACH PAGE OF INFORMATION ENTERED FROM THIS PAGE UNTIL A PAGE CONTAINING END DO FUNCTION WILL BE REPEATED 5 TIMES.
07	G91	INCREMENTAL FORMAT SELECTED.
08	G00	THIS PAGE MOVES THE TOOL IN A DIRECTION TOWARDS THE CENTRE LINE OF THE SPINDLE OF ONE MILLIMETRE TO POSITON (3).
09	G01	THE TOOL IS PROGRAMMED TO MOVE TOWARDS THE CHUCK 30.2 MM GIVING A TURNED LENGTH OF 30 MM.
10	G00	THE TOOL NOW WITHDRAWS 0.5 MM TO CLEAR THE WORK.
11	G00	THE TOOL IS PROGRAMMED TO RETURN TO 'Z' POSITION OF PAGE 7.
12	G06	THIS WILL END THE DO LOOP AFTER 5 PASSES HAVE BEEN COMPLETED. EACH PASS HAVING A DEPTH OF 0.5 MM. I.E.



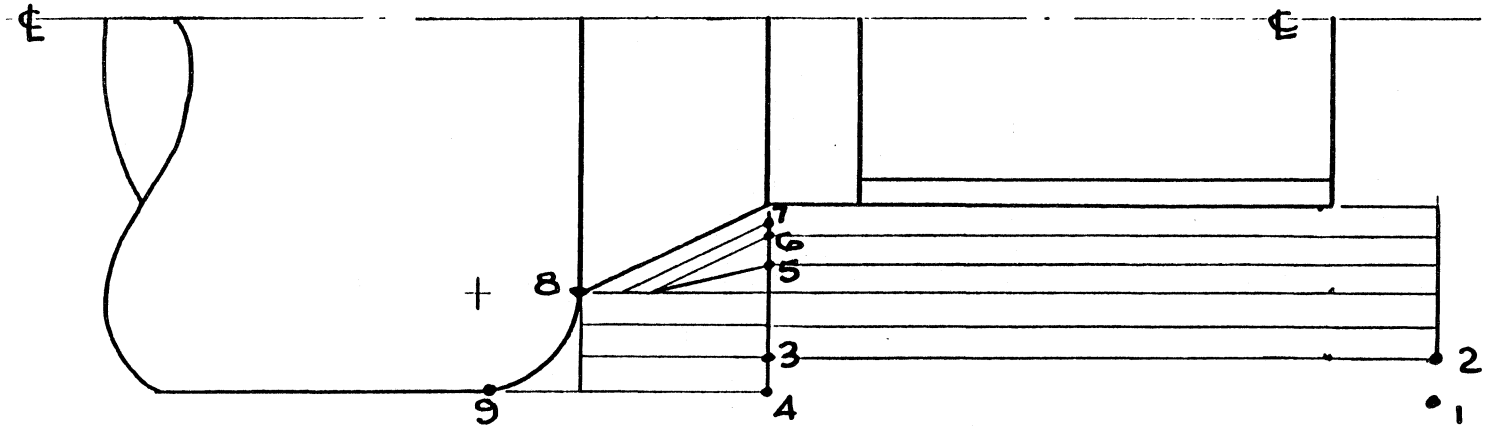
/CONTINUED

TEST PIECE 1 /CONTINUED

Page No.	G & M Function	
13	G90	ABSOLUTE FORMAT NOW SELECTED.
14	G00	A POINT TO POINT PAGE WILL NOW MOVE THE TOOL JUST SHORT OF THE CORNER OF THE SHOULDER JUST TURNED. POSITION (4).
15	G01	THIS POINT TO POINT PAGE MOVES THE TOOL DIRECTLY INTO THE CORNER AT A SLOW FEED.
16	G02	CIRCULAR INTERPOLATION PROGRAMMED TO GIVE A RADIUS OF 2.5 MM IN A QUADRANT.
17	G00	THIS PAGE TAKE THE TOOL CLEAR OF THE WORK READY TO CHANGE TO TOOL 0.
18	G00	THIS POINT TO POINT PAGE WILL TAKE THE TOOL BACK TO THE PROGRAM DATUM AT FAST TRAVERSE.
19	M05	STOPS THE SPINDLE.
20	M02	THIS PAGE WILL END THE PROGRAM.



TEST PIECE Nº 2

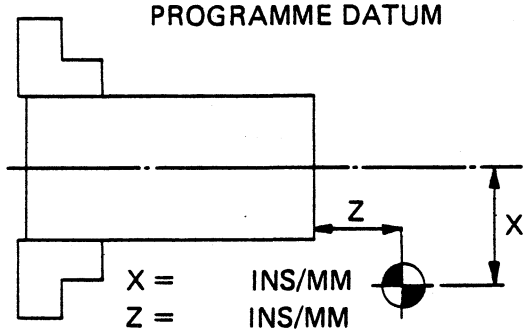


ENLARGEMENT OF TEST PIECE Nº 2

DRAWING No.	TEST PIECE 2
DESCRIPTION	
CASSETTE I/D	
MATERIAL	M/S AL
PROGRAMME BY	AMD
DATE	

BELOW IS AN EXAMPLE OF A THREAD CUTTING PAGE

PROGRAMME DATUM



ORAC

TOOLING:

No. 0 -	TOOL REF
" 1	R.H. KNIFE TOOL
" 2	55° SCREW CUTTER
" 3	
" 4	
" 5	
" 6	
" 7	
" 8	
" 9	

PAGE _____ THREAD DIA _____ ROOT DIA ____ CUT. INCR...X ____ LENGTH.Z (INCR) _____ PITCH _____

.. STARTS _____ TOOL No _____ SPINDLE SPEED _____

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
01	G70									
02	G90									
03	G50	0.5	0.2							
04	M03									
05	G73	5								
06	G91									
07	G00			-0.05	0			47	1	900
08	G01			0	-0.95			4		
09	G00			0	0.95			47		
10	G06									
11	G90									
12	G00	0.5	-0.75					47		1000
13	G73	3								
14	G91									
15	G00			-0.041	0			47		
16	G01			0	-0.25			3		
17	G00			0	0.25			47		
18	G06									
19	G90									
20	G01	0.325	-0.75					20		1200
21	G01	0.375	-0.95					3		
22	G00	0.325	-0.75					47		
23	G00	0.28	-0.75							
24	G01	0.375	-0.95					3		
25	G00	0.28	-0.75					47		
26	G00	0.255	-0.75							
27	G01	0.37	-0.99					3		
28	G00	0.255	-0.75					47		

SHEET No. ....2..... TEST PIECE 2

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
29	G00	0.25	-0.75					47	1	1300
30	G01	0.375	-1.0					3		
31	G02	0.5	-1.125			0.125	CW			1300
32	G00	1	0.1					47		
33	M05									
34	G00	0.75	0.1					47	2	130
35	M03									
36	G00	0.25	0.1					47		
37	G33	DIA=0.5		ROOT DIA=0.393			X(INC)	=0.001		
		LEN=-0.75		PITCH =0.083			STARTS	=1	TOOL=2	130
38	G00	0.5	0.2					47		
39	G00	0.75	0.2					47	0	
40	M05									
41	M02									

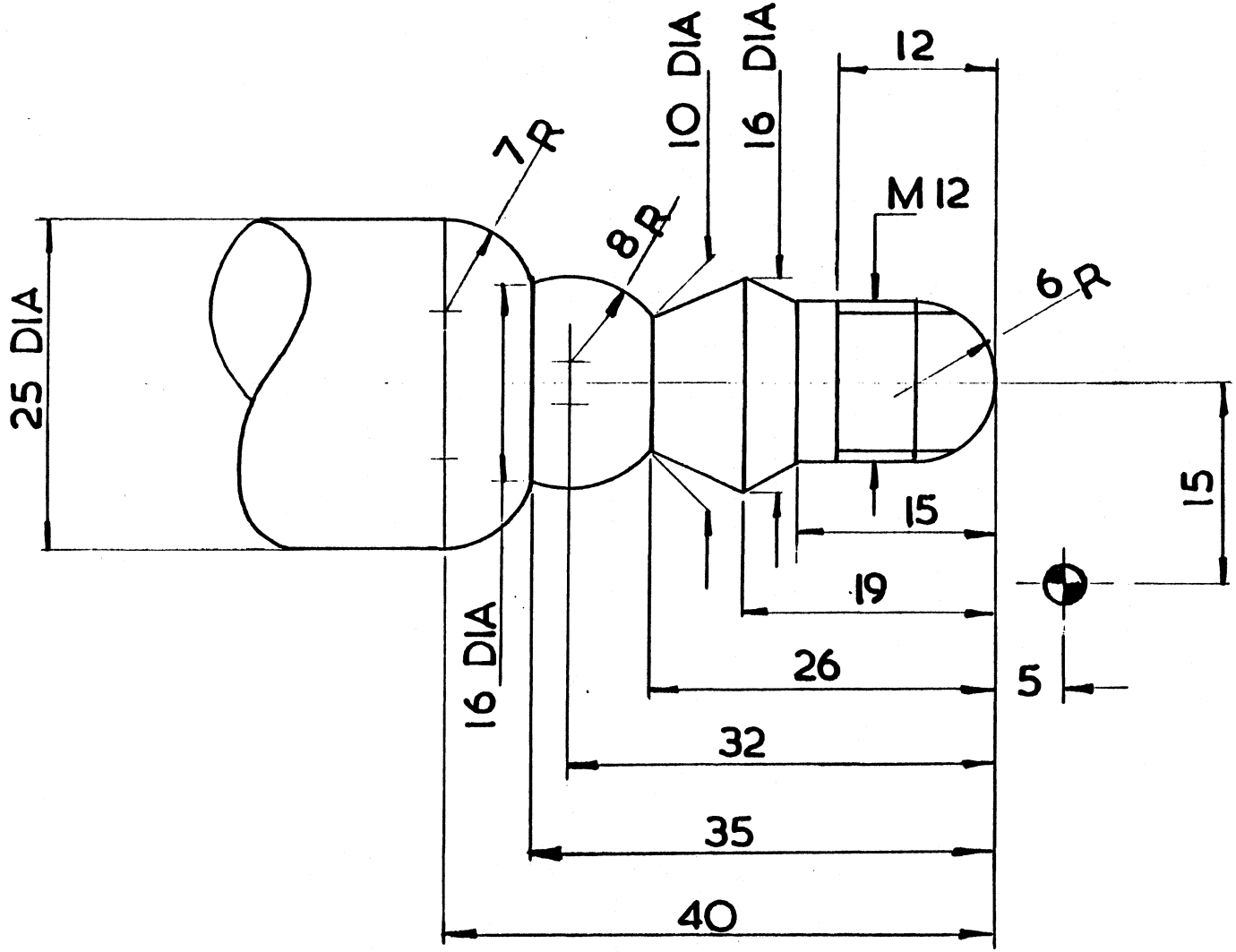
TEST PIECE 2

Page No.	G & M Function	
01	G70	IMPERIAL UNITS HAVE BEEN SELECTED AND WILL EFFECT UNTIL CHANGED.
02	G90	ABSOLUTE FORMAT SELECTED AND WILL EFFECT UNTIL CHANGED.
03	G50	THE PROGRAM DATUM SHOULD NOW BE SET WITH THE 'X' VALUE TAKEN FROM THE CENTRE LINE OF THE SPINDLE AND THE 'Z' AXIS FROM THE END OF THE WORKPIECE (1).
04	M03	THIS PAGE STARTS THE SPINDLE.
05	G73	THE START OF A DO LOOP IS NOW BEING CALLED. A COUNT IS ENTERED OF 5. EACH PAGE OF INFORMATION ENTERED FROM THIS PAGE UNTIL A PAGE CONTAINING AN END DO FUNCTION WILL BE REPEATED 5 TIMES.
06	G91	INCREMENTAL FORMAT ENTERED.
07	G00	THIS PAGE MOVES THE TOOL IN A DIRECTION TOWARDS THE CENTRE LINE OF THE SPINDLE OF 0.050" TO POSITION (2).
08	G01	THE TOOL IS NOW PROGRAMMED TO TURN A LENGTH OF 0.75". AN ACTUAL TOOL MOVEMENT OF 0.95".
09	G00	THIS PAGE RETURNS THE TOOL TO ITS ORIGINAL 'Z' POSITION.
10	G06	THIS WILL END THE DO LOOP AFTER FIVE PASSES HAVE BEEN COMPLETED. EACH PASS HAVING A DEPTH OF 0.050". I.E. PAGE 7 .050 2ND PASS PAGE 8 -.95 1ST PASS PAGE 9 .95 REPEAT 5 TIMES.
11	G90	ABSOLUTE FORMAT NOW SELECTED.
12	G00	TOOL PROGRAMMED TO MOVE TO THE CORNER OF THE SHOULDER FIRST TURNED (4).
13	G73	THE START OF A DO LOOP IS NOW BEING CALLED. A COUNT OF 3 IS ENTERED.
14	G91	INCREMENTAL FORMAT NOW SELECTED.
15	G00	THIS PAGE MOVES THE TOOL IN A DIRECTION TOWARDS THE CNETRE LINE OF THE SPINDLE OF 0.041".
16	G01	THE TOOL WILL NOW TURN A LENGTH OF 0.25".
17	G00	THIS PAGE RETURNS THE TOOL.
18	G06	THIS WILL END THE DO LOOP AFTER 3 PASSES HAVE BEEN COMPLETED.
19	G90	ABSOLUTE FORMAT NOW SELECTED.

/CONTINUED

TEST PIECE 2 /CONTINUED

Page No.	G & M Function	
20	G01	THE TOOL NOW MOVES TO POSITION (5) TO COMMENCE PRODUCING THE TAPER IN A SERIES OF CUTS.
21	G01	THE TOOL PRODUCES A TAPER FLUSH WITH THE DIAMETER.
22	G00	TOOL MOVES BACK TO POSITION (5).
23	G00	PROGRAMMED MOVEMENT TO POSITION (6).
24	G01	PRODUCES A TAPER FLUSH WITH THE DIAMETER.
25	G00	TOOL MOVES BACK TO POSITION (6).
26	G00	PROGRAMMED MOVEMENT TO POSITION (7) 0.005" OFF THE DIAMETER.
27	G01	PRODUCES A TAPER LEAVING SOME MATERIAL FOR A FINISHING CUT.
28	G00	TOOL NOW RETURNS TO POSITION (7).
29	G00	TOOL FEEDS IN READY FOR FINISHING CUT ALONG THE TAPER.
30	G01	PRODUCES FINAL TAPER FINISHING AT POSITION (8).
31	G02	THE TOOL CIRCULAR INTERPOLATES AT A RADIUS OF .125" TO PRODUCE A QUADRANT FINISHING AT POSITION (9).
32	G00	THE TOOL IS WITHDRAWN FROM THE WORKPIECE READY FOR A TOOL CHANGE.
33	M05	STOPS THE SPINDLE.
34	G00	TOOL CHANGE POSITION FOR SCREWCUTTING.
35	M03	SPINDLE STARTS TO PROGRAMMED SPEED.
36	G00	ONCE THE TOOL CHANGE HAS BEEN MADE RE-START THE CYCLE AND THE TOOL MOVES IN READY FOR SCREWCUTTING AT A REDUCED SPINDLE SPEED.
37	G33	THE THREAD IS PRODUCED WITH A SERIES OF 0.004" CUTS.
38	G00	SCREWCUTTING TOOL MOVES AWAY FROM WORK.
39	G00	THE TOOL NOW RETURNS TO THE PROGRAM DATUM.
40	M05	THIS PAGE STOPS THE SPINDLE.
41	M02	THIS FUNCTION ENDS THE PROGRAM.

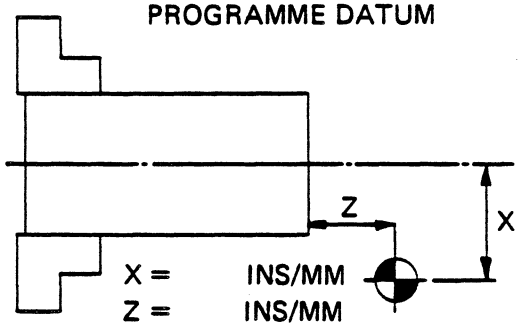


TEST PIECE Nº 3

DRAWING No.	TEST PIECE 3
DESCRIPTION	
CASSETTE I/D	
MATERIAL	M/S AL
PROGRAMME BY	AMD
DATE	

BELOW IS AN EXAMPLE OF A THREAD CUTTING PAGE

PROGRAMME DATUM



ORAC

TOOLING:

No. 0 - TOOL REF	
" 1	R.H. KNIFE TOOL
" 2	SCREW CUTTING
" 3	
" 4	
" 5	
" 6	
" 7	
" 8	
" 9	

PAGE _____ THREAD DIA _____ ROOT DIA _____ CUT. INCR...X _____ LENGTH.Z (INCR) _____ PITCH _____

.. STARTS _____ TOOL No _____ SPINDLE SPEED _____

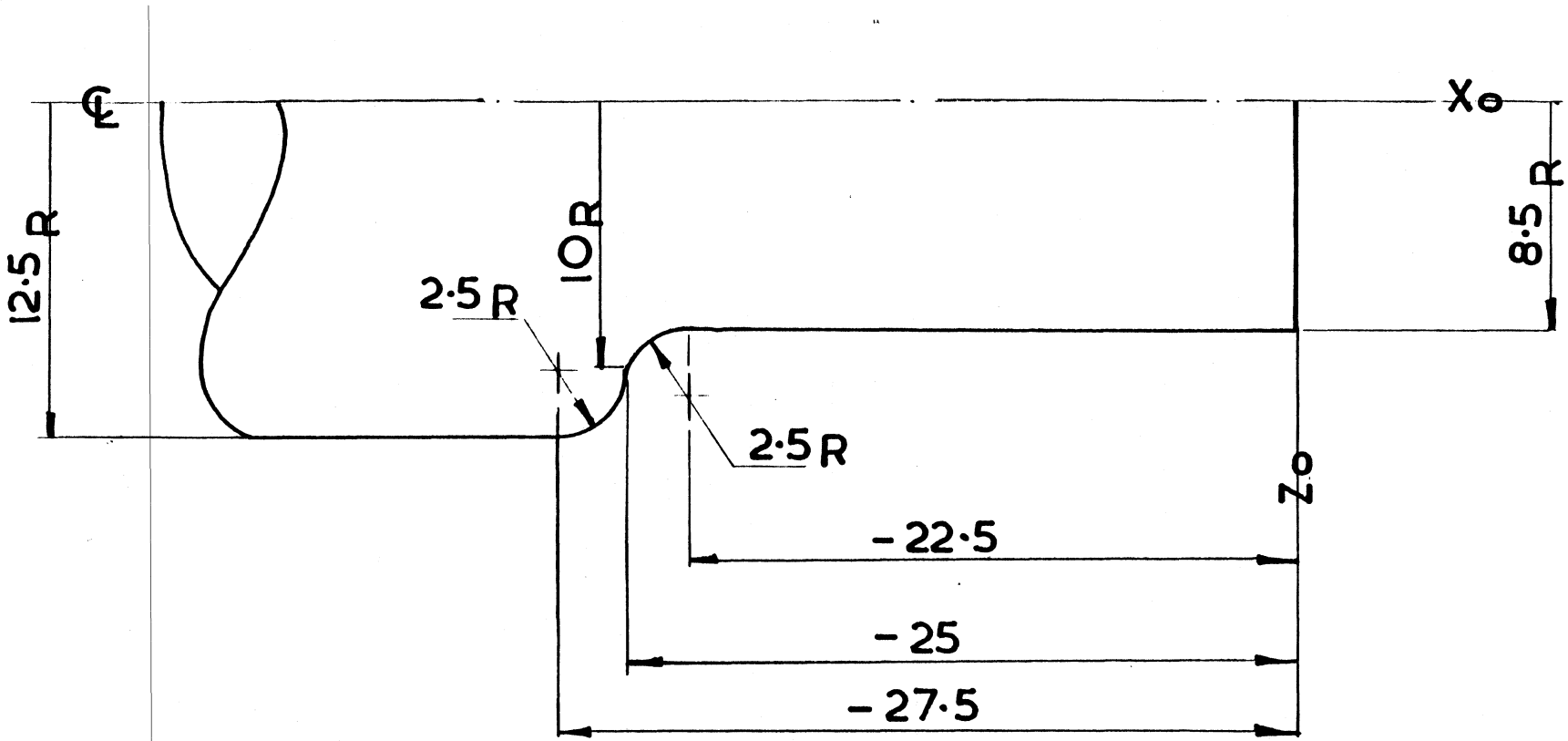
PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
01	G71									
02	G90									
03	G50	15	5							
04	M03									
05	G00	12.5	0.5					1200	1	1200
06	G73	7								
07	G91									
08	G00			-0.5	0			1200		
09	G01			0	-35.5			80		
10	G00			0	35.5			1200		
11	G06									
12	G90									
13	G00	9.0	0.2					1200		
14	G91									
15	G73	5								
16	G00			-0.5	0			1200		1300
17	G01			0	-15.2			80		
18	G00			0	15.2			1200		
19	G06									
20	G90									
21	G01	5.5	0					200		1400
22	G01	6.5	-3					50		
23	G01	5.5	0					300		
24	G01	4.5	0							
25	G01	6.5	-3					50		
26	G01	4.5	0					300		
27	G01	3.5	0							
28	G01	6.5	-3					50		

SHEET No. ....2..... TEST PIECE 3

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
29	G01	3.5	0					300	1	1400
30	G01	2.5	0							
31	G01	6.5	-3					50		
32	G01	2.5	0					300		
33	G01	1.0	0							
34	G02	6.5	-6.0			6.0	CW	50		
35	G01	6.5	-15					200		
36	G01	8.0	-15							
37	G01	9.0	-19					50		
38	G01	8.0	-15					200		
39	G01	7.0	-15							
40	G01	9.0	-19					50		
41	G01	7.0	-15					200		
42	G01	6.5	-15							
43	G01	8.5	-19					50		
44	G01	8.5	-26							
45	G01	8.5	-19					200		
46	G01	7.5	-26					50		
47	G01	8.5	-19					200		
48	G01	6.5	-26					50		
49	G01	8.5	-19					200		
50	G01	5.5	-26					50		
51	G01	7.5	-26					200		
52	G01	8.5	-32					50		
53	G01	7.5	-26					200		
54	G01	5.5	-26							
55	G02	8.0	-35			8.0	CW	50		
56	G01	11.5	-35					200		
57	G01	12.5	-39					50		
58	G01	11.5	-35					200	1	1400
59	G01	10.5	-35							
60	G01	12.5	-39					50		
61	G01	10.5	-35					200		
62	G01	9.5	-35							
63	G01	12.5	-38					50		
64	G01	12.5	0					1000		
65	G01	0	0					200		
66	G01	6.0	-6			6.0	CW	40		

SHEET No. .....3..... TEST PIECE 3

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
67	G01	6.0	-15							
68	G01	8.0	-19							
69	G01	5.0	-26							
70	G02	8.0	-35			8.0	CW			
71	G02	12.5	-40			7.0	CW			
72	G00	15	5					1200		
73	M05									
72	G00	14	2					1200	2	150
73	M03									
74	G00	6	2					1200		
75	G33	O/D=12		RD=9.85		CUT	(INCR)	X=0.04		LENGTH 15
		PITCH=1.75		STARTS 1		TOOL 2		SPINDLE SPEED=150		
76	G00	14	2					1200	2	
77	G00	15	5						0	
78	M05									
79	M02									

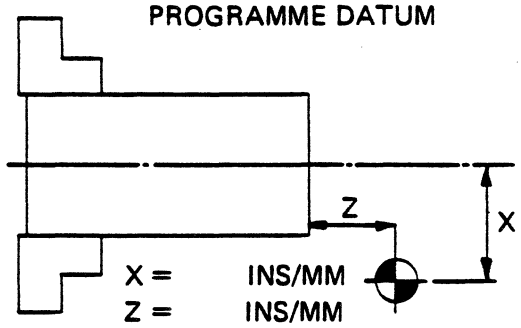


TEST PIECE Nº 4

DRAWING No.	TEST PIECE 4
DESCRIPTION	
CASSETTE I/D	
MATERIAL	M/S AL
PROGRAMME BY	AMD
DATE	

BELOW IS AN EXAMPLE OF A THREAD CUTTING PAGE

PROGRAMME DATUM



ORAC

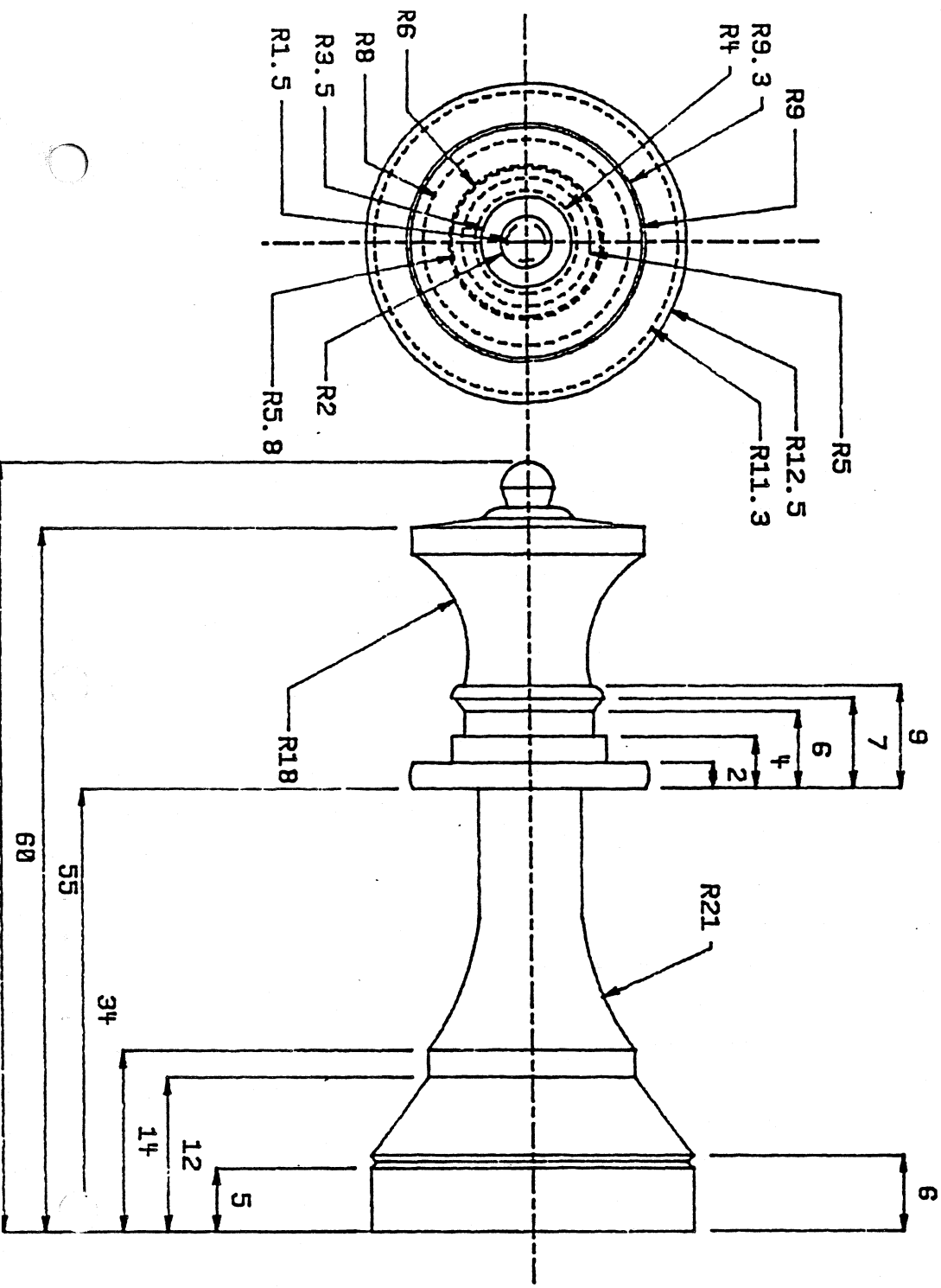
TOOLING:

No. 0 - TOOL REF	
" 1	R.H. KNIFE TOOL
" 2	
" 3	
" 4	
" 5	
" 6	
" 7	
" 8	
" 9	

PAGE _____ THREAD DIA _____ ROOT DIA _____ CUT. INCR...X _____ LENGTH.Z (INCR) _____ PITCH _____

.. STARTS _____ TOOL No _____ SPINDLE SPEED _____

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
01	G71									
02	G90									
03	G50	15	5							
04	M03									
05	G00	13	0.5					1200	1	800
06	G73	3								
07	G91									
08	G00			-1.0	0			1200		
09	G01			0	-25.5			80		
10	G00			0	25.5			1200		
11	G06									
12	G73	2								
13	G00			-1	0			1200		1000
14	G01			0	-23			100		
15	G00			0.5	0			1200		
16	G00			0	23					
17	G06									
18	G90									
19	G00	8.6	-22.4					1200		
20	G01	8.5	-22.5					100		
21	G02	10	-25			2.5	CCW	40		
22	G02	12.5	-27.5			2.5	CW	40		
23	G00	15	0					1200		
24	G00	15	5						0	
25	M05									
26	M02									

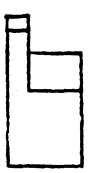


TOOL LIBRARY

TOOL 1

TOOL 2

TOOL 3

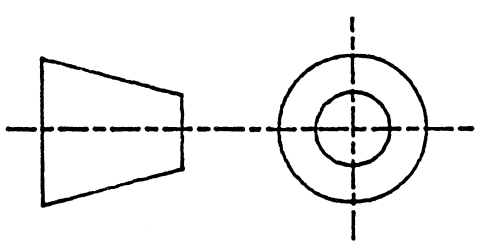


TOOL 4

TOOL 6

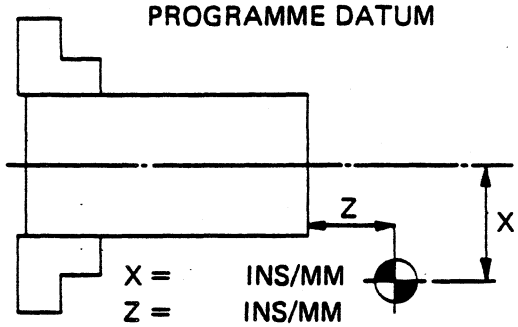
ALL DIMENSIONS IN MM

DENFORD	
ORAC CHESS SET	
SCALE 2:1	TITLE QUEEN
BAR STOCK 25.4x96	MATL EN 1A



DRAWING No.	1
DESCRIPTION	QUEEN
CASSETTE I/D	
MATERIAL	
PROGRAMME BY	
DATE	

PROGRAMME DATUM



ORAC

TOOLING:

No. 0 - TOOL REF
" 1
" 2
" 3
" 4
" 5
" 6
" 7
" 8
" 9

BELOW IS AN EXAMPLE OF A THREAD CUTTING PAGE

PAGE____ THREAD DIA____ ROOT DIA____ CUT. INCR...X____ LENGTH.Z (INCR)____ PITCH____

.. STARTS____ TOOL No____ SPINDLE SPEED____

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
01	G71									
02	G91									
03	G50	15	5							
04	M03									
05	G00			-2	-4			1200	1	1000
06	G73	4								
07	G01			0	-0.5			1000		
08	G01			-13	0			80		
09	G01			13	0			1000		
10	G01									
11	G01			-0.4	0.2			1000		
12	G73	3								
13	G01			-0.9	1.2			1000		1200
14	G01			0	-54			80		
15	G01			0	54			1000		
16	G06									
17	G01			-0.9	-3.6			1000		
18	G01			0	-22			80		
19	G01			0	22			1000		
20	G73	9								
21	G01			-0.75	0.16			1000		
22	G01			0	-5			80		
23	G01			0	5			1000		
24	G06									
25	G90									
26	G01	0	-1					80		
27	G02	2	-3			2	CW	80		1200
28	G01	1.5	-4.5					80		
					100					

SHEET No. .....2..... QUEEN

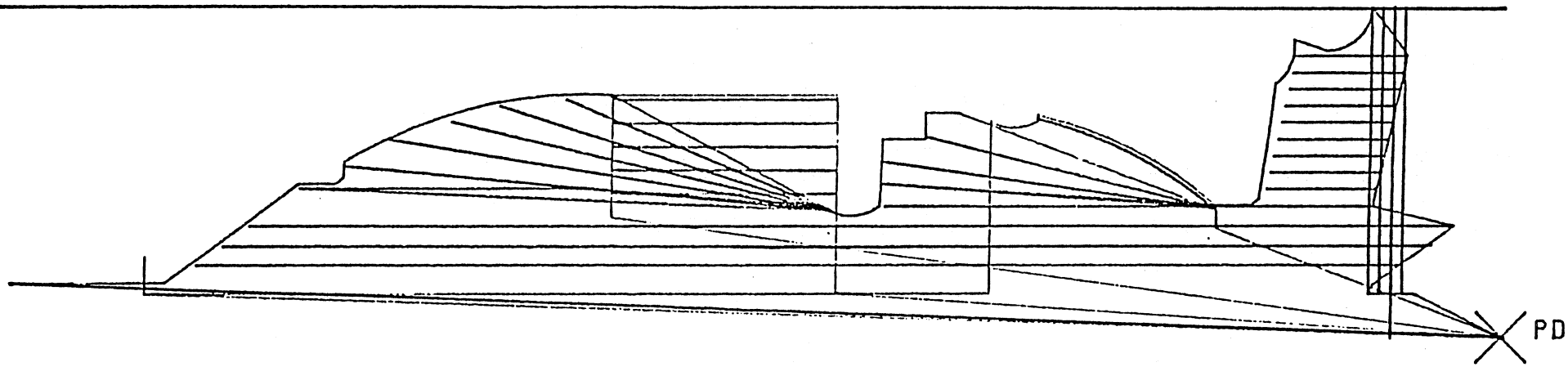
PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
29	G02	3.5	-5.3			2	CW	80		1200
30	G01	8.7	-6					80		
31	G01	8.95	-6.3					80		
32	G01	8.95	-8.1					80		
33	G01	8	-22.9					80		
34	G01	9.1	-8.1					1000		
35	G01	7	-22.9					80		
36	G01	9.1	8.1					1000		
37	G01	5.9	-20.9					80		
38	G01	9.1	-8.1					1000		
39	G01	4.8	-19.5					60		
40	G01	4.8	-21					80		
41	G01	6	-21					100		
42	G01	6	-22.9					80		
43	G01	9	-23					80		
44	G02	9	-25.5			2	CW	80		1200
45	G01	8.2	-36					80		
46	G01	8.2	-49					80		
47	G01	9.2	-25.2					1000		
48	G01	7.2	-47					60		
49	G01	9.2	-25.2					1000		
50	G01	6	-45					60		
51	G01	9.2	-25.2					1000		
52	G01	5.2	-42.2					60		
53	G01	9.2	-25.2					1000		
54	G01	4.5	-40					60		
55	G01	9.2	-25.2					1000		
56	G01	4.2	-37					60		
57	G01	9.2	-25.2					1000		
58	G01	4	-35					60		
59	G03	7	-47			21	CCW	80		1200
60	G01	7.7	-47					80		
61	G01	8	-47.3					100	1	1200
62	G01	8	-49					100		
63	G01	12.5	-55					100		
64	G01	12.5	-62					100		
65	G00	15	5					1200		
6	M05									
					101					

SHEET No. 3 QUEEN

PAGE	G & M FUNCTION	ABSOLUTE		INCREMENTAL		RADIUS	SENSE CW/CCW	FEED RATE	TOOL	SPINDLE SPEED
		X	Z	X	Z					
67	G00	14	2					1200	4	1200
68	M03									
69	G91									
70	G73	5								
71	G01			-1.06	0			1000		
72	G01			0	10			80		
73	G01			0	-10			1000		
74	G06									
74	G90									
75	G01	4	-35.2					100		
76	G01	4	-25					100		
77	G01	13	-25					100		
78	G00	15	5					1200		
79	M05									
80	G01	14	2					1200	2	1200
81	M03									
82	G01	10	-8					1000		
83	G01	9.25	-8					80		
84	G03	5.1	-16			19	CCW	60		1200
85	G02	9.25	-8			19	CW	60		1200
86	G01	9	-8					60		
87	G03	4.9	-16			18	CCW	60		1200
89	G01	5.2	-16					100		
90	G02	5.2	-18.1			2	CW	80		1200
91	G01	13	-18.1					1000	2	1200
92	G01	13	-56					1000		
93	G01	11.3	-56					20		
94	G01	13	-56					500		
95	G00	15	5					1200		
96	M05									
97	G00	14	2					1200	3	350
98	M03									
99	G00	14	-64					1200		
100	G01	-0.1	-64					10		
101	G01	14	-64					500		
102	G00	14	2					1200		
103	M05									
104	G00	15	5					1200	0	
105	M02									
					102					

QUEEN

SCALE 3·5:1



SECTION 32

TO LOAD FROM A COMPUTER

If it is required to load ORACS memory form some external device, for example a computer or a paper tape reader unit, this can be done through the RS232C serial Data link located at the rear of the machine. Connection is made via a standard 25 way 'D' type connector. (For connection and data format see RS232 Data Format, section 35 page 108.)

Once ORAC, and for example a computer, are both connected, depress button 3 then E. Three separate Baud rates are now displayed

1. 300 Baud.
2. 1200 Baud.
3. 2400 Baud.

This is the rate at which ORAC will accept information, and it must be set at the same rate as the computèr is transmitting. Make your selection by depressing the appropriate number and then E.

The screen will now display "READY" below the Baud rates.

Use the computer to transmit the information to ORAC. When all the information is in ORACS memory the screen will diplay "TRANSFER COMPLETE".

SECTION 33

TO TRANSMIT TO A COMPUTER

Once a program is in ORACS memory, it can be transmitted to external devices, through the RS232C serial Data link. These devices could be computers, printers, paper tape punch units etc. Make the connection with the device (as explained in section 34 page 107) and with the memory in ORAC loaded, depress 4 then E. The screen will now ask for a choice to be made between

1. FILE FORMAT.
2. PRINTER FORMAT.

File format should be selected when connecting up to a computer, and printer format when connecting to a printer. The latter format provides a listing heading and separate pages with 4 line feed characters between the pages.

File format should also be selected when using a paper type punch unit as a form of program storage.

Make your selection by depressing 1 or 2 and then E. Three different Baud rates are now displayed on the screen

1. 300 Baud.
2. 1200 Baud.
3. 2400 Baud.

This is the rate at which ORAC transmits information, and it must be set at the same rate as the external device will accept. Make your selection and depress E.

"OK?" will now be displayed on the screen. Set up the device to accept information, and when all is OK depress E. The program will now be transmitted at the set rate, and on completion "TRANSFER COMPLETE" will be displayed on the screen for 2 seconds after which the main menu will return.

NOTE: The memory of ORAC is not cleared when a program has been transmitted.

For further information on the external devices mentioned in section 32 and 33 please contact us at our Brighouse Headquarters.

EXAMPLE OF PRINTOUT FROM * ORAC *

P R O G R A M L I S T I N G

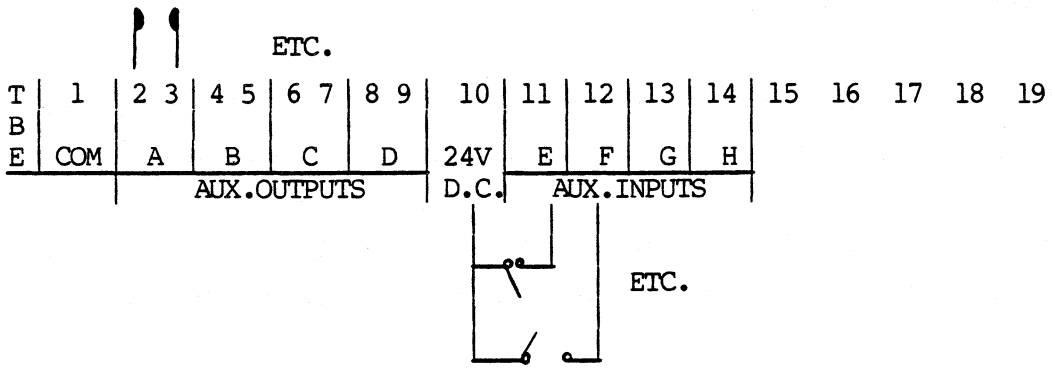
```
 TITLE .....................
 I.D.  ............

PAGE 01  INCH-UNITS..G70

PAGE 02  INCREMENTAL-FORMAT.G91

PAGE 03  THREADING..G33
  IN/OUT-SIDE.DIAM  2
  ROOT-DIAMTER   1.99
  CUT.(INCR)..X  0.01
  LENGTH..Z  -1

PITCH  0.10
STARTS  1
TOOL-NO  1
SPINDLE-SPEED  100

PAGE 04  DWELL..G04

  TIME.(SECS)  05

PAGE 05  THREADING..G33
  IN/OUT-SIDE.DIAM  2
  TOOT-DIAMETER  1.99
  CUT.(INCR)..X  0.01
  LENGTH..Z  -1

PITCH  0.04
STARTS  1
TOOL-NO 1
SPINDLE-SPEED  100

PAGE 06  DWELL..G04

  TIME.(SECS)  05

PAGE 07  POINT-TO-POINT.G00,G01

    X  0.562
    Z  0.562

  FEEDRATE  10
  TOOL-NO  1
SPINDLE-SPEED  1000

PAGE 08  CALL-SUBROUTINE
```

SECTION 34

EXTERNAL CONNECTIONS

THE TERMINAL STRIP FOR THE AUXILLIARY INPUTS AND OUTPUTS IS SITUATED INSIDE AT THE REAR OF THE MACHINE.

AUXILLIARIES:



OUTPUTS; ON THE TERMINAL STRIP RELAY 'A' CONTACTS ARE CONNECTED ACROSS TERMINALS '2' AND '3'. THEY ARE NORMALLY OPEN CONTACTS RATED AT 3A RESISTIVE, 240V AC MAX. SIMILAR CONTACTS FOR RELAYS B, C AND D, ARE CONNECTED AS SHOWN.

INPUTS; THE INPUT SIGNALS CAN COME FROM SWITCHES CONNECTED AS SHOWN, USING THE INTERNAL 24V DC SUPPLY FROM TERMINALS 10.

T.V. SOCKET; A SOCKET IS PROVIDED ON THE REAR PANEL FOR THE CONNECTION OF A UHF 625 LINE STANDARD U.K. T.V. SET VIA AN INTERNAL MODULATOR IN * ORAC *. SIMPLY CONNECT THE SOCKET TO THE AERIAL INPUT ON THE T.V., TUNE T.V. UNTIL PICTURE IS OBTAINED (APPROX. CH. 36).

SECTION 35

RS232 DATA FORMAT

ORAC DATA FORMAT

For maximum compatibility with all computer types ORAC works exclusively with standard ASCll text. This format is used for internal editing and external (via RS232 link) communication.

ORAC works with a file made up of text pages. Each page represents a single machining function and contains all parameters associated with it.

Each page is preceeded by the ascii START-OF-TEXT character (hexadecimal 02), and is terminated by a record-separator character (hexadecimal 1E).

The whole file starts with an ascii START-OF-HEADER character (hexadecimal 01) and is terminated by an ascii END-OF-TRANSMISSION character (hexadecimal 04).

PAGES

Each page must have the word "PAGE" as the first work on the first line. All words and numbers on the same line must be separated by one (or more) ascii space characters (hexadecimal 20). All lines must be separated by the ascii carriage-return and line-feed characters (hexadecimal 00,0A).

Following the word "PAGE" on the top line (and separated by a space) must be the page number (01 to 99). Pages must follow in numerical order.

Lastly on the top line must be the page heading (e.g. AUX-INPUTS, START-DO-LOOP etc.). These headings must be written exactly as in ORAC and contain no spaces. For example, "POINT-TO-POINT. G00,G01". Note that the number 0 and the O are not interchangeable.

The rest of each page is made up of "key-words", for example, X,Z, FEEDRATE, TOOL-NO, SPINDLE-SPEED.

Keywords must also be written exactly as on the ORAC display and contain no embedded spaces.

The order in which the keywords appear on a page is not critical. However, all relevant keywords must be present and must be the first word of any line.

On the same line as each keyword must be the associated numerical value. The numberical value must be separated from the keyword by at least one space.

All numerical values are ascii characters (e.g. 1 is hexadecimal 31).

RS232 COMMUNICATION

ORAC allows selection of 300, 1200 and 2400 BAUD rates (bits per second).

ORAC allows transmission of the standard file format (previously described) or printer-format. The printer format suppresses the transmission of SOH, STX, RS, and EOT control characters. It also provides a listing heading and separates pages with 4 LINE-FEED characters.

ORAC senses the RS232 DTR line (pin 20) before transmitting each character i.e. this line represents a busy-line. If the external computer or printer is not ready to accept data it sets DTR to -12V.

In the reverse direction ORAC will set DSR (pin 6) line to +12V when ready to input data.

Each word transmitted consists of:-

8 Data bits,
1 Stop bit,
No Parity bits.

ORAC RS232 INTERFACE

ORAC is connected in the 'MODEM' configuration - pin numbers refer to the standard 25 way D-type connector. Only six pins on the connector are used.

PIN NO.	DESIGNATION	DESCRIPTION
1	GND	Protective Ground.
2	TXD	Data is transmitted on this line from an external device to ORAC.
3	RXD	Data is transmitted on this line from ORAC to an external device.
6	DSR	This line is used by ORAC to indicate to an external device that it is ready to receive data.
7	GND	Signal Ground.
20	DTR	This line is monitored by ORAC when transmitting data. ORAC checks this line is high (+12V) before sending each character.

FOREWORD

This section has been prepared with the intention of providing assistance to persons in an organisation where there is a Denford ORAC CNC training lathe available as a principal aid in the teaching of NC techniques.

Syllabuses, course content, student level and time available for numerical control teaching, instruction or practice vary widely and in consequence the material which has been set out in this book is based on the assumption that there will be a minimum of 20 hours classwork to supplement practical or laboratory work with ORAC and the orac Manual.

Due to the large extent that the overall teaching program can or should be taught directly with ORAC and its aids, including the Manual, the classroom topics can be expanded or reduced with the initiative of the course supervisors and in accordance with the relevant course contents and objectives.

The whole area of numerical control is the subject of vigorous change and development. For that reason alone it is advisable to seek for further source material from the technical literature of manufacturers of control systems and machine tools and, of course, maintain contact with Denford Machine Tools where the policy is constant development and service to Further Education, Higher Education and Industry.

INDEX

PART 1

STUDENT READINESS

- Ensure that students have had opportunity to acquaint themselves with a digital readout unit, automatic lathe or some other machine or equipment using the open loop control principle.
- Similarly ensure that students have studied a hydraulic copying unit in theory and practice or some other servo-control unit.
- Ensure, preferably as a result of workshop practice or laboratory work, that students understand the importance of well-planned and calculated planning in the machining of parts on lathe or milling machines.

OBJECTIVES

During the teaching of Part 1 the principles of open and closed loop systems are taught, where they are used and why.

The second objective of this Part is to teach the concept of the numerical control system and to describe the role of the machinist in the workshop yesterday and today if not tomorrow, in the workshop where numerical control is in use.

(There is good material here for those courses in which there are General Studies periods.) The aim is, however, motivation to study NC technology.

PART 1

INTRODUCTION

1. MACHINE TOOL CONTROL

From the earliest times of using machine tools for specified production tasks in the metal industry, the trend has been to make machines more and more automatic. The trends began to be noticed in certain industries, for example Eli Whitney's work in the spinning industries and Samuel Cold of Wild West fame, even though their work was mainly in the jig and fixture fields. One objective has always been the reduction of labour costs, but nowadays there are many other equally important reasons for automation, some of which will be mentioned later.

Automation techniques have been adapted to machine control in many ways. Already in the 19th century the capstan lathe, and the automatic lathes of Swiss or turret type having a mechanical control enabling the operator to perform other tasks while the machine was going through its cycle, were well-developed. Indeed the automatic lathe had not changed its basic design until the advent of CNC applications in just the last few years. Copying devices, copying lathes and milling machines and tracing machines have been developed using various controls, based on mechanical, electrical or hydraulic principles, thus creating a measure of automated operation. Really complicated transfer lines and production lines linking a number of conventional and special machine tools have been in operation, and under development for many decades, providing automation in mass production of parts, repeated accuracy and interchangeability of parts, higher overall manufacturing rates, reduced labour etc., etc., - and sometimes a reduction in the quality of the final product, resulting in a shortened working life for the product and the dawn of the throw-away, rather than renovate or repair philosophy.

Such production lines are very costly and are not suitable for any product to be produced in quantities less that tens or hundreds of thousands. Machine tools of this category, either in single units or as part of a line, are known as dedicated machine tools.

Every machine tool control system, whether it be large or small machine, is either an open-loop system or a closed-loop system. A variation of the latter is the partially closed loop system.

1.1 OPEN-LOOP SYSTEM

An input signal, a command, is given to the machine tool, in order that is shall perform a certain operation. A cutting tool may move to a positon which has been defined, and stop there. If the loop is open there is no return of information concerning the actual position of the tool, the system does not provide a feedback signal to verify that the tool has indeed moved to te specified position. The control loop is not closed. It is not known whether the result corresponds to the command. It is not known whether an error has been created.

An open-loop system is satisfactory in those applications in which very tight tolerances are not applied and reliance is placed upon the accuracy of the machine and its construction. It may well be that the extra expense of a closed-loop system cannot be generally justified by the standard of work.

An open-loop system is used in ORAC, in which the stepping motors which drive the x-axis and z-axis leadscrews, give 200 signal pulses per motor revolution and the transmission between motor and screws is reduced by 2.5 to 1 to the screws which are of 5 mm pitch, and use ball nuts set with zero backlash.

1.2 CLOSED-LOOP SYSTEM

In a closed-loop system there is a feedback signal. When a cutting tool is moved to a new position, in accordance with the received command, its positon is continuously monitored, as a signal which indicates that the tool has either reached its new position or not. If it has not, then its position is automatically corrected until the correct specified position has been reached.

It can be readily understood that machine tool construction elements, such as carriages, tables, tool slides, turret heads and spindle housings may often weigh hundreds of kilogrammes. In the numerically controlled production machine tools of today some of these elements are required to move at speeds in excess of 10 m/min (17 cm/sec). The adoption of a closed-loop system of control is unavoidable to ensure that the numerically controlled machine elements reach, and repeatedly reach, their specified positions.

It is commonly required in an NC machine tool that with an accuracy of ± 12 μm over a distance of 300 m, that machine element movements, for example, tool slides, are repeated to an accuracy of ± 3 μm. The accuracy of a modern numerical control system, the resolution, is of the order of ± 1 μm and thus much greater than that which the machine tool itself can attain.

The automatic lathe, in which tools and tool slides are moved to the required positon by the fixed rise of a cam profile, is an example of an open-loop machine tool control system. There is no feedback to indicate that the tool has arrived at the desired position. The machine setter performs this function by measuring the workpiece and then adjusting the tool position to obtain the machined dimension required.

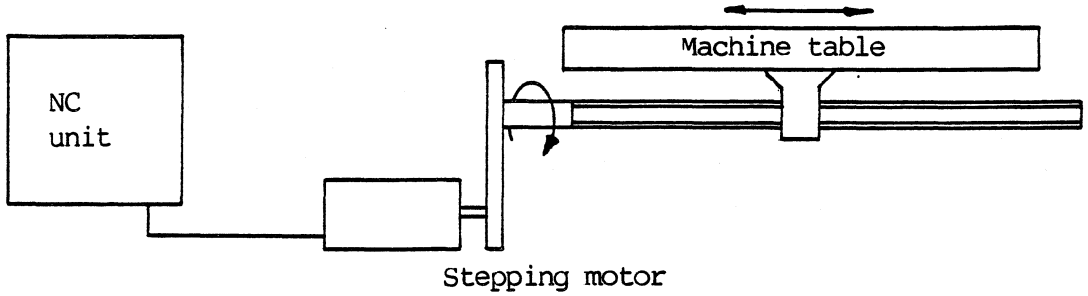
The hydraulic copying unit, which is a servo-mechanism, is an example of a closed-loop system. The tool position is continually under the influence of the hydraulic balance between its own position and that of the stylus sensor which is following the master profile. The tool is, because of this balance, self-adjusting and does not need operator intervention to monitor or measure the tool position, once it has been correctly set.

1.3 NUMERICAL CONTROL SYSTEM

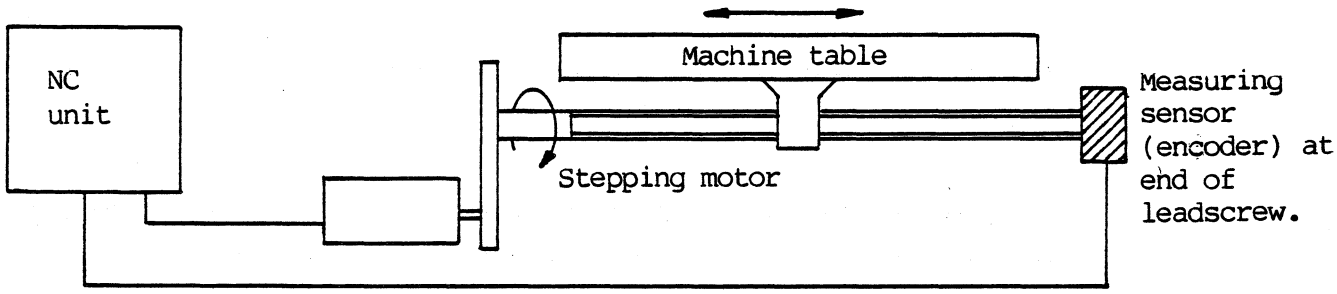
A numerical control system is one in which there is a programme, the command signals of which are successive and which is held in a memory as numbers, hence the name numerical control.

Before discussing the numerical control system further, let us look a little at the function of the machinist using a manually controlled lathe or milling machine.

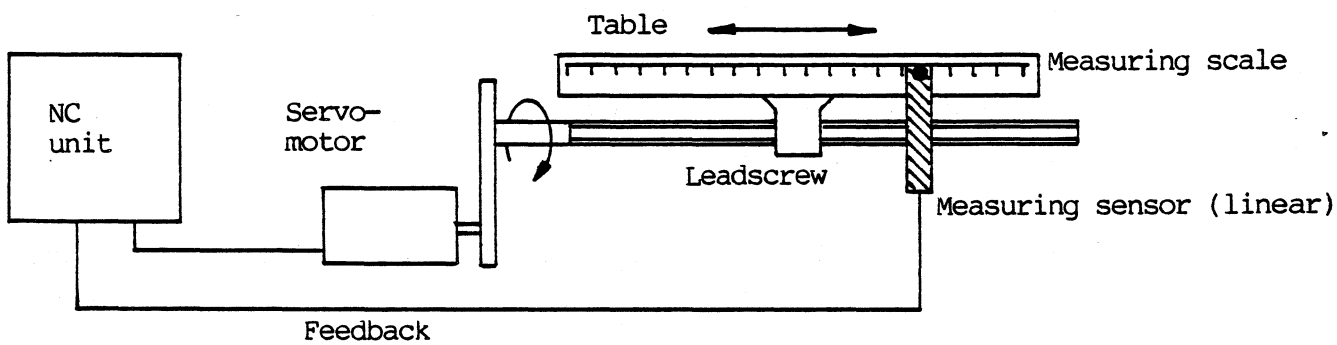
The machinist has come to use the machine tool in question for several years. Knowledge has been gained about cutting speeds and feeds for various metals on this and other types of machine tool. The machinist knows how to read the drawings that have come from the design office providing geometric information about the component to be machined and also to use the drawing and perhaps other planning information that we may call technical information, that is the appropriate cutting speeds, depths of cut, tools to be used and so on. There has been a preliminary programme or programmes made before the drawings and material comes to the machinist.



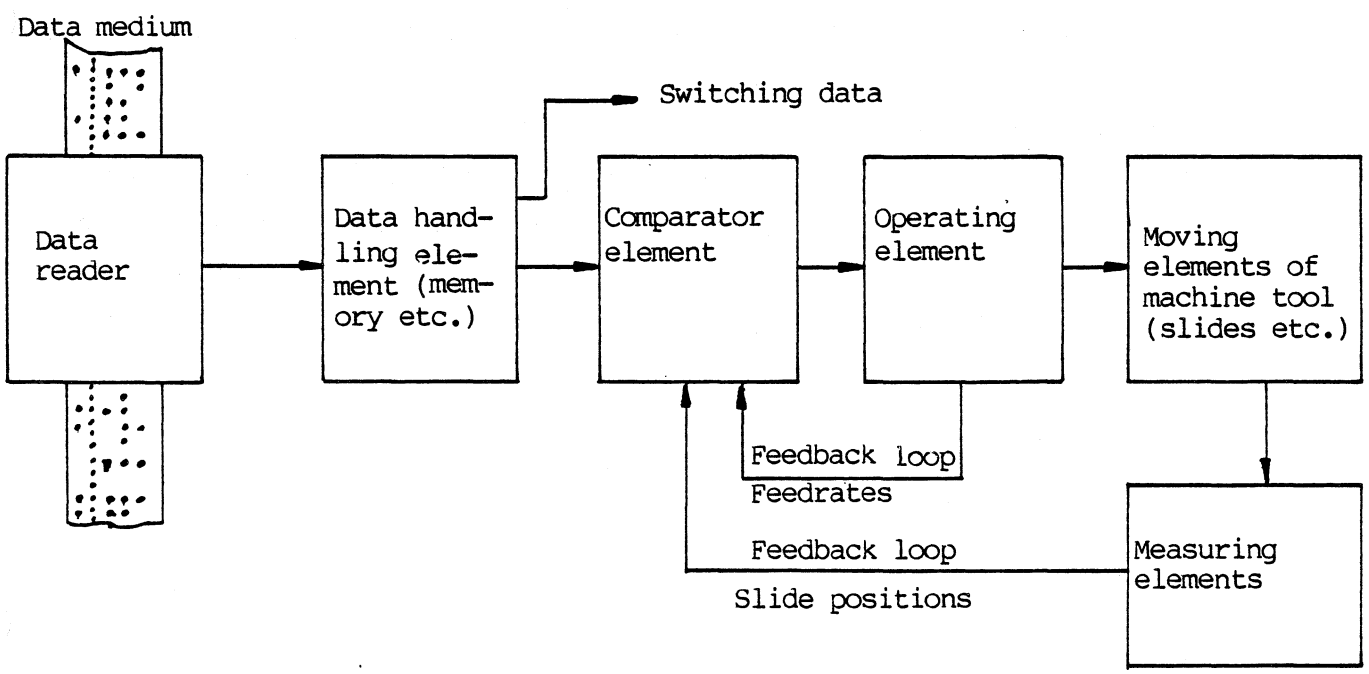
Open-loop circuit. No feedback signals.



Semiclosed loop circuit, in which feedback does not come from table or carriage, but from the end of the leadscrew.



Closed-loop circuit, providing complete feedback close to cutting operation.



Principle elements of a NC system.

Our machinist is a skilled and experienced person who knows that there is great value in an ordered and well-though out sequence of machining operations, with efficient speeds and feeds and roughing and finishing cuts, appropriate to the tools being used and the material being cut.

The machinist begins to feed the geometric and technical information to the machine tool, using the machine graduated hand wheels, switches and levers, etc. There may be digital readouts to assist in this input of information while the machine is being set up to produce the finished workpiece.

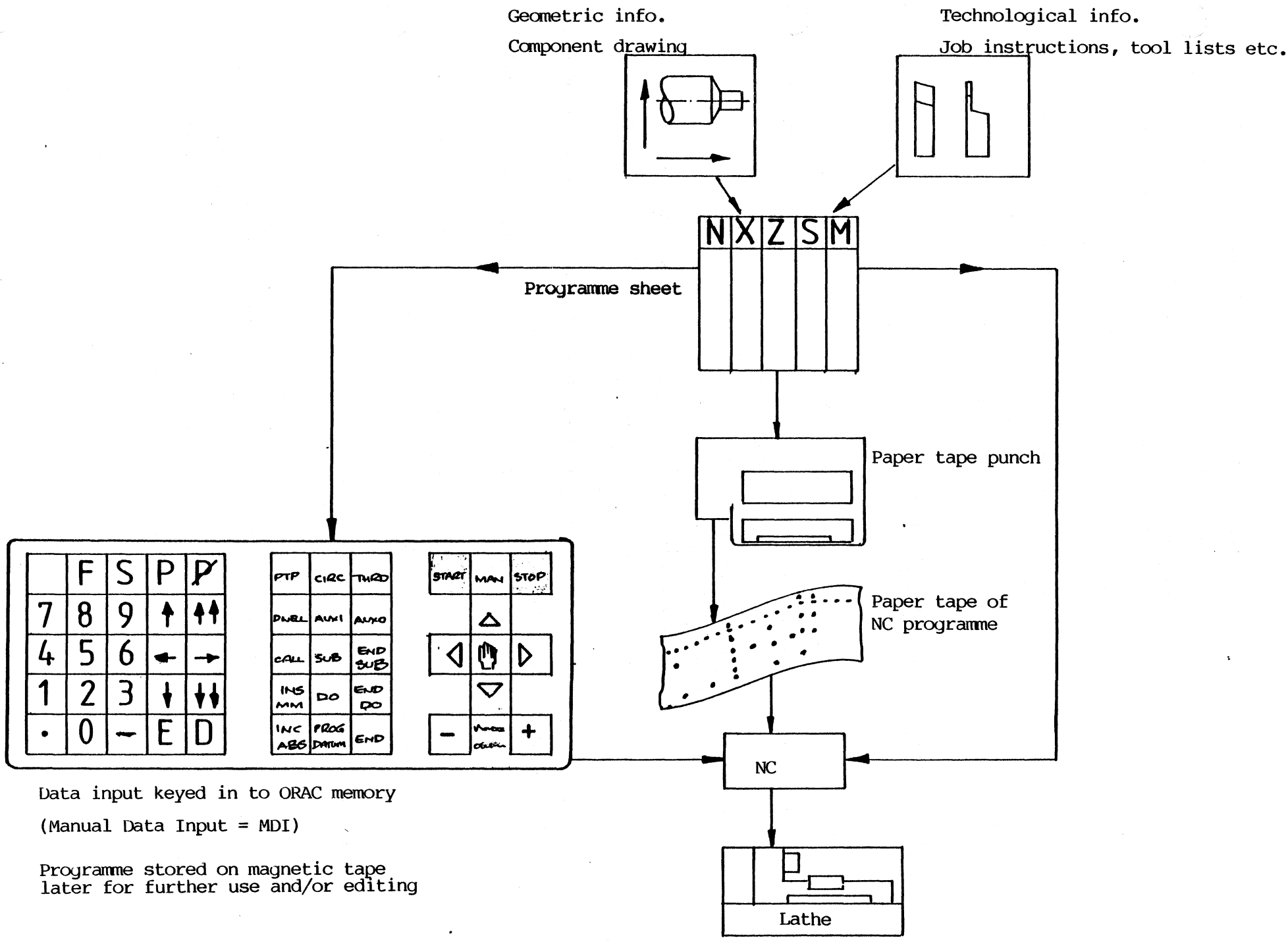
The machinist then translates the component drawings and planning sheets into such linear and angular dimensions that are acceptable to both the machine tool and to the machinist. The machinist monitors the position of the cutting tool during the machining stages and makes the corrections necessary to correspond to the requirements of the component drawing. This familiar situation is an example of a closed-loop system. The machinist translates the data, inputting positional commands, acting upon feedback signals and executing necessary compensations.

In a numerical control programme some of our machinist functions are carried out by other means.

The machine tool is equipped with a control unit, which inputs the positional command data to a slide control unit and compares that positional command automatically with the position of the monitored slide.

The component drawing must be translated into a form that the control unit can accept and act upon. This is carried out in the translator part of the computer, in which co-ordinate information is recorded with the aid of a teleprinter type unit onto recording tape or preserved in the computer memory. The systems are closed-loop systems when there are data feedback links which provide to the control system information concerning the current position of tool or slide until the required positions have been reached.

When our machinist used a manual machine there is the possibility of making conclusions relating to the behaviour of the machine and act accordingly. Based on personal experience of the machine tool, compensation for leadscrew backlash, slideway friction, slide stiffness and so on can be made. The approach to the final precise cut can be made in stages.



Data input keyed in to ORAC memory

(Manual Data Input = MDI)

Programme stored on magnetic tape
later for further use and/or editing

A numerical control system does not, however, recognise such characteristics but can only accept the ideal concept. The retrofitting of a numerical control system to a manual machine might result in a reduction in the accuracy of work produced by 0.02 to 0.08 mm as compared with the work of our skilled and careful machinist.

In an open-loop system such as is employed in ORAC the best accuracies are to be obtained by care in programming, with a finishing cut, chip thicknesses and approach speeds to finishing surfaces.

1.4 ADVANTAGES OF NUMERICAL CONTROL (NC)

1. Shorter floor to floor times.
2. Less scrap, similar quality level, less quality control required.
3. Machinist or operator work is less physically tiring than when conventional machine (also suitable for female workers).
4. Labour costs saved per piece part:
   a) machining times are shorter,
   b) set-up times are reduced and are shorter for repeat batches.
5. Batches can be smaller in number, less downtime. Less stock in stores.
6. Savings in tool costs, longer tool life with planned cutting values, more efficient and consistent material use.
7. Construction and design modifications can be carried out more flexibly.
8. Simple to duplicate the component at a later date - rescheduling exactly the same as the first production run.

1.5 DISADVANTAGES OF NC

1. Expense of original machine tool is high.
2. Either NC operators must be trained, (and encouraged to stay in employ) given higher wages to enter service from outside or computer programming must be used (more expense for equipment and software).
3. Employees may be difficult to obtain with suitable skill or experience.
4. NC is not suited to all kinds of work and is not really suitable for batches of less than five unless very complex work is involved. Automatic lathes may still be better machine choice than NC for some classes of work.

From the above it can be seen that:

a) a very careful study must be made of own operations and future prospects before the decision to enter into NC,

b) machinists are a very important factor in the above consideration and with the development of CNC and use of graphics on the shopfloor, the machinist is regaining more and more responsibility for control of the NC machine in planning and programming on the shopfloor.

PART 2

NUMERICAL CONTROL SYSTEM AND MACHINE FUNCTIONS

STUDENT READINESS

- Ensure that students are already familiar with the principle component parts of a machine tool, e.g. bed or column, headstock or spindle head, leadscrews, etc. and also their importance, both in the essential metal-removing function and also in the geometry which creates the accuracy to which the machine can perform.
- Best endeavours should be made to ensure that all students have seen an NC or CNC production machine in operation, even though it will not be necessary at this stage to cover more than a familiarisation with its major differences from a manual production or training lathe. E.G. leadscrew drives, programmable speeds, feeds, rapid traverse, VDU assistance etc. Students can be reminded of this visit in demonstrating ORAC.

OBJECTIVES

- Teaching and view of numerical control system functions, machine functions, speeds and feeds. If time and teaching syllabus permits, time can be well spent on some of the more important constructional features of an NC machine tool, e.g. the control system itself, drives to headstock or spindle (AC and DC), ballscrews, slides and slideways, hydrostatics etc.
- Special attention should be paid to safety measures and equipment, first emphasis having been paid to those features on ORAC.
- Point to point, paraxial (now largely obsolete) and continuous path control defined and revised, related to practical work with ORAC in lab. or workshop.

NOTE: Wherever possible it is intended here that classroom studies should be related as closely as possible with practical demonstration or use and with use of the ORAC Programming Manual video film and use of audio teaching tapes.

2.1 FUNCTIONS OF A NUMERICAL CONTROL SYSTEM FOR LATHE OR MILLING MACHINE

a) One or more machine axes slide movements controlled, either singly or simultaneously.
b) Control of feedrate along slideways and its direction.
c) Control of spindle rotational speeds (stepless, constant surface speed).
d) Start/stop of main spindle rotation, direction of rotation.
e) Control of coolant, on/off, flood/mist.
f) Control of tool change, turret head indexing, block tool selection, selected tool from automatic tool changer, etc.
g) Control of numerous other functions e.g. tool wear/breakage monitoring functions, pallet-changing, robot loading functions. Also other functions related to operator and/or machine safety e.g. system software and limit switch boundaries, chuck guard locks, overload monitoring.

2.2 NC MACHINE MAIN CONSTRUCTIONAL ELEMENTS

SLIDES AND SLIDEWAYS

Lathes are more commonly provided with two axes of numerical control to the slideways, linked to the spindle rotation functions. Lathes are also obtainable for high-production work with three or four axes of control, primarily for turning shafts with two opposing tools at one time or for work where other than turning functions, e.g. cross-drilling or milling will be regular features of work on the machine.

Milling machines and machining centres based on milling machine designs commonly have two axes of numerical control for table slide movements, the knee-type machines more rarely having nc to the vertical movement because of the mass of the knee casting unit which must be free to move if under nc. The vertical axis of movement in a milling machine is usually arranged by controlled movement of the spindle quill or by movement of the main spindle unit, which being in the downward cutting direction is not subject to as much resistance to movement as the knee unit.

Milling machines may have an additional two axes of movement applied to a rotatory table or CNC dividing head. It is rather uncommon for more than three axes of simultaneous movement to be used in cutting on a milling machine, but one application in which five axes of movement are used in a

complete programme is the milling of a tapered helical form on a vertical mill equipped with a CNC dividing head with tilting facility. In certain CNC machines rapid traverse slide movements as high as 45 m/min (laser cutting) are in use, but quite commonly 10-12 m/min.

These high rapid traverse rates in a CNC machine are slowed down in approaching an area to be machined and to achieve sufficient accuracy at this stage and to avoid unnecessary wear at sliding surfaces the machine tool has to be carefully designed and attention paid in particular to the effects of the accelerating and decelerating machine elements on accuracy and to means of reducing friction between surfaces. In the latter, two common approaches are the use of plastic coated surfaces (e.g. Turcite) and a more costly but very satisfactory solution, use of hydrostatic techniques to prevent metal to metal contact at the slide.

MAIN SPINDLE AND HEADSTOCK

The main spindle, its bearing design and that of the headstock, and similarly the spindle and spindle housing of the vertical milling machine are critically important components in a machine tool, giving supoort in cuts for roughing out metal and aiding accurate finishing cuts in close tolerance machining. Principle features of the main spindle and its drive in numerical control machines include a wide range of steplessly variable speeds to cater for different cutting materials and materials to be cut, rapid starting and braking, revolution in either direction, speed ranges to provide high torque at upper and lower speeds for roughing out operations and tough materials etc.

A control feature of production CNC lathes is the provision of constant surface cutting speed so that if a material to be machined has characteristics such that its recommended machining speed is 160 m/min, the spindle speed in a facing operation is automatically increased as the diameter at the tool point decreases, to maintain the cutting speed at the tool at 160 m/min. This is also controlled for reducing shaft diameters during a programme.

BALLSCREWS AND RECIRCULATING NUTS

To reduce the friction in leadscrews and to maintain very accurate pitch movements of lathe carriage and tool slide or milling machine table, the recirculating ball nut and screw is almost universally used in NC machine

design. The nuts are usually of double type and/or preloaded and may be adjusted to maintain the pitch accuracy to the required level. There is also provision in certain control systems for calibration of leadscrew pitch error and its compensation.

AUXILIARY MACHINE FUNCTIONS

Naturally there are many more features of the NC machine tool worthy of study which must remain outside the scope of these teaching notes. It is recommended that if needed in the teaching syllabus a special study be made of some CNC machine in your own place of employment or nearby, to the extent required. Most machine tool manufacturers have available helpful literature and drawings which can be used to bring out salient design features in the course of your teaching. In any case, such a study will be of assistance in appreciating the features of ORAC and other machines in the Denford Machine Tools stable.

Various functions which are brought into operation by the NC systems are available today in addition to the more normal functions such as tool indexing, coolant control, opening and closing of guards etc. Many of these additional functions are used in high-production and unmanned working, and include tool wear and breakage monitoring, automatic workpiece loading, in-process measurement and tool compensation, pallet loading and so on.

SAFETY FEATURES

As in all automatic and semi-automatic machinery and processes, industrial safety features are of great significance and these are built into the NC machine tool and its control.

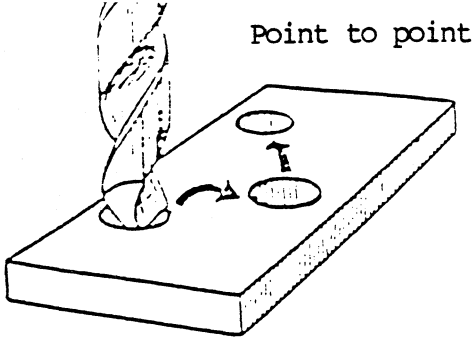
Of these the first to be mentioned is the EMERGENCY STOP button which in accordance with international standards should be red in colour and must cut out all machine functions immediately on depression, power only being restored by switching on again in a prescribed manner. STOP and START buttons and other operating switches, levers, pedals etc. must be ergonomically positioned. The operator must be protected from flying chips and swarf and there must be prevention from physical contract with cutting tools whilst they are cutting (chuck or milling machine guards). Limit switches must be provided to prevent accident to operator or machine if tool or slide travel into danger areas.

ORAC IS PROTECTED BY LIMIT SWITCHES TO X AXIS AND Z AXIS (adjustable). These cut out slide travel and spindle rotation when contacted. The spindle and drives are protected by an overload device on capacitor discharge and spindle and feeds become inoperative if overloaded.

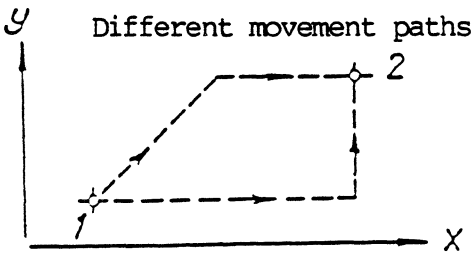
2.3 POINT TO POINT

G00 POINT TO POINT CONTROL

Controlled movement occurs in the direction of the axes or at any angle. (Simultaneous travel in two axes.) The travel is linear and at a fast traverse rate. THERE IS NO CUTTING DONE DURING THE MOVEMENT.



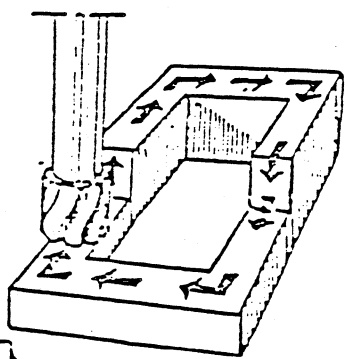
Point to point



Different movement paths PTP

G01 PARAXIAL (LINEAR PATH) CONTROL

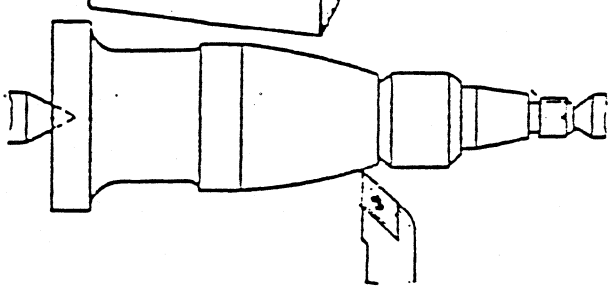
Controlled movement occurs linearly in the axial directions or at any angle provided by the suitably programmed feed rates of two axes (linear interpolation). Cutting can be performed.



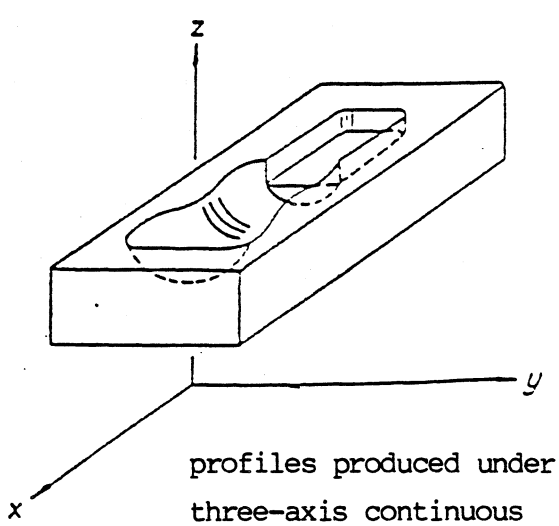
3-axis paraxial control

CONTINUOUS PATH CONTROL

The cutting path is simulataneously generated from movement in two axes at rates suitable to produce the required workpiece contour. The path may be linear at a desired angle or circular. For this reason the control unit has linear and circular interpolators which automatically calculate the combined axial movements which will produce the desired profile.

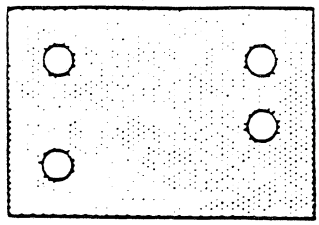


Various profiles produced under two-axis continuous path control



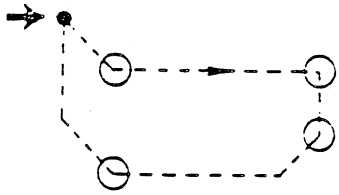
profiles produced under three-axis continuous path control (e.g. die mould)

A. Point to point (Positional) control. Typical example, NC drilling machine, spot welding.



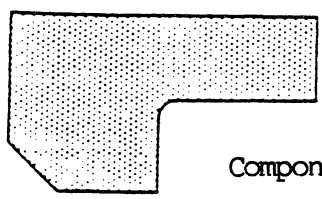
A

Component drawing



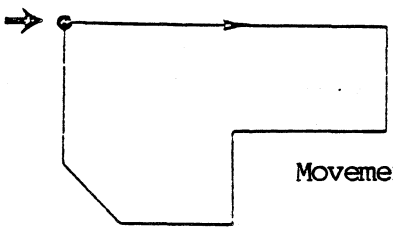
Movement path (rapid traverse)

B. Paraxial control. Typical example, simple rectangular milling work. This type of control is less common, the features being available in controls with both linear and circular interpolation.



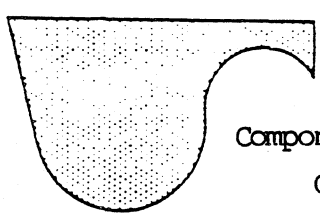
Component drawin

B



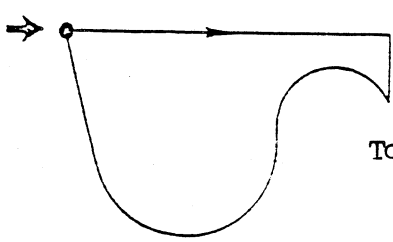
Movement path

C. Continuous path control. Profiles produced on lathe or milling machine by blending linear and circular inter- polation movements. Accuracy of form is only limited by machine tool design features and response of mechanical machine elements to the electronic control signals which input profile data into the control unit and correct tool position through the feedback loop.



Component drawing

C



Tool path

PART 3

THE CO-ORDINATE SYSTEM OF AN NC MACHINE TOOL

STUDENT READINESS

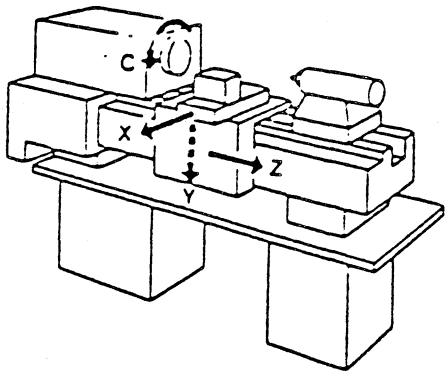
- Ensure that students understand the Cartesian rectilinear co-ordinate system (an extension of the familiar X-Y graph into the third dimension) and the importance of squareness, straightness and flatness in machine elements in terms of workpiece geometry.
- Revision of rectangular, cylindrical and conical forms as component features i.e. surfaces generated by the machine tool.

OBJECTIVES

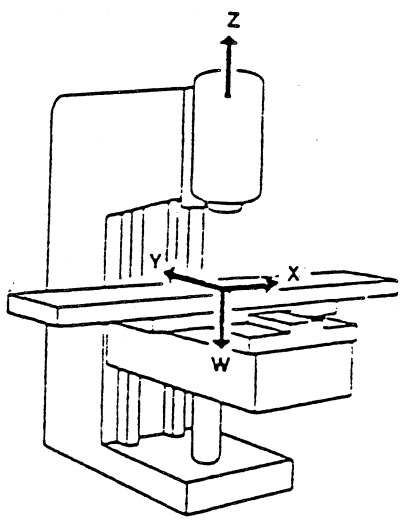
- The conventional relationship of the X, Y, Z axes to lathe and milling machine numerical control, taught or revised.
- The conventional relationship of the Z axis to the machine tool main spindle of rotation to be taguht.
  If time and syllabus permit Right Hand Rule and ± axial directions taught here. Reference to British Standard, ISO etc. advisable.
- Machine/component zero point,. programme start point and mention of machine reference (Home) points made. Depending on type of course and aims, this area can be taught to more depth, but for machinists further treatment than above may not be justified.
- Teaching of absolute and incremental mode programming. May be more practicable in programming ORAC and using the Manual.
- Mention made of diameter and radius programming.

THE CO-ORDINATE SYSTEM OF A NUMERICAL CONTROL MACHINE TOOL

In a numerical control system the tool path (or the workpiece movements, are described with the aid of a rectilinear co-ordinate system, the Cartesian system first put forward by the French mathematician and philosopher Rene Descartes. Using two or three axis rectangular co-ordinates, it is possible to unambiguously define in mathematical form any point on a plane or in space relative to the origin or zero point. This system, which is over 300 years old, is now standardised by ISO for use in NC definitions.

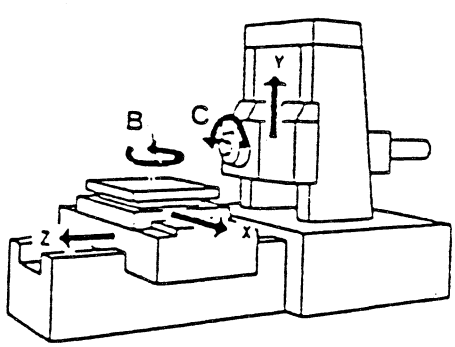


In a lathe the tool is commonly controlled in two axes, in which the slideway movement parallel to the centre of revolution of the chuck is the Z axis and the cross-slide travels in the X axis direction. X axis may be horizontal (as in ORAC) or slanted at e.g. 40° in accordance with the bed design.



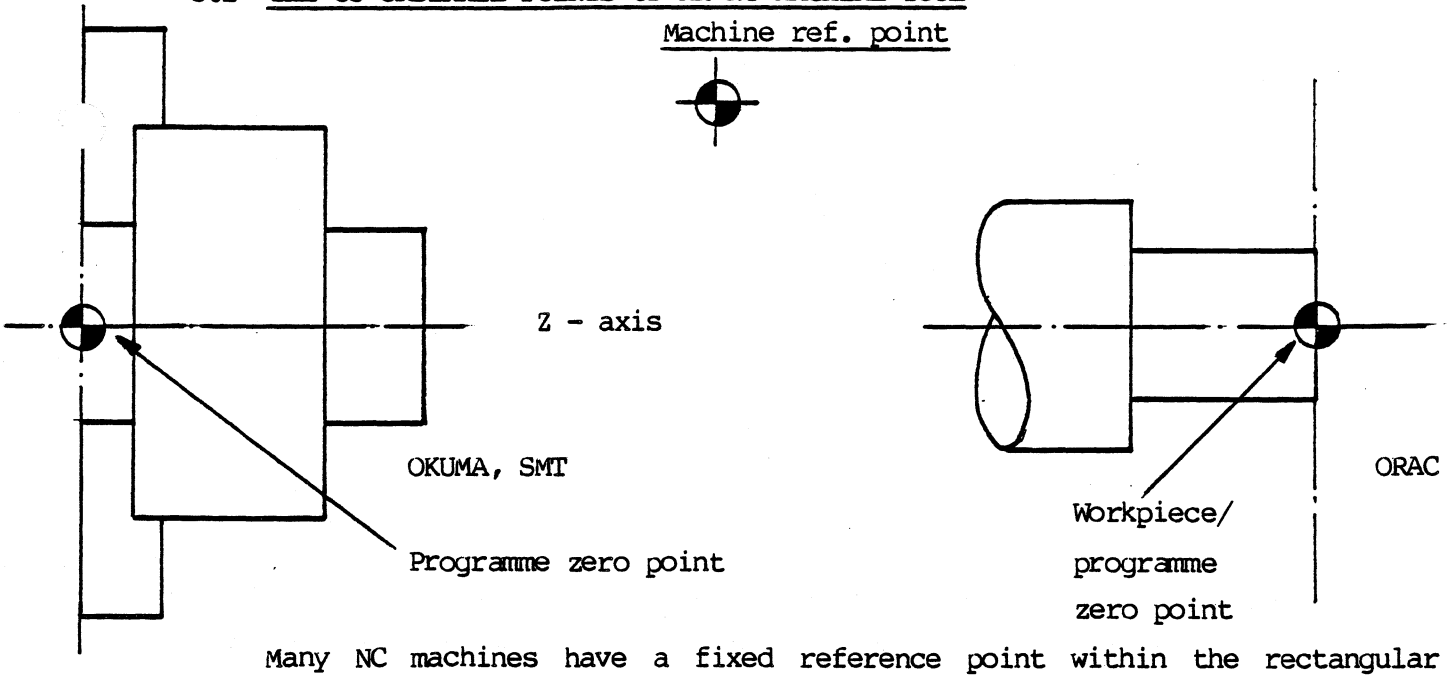
By convention the centre line of revolution of the machine tool main spindle is the Z co-ordinate axis.

In the milling machine above, the Z axis is therefore the vertical cutter spindle axis, in the boring machine below, in which the cutting spindle is not in a fixing position, it is the slideway axis parallel to the spindle which is the Z axis movement path.



To define the X, Y, Z basic co-ordinate system ISO 841 used the right hand rule, thumb, first and second fingers, thumb is X, first finger pointing vertically upwards is Y and second finger, horizontal, is Z. These are all positive directions. Students may learn this right hand rule more thoroughly at a later date; it is sufficient at this stage to know the ORAC co-ordiantes well.

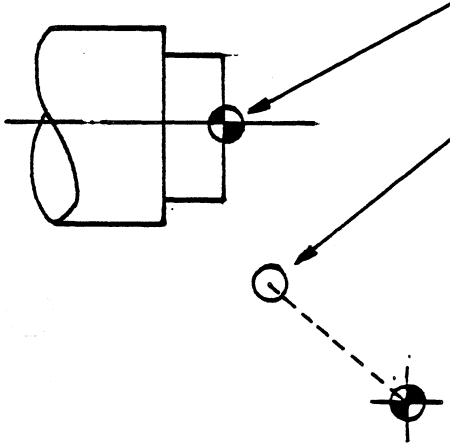
3.1 THE CO-ORDINATE POINTS OF AN NC MACHINE TOOL



Many NC machines have a fixed reference point within the rectangular co-ordinate system of the machine axes. This fixed point is recognised by the control system as a "HOME" position and for example, on start up in the morning, all machine elements drive to the home position while a diagnostic check is run on the machine functions. This reference point automatically relates the NC programme to the machines own co-ordinates.

In ORAC there is no such fixed point in the area of machine movements the position of which is known. The reference point is a FLOATING DATUM which can be set as desired and is related to the axis of revolution of the workpiece (Z = 0) and the outer face of the workpiece. This is shown in the sketch above, together with the programme zero points adopted in two makes of production machine in which the floating datum is related to the fixed point made up by axis of revolution and the plane of the chuck jaw back faces.

Programme start point



In a production lathe with HOME reference point, after start up and HOME POSITION routine, tool will be run to the programme start point, from which the programme cycle will be executed as many times as desired.

3.2 ABSOLUTE AND INCREMENTAL PROGRAMMING MODE

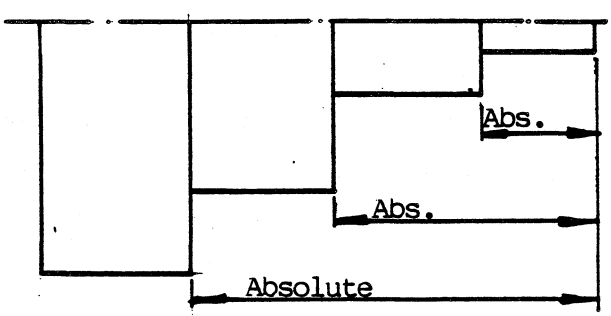
The movement of a lathe cutting tool in X or Z axis directions or the table movements X and Y of a milling machine and its quill movements Z can be described and programmed as:

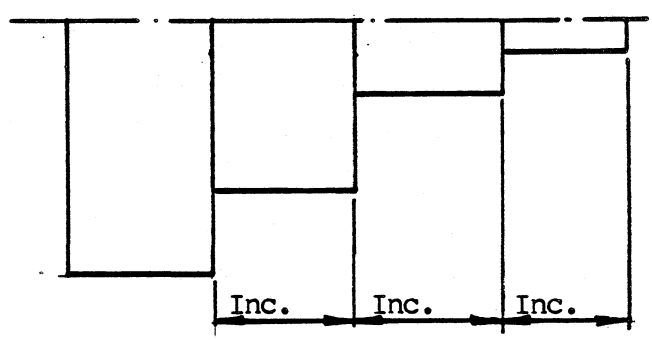
- absolute moves, or
- incremental moves.

In CNC systems either of these modes of movement can be freely selected and interchanged within the construction of a single programme.

ABSOLUTE MODE. Movement is programmed as the complete distance from a specified point, say the start point or the zero point of a programme.

INCREMENTAL MODE. In this mode the movement of tool, slide or table is described or programmed as the distance from the end point of the previous move and must be given the appropriate negative or positive sign.

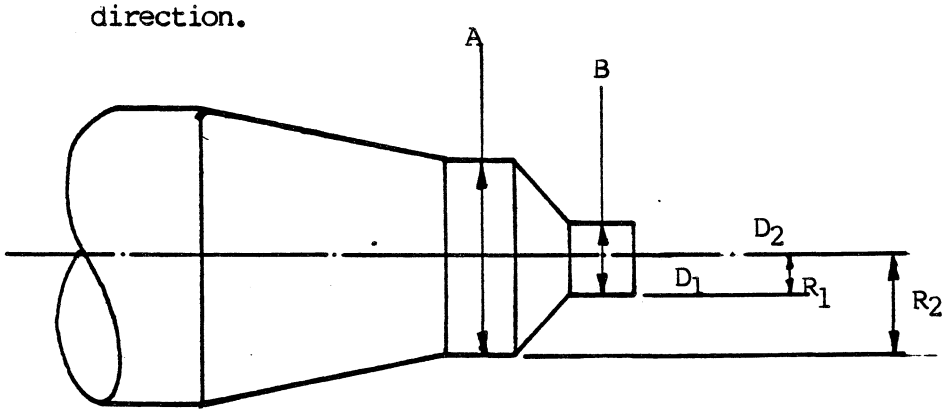


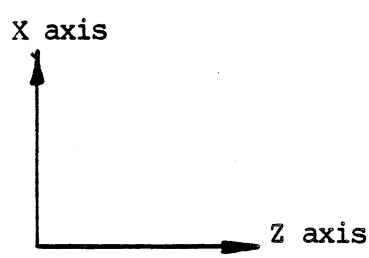


Incremental

3.3 DIAMETER AND RADIUS PROGRAMMING

Diameter programming is sometimes used in NC turning as the necessary dimension is obtained directly from the drawing. Radius programming is also used as in the ORAC control for all traverses in the X axis direction.





D_1, D_2 ..... Diameter programming

R_1, R_2 ..... Radius programming

PART 4

PROGRAMMING PRINCIPLES IN ORAC FORMAT

STUDENT READINESS

- Ensure that the student understands principles of setting workpieces in chuck or between centres. (This is more to ensure that work is properly supported - does not extend excessively from chuck without support etc.)
  Use of a simple setting gauge for repetition of chuck work can also be demonstrated/explained. (Control of Z axis extensiion.)
- Ensure students understand the use of the Multifix toolholder and setting of the main body and various tools.
- Ensure that students understand importance of job plan.
- Students have seen or have themselves programmed the Test Piece revised.

OBJECTIVES

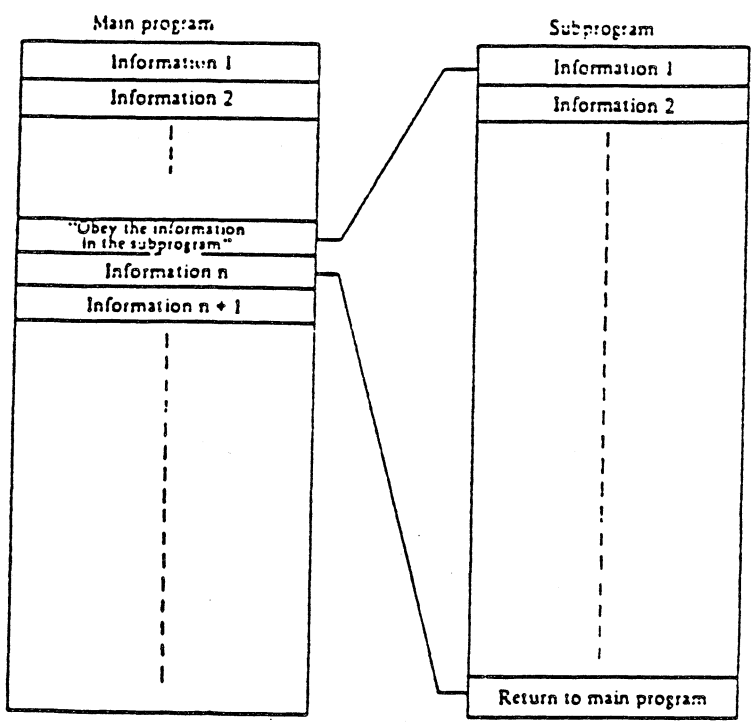
- In addition to knowing the conventional machining functions, student can interpret and apply to the programme keys of the ORAC function panel, e.g. PTP, CIRC, THRD. (Note: Check that INS and INC and END and END SUB are not confused.)
- Student is able to construct a main programme, either set or of own devising.
- Editing is taught or revised, depending on circumstance of student use of ORAC and Manual and the use of the cursor.

4.1 PROGRAMMING PRINCIPLES USING ORAC

The main emphasis in this part is on use of ORAC and the Manual to create programmes in ORAC format and for the student to follow through and understand the construction of those programmes.

The first exercises in the manual being concerned with the structure of the MAIN PROGRAMME it is not necessary to become involved in the construction of subprogrammes, but it should be made plain that the threading page is different from the others and is a CANNED CYCLE. We have chosen to discuss the formation of subprogrammes and canned cycles in Part 5 of this book, in which the relation of the ORAC format to the ISO 646 format used in European industry is introduced.

In the constructoion of a programme in ORAC format we begin, as is normal, with the parts of the main programme, and discuss how the MDI commands SUB and END SUB by means of which the main programme can be interrupted to introduce a subprogramme at a desired stage.



In production CNC machines, the memory capacity is such that a number of main programmes and subprogrammes can be entered into memory, by MDI or more commonly, when a repeated batch of components is in question, from magnetic or punched paper tape. This method is also commonly used when the programme in question is long and complex, since the entry time to memory is a great deal faster in that manner than by manual data input, when the programme is keyed in block by block.

ORAC is intended for teaching purposes. Only the main programme, maximum lenth 160 blocks, and its subprogrammes, also maximum length 160 blocks, necessary to produce one workpiece, are stored in memory at one time. These can, of course, be repeated without limit as batches if so desired.

4.2 MAIN PROGRAMME COMPONENTS

The main programme is composed of a number of commands.

One command is known as a block of data. Each block is separated from the next block (keying in of the double downward-pointing arrows). Each ORAC page is then a block. Each programme is given an identification number; in the ORAC FORMAT THIS IS DONE IN STORING THE PROGRAMME ONTO MAGNETIC TAPE. The end of the main programme is signified and recorded in memory with the END key.

4.3 SUBPROGRAMMES

The subprogramme is built up in exactly the same way as the main programme but terminates with the command END SUB, to indicate resumption of the main programme, and introduced with the CALL key. Remember to emphasise to students that these subprogrammes are constructed after completion of the main programmes (see diagram).

4.4 REVISION OF TEST PIECE 2

It is suggested that it is appropriate at some stage in this Part to revise one of the programmes in the ORAC Manual, step by step to ensure that all is understood.

Whether this revision is carried out as a classroom exercise or in practical activity in front of ORAC is at the discretion of the teacher and may to some extent depend on size of the student group, their grasp of

the principles in question and, of course, the time available.

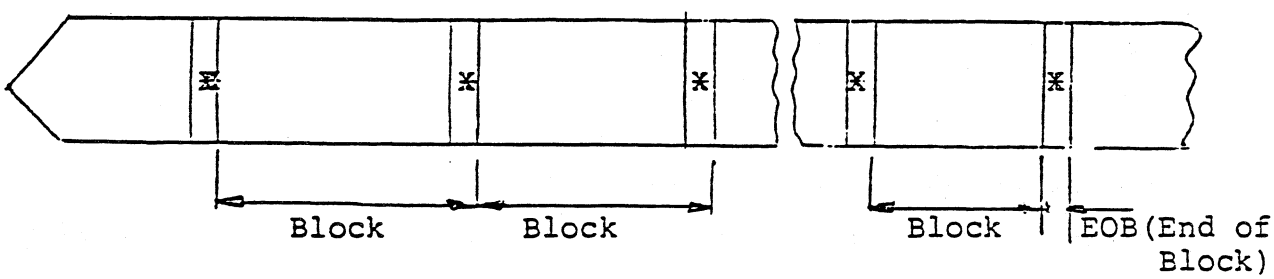
4.5 EDITING

By now students will have become familiar, to some extent, with editing procedures. Revision of the use of the cursor and keys S, D, P, P' is best performed in front of ORAC and as an exercise that each student performs personally.

It should be pointed out that editing is not only a means of correcting programming mistakes, but also a means of modifying existing components. The flexibility that NC gives to design changes, NC production of component families and group technology, and the savings this made in programming time can be discussed here to the appropriate level.

The programme for the workpiece must be prepared observing specified rules, in order that the control device can understand data and transmit it to the operating element of the machine tool. These rules are standardised, for example the United States Electronic Industries Association (EIA) in their Standard RS-244 and the International Standards Organisation (ISO) in their Standard 646.

The programme is composed of blocks, each block containing WORDS.



For example the ORAC Page 4 block is composed of:

- Function ..... PTP Point to point
- X co-ordinate ..... X or - X (towards spindle centre of revolution)
- Z co-ordinate ..... Z or - Z (towards chuck)
- Tool number ..... TOOL
- Speed ..... SPEED revolutions of spindle per min
- Feedrate ..... FEEDRATE ins/minute or mm/minute traverse rate
- End of block ..... Downward - pointing double arrow, PAGE shift.

In Part 5 the ORAC word format (WORD ADDRESS) is compared with that used in the ISO 646 standard.

PART 5

ISO CODES AND ADDRESSES

STUDENT READINESS

- The ORAC functions which comprise the main programme should be known and their application in making a programme.
- Ensure that the meaning of the block and its words is understood.
- Ensure that all students have sufficient theoretical teaching to readily understand circular interpolation (e.g. craft students may get this in the related workshop mathematics class).

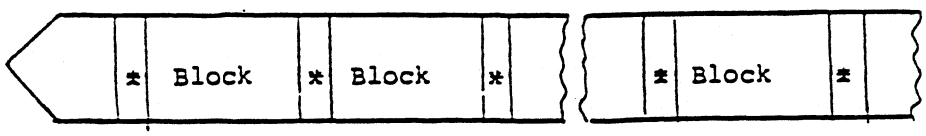
OBJECTIVES

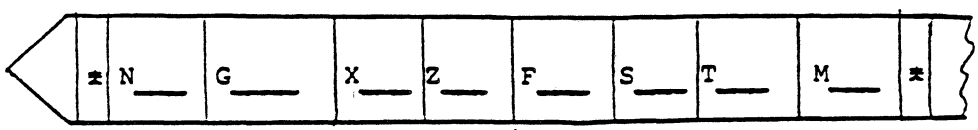
- Comparison of ORAC and ISO block.
- Teaching of the preparatory function, G code.
- Teaching of the miscellaneous (auxiliary) function, M code.
- Teaching of the ISO coding of Test Piece 1.
- Teaching of the subprogramme, firstly in ORAC mode, with the example in the ORAC Manual, then the ISO code comparison.
- Teaching of the concept of the canned cycle. Turning cycles.

5.1 ISO 646 CODES AND ADDRESSES

The programme is composed of blocks, separated from one another by an asterisk or the letters cr (Carriage Return of the punched paper teletype machine).

Each block contains words, as we have seen in Part 4. The length of blocks and words can be changed within the limits of the control. Generally blocks are only programmed with information which differs from that in the preceding block.





The words contained in the block may be built up as in the example shown here. A WORD ADDRESS system is used. Words are begun with the address letter, which specifies for which function the numerical information of the word is intended. The letters of the WORD ADDRESS system according to ISO 646 are shown in Table 1.

In the example here, which is also applicable to ORAC programming, the addresses are:

N = Block number (three digits, ORACS 160 blocks maximum)
G = Preparatory function, two digits
X = Operative X axis co-ordinate point (positive/negative)
Z = Operative Z axis co-ordinate point (positive/negative)
F = Feedrate, (ORAC maximum = 1200 mm/min)
S = Rotational speed function
T = Tool number.

The significance of the digit allocations is that, for example, n3 indicates the capacity to accept 999 blocks of information in memory, g2 means that G codes do not exceed G99, and that s4 indicates that 9999 spindle speeds can be numerical control specification and it is not necessary to expand the abridged explanation above at this stage.

TABLE 1 ADDRESS LETTERS ACCORDING TO ISO 646

A	Angular rotation about axis X
B	Angular rotation about axis Y
C	Angular rotation about axis Z
D	Angular rotation about some arbitrary axis, feed function or second tool function (If not used for one of these functions is freely available for special purposes)
E	Angular rotation about arbitrary axis or second tool function
F	Primary feed function
G	Preparatory function, operation function
H	Freely available for arbitrary use (Will never be used in this standard for any particular meaning)
I	Distance from circle centre point or thread pitch in the X axis direction
J	Distance from circle centre point or thread pitch in Y axis direction
K	Distance from circle centre point or thread pitch in Z axis direction
L	Freely available for use (as H) -
M	M function, that is Miscellaneous or auxiliary function
O	Freely available for use (as H)
P	Third axis in the X axis direction or tool diameter compensation parameter
Q	Third axis in the Y axis direction or tool diameter compensation parameter
R	Third axis in the Z axis direction or tool diameter compensatin parameter
S	Spindle rotation speed function
T	Tool function
U	Second axis in the X axis direction (If not used in this context, freely available for special purposes, as D above)
V	Second axis in the Y axis direction (Same note as D and U)
W	Second axis in the Z axis direction (Same note as D, U, V)
X	Primary X axis
Y	Primary Y axis
Z	Primary Z axis

FUNCTION	ISO ADDRESS	ORAC WORD	MEANING
Block number	N	PAGE	Block number address.
Preparatory function	G	G and PTP, CIRC etc.	Machine commanded to perform set operation.
Co-ordinate values	X, Z	X, Z	Move command in axial direction. Travel defined by value.
	R	RADIUS	Radius of blending arc.
	I, K	-	Circle point co-ordinates. Distance from centre line X, Z axes.
Feedrate	F	FEEDRATE	Feedrate of tool.
	K	PITCH	Screwcutting pitch.
Spindle function	S (revs/min)	SPINDLE SPEED	Momentary spindle
	(surface speed)	-	speed.
Tool command	T	TOOLNUMBER	Tool number.
	+ compens. no.	-	Tool compensation factor.
Miscellaneous function	M	END PROG M02	Control of machine tool functions.

The above comparison is drawn between the WORD ADDRESS format of ISO 646 and the Machinist Language format used with ORAC.

In Table 2 the Preparatory Functions of ISO 646 are listed and in Table 3 the Miscellaneous Functions.

A similar comparison will then be drawn up between the functions built into ORAC and the corresponding ISO functions.

5.2 THE PREPARATORY FUNCTION - G CODE

The code which represents the preparatory function follows immediately after the sequence number of the block, that is after the letter N and the number in question. preparatory functions are represented by a two-digit number prefixed by the letter G and therefore known as G Codes.

The purpose of the G function is to command the machine tool to carry out the function which is represented by the selected code number, for example, G00, move in the given axis at rapid traverse.

In the ISO and EIA standards a range of numbers is reserved for special purposes, for example, G00, G01, G02 and G03 are all moves; the machine tool manufacturer or the control manufacturer applies these code numbers to those functions which are appropriate to the machine tool (lathe, mill, boring machine, EDM machines etc.).

5.3 MOVE COMMANDS G00, G01, G02, G03

a) G00 Positioning of the axis slides or spindle at rapid traverse rate (ORAC 1200 mm/min, production lathe e.g. 10/12 m/min). Since no cutting is performed as little time as necessary is occupied in these moves.

b) G01 Linear interpolation. A move is made between two co-ordinate points at a selected traverse rate which is normally the selected feedrate. When programmed with a G01 command a lathe tool, for example, will be moved from its current co-ordinate position to the programmed position at the programmed feedrate and stops there to await the next command.

Linear interpolation can be made simultaneously in more than one axis and G01 functions are used in all linear machining moves such as internal/external turning, facing, chamfering, taper turning, parting off etc.

c) G02, G03 Circular arc interpolation, more commonly known as circular interpolation. The path followed by the tool is an arc or a series of circular arcs to provide the profile required.

In G02, G03 moves the tool follows a circular path from its current position (start of the arc) to the programmed end point, at the feedrate programmed. In using ORAC this is a minimum value of 40 mm/min to allow the interpolation to be accurate. To achieve the best finish it follows that a high rotational speed should be selected.

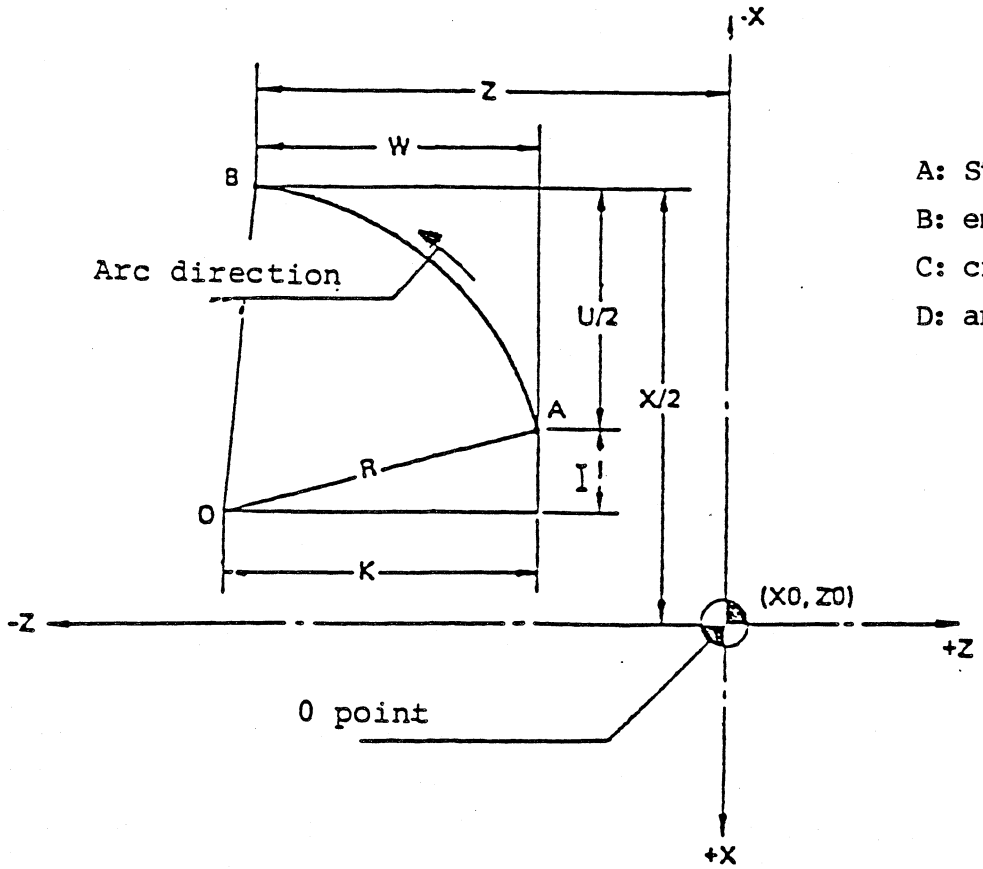
G02 interpolation follows a clockwise (CW) path.

G03 interpolation is in the counterclockwise (CCW) direction.

(All students with digital watches, please look at the clock....)

The procedure for circular interpolation with ORAC, as has been seen, is simple. We need only decide in which segment the arc is to be machined, is the movement clockwise or anticlockewise, adn delete the character not wanted, enter the radius of the arc and the co-ordinates of the end point.

The diagram on the next page illustrates the format for circular interpolation programming in ISO codes:



A: Start of arc
B: end of arc
C: circle centre
D: arc radius

X(U) Co-ordinates of arc endpoint
Z(W) (incremental values)
I The distance of the arc startpoint from circle centre in the X direction or the centre point X co-ordinate
K The distance of the arc startpoint from circle centre in the Z axis direction or the centre point Z co-ordinate
F Momentary feed in tangential direction.

5.4 OTHER PREPARATORY G FUNCTIONS IN ORAC

G04 DWELL

The programmable dwell G04 is freely selectable for programme construciton. It is intended for such purposes as holding the tool at a given position for a programmed length of time and NEVER for use as toolchange time or swarf clearance.

Operations where G04 may be used include burnishing time with a finishing profile tool at full depth, short interruption of cut for breakage of long coils of swarf, possibly in parting off operations, and so on.

Allocation of the time in seconds of application of the dwell, listed as

COUNT on ORAC can be given, for example, the free ISO address letter L which is in use in some NC systems in this meaning.

G33 THREADING

In ORAC the G33 THREADING page is a canned cycle in which all the parameters of single start screwcutting, internal or external, at constance pitch and diameter, can be programmed with one block. This operation has required that the rotation of the spindle and the feedrate is arranged by the sensor at the spindle drive. The carriage of the machine moves a defined distance for each pulse transmitted. The zero pulse of the sensor controls that each threading cut begins from exactly the same point.

G45 TOOL OFFSET

The tool offset, or compensation procedure, will have been met already in practice, using the ORAC MANUAL. Further discussion of the relevant G codes will be made later.

G73 REPEAT FACILITY

This code is listed as free is ISO code but is in the region associated with canned cycles, G72-G89.

In ORAC the DO LOOP, Repeat Facility is coded as G73 in associated software and with the DO LOOP certain canned cycles of turning can be built up.

OTHER G CODES IN ORAC (LATER MARK II MODELS)

G05	END OF SUBROUTINE
G06	END OF DO LOOP
G26	AUXILIARY INPUTS
G27	AUXILIARY OUTPUTS
G28	SUBROUTINE START
G50	PROGRAM DATUM
G65	CALL SUBROUTINE
G70	IMPERIAL UNITS
G71	METRIC UNITS
G73	START DO LOOP
G90	ABSOLUTE FORMAT
G91	INCREMENTAL FORMAT

TABLE 2 G FUNCTIONS ISO 646

G00	Positioning at rapid traverse
G01	Linear interpolation
G02	Circular interpolation, clockwise
G03	Circular interpolation, counterclockwise
G04	Programmable dwell
G05	Free [1]
G06	Parabolic interpolation
G07	Free [1]
G08	Automatic acceleration to a known speed
G09	Automatic deceleration to a known speed
G10-G16	Free [1]
G17	Selection of circular interpolation in the XY place, for compensation of rotating tool or the like
G18	As above, for ZX plane
G19	As above, for YZ plane
G20-G24	Free [1]
G25-G29	Continuously free [2]
G30-G32	Free [1]
G33	Thread turning constant pitch
G34	Thread turning increasing pitch
G35	Thread turning decreasing pitch
G36-G39	Continuously free [2]
G40	Cancellation of tool compensation
G41	Rotating tool compensation, right hand side
G42	Rotating tool compensation, on the left hand side
G43	Tool positive compensation move
G44	Tool negative compensation move
G45-G52	Free [1]
G53	Cancellation of zero point shift
G54-G60	Zero point shift codes
G60-G62	Free [1]
G63	Threading by tap
G64-G69	Free [1]
G70	Programming in inches
G71	Metric unit programming
G72-G73	Free [1]
G74	Move to start point
G75-G79	Free [1]
G80	Cancellation of canned cycle

G81-G89	Reserved for canned cycles
G90	Absolute programming mode
G91	Incremental programming mode
G92	Data input to memory in advance
G93	Feedrate value is translated proportional to time
G94	Feed in mm/min
G95	Feed in mm/spindle revolution
G96	Constant peripheral speed (Spindle rotation speed automatically regulated to keep peripheral surface speed constant)
G97	Spindle revolutions/min
G98-G99	Free [2])

1. Free codes. This means that codes are not, at least for the time being, reserved for some purpose, but are at the free disposal of the control device or machine tool, manufacture to use arbitrarily.

2. Continuously free codes will not be used in the future in the meaning of the standard for any prescribed function but are at the disposal of control manufacutre or machine tool builder to use arbitrarily.

5.5 MISCELLANEOUS FUNCTIONS, M CODES

The M function is the last item of data to appear in the block before the end of block (EOB).

Miscellaneous functions, also known as auxiliary functions, are those other than positioning controls, which have to be set to ensure correct operation of the machine tool. Such functions include start and stop of spindle, coolant pump, selection of coolant type, toolchange, component change with robot loading, clamping, and a number of functions connected with spindle speed and direction of rotation.

The first three M codes, M00, M01, M02 are related to the programme itself.

M CODES IN ORAC

M00 PROGRAM STOP

The progress of the programme is halted for the time being and spindle, feeds and coolant (if present) are switched off.

In ORAC this occurs, for example, at any stage to allow the operator to change the workpiece or the tools. The programme must be restarted by the operator using the START CYCLE button.

M01 SELECTIVE STOP

Provision is made to stop the programme running by depression of an Optional Stop button. This button must be depressed before the programmed entry is read as the system otherwise ignores the M01 code. In production machines this is useful for swarf clearance etc. The operator must restart the cycle manually. M01 cannot be written for ORAC as there is no optional stop button.

Certain software written for ORAC codes the stop after screwcutting, awaiting toolchange and continuation of programme as M01, but in ISO code this is a M00 programme stop.

M02 PROGRAM END

In ORAC the meaning is self explanatory. The programme in memory has come to its end. After the M02 command has been read the machine spindle and feeds stop and the programme in memory is readied for repeat of execution or for editing if so desired.

In Numerical Control machines in which the programme is run off tape rather than from memory the M02 functions stops spindle, coolant and feed functions after completion of programme commands and rewinds the tape to its beginning.

INTERPRETATION OF OTHER ORAC FUNCTIONS AS ISO M CODES

M03 ORAC Main spindle rotation is towards the operator, that is counterclockwise. It is therefore in ISO coding M03.

M06 TOOLCHANGE

Toolchanging in ORAC is of two kinds.

a) Manual using Multifix toolholders.
Signal for tool change requirement is a flashing cursor indicating which tool is in question. This may be interpreted as M06.

b) Toolchange using a programmable turret head.

OTHER AUX I - AUX O M CODES

Selection of other M codes for the AUX I - AUX O functions is entirely arbitrary and can, in principle, use any of the Free M codes e.g. M12-M18, or codes M06, M60.

NOTE: In writing programmes in ISO format for direct use with ORAC, it is essential that the ISO code be translated into such form that the ORAC control will recognise. It is not possible to programme ORAC direction of spindle rotation, for example. Furthermore, all software written for this purpose must be examined to ensure that this capacity to translate in the codes you have written is present.

In later model of ORAC the WORD ADDRESS codes visible on screen and the assistance of graphics at the screen has simplified this matter, software becoming more standardised with these later developments.

TABLE 3 MISCELLANEOUS FUNCTIONS ISO 646

M00	Program stop
M01	Intermediate stop
M02	Program end
M03	Spindle rotation clockwise
M04	Spindle rotation counterclockwise
M05	Spindle off: coolant off
M06	Toolchange
M07	Cooland N:o 1 on (e.g. Mist coolant)
M08	Cooland N:o 2 on (e.g. Flood coolant)
M09	Coolant off
M10	Clamping (e.g. table, slide, workpiece, fixture, spindle etc.)
M11	Clamping released
M12-M12	Free [1]
M19	Spindle stop in specified angular orientation
M20-M29	Continuous free [2]
M30	Program end. Stop and return to start character
M31	Clamping override
M32-M39	Free [1]
M40-M45	Change of gear ratio if this required. Otherwise free [1]
M46-M47	Free [1]
M48	Cancels M49
M49	Deletion of manually adjusted feedrate or rotation speed, i.e. return to programmed values
M50-M57	Free [1]
M58	Cancels M59
M59	Maintains the spindle speed constant even though a G96 initiated (const. surface speed)
M60	Workpiece change
M61-M89	Free [1]
M90-M99	Continuously free

1 and 2: These notes have the same meaning as for the preparatory functions, that is they are free for the use of control unit or machine tool manufacturer to select as he feels appropriate.

5.6 TEST PIECE 1. WORD ADDRESS FORMAT PROGRAMME SHEET

N	G	X	Z	I	K	F	S	T	M
N01	G71								
N02	G90								
N03	G50	X15	Z5						
N04	G00	X13	Z0.2			1000	800	1	(Spindle rot. M03)
N05	G91								
N06	G73			I3					
N07	G00	X-1	Z0						
N08	G01	X0	Z-30.2			90			
N09	G00	X0.5	Z0			1000			
N10	G00	X0	Z30.2						
N11	G06		Z0						
N12	G90								
N13	G00	X10.1	Z-29.9			1000			
N14	G01	X10	Z-30						
N15	G02	X12.5	Z-32.5	I2.5		50	900		
N16	G00	X15	Z0			1000			
N17	G01		Z5			50		0	M00 (toolchange ref. end programme)
N18	G00	X0	Z0					0	M02

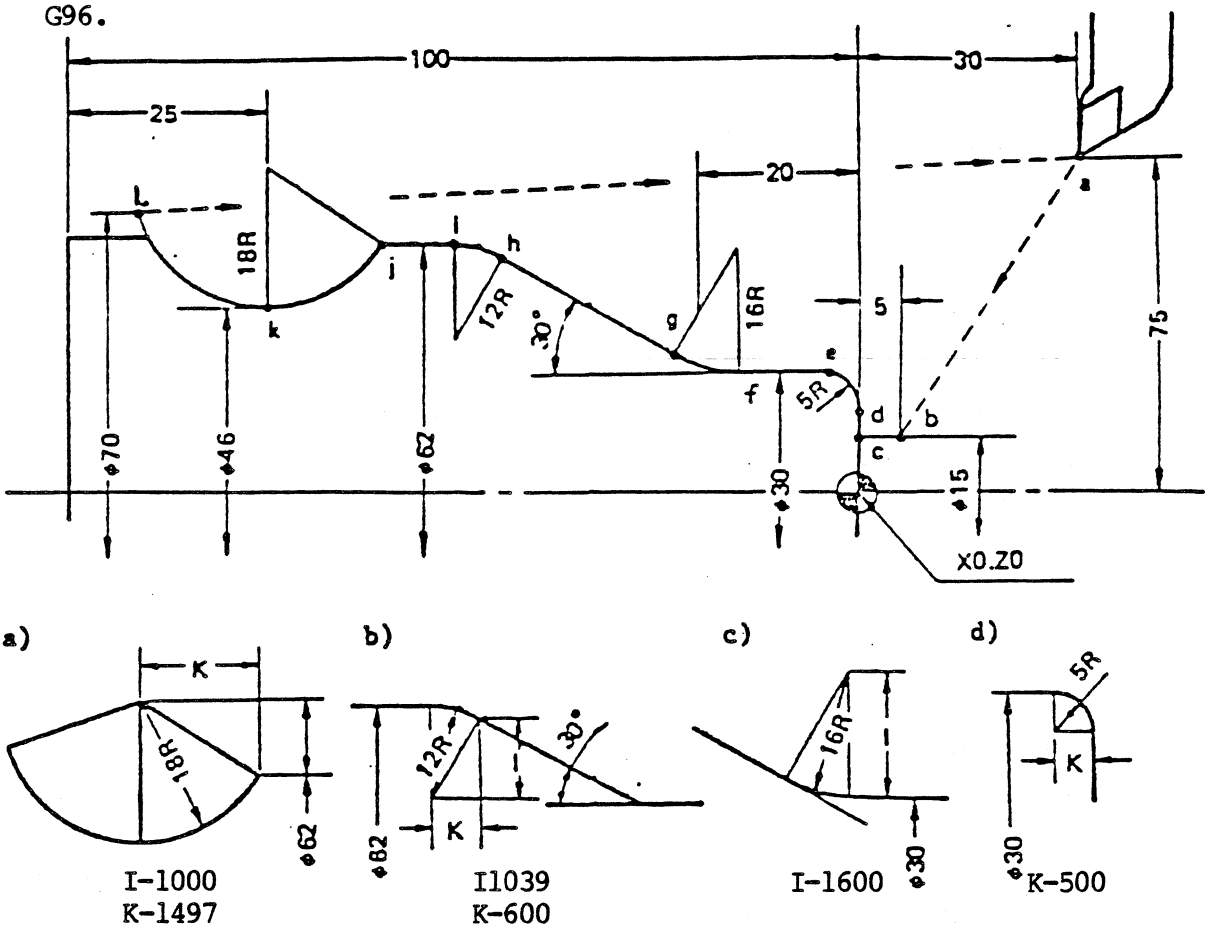
NOTE: In the above interpretation G50, G73, G06 are taken as free codes for the use of Denford Machine Tool on ORAC.

Note also in block 6 that the count 3 of the ORAC format, indicating three cuts each of 1 mm is replaced by the address I and number 3, indicating three cuts. Also note in block 15 that the radius value 2.5 mm used on the CIRC page is now described using the I notation, again an X axis distance of 2.5 mm.

In writing WORD ADDRESS programmes it is not necessary to repeat in the following block identical data, but I (and K) values are cancelled if not required in the next block by writing I0, K0.

Examples of use of I and K are given in the following extract from an industrial programme.

Below is an extract from an NC programme for a production lathe. Note that tool is now approaching from the rear, probably in a revolving turret head, and that workpiece rotation is now clockwise (m03) constant speed G96.



This extract is meant to illustrate the uses of I and K in linear and radial moves.

```
N001
N002 G50 X-15000 Z3000 S2000
N003 G00 T0303 M42          (Tool 3, offset 3, Turret index)
N004 G96 S150 M03
N005     X-1500 Z500 ..................................... a - b
N006 G01 Z0 F050 ......................................... b - c
N007     X-2000 F015 ..................................... c - d
N008 G02 X-3000 Z-500 I0 K-500 ........................... d - e
N009 G01 Z-1571 .......................................... e - f
N010 G03 X-3429 Z-2371 I-1600 K0 ......................... f - g
N011 G01 X-5878 Z-4493 ................................... g - h
N012 G02 X-6200 Z-5093 I1039 K-600 ....................... h - i
N013 G01 Z-6003 .......................................... i - j
N014 G03 X-4600 Z-7500 I-1000 K-1497 ..................... j - k
N015     X-7000 Z 9255 I-1800 K0 ......................... k - l
N016 G00 X-15000 Z3000 ................................... l - a
N017     T0300 ..................... (Tool offset cancelled)
```

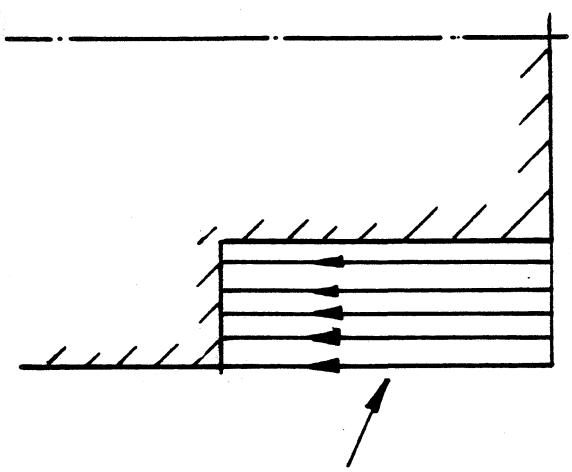
5.7 SUBROUTINES

A subroutine is a discrete part of a computer programme which carries out a particular function and which can be brought into operation at any time with information generated in another part of the programme.

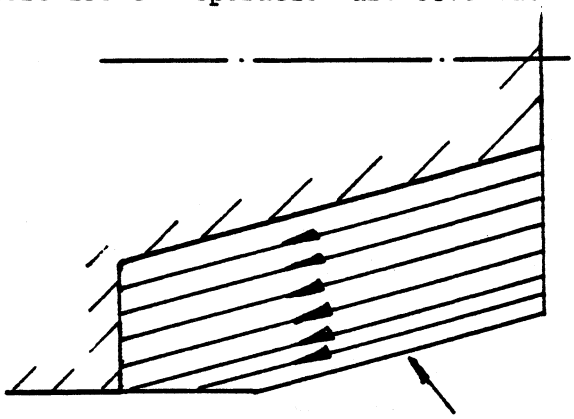
Thus in NC programming terms the programme means the main programme together with its subroutines.

Subroutines fall into two categories:

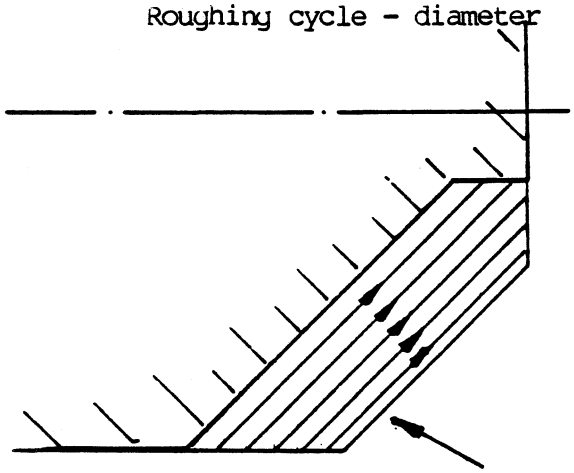
a) Fixed or canned cycles in which one complete operation, such as screwcutting, drilling or tapping, can be programmed by a single block in which all the required parameters for the operation are covered.



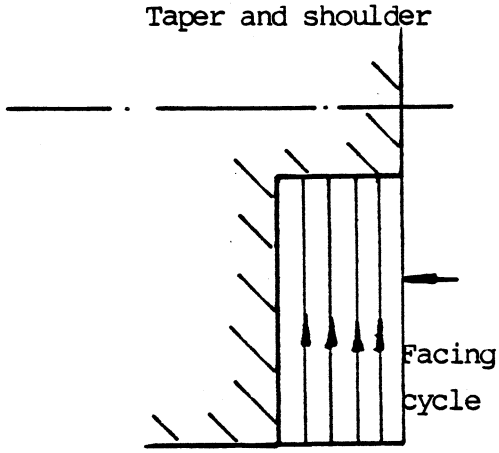
Roughing cycle - diameter



Roughing cycle - Taper and shoulder



Oblique shoulder to spigot



The ORAC THRD page, G33, is the only example of this so-called canned cycle in ORAC and it is part of the system software. Most systems nowadays sport a generous number of these canned cycles, which noticeably shorten MDI and NC programming in general.

b) User subroutines, known as macros. These are built up by the operator and stored in memory in accordance with the needs of the particular range of work to be dealt with. In principle there is no difference between the construction of the canned cycle and that of the user routine.

SUBPROGRAMME EXAMPLE FROM ORAC MANUAL IN WORD ADDRESS FORMAT

N	G	X	Z	F	S	T	M	
N01	G71							
N02	G90							
N03	G50	X20	Z15	1000	600	1		(PROG DATUM)
N04	G00	X16	Z-12					(Note total travel towards chuck 27 mm)
N05	G65							(CALL)
N06	G00		Z-32					
N07	G65							
N08	G00	X20	Z15					
N09							M02	
N11	G28							(Start SUB)
N12	G91							
N13	G01	X-6	Z0	40	600	1		
N14		X6		1000				
N15		X0	Z-8					
N16		X-6	Z0					
N17		X6						
N18	G90							
N19	G05							(END SUB)

NOTE: In this example call of subprogramme has been given G code 65, the subprogramme has been given code G28 and the cancellation, or end of the subprogramme, G05.

It should be noted also that the number of repeats of the subprogramme (in this case one run only), and the code or subprogramme number identification have not been given in this example. This is not a problem with ORAC since only one main programmme is run at a time and subprogrammes are identified by different identity numbers.

The above subprogramme consists of a tool inward feed on the X axis of 6 mm, return 6 mm, traverse of 8 mm in the Z axis towards the chuck, repeat of the infeed and the withdrawal, this terminating the subprogramme.

PART 6

TOOL SETTING, TOOL OFFSETS

STUDENT READINESS

- Ensure that students understand principle and operation of Multifix body and toolholder, the need to keep the body and toolholders scrupulously clean during use and the main frame locked in one position during each programme.
- Students will already have performed the tool offset routines as described in the ORAC Manual and the teacher will then have made observations to them concerning the need for the offsets, positive or negative, and the principles and practice of making and storing them for future use. The whole of the offsetting method should be revised and, time and syllabus permitting, the principle of tool diameter compensation, as in milling, discussed.
- Before embarking upon tool nose radius compensation, and depending upon the depth to which the topic will be dealt with, ensure that students have sufficient mathematical knowledge to understand the geometrical errors generated in certain profiles if this compensation is not made.

OBJECTIVES

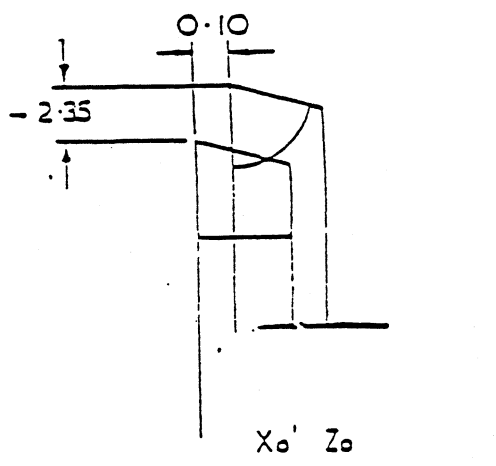
- To ensure that students understand the function of reference tool 0, the relation to it and to the Programme Start Point of subsequent tools used in any one programme.
- To teach basic principles of various toolsetting alternative on production NC machines (time and facilities permitting).
- To teach the principles of qualified tooling, precision indexable tips (e.g. Stellram) etc.
- Teaching of compensation for tool nose radius and ISO coding of tool compensation (depth of teaching dependent on needs of syllabus, student course and time available).

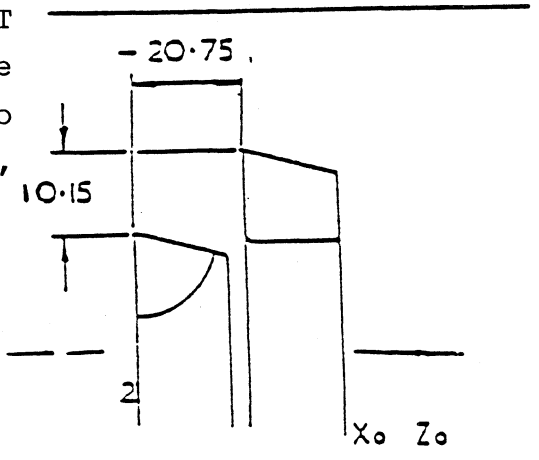
6.1 TOOL SETTING

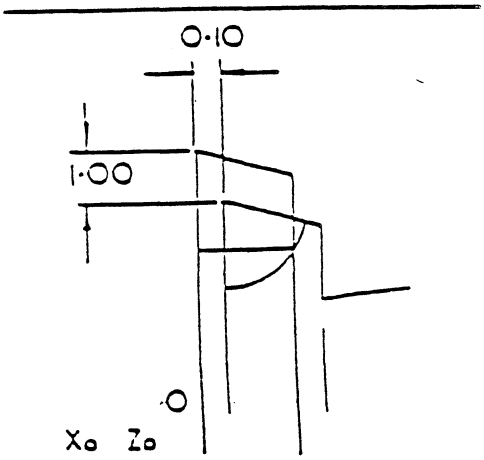
The objective in setting the tools in an NC machine is to position them in relation to the numerical Cartesian co-ordinates of the machine tool in such a manner that the co-ordinates of their cutting faces are in fixed and known locations.

This objective is achieved in some systems by clamping the tools, or the tools with their individual holders into place in the machine, they having been set beforehand in a tool-setting unit in order that their locations relative to the machine zero point are known.

In some machines, including ORAC, the tools may be arbitrarily clamped in position in unknown locations. In these circumstances, using manual controls, a location cut is taken on the end face of the workpiece, which then is taken as Z axis zero point. A second cut is then taken on the diamter, the workpiece measured and its diameter keyed into memory. This represents the distance of the X axis zero point. The procedure is repeated for the remaining tools by just touching the Z zero plane, and setting the X axis in the same manner, the offsets from the zero datum being automatically calculated and registered in memroy (see ORAC TOOL OFFSET EDIT FACILITY). Naturally these offsets can be edited to achieve required accuracy or to compensate for wear if this becomes excessive, by the editing procedure.








```
**  TOOL  OFFSET  EDIT  **
            X       Z
TOOL.0    000.00  000.00
TOOL.1   -002.35  000.10
TOOL.2    010.15 -020.75
TOOL.3    001.00  000.10
TOOL.4    000.00  000.00
TOOL.5    000.00  000.00
TOOL.6    000.00  000.00
TOOL.7    000.00  000.00
TOOL.8    000.00  000.00
TOOL.9    000.00  000.00

"F" TO QUIT
```

This procedure also defines the location of the Programme Start Point (PROG DAT) relative to the now-defined Zero Point. Tool 0 is kept as a reference tool to avoid the necessity to repeat the offset procedure should one of the tools break or become excessively worn.

In this kind of system it is not necessary to specify the tool setting dimensions at the programming stage.

6.2 SOME ALTERNATIVE TOOL SETTING METHODS

Several methods employed in industrial circumstances for tool setting are briefly mentioned in the following. The setting methods can be grouped according to the principle, at which stage the necessary measurements take place.

Measurement may take place in machining of the first workpiece, on the machine tool when mounting the tools, or during tool pre-setting operations. A further method of considering the offset/compensation method is on the basis of whether the tool position is to be measured or the workpeice. Compensations are performed when tools are located more precisely in the machine co-ordinate system.

SETTING WITH THE AID OF THE CONTROL UNIT

In ORAC use the measurement occurs in machining the first workpiece with reference to its reference surfaces. Another possibility is to use a simple receiver gauge of known dimensions on which the tool can be set, and a similar gauge can be used for the setting bar stock of known diameter in the Z axis for batch machining purposes.

SETTING BY MANUAL MEASUREMENT ON THE MACHINE TOOL

Tools can be set into position on the machine tool to known measurements or the setting lengths of fixed tools can be confirmed, using a depth micrometer, vernier or setting gauge for this purpose.

TOOL PRE-SETTING MACHINE

Tools are set up in their holders in an inspection room and/or using a specially designed machine for pre-setting the tool tip lengths in defined X and Z axis positions (or other axes for other types of machine). The

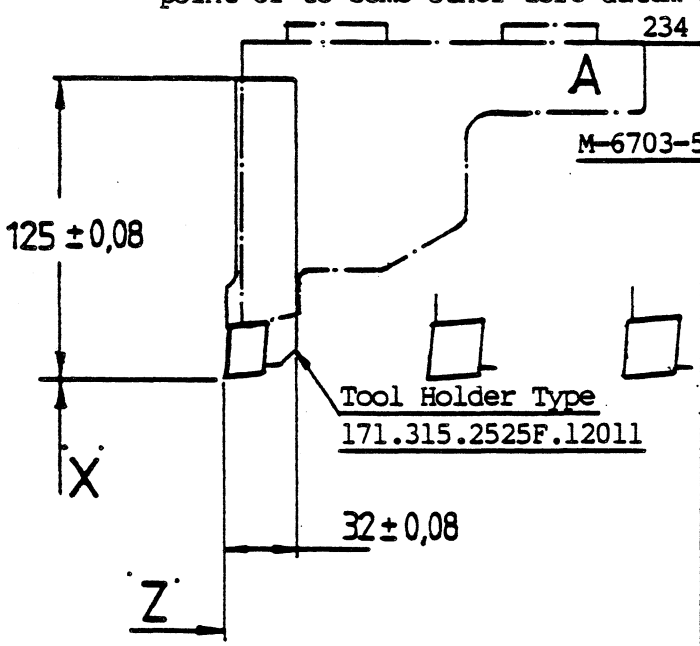
objective in using the pre-setting technique is to reduce the setting time on the numerical control machine to a minimum, since all time taken at the machine when it is not actually cutting is unprofitable. Cutting metal can then begin with the least possible editing of the tool position.

QUALIFIED TOOLS

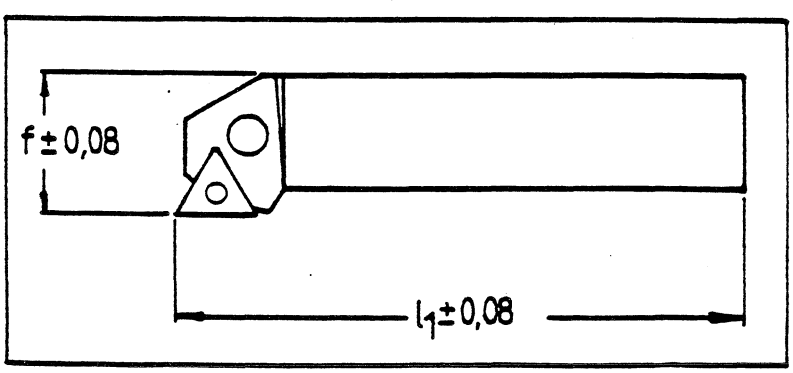
Tool setting in the numerical control machine tool can be made without any pre-setting procedures using tools which have been made accurately to dimensions such that the position of the tool tip comes to a precisely known location when mounted in the machine tool. This technique was introduced by the manufacturers of automatic lathes, Warner and Swasey, who gave this type of tooling the name 'qualified tooling'.

The technique involves the use of a shank or other tool holder, the length and cross-sectional dimensions of which, together with the seating into which hard-metal indexable inserts are clamped, are manufactured to precise standards. The inserts, which may be single or double sided, and commonly have three or four cutting edges per side, are made to the same standards of accuracy. The tool holder is then located against precision machined faces in the machine tool holder blocks for turret head external turning or for slide turret holders.

Thus the tool tip position relative to the machine tool's own reference point or to some other zero datum is defined.



INSERT RADIUS	X	TOOL POSITION		
		A	B	C
		Z		
0	95.92	4.92	84.92	164.92
0.4	95.95	4.96	84.96	164.96
0.3	96.00	5.00	85.00	165.00
1.2	96.04	5.04	85.04	165.04
1.6	96.08	5.08	85.08	165.08
2.4	96.16	5.16	85.16	105.16



6.3 TOOL RADIUS COMPENSATION AND TOOL OFFSETS IN ISO CODES

The meaning of the term tool radius compensation is an automatic NC function in which the generation of a geometrically incorrect contour or taper as the result of using a cutting tool with a nose radius is prevented. Such geometric errors arise in programming since it is then assumed for mathematical reasons that the tool has no such radius. (See Figure 6.3.1.)

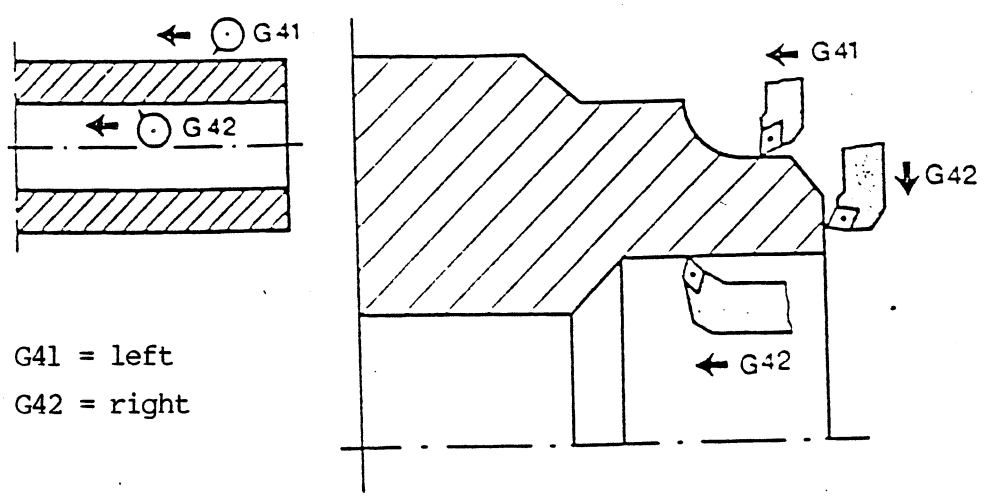
In machining an internal or external cylindrical surface and in facing operations when the tool path is linear no matter whether there is radius to the tool nose or not, there is no geometrical error.

However, in making chamfers and tapers and alos in circular arc movements, the points which are programmed for the path in question and the actual dimensions of the workpiece produced deviate from one another due to the radius at the tool nose. This radius is of standard value according to values published by the manufacturers, or is ground to a known value in the user factory.

Effects of uncompensated turning and illustration of the profile after compensation are shown at Figure 6.3.2.

TOOL COMPENSATION CODES, ISO 646

In a production NC lathe there are commonly 10 to 16 lathe tools mounted on one or two turrets or tool blocks. The ISO tool code T is given four digits. The first two digits indicate tools up to 99 in number and the last two are for the purpose of registering the current compensation correction, e.g. T0202.



The G codes given for tool compensation define, when feeding in a given direction, whether the workpiece surface being machined is to the left of the tool cutting point or to the right. (See figure on previous page.)

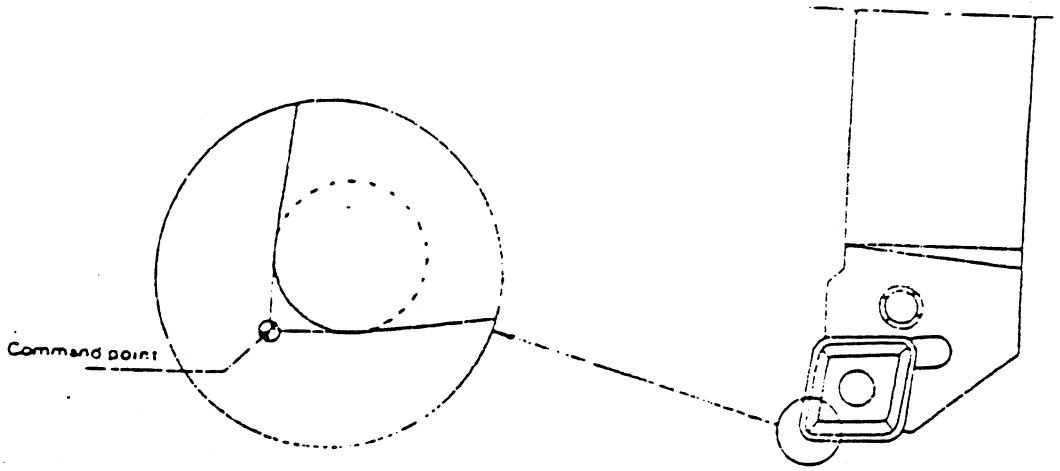


Figure 6.3.1
Lathe tool holder, indexable tip
and assumed toolpoint for programme.

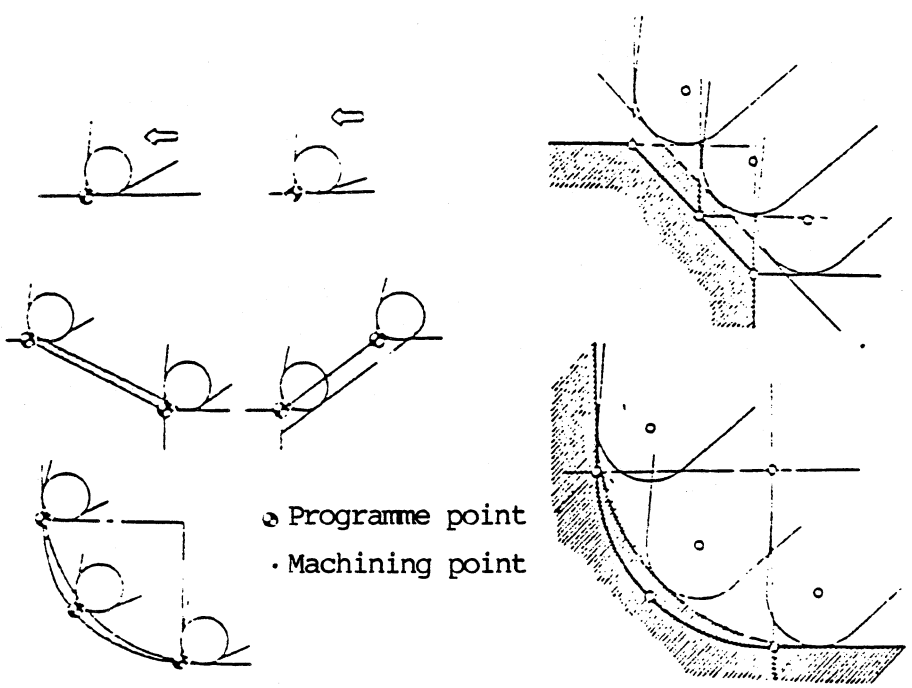


Figure 6.3.2
Form produced by nose radius when compensation for it has been made.

Typical prifile error produced when nose radius compensation has not been made.

PART 7

GENERAL REVIEW OF NC PROGRAMMING

STUDENT READINESS

- Understanding of job planning and preparation for machining.
- Understanding of programme construction with ORAC and in Word Address format and ability to perform all necessary calculations up to the level taught.
- Preparation of programme sheets for own sketches and drawings in ORAC and Word Address format.
- Understanding of Manual Data Input to ORAC of the programme, cassette techniques, tool offsetting procedure, editing of programmes in memory.

OBJECTIVES

- To give understanding of extent that the microcomputer can assist in programming and checking tasks; the influence of this in bringing more responsibility (and motivation) to the machinist in charge of the NC machine. (These topics can be extended according to time and facilities available and the needs of the syllabus.
- Brief reference to differences between large central computer aid to NC and the microcomputer levels of use.
- Teaching as required the idea of the computer language and the concept of binary data input for ON/OFF switching.
- Recognition of the essential differences between paper tape input and magnetic tape input to the NC machine.
- Ensure that students know and if possible can recognise what equipment is needed for paper tape input of NC data and know about the principal tape codes, EIA, ISO, BS etc., for this input.

NOTE: The intention of this book has been to provide ideas and assistance to the teacher and instructor of NC techniques, using ORAC as a principal teaching aid. We have not, therefore, taken discussions in areas outside that level beyond what may be considered as an introduction to essential topics to be covered and these are by no means exclusive.

As CNC techniques are the subject of very rapid technical progress it is suggested that further sources of information on CNC topics must include continuous reference to national and international Standards and the technical literature and manuals of manufacturers of CNC systems and of machine tools.

7.1 GENERAL REVIEW OF NC PROGRAMMING

Until this point we have discussed the features which make up manual programming, in which the calculation of geometrical data has been undertaken.

The programming can also be performed by computer as was largely the case in the earlier days of numerical control. The advent of the microprocessor and the microcomputer has nowadays brought NC programming out of the Programming office more onto the shopfloor, but there is still large reliance on computer-aided programming. When this is performed away from the machine tool, whether it be with mainframe computer facilities, or with some less powerful computing unit, one speaks of OFFLINE PROGRAMMING.

In using ORAC the central processing unit of the control performs all calculations within its capacity and in addition its RS 232 interface allows communication with an OFFLINE terminal where programmes can also be prepared and checked (debugged) and also translated into another format, with the aid of suitable software.

The advantage of using offline programming in industry is that input of the programme to the machine is very fast and the machine does not stand idle during input of a programme.

In the teaching situation offline programming allows more students to use the machine but at the same time those students who need to practice making and testing programmes in their future jobs do not benefit directly from offline programming. They do, however, benefit from the checks it provides on the programmes they have made.

To review the stages involved in constructing an NC programme the following are listed:

1. Machining plan
   - work stages
   - fixtures, machine accessories, clamping, mounting
   - tools, tool holders, measuring tools and gauges etc. for set-up
   - preliminary instructions and drawings.

2. Carrying out necessary calculations
   - co-ordinate points
   - machining calculations, relevant feeds and speeds, depths of cut etc.

3. NC programme construction
   - programme sheet
   - co-ordinates, preliminary and miscellaneous functions, addresses.

4. Input of data on the programme sheet to the control or to paper tape punch and teletype unit paper tape output, for transfer to machine memory on the shopfloor (data transfer medium may be magnetic tape).

5. Pre-setting of tools if applicable.

6. Running of the programme on the machine tool
   - performing setup
   - editing, compensations, etc.
   - 'dry run', test run, first off workpiece
   - inspection of workpiece, revision of programme values, e.g. feeds/ speeds.

7. Documentation
   - programme listing
   - setup lists (tools, fixtures, etc. for subsequent batches)
   - filing procedures, microfilm store etc.

7.2 MANUAL PROGRAMMING

In manual programming the programmer calculates the tool paths, that is the mutual locations of tools and the workpiece to be machined, defines the machining values of feed, speed and depth of cut, decides on the necessary commands required and draws these up in the form of a handwritten programme sheet, usually of standard type, in which the data has individual columns for function, co-ordiante etc.

After checking, this programme sheet will be taken for typing out on a teletype design of writer connected to a unit for producing the punched paper tape version of the data on the programme sheet. Separate instructions for the user of the machine are generally also prepared at this stage, since information lacking of deficiences in the programme

sheet will lead to lost time or scrap work.

In cases where paper tape input to the machine is not used the programme sheet may be drawn up by the user of the machine. Whoever fills out the programme sheet must approach the matter in an orderly manner and needs to have excellent knowledge of manufacturing techniques in general and machining in particular, tools and machining calculations.

Experience has shown that the machinist programmer is a satisfactory solution of small batch work, praticularly as some control units allow programming of the next workpiece whilst the current piece is being machined.

In general, it must be said that the best results on an expensive NC machine will be achieved if operated by a good, experienced machinist.

7.3 COMPUTER PROGRAMMING

In Computer Programming, also referred to as 'Computer-Aided Programming (CAP)', the greatest possible amount of routine matters are transferred to the computer to perform. The computer calculates from the data supplied to it the necessary points for the tool path, translates the programme into a language which the machine tool can understand and outputs a ready tape, programme listing and machining instructions. In addition the computer performs an inspection for basic programming faults.

7.4 EQUIPMENT REQUIRED FOR CAP

The calculations required for the programme are carried out on a COMPUTER. The computer may be a large and powerful unit, perhaps belonging to a large company and used for other tasks as well as NC programming. It is sufficient for NC programming purposes if there is available one of the NC language processors and suitable translators (postprocessors) for the NC machines in the organisation. In using such a computer the run can be performed in one of three methods:

- REALTIME. The data is input and the results are output immediately after the calculations have been completed.
- TIME-SHARING. The user only has a short time available, reserved for the handling of his programme. The input of the data directed through various terminals is so shart that the user does not in practice notice any difference.

- BATCH-PROCESSING. One user task is executed completely to the end, before transfer is made to another task. The computer calculates the batches one at a time.

If the computer is one of the microcomputer types which are within the reach of quite small companies and organisations, it will probably have a central memory store of 64 to 198 kilobytes and the word length 12 to 16 bits.

In addition, common peripheral equipment required will be a printer, which may be part of the computer package, a paper tape punch unit, a paper tape reader unit, a plotter of about A3 size and an externally connected memory unit, such as magnetic tape, diskette or disk, or cassette. A plotter is not necessary if the computer is furnished with own graphics display or Hard Copy can be taken from the graphics for reference.

The computer processes the programme using a relevant programme language processor. The programme in question is generally based on a computer language (e.g. FORTRAN, BASIC, ALGOL) and translates the machining programme, performs any necessary mirror-functions, repeats and pattern transformations and calculates the co-ordinates of the tool centre point along the tool path. This tool path data, plus the still unprocesses technological instructions (speeds, auxiliary functions etc.), are deposited in a file known as the CLDATA file. (CUTTER LOCATION DATA.)

In some systems (for example EXAPT, GTL, CONTURN) there is an additional technological processor which, with the aid of methods, materials and tooling files deposited in memory also prepares the programmer technological decisions, that is to say selects suitable tools, order of machining, speed and feed selections, chip thicknesses and calculates toolpaths.

The contents of the CLDATA file are handled by a postprocessor written for the machine tool to be programmed. The postprocessor is a computer programme which formulates from the CLDATA file co-ordinate information the co-ordinates required for the machine tool and supplements them with the necessary N, G and M codes so that blocks are made up which the machine in question can understand. The postprocessor usually also calculates the machining cycle time and checks that the capacities of the machine are not exceeded.

7.5 INPUT OF THE NC PROGRAMME BY PAPER TAPE

In using ORAC, the ORAC Manual and this book, we have seen how NC programmes are constructed and how they are input into ORAC memory by Manual Data Input (MDI) and by magnetic tape from cassette.

In the early days of NC in the beginning of the 1950's however, the only means of operating machines was to run them from paper tape input and there was not the flexibility of editing programmes that the CNC units of today afford.

Paper tape input is still in wide use today for the longer and complicated programme and, of course, with the older NC type of machine which is still operating and doing good work.

The use of punched tape is based on the use of alpha numeric data being changed into binary form. Students are all familiar with the decimal system with its base of 10 and in which the value of a whole number is built up from multiples of units, tens, hundred, thousands and so on.

Using the decimal system the number 1984 is composed of four units, eight tens, nine hundreds and one thousand. In terms of their powers the four groups making up the number 1984 are:

$$10^3 + 10^2 + 10^1 + 10^0$$
$$1 \quad 9 \quad 8 \quad 4$$

Using as the base the number 2

$$2^0 = 1$$
$$2^1 = 2$$
$$2^2 = 4$$
$$2^3 = 8 \text{ etc.}$$

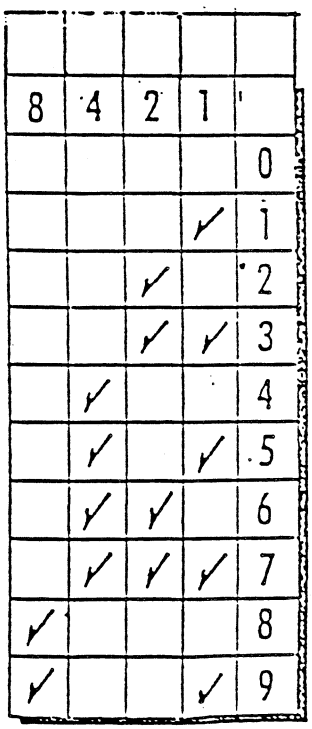
Why then are powers of 2 used to represent numbers in control systems? In very many applications of control engineering, all that is required is to swtich some function ON or OFF. Using the binary system a circuit can be made for a control situation which is a binary condition. a valve or switch or relay is either ON or OFF. As we have a numbering system which only uses two characters, which we can make to be 0 and 1 and which furthermore can be related to the positions of an ON/OFF switch, the binary application is clearly advantageous to use. Since the highest value of a decimal digit is 9 it is not necessary to extend the construction of binary numbers beyond 1 to 9.

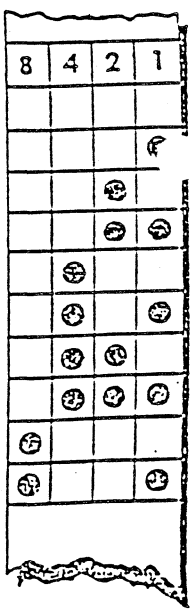
In the tables below it can be seen how the numbers 1 to 9 are made up in the binary scale.

In the application of the binary scale to numerical control systems the first step is to arrange that in a tape passing across sensing elements there are holes punched across the face of the tape. If we start by assuming that there are four such hole-making punch units, each representing one of the binary powers 2^0, 2^1, 2^2 and 2^3 and that the sensing elements across which the tape is passed are able to recognise the presence or otherwise of a hole passing over or between then we have the essential components of a continuous control system. The sensing element, for example a photosensitive cell coupled to a light source, is energised by the spot of light passing through the hole in the intervening tape or remains in its passive OFF state if there is a <u>space</u> (NO hole) in the tape.

The above illustration is, of course, oversimplified. Punched tape has been in use for very many years in the telecommunications industries and the idea of using two symbols in combination will be familiar to students from the dot-dash communication mode of the Morse Code.

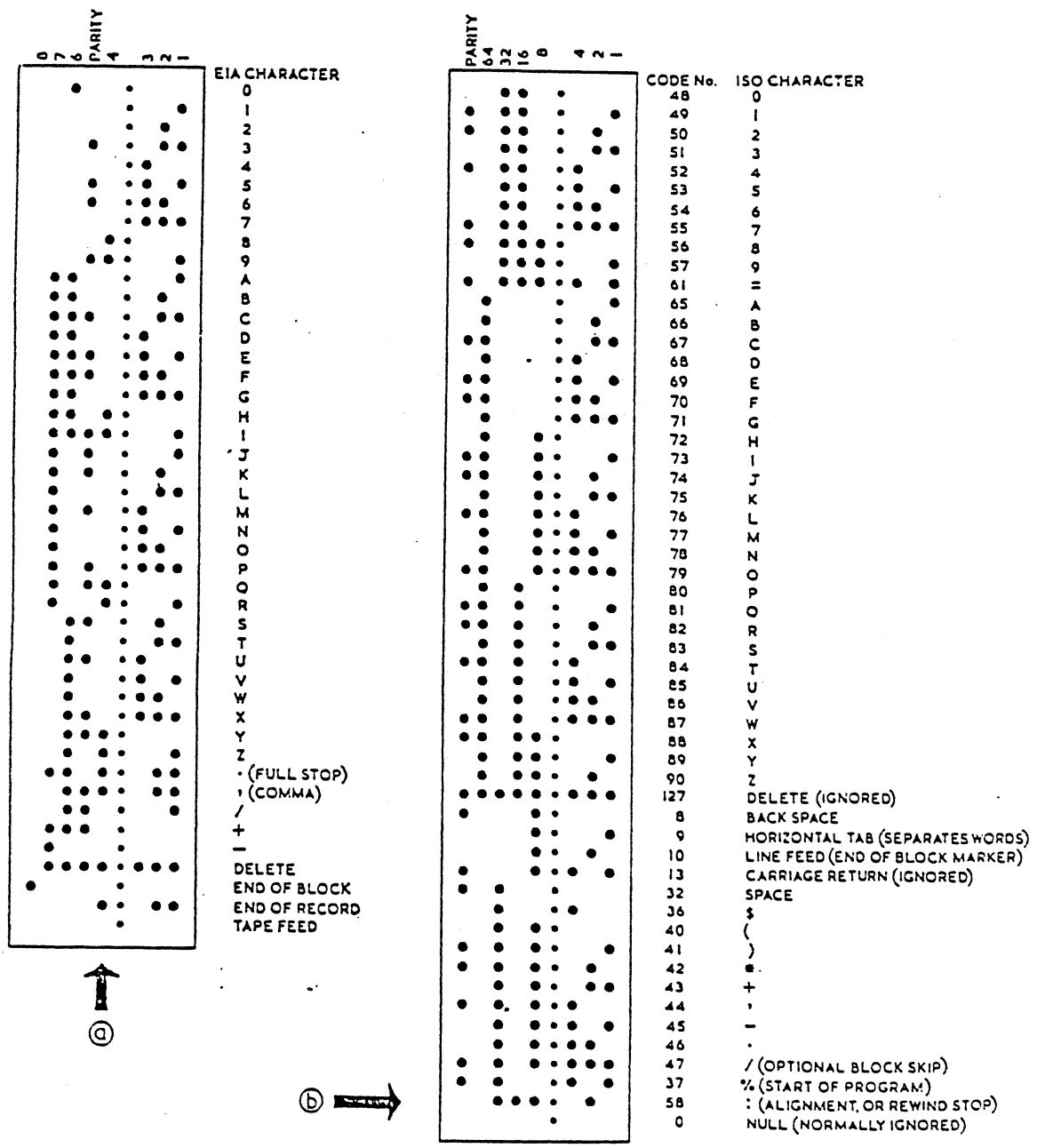
2^3	2^2	2^1	2^0	
			1	$2^0=1$
		1	0	$2^1+0=2$
		1	1	$2^1+2^0=3$
	1	0	0	$2^2+0+0=4$
	1	0	1	$2^2+0+1=5$
	1	1	0	$2^2+2^1+0=6$
	1	1	1	$2^2+2^1+1=7$
1	0	0	0	$2^3+0+0+0=8$
1	0	0	1	$2^3+0+0+1=9$





In NC applications the information which must be conveyed by the holes in the tape is dimensional, letters making up the WORD ADDRESS format e.g. X, Y, Z, prefixes G, N, F, S etc., and numbers relating to the programme component blocks. These are put together into codes which are recognisable to the machine an its control system. Each character (digit or letter) is represented by a combination of holes or spaces in one row across the tape. Thus each row of holes across the tape can be read and identified.

Two of the commonest codes are illustrated below, the ISO (International Standards Organisation) Code and the EIA (Electronic Industries Association) Code of the USA. British Standard 3635, Codes for Punched Tape for Numerically Controlled Machine Tools is based on the ISO recommendations.



Codes for 8-hole, 1-in. wide punched paper tape, showing (a) the standard EIA code and (b) the ISO code In the ISO code, the functions specific to numerical control are given in brackets

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 algerbraic 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 rotation 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 value 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 communcates 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 macine 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 that 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 (CADCAM) - 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 micro 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.

REPRODUCTIBILITY - 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 word-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.)

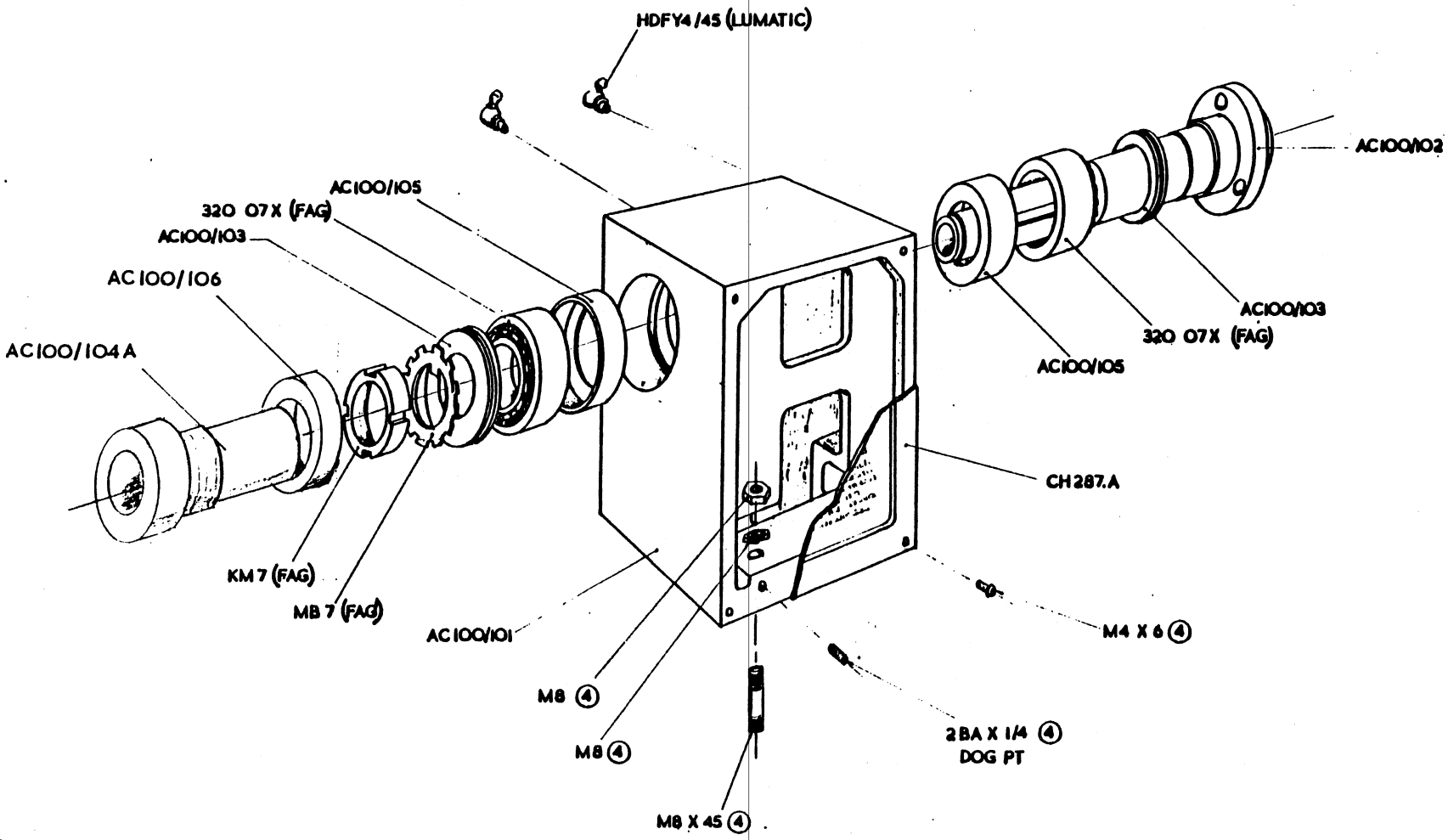
ZERO SHIFT - A characteristic of a numerical machine tool control permitting the zero point on an axis to be shifted readily over a specified range. (The control does **not** retain information on the location of the 'permanent' zero.)

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.

PARTS ILLUSTRATIONS

IF IN DOUBT ASK.



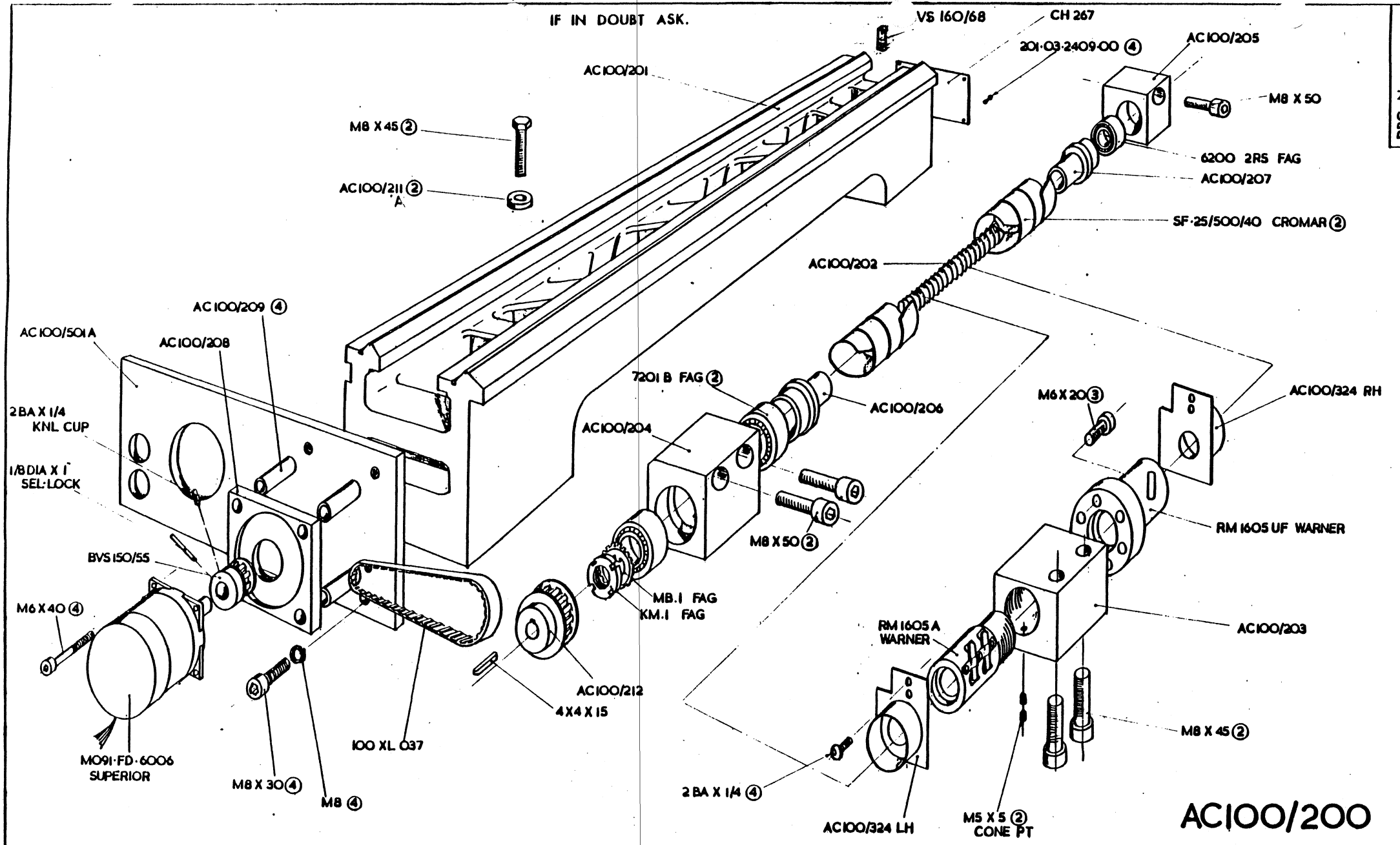
AC100/100

No.	DESCRIPTION	CHKD.	APPD.	DATE	DENFORD MACHINE TOOLS LTD. BRIGHOUSE, YORKSHIRE.	LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED.	MATL.	DRAWN	TRACED	CHECKED	APPROVED	DATE	SCALE
	ALTERATIONS					ANGULAR ± 1° 3 PLACE DECIMAL ± .005"	MATL. SIZE	N				14/2/64	
						FRACTIONAL ± .010" 4 PLACE DECIMAL ± .0005"	No. REQD.	DRAWING No.					
							MACHINE AT 'W'						
							GRIND AT 'G'						

'ORAC'	HEADSTOCK & SPINDLE	No. OFF
AC. 100/101	HEADSTOCK	1
102	MAIN SPINDLE	1
103	GREASE RETAINING PLATE	2
104A	SPINDLE END TUBE	1
105	GREASE CAP	2
106	SPINDLE END TUBE NUT	1
107	CHUCK GUARD SPIGOT	1
108A	CHUCK GUARD	1
CH. 287. A.	HEADSTOCK NAMEPLATE	1

DESCRIPTION	MANUFACTURER	REF.	No. OFF
TAPER ROLLER BEARINGS	FAG	320 07X	2
LOCKNUT	FAG	KM 7	1
TAB	FAG	MB. 7	1
GREASE NIPPLES	LUMATIC	HDFY4/45	2
BUTTON HEADS		M4x6	4
HEX NUT		M8	4
WASHER		M8	4
GRUB SCREW		2BA x $\frac{1}{4}$ Dog PT	4
SPRING WASHER		M8	4

IF IN DOUBT ASK.



AC100/200

DRG. No.

DESCRIPTION	CHKD	APP'D	DATE
ALTERATIONS			

DENFORD MACHINE TOOLS LTD. BRIGHOUSE, YORKSHIRE.

LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED.
ANGULAR ± 1° 2 PLACE DECIMAL ± ·005"
FRACTIONAL ± ·010" 4 PLACE DECIMAL ± ·0005"

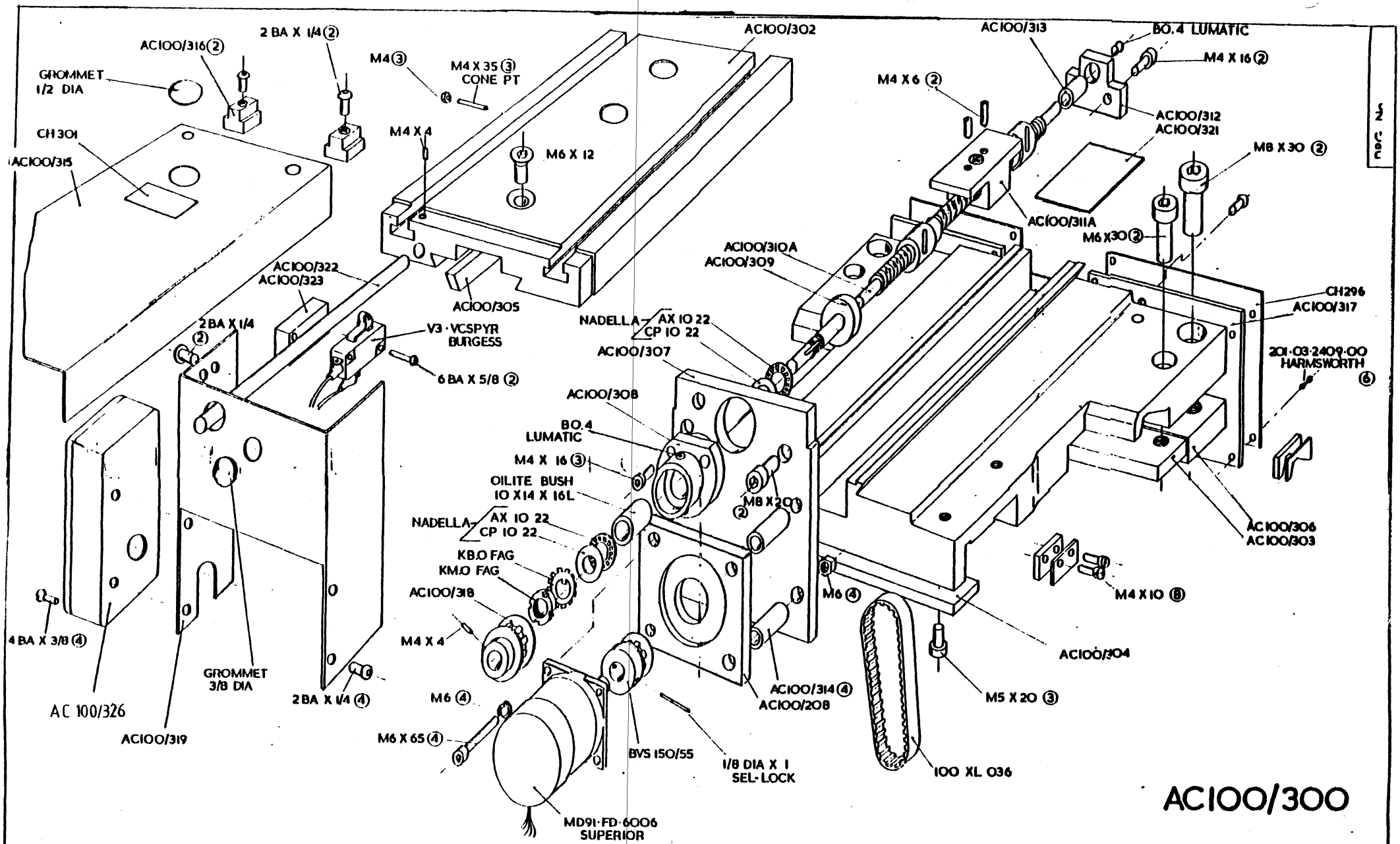
MATL.
MATL. SIZE
No. REQD.
MACHINE AT 'W'
GRIND AT 'G'

DRAWN	TRACED	CHECKED	APPROVED	DATE	SCALE

DRAWING No.

'ORAC'	BED & SADDLE DRIVE	No. OFF
AC. 100/201	BED	1
202	SADDLE BALLSCREW	1
203	BALLNUT HOUSING	1
204	BEARING HOUSING	1
205	END SUPPORT BLOCK	1
206	CENTERING FLANGE	1
207	CENTERING FLANGE	1
208	MOTOR PLATE	1
209	MOTOR PLATE SPACER	4
210		
211A	BED WASHER	2
212	30T PULLEY	
213	ADJUSTABLE SADDLE STOP	1
214	SADDLE STOP PLUNGER	1
215	SADDLE STOP CLAMP PLATE	1
216	PLUNGER HEAD	1
CH. 267	SPECIFICATION PLATE	1
BVS150/55	12T PULLEY	1
BVS160/68	BED END STOP	1

DESCRIPTION	MANUFACTURER	REF.	No. OFF
STEPPING MOTOR	ELECTRONIC DYNAMICS LTD	MHY 200 3424 310 A8	1
BALL NUT	WARNER	RM 1605 A	1
BALL NUT "	WARNER	RM 1605 UF	1
BEARING	FAG	7201 B	2
BEARING	FAG	6200 2RS	1
LOCKNUT	FAG	KM 1	1
TABWASHER	FAG	MB 1	1
TIMING BELT UNIROYAL	UNIROYAL	100 XL 037	1
SPRING COVERS	CROMAR	SF 25/500/40	2
SKT CAP HEAD		M8 x 50	5
" " "		M8 x 30	2
" " "		M8 x 10	1
" " "		M6 x 40	4
" " "		M6 x 20	3
SET SCREW		M8 x 45	2
GRUB SCREW		M5 x 5 CONE POINT	2
WASHER		M8	2
KEY		3 x 3 x 15	1
RIVETS (BLACK)	HARMSWORTH	201-03-2409-80	4



AC100/300

No.	DESCRIPTION	DRWN	APPD	DATE
	AFTER 3068 16/2/83			

ALTERATIONS

DENFORD MACHINE TOOLS LTD. BRIGHOUSE, YORKSHIRE.

LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED.
ANGULAR ± 1° 3 PLACE DECIMAL ± .005
FRACTIONAL ± .010" 4 PLACE DECIMAL ± .0005"

MAT'L
MAT'L SIZE
No REQD
MACHINE AT 90
GRIND AT 'G'

DRAWN	TRACED	CHECKED	APPROVED	DATE	SCALE
W				23/2/82	

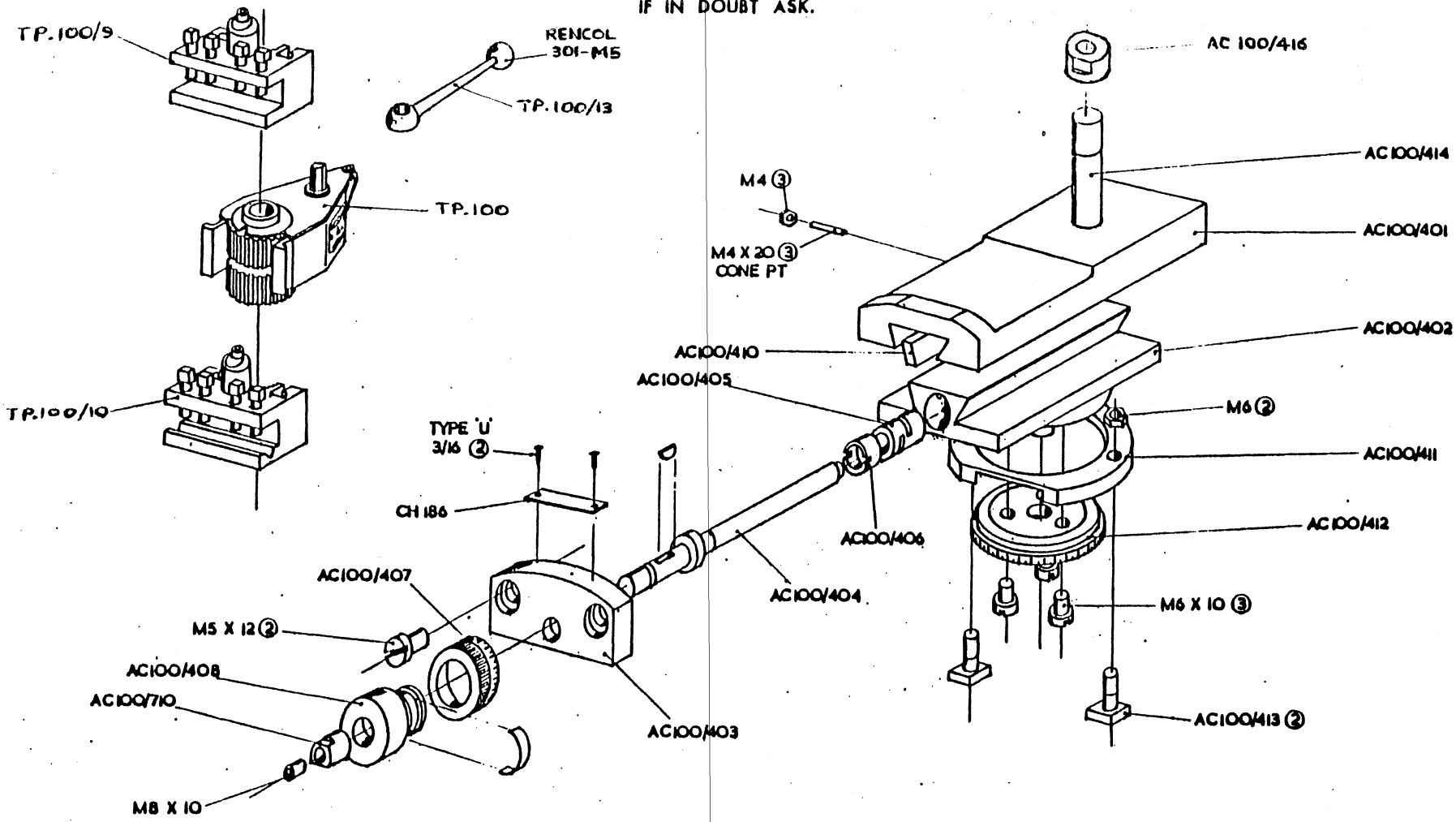
DRAWING No.

'ORAC'	SADDLE & CROSS SLIDE DRIVE	No. OFF
AC. 100/301	SADDLE	1
302	CROSS SLIDE	1
303	SADDLE FRONT GIB STRIP	1
304	SADDLE REAR GIB STRIP	1
305	CROSS SLIDE GIB STRIP	1
306	ADJUSTING STRIP	1
307	REAR DRIVE BRACKET	1
308	BEARING HOUSING	1
309	SPINDLE ADAPTOR	1
310A	CROSS SLIDE BALLSCREW	1
311A	BALLSCREW HOUSING	1
312	FRONT SUPPORT PLATE	1
313	BUSH	1
314	MOTOR PLATE SPACER	4
315	CROSS SLIDE COVER	1
316	TEE NUT	2
317	APRON PLATE	1
318	15T PULLEY	1
319	DRIVE GUARD	1
320		
321	SADDLE FILL IN PLATE	1
322	TRIP ROD	1
323	MICRO SWITCH SPACER	1
324	APRON END CAPS (LH & RH)	1 SET
325	MICRO-SWITCH BEZEL	1
326	JUNCTION BOX	1
208	MOTOR PLATE	1
CH. 296	APRON COVER PLATE	1
CH. 301	LUBRICATION PLATE	1

DESCRIPTION	MANUFACTURER	REF.	No. OFF
STEPPING MOTOR	CETRONIC DYNAMICS LTD	MHY 200 3424 310A8	1
TIMING BELT	UNIROYAL	100 XL 037	1
THRUST BEARING	NADELLA	AX 10 22	2
THRUST PLATE	NADELLA	CP 10 22	2
OILITE BUSH	MANGANESE BRONZE	10 x 10 x 16L	1
LOCKNUT	FAG	KM. 0	1
TAB WASHER	FAG	MB. 0	1
OILER	UNIMATIC	B 0 4	2
MICRO SWITCH	BURGESS	V3 SERIES VCSPYR	1
TERMINAL BOX	RADIO SPARES (AC. 100/326)	509-939	1
GRUMET	PRESTIGE	½ DIA	1
SKT CAP HEAD		M6 x 65	4
" " "		M6 x 30	2
" " "		M5 x 20	3
" " "		M4 x 16	2
" " "		M4 x 10	5
SKT C/SUNK		M4 x 12	1
" "		M4 x 6	4

DESCRIPTION	MANUFACTURER	REF.	No. OFF
SKT CAP HEAD		M8 x 20	2
BUTTON HEAD		$2B^A$ x $\frac{1}{4}$	12
GRUB SCREW		M4 x 35 CONE POINT	3
" "		M4 x 4 DOG POINT	4
HEX NUT		M4	3
" "		M6	4
RIVETS	HARMSWORTH	201-03-2409-00	6
SPRING WASHER		M6	4
MICRO-SWITCH	BURGESS	V3 SERIES OVCF9D	1

IF IN DOUBT ASK.

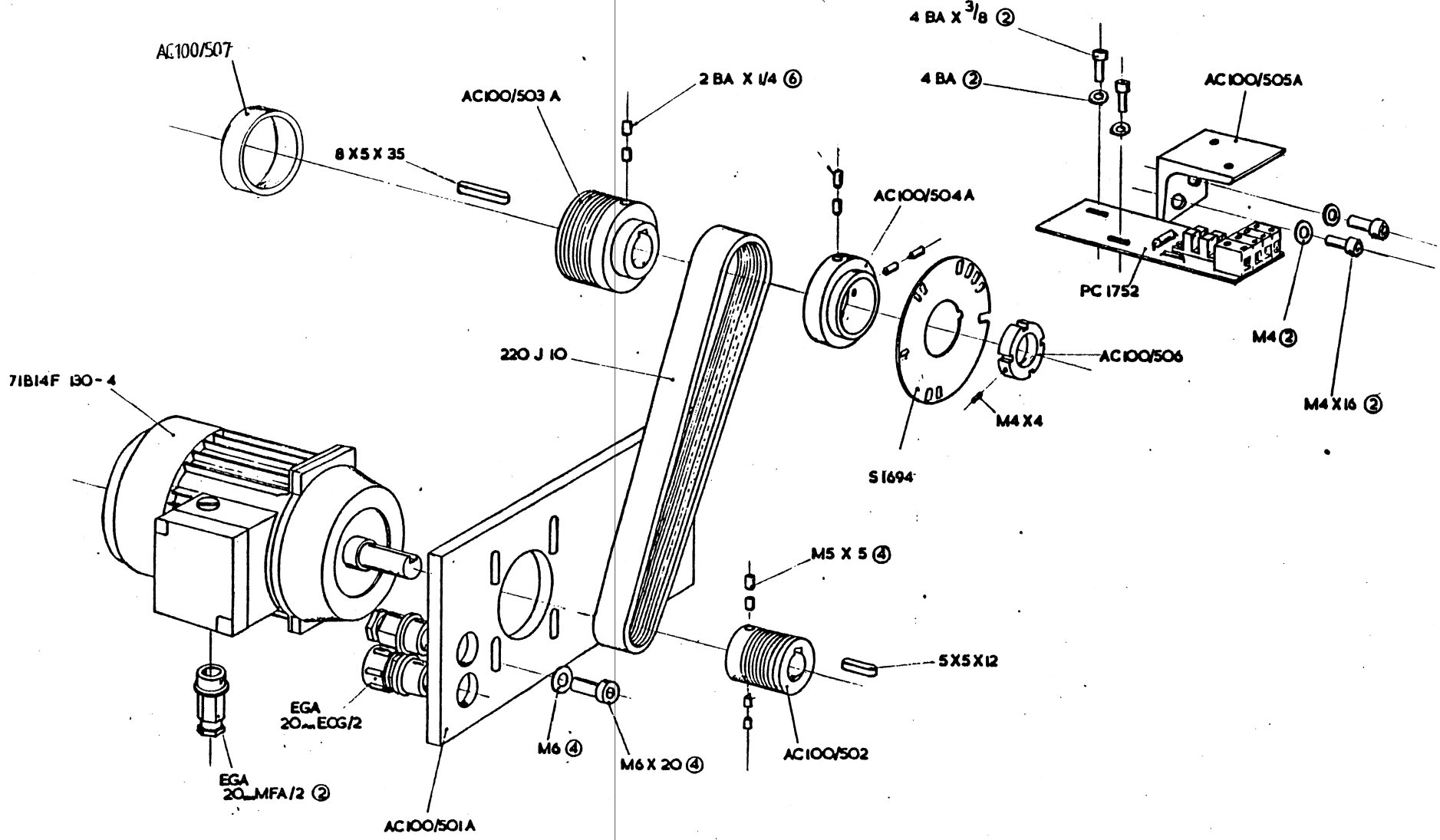


AC100/400

					DENFORD MACHINE TOOLS LTD. BRIGHOUSE, YORKSHIRE.	LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED.	MATL.	DRAWN	TRACED	CHECKED	APPROVED	DATE
No.	DESCRIPTION	CHKD	APPD	DATE	'ORAC' - TOP SLIDE SWIVEL & TOOLPOST	ANGULAR ± ½° 2 PLACE DECIMAL ± .005"	MATL. SIZE					
	ALTERATIONS					FRACTIONAL ± .010" 4 PLACE DECIMAL ± .0005"	No. REQD.	DRAWING No.				
							MACHINE AT 'W'					
							GRIND AT 'G'					

'ORAC'	TOP SLIDE, SWIVEL & TOOLPOST	No. OFF
AC. 100/401	TOP SLIDE	1
402	SWIVEL SLIDE	1
403	TOP SLIDE END PLATE	1
404	TOP SLIDE SCREW	1
405	FEED NUT	1
406	FEED NUT RETAINING SCREW	1
407	FEED DIAL	1
408	TOP SLIDE HANDWHEEL	1
409		
410	GIB STRIP	1
411	CLAMPING COLLAR	1
412	GRADUATION PLATE	1
413	TEE BOLT	2
414	TOOLPOST STUD	1
415	NO. 2 MT SOCKET ADAPTOR	1
416	TOOLPOST CLAMP NUT	1
710	ADJUSTMENT SLEEVE	

DESCRIPTION	MANUFACTURER	REF.	No. OFF
TOOLPOST	HAHN & KOLB	TYPE 'AA'	1
TOOLHOLDER	HAHN & KOLB	TYPE AAD 1250	1
HEX LOCKNUT		M10	1
HEX NUT		M6	2
" "		M4	3
CHEESE HEAD SCREW		M6 x 10	3
GRUB SCREWS		M4 x 20 CONE POINT	3
RIVETS (BRASS)	G.K.N.	TYPE 'U' - 3/16	2



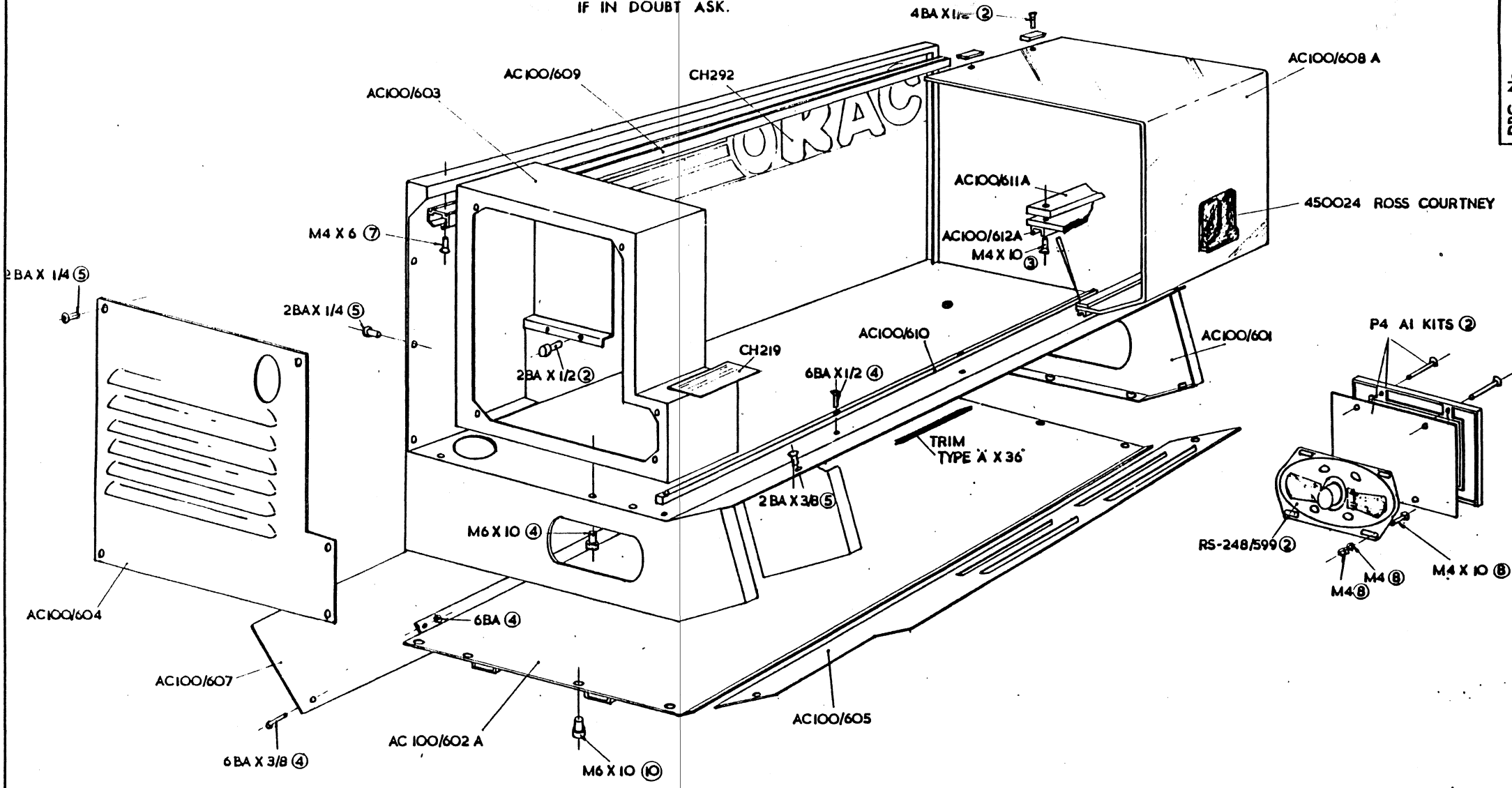
AC100/500

DENFORD MACHINE TOOLS LTD. BRIGHOUSE, YORKSHIRE.	LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED. ANGULAR ± ½° 3 PLACE DECIMAL ± .005" FRACTIONAL ± .010" 4 PLACE DECIMAL ± .0005"	MATL.	DRAWN	TRACED	CHECKED	APPROVED	DATE	SCALE
		MATL. SIZE	IV					
		No. REQD.	DRAWING No.					
		MACHINE AT 99						

'ORAC'	SPINDLE DRIVE	No. OFF
AC. 100/501A	SPINDLE DRIVE PLATE	1
502	MOTOR PULLEY	1
503A	MAIN SPINDLE PULLEY	1
504	SPINDLE TRANSDUCER DISC	1
505A	SPINDLE SENSOR BRACKET	1
506	LOCKNUT	1
507	SPINDLE PULLEY SPACER	1

DESCRIPTION	MANUFACTURER	REF.	No. OFF
DRIVE MOTOR	ASEA	MT 71 B1 4F 130-4	1
DRIVE BELT		POLY 'V' J10220	1
COMPRESSION GLAND	EGA	20mm ECG/2	1
STRAIGHT ADAPTOR	EGA	20mm MFA/2	1
KEY		8 x 5 x 35 LONG	1
KEY		5 x 5 x 12 LONG	1
SKT CAP HEAD		M6 x 20	4
GRUB SCREW		M5 x 5 PLAIN CUP	2
" "		2BA x 3/8" PLAIN CUP	1
" "		2BA x ¼" PLAIN CUP	2
WASHER		M6	4
SKT CAP HEAD		M8 x 20	4
SPRING WASHER		M8	4
SKT CAP HEAD		M4 x 16	2
" " "		6BA x 3/8"	2

IF IN DOUBT ASK.



AC 100/600

DRG. No

DESCRIPTION	CHKD.	APP'D.	DATE
ALTERATIONS			

DENFORD MACHINE TOOLS LTD. BRIGHOUSE, YORKSHIRE.

LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED.
ANGULAR ± ½° 3 PLACE DECIMAL ± ·005"
FRACTIONAL ± ·010" 4 PLACE DECIMAL ± ·0005"

MATL.
MATL. SIZE
No. REQD.
MACHINE AT '19'
GRIND AT 'G'

DRAWN	TRACED	CHECKED	APPROVED	DATE	SCALE
N.				12/	

DRAWING No.

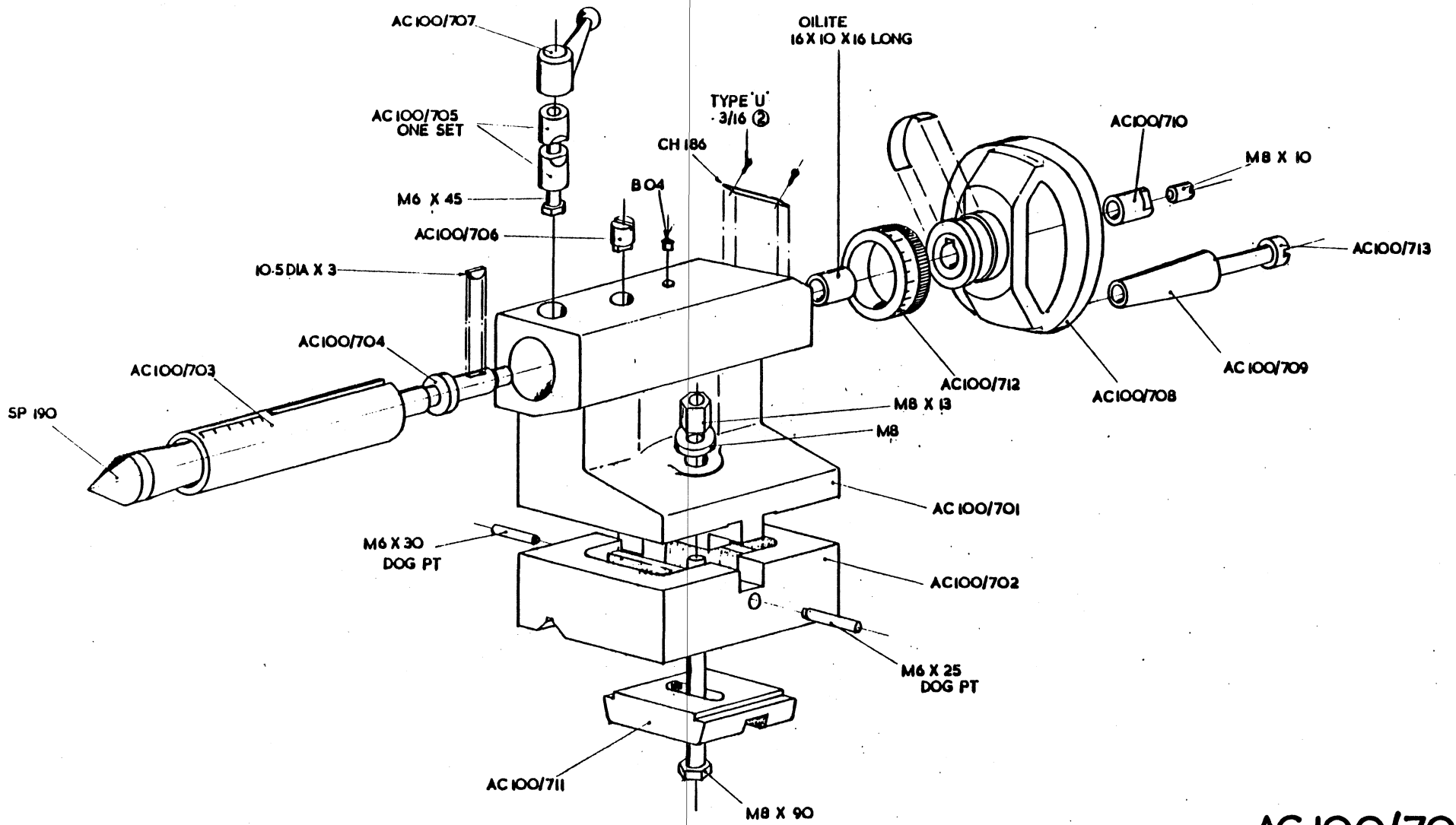
'ORAC' **CABINET & SLIDING GUARD**

PART No.	DESCRIPTION	QTY.
AC. 100/601A	CABINET	1
602A	CABINET BASE	1
603	END DRIVE HOUSING	1
604	END DRIVE COVER	1
605	VENTILATION PANEL	1
606A		
607	REAR DOOR	1
608A	SLIDING GUARD	1
609	TOP SLIDING RAIL	1
610	BOTTOM RAIL	1
611A	GUARD CLAMP PLATE	1
612A	GUARD RETAINING CHANNEL	1
618	DIVIDING PANEL	1
CH. 219	DENFORD LABEL	1
292	'ORAC' NAMEPLATE	1
304A	EARPHONE PLATE	1
305A	T.V. SOCKET PLATE	1
351	MAINS SUPPLY PLATE	1

DESCRIPTION	MANUFACTURER & REF.	COMPUTER NO.	QTY.
SLIDING GEAR	APEX ENTERPRISE	55501430	1
SPEAKER	RADIO SPARES 248/599	248/599	2
SPEAKER GRILL	UNICAR 1-05.071	55501432	2
KNOB	ELESA VTR 40B M8	55501214	1
EARPHONE (EXTRA)	EAGLE SE 500N	55501442	1

IF IN DOUBT ASK.

DRG. No.



AC 100/700

				DENFORD MACHINE TOOLS LTD. BRIGHOUSE, YORKSHIRE.	LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED.	MATL.	DRAWN	TRACED	CHECKED	APPROVED	DATE	SCALE
No.	DESCRIPTION	CHKD.	APP'D	DATE	ANGULAR ± ½° 3 PLACE DECIMAL ± ·005"	MATL. SIZE	W.				11/11/-	
	ALTERATIONS				FRACTIONAL ± ·010" 4 PLACE DECIMAL ± ·0005"	No. REQD.	DRAWING No.					
						MACHINE AT 'W'						
						GRIND AT 'G'						

'ORAC'	TAILSTOCK	No. OFF
AC. 100/701	TAILSTOCK BODY	1
702	TAILSTOCK SHOE	1
703	TAILSTOCK BARREL	1
704	BARREL SCREW	1
705	BARREL CLAMPS	1 SET
706	BARREL KEY	1
707	CLAMP LEVEL	1
708	TAILSTOCK HANDWHEEL	1
709	HANDWHEEL HANDLE	1
710	ADJUSTMENT SLEEVE	1
711	TAILSTOCK CLAMP	1
712	DIAL	1
713	SHOULDER SCREW	1
SP. 190	NO. 2 SOFT CENTRE	1

DESCRIPTION	MANUFACTURER	REF.	No. OFF
WOODRUFF KEY		10.5 DIA x 3	1
OILITE BUSH		16 x 10 x 10 LONG	1
OILER	LUMATIC	B04	1
SET SCREW		M8 x 90	1
SET SCREW		M6 x 45	1
GRUB SCREW		M6 x 25 DOG POINT	1
GRUB SCREW		M6 x 30 DOG POINT	1
HEX NUT		M8 x 13 LONG	1
STD WASHER		M8	1
RIVETS (BRASS)	G.K.N.	TYPE 'U' - 3/16"	1

DENFORD MACHINE TOOLS LIMITED

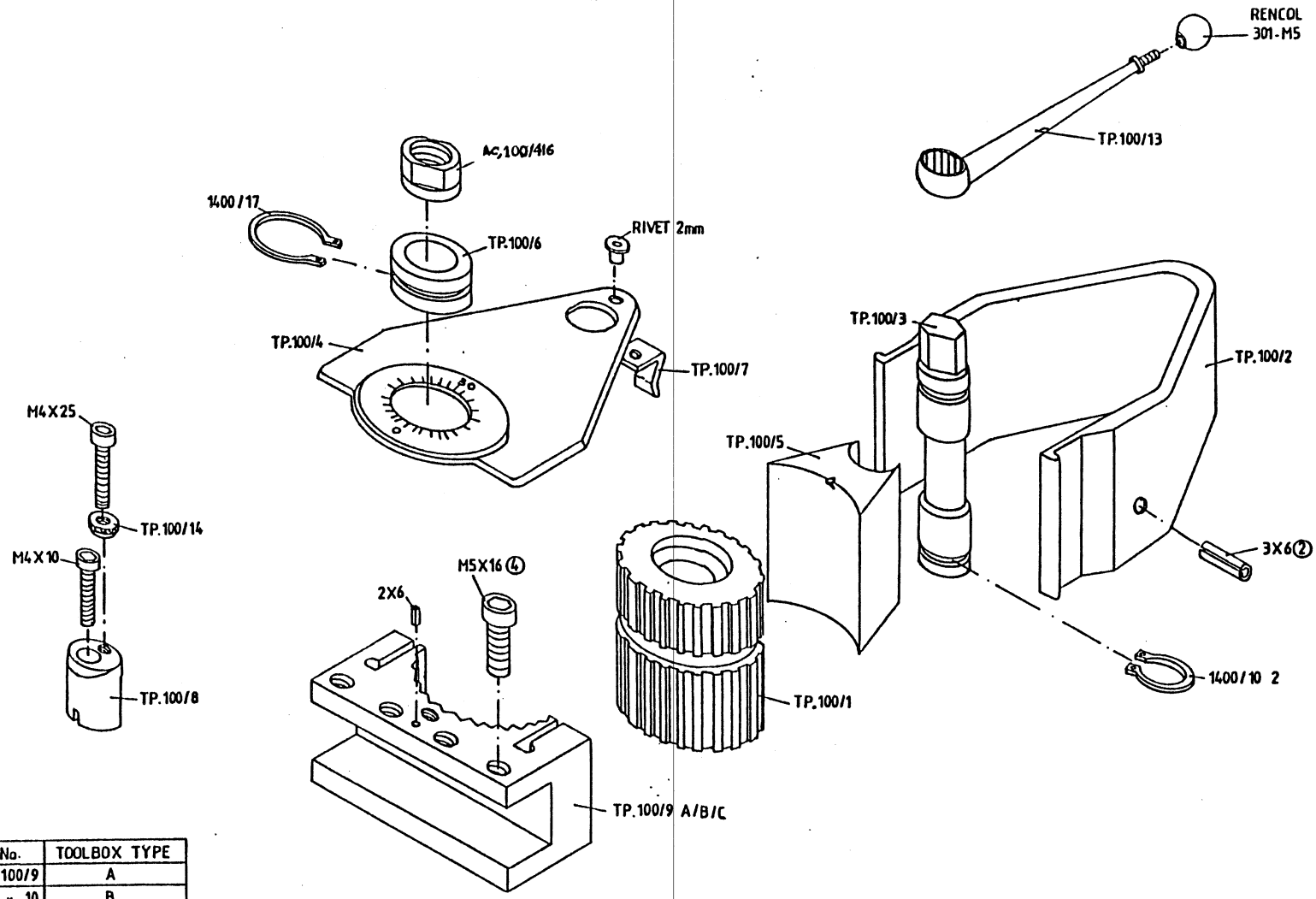
PARTS LIST 'ORAC' TRANSFORMER

AC. 101/1	TRANSFORMER BOX	1
2	TRANSFORMER BOX LID	1
AC. 100/211.A.	WASHER	1
CH. 329	PANEL PLATE	1

DESCRIPTION	MANUFACTURER	REF.	No. OFF
TRANSFORMER	I.L.P.	XA 0375	1
SWITCH	R.S.	338 - 529	1
FUSE HOLDER	R.S.	412 - 863	1
FUSE HOLDER	R.S.	412 - 021	1
STRAIN BUSH	R.S.	542 - 894	2
CABLE TIE BASE	R.S.	543 - 901	1
PLUG	R.S.	488 - 208	1
TERMINAL BLOCK	KLIPPON	2435-2	4
SCREWED ROD		M8 - 120 LONG	1
HEX NUT		STD. M8	2

IF IN DOUBT ASK.

DRG. No.



No.	TOOLBOX TYPE
TP100/9	A
" - 10	B
" - 11	C

TP. 100

	DESCRIPTION	CHKD	APPD	DATE
	ALTERATIONS			

DENFORD MACHINE TOOLS LTD. BRIGHOUSE. YORKSHIRE.

LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED.
ANGULAR ± 1° 3 PLACE DECIMAL ± .005"
FRACTIONAL ± .010" 4 PLACE DECIMAL ± .0005"

MAIL
MATL. SIZE
No READ
MACHINE AT 99
GRIND AT 'G'

DRAWN	TRACED	CHECKED	APPROVED	DATE	SCALE
A.M.				23.4.85	

DRAWING No.

DENFORD MACHINE TOOLS LIMITED

ORAC

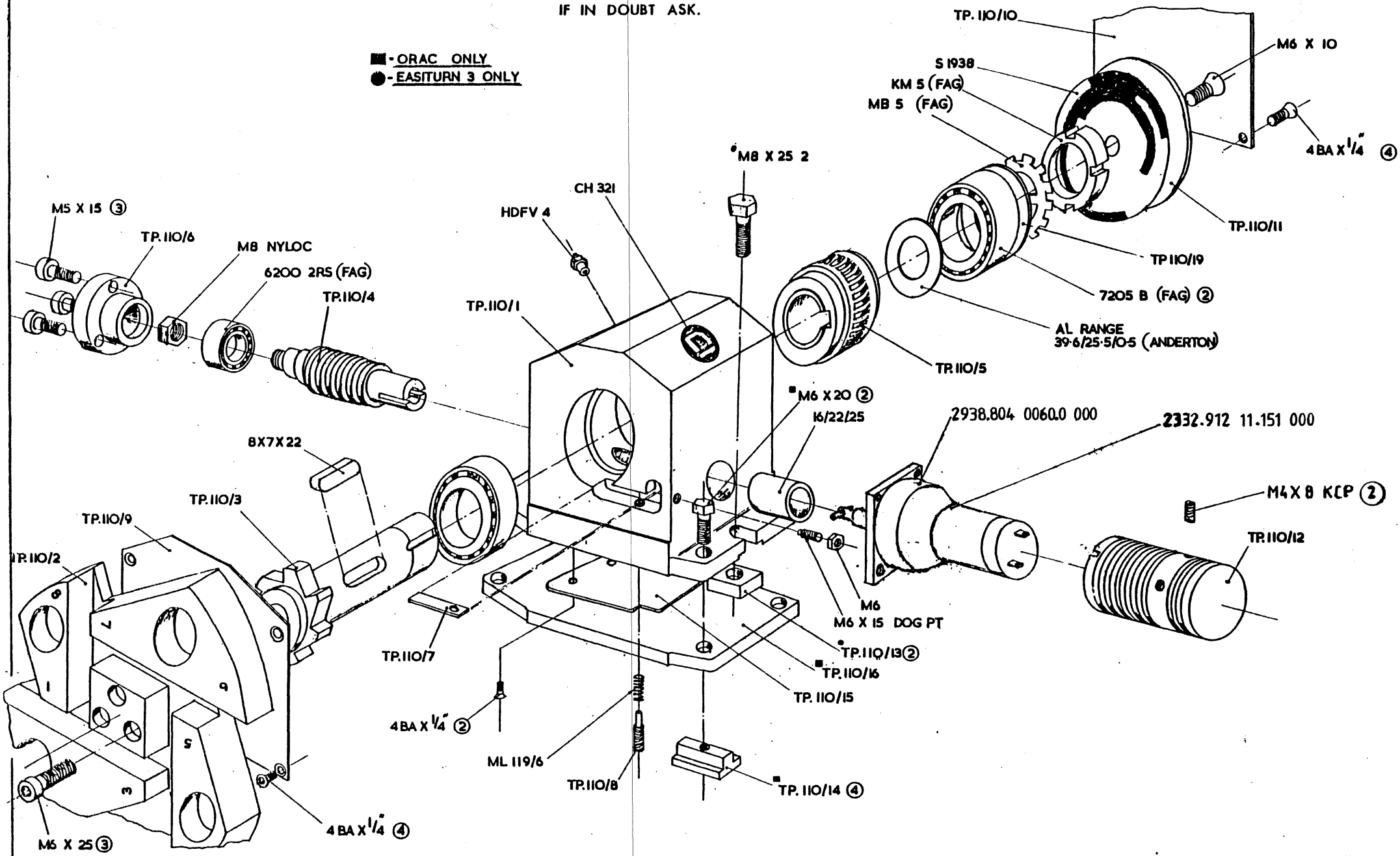
TP 100 — **QUICK CHANGE TOOLPOST**

PART No.	DESCRIPTION	QTY.
TP 100/ 1	BASE BODY	1
2	SLIDE ARMS	1
3	ECCENTRIC PIN	1
4	COVER	1
5	CLAMP	1
6	CLAMPING BUSH	1
7	TENSION SPRING	1
8	ADJUSTING BRACKET	1
9	TOOL BOX "TYPE A"	1
10	TOOL BOX "TYPE B"	1
11	TOOL BOX "TYPE C"	1
12		
13	HANDLE	1
14	LOCKING NUT	1

DESCRIPTION	MANUFACTURER & REF.	COMPUTER NO.	QTY.
KNOB	RENCOL 301-M5		1

IF IN DOUBT ASK.

■ - ORAC ONLY
● - EASITURN 3 ONLY



DESCRIPTION	CHKD	APP'D	DATE
ALTERATIONS			

DENFORD MACHINE TOOLS LTD. BRIGHOUSE, YORKSHIRE.

INDEXING TOOLPOST

LIMITS ON DIMENSIONS UNLESS OTHERWISE STATED.
ANGULAR ± ½° 3 PLACE DECIMAL ± ·005"
FRACTIONAL ± ·010" 4 PLACE DECIMAL ± ·0005"

MATL.
MATL. SIZE
No. REQD.
MACHINE AT 'W'
GRIND AT 'G'

DRAWN	TRACED	CHECKED	APPROVED	DATE	SC
IV				NOV 84	—

DRAWING No. TP. 110

DENFORD MACHINE TOOLS LIMITED

'ORAC' INDEXING TOOLPOST PARTS LIST

PART No.	DESCRIPTION	QTY.
TP 110/ 1	TOOLPOST BODY	1
2	TURRET	1
3	MAIN SHAFT	1
4	WORM SHAFT	1
5	WORM GEAR	1
6	WORM SHAFT END CAP	1
7	RATCHET STOP	1
8	RETAINING PIN	1
9	FRONT PLATE	1
10	REAR PLATE	1
11	TRANSDUCER DISC	1
12A	MOTOR JACKET	1
13		
14A	TEE BOLT	4
15	ELECTRICAL COVER	1
16	ADAPTOR PLATE	1
17A,B&C	COLLETS 6, 8 & 12 DIA	1 SET
18	CHUCK ADAPTOR	1
19	GREASE RETAINING PLATE	1
20	SENSOR BOARD BRACKET	1
21		
22	CHIP GUARD EXTENSION (STARTURN 8 ONLY)	1
23	MANUAL SWITCH BRACKET	1
CH. 321	'D' SYMBOL	1
CH. 364	LIFTING WARNING PLATE	1
AC. 100/608B	CHIP GUARD (EXTENDED)	1
611A	GUARD CLAMP PLATE	1
612A	GUARD RETAINING CHANNEL	1

DESCRIPTION	MANUFACTURER & REF.	COMPUTER No.	QTY.
MOTOR	TRIDENT : 2332.912 11.151 000	55500302	1
GEARBOX	TRIDENT : 2938.804 0060.0 000	55500302A	1
BEARING	FAG : 7205 B	55500102B	1
BEARING	FAG : 6200 2RS	55500110	1
OILITE BUSH	16/22/25	55500195F	1
LOCKNUT	FAG : KM5	55500184A	1
TABWASHER	FAG : MB5	55500184B	1
OPTO SWITCH	RS 307 913	307 913	3
GREASE NIPPLE	LUMATIC : HDFV4		1
DISC SPRING	ANDERTON : AL 4017	55500196D	1
DRILL CHUCK	JACOBS : K10 ACG 3/8 x 24M		1

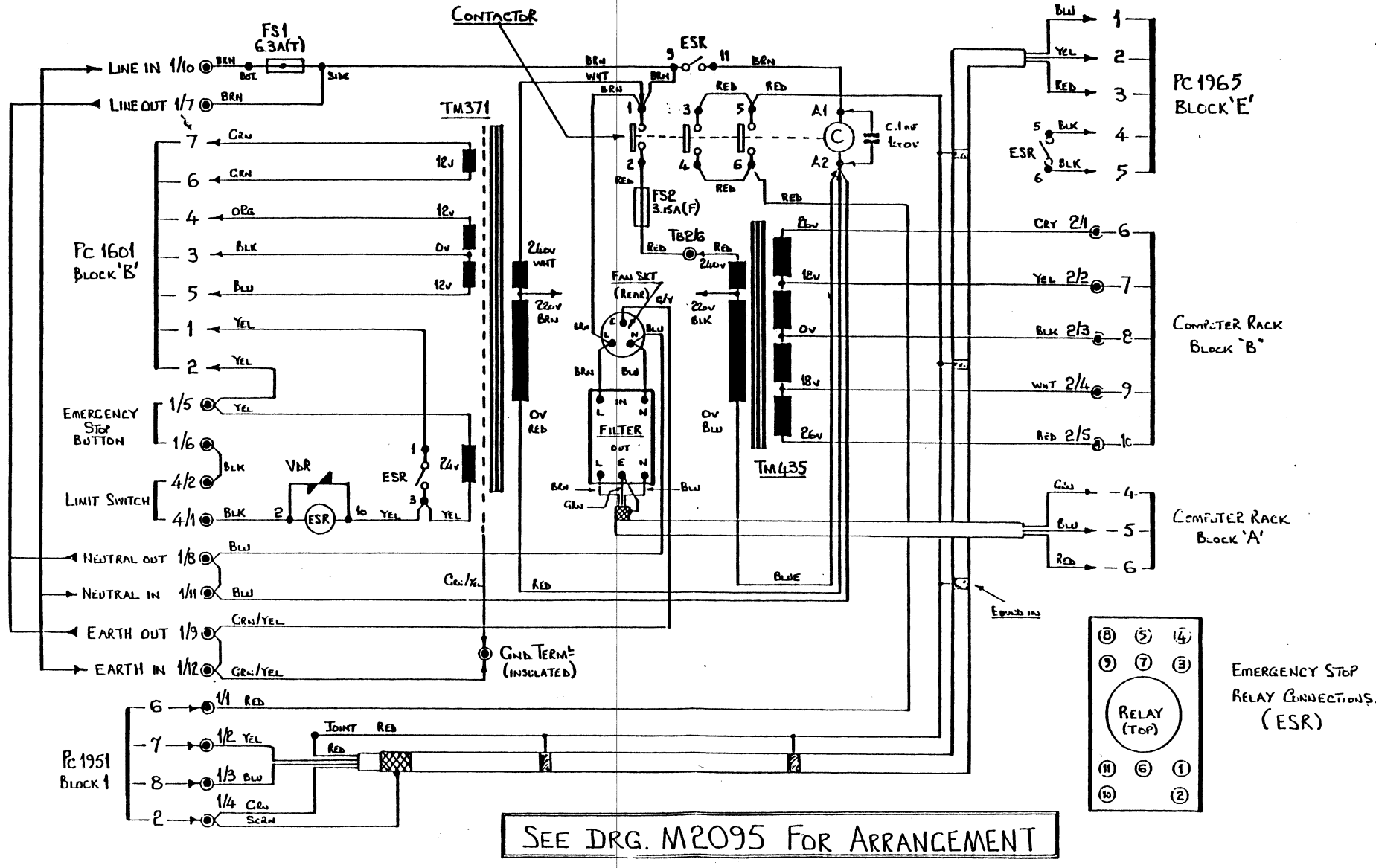
'ORAC' **INTERLOCKING GUARD**

PART No.	DESCRIPTION	QTY.
AC. 105/1	KNOCK OFF SUPPORT BRACKET	1
2	KNOCK OFF	2
3	ROD SUPPORT BLOCK	2
4	ROD	1
5	BEARING HOUSING	2
6	STOP	1
AC. 100/608B	SLIDING GUARD	1
611A	GUARD CLAMP PLATE	1
615	BUNDY TUBE ADAPTOR	2

DESCRIPTION	MANUFACTURER & REF.	COMPUTER No.	QTY.
MICRO SWITCH	BURGESS KB5EQR	55500380	1
TRACK	WIDNEY 2012-FN x 35½"	55501431	1
KNOB	ELESA VTR 40B M8	55501214	1
TUBE	BUNDY 5/16" O.D. x 13 7/8"		1
OILITE BUSH	MANGANESE BRONZE ½" x 5/8" x 1"	55500194B	2

ORAC/ELECTRICAL DRAWINGS

DRAWING NO.	DESCRIPTION	REMARKS
M2050	Main Interconnections (Cables)	REVISED VERSION
*M2119	" " "	(PRESENTATION)
*M2094	Power Supply Unit - circ. diag.	
*M2095	" " - L/O	
M2011	Comptr. VF. PC 1965 - circ/diag.	
*M2106	" " - L/O	
*S2098	Regulator Board PC 1601 - circ/diag.	
S2074	" " - L/O	
*S2108	Spindle Control Unit PC 1951 - circ/diag	
*S2109	" " - L/O	
*S2097	Bleeper Board - L/O (only)	
M1958	Modulator for Nevin Monitor circ/diag.	
*S2099	" " " L/O	
S2077	Modulator for KME Monitor circ/diag. (PC 2075)	
S2076	" " " L/O	
	Leaflet Re: Conns	
*M2105	Ribbon Cable Interconns.	
*S2123	Interconns - 2501 PSU to Rack	APPLICABLE TO A SMALL NUMBER OF UNITS
S1861	" - 8151 PSU to Rack	MOST UNITS
*S2100	" - T10-A to Cassette (Data)	
S1632	" - Cassette to H/phone Jack	
*M2102	T10 - A board - circ. diag.	
S2016	" " - L/O	
*M2103	T10 - B board - circ. diag.	
S2013	" " - L/O	
*M2107	T10 - C board - circ. diag.	
S2044	" " - L/O	
*M2104	MPØ9 Processor Board - L/O only	
S2101	PRM-1 (dedicated) REF X84 - L/O only	
S0061 (syn)	GDM - 1 - L/O only	
*S2120	Opto Sensor PC 1852 - L/O only	
*S2124	Indexing Tool Post - Sensor PC 1928-circ	
*S2121	" " " - L/O	
S1938	" " " - Disk encoding	
*M2125	Brown Pestell Spindle Motor Speed Controller - General Arrangement	
-	Data Sheet	
-	Manual	



REVISIONS

TITLE

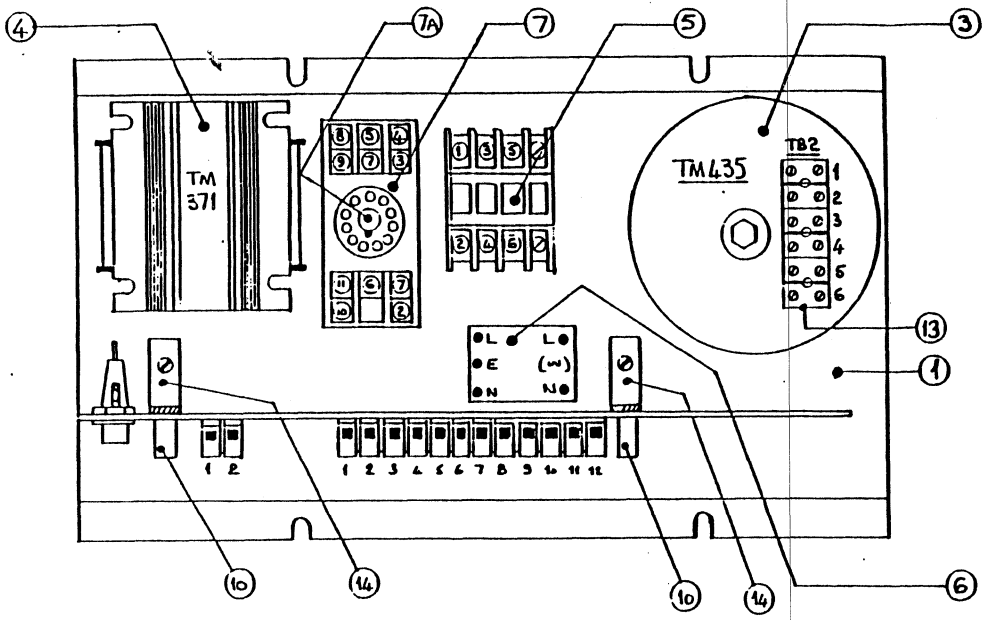
ORAC 85:- CIRCUIT DIAGRAM OF P.S.U. CHASSIS.

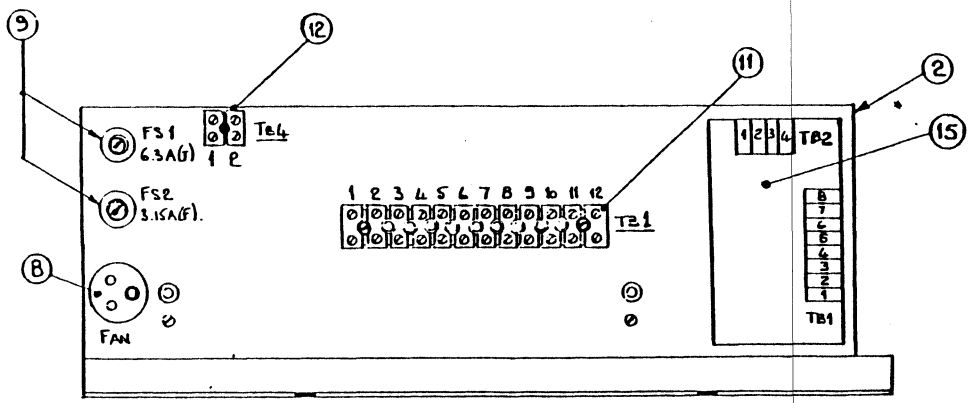
JOB	
CODE	
DRN.	
CKD.	
DATE	18·5·86

GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PG
Phone: 0484 38101/8

DRG. No.

M2094





ITEM	DESCRIPTION	STORES REF.	Nº OFF	REMARKS
1	CHASSIS PLATE		1	SEE DRG. M1970
2	5mm BLACK PLASTIC PANEL 318 x 100 mm		1	
3	TOROIDAL TRANSFORMER	TM435	1	DRIVES TRFR.
4	TRANSFORMER	TM371	1	CONTROL_LOGIC ETC.
5	K2_09_A01 CONTACTOR	CR148	1	240V COIL
6	MAINS FILTER	GH1E5	1	
7	11_PIN RELAY BASE	CR146	1	COMPLETE WITH .....
7A	11_PIN RELAY	CR145	1	24V. AC COIL 3POLE C/O
8	L1435 BS SOCKET	TS63	1	
9	FUSE HOLDER 20mm	FD3	2	
10	4mm NYLON PILLAR	GH175	2	
11	MK3/12 TERM. BLOCK	TS29	1	
12	MK3/2 " "	TS—	1	OFF_CUT.
13	MK6/6 " "	TS96	1	
14	MILD STEEL BRACKET		2	TO DRG. S1990
15	SPINDLE CONTROL UNIT	PC1951	1	SEE DRG. S2109 ETC.

SEE DRG. M2094 FOR CIRCUIT DIAGRAM.

REVISIONS

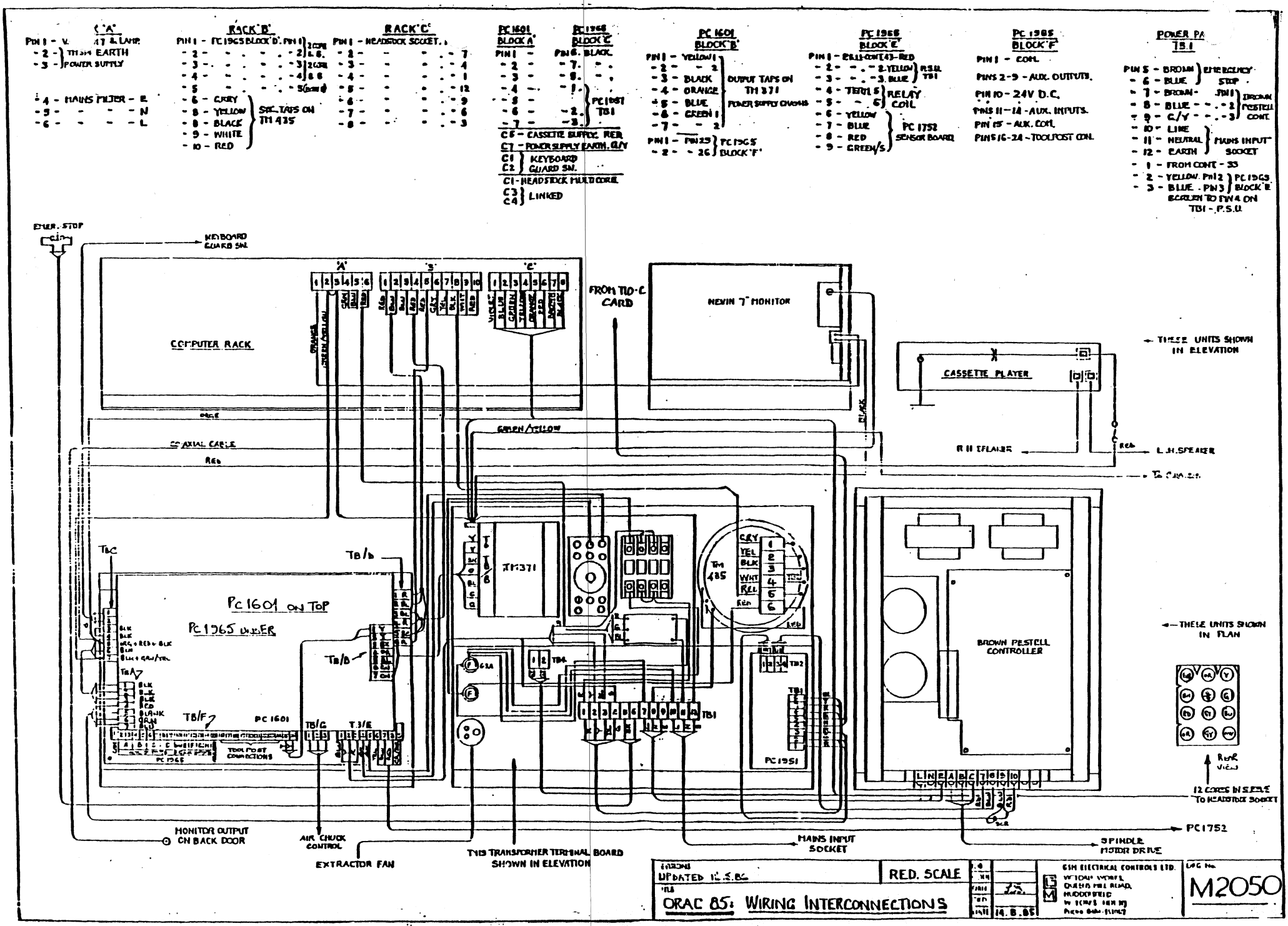
TITLE

ORAC 85 :- ARRANGEMENT OF P.S.U. CHASSIS.

JOB	
CODE	
DRN.	PRP
CKD.	
DATE	14·5·86

GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PG
Phone: 0484 35101/2

DRG. No. M2095



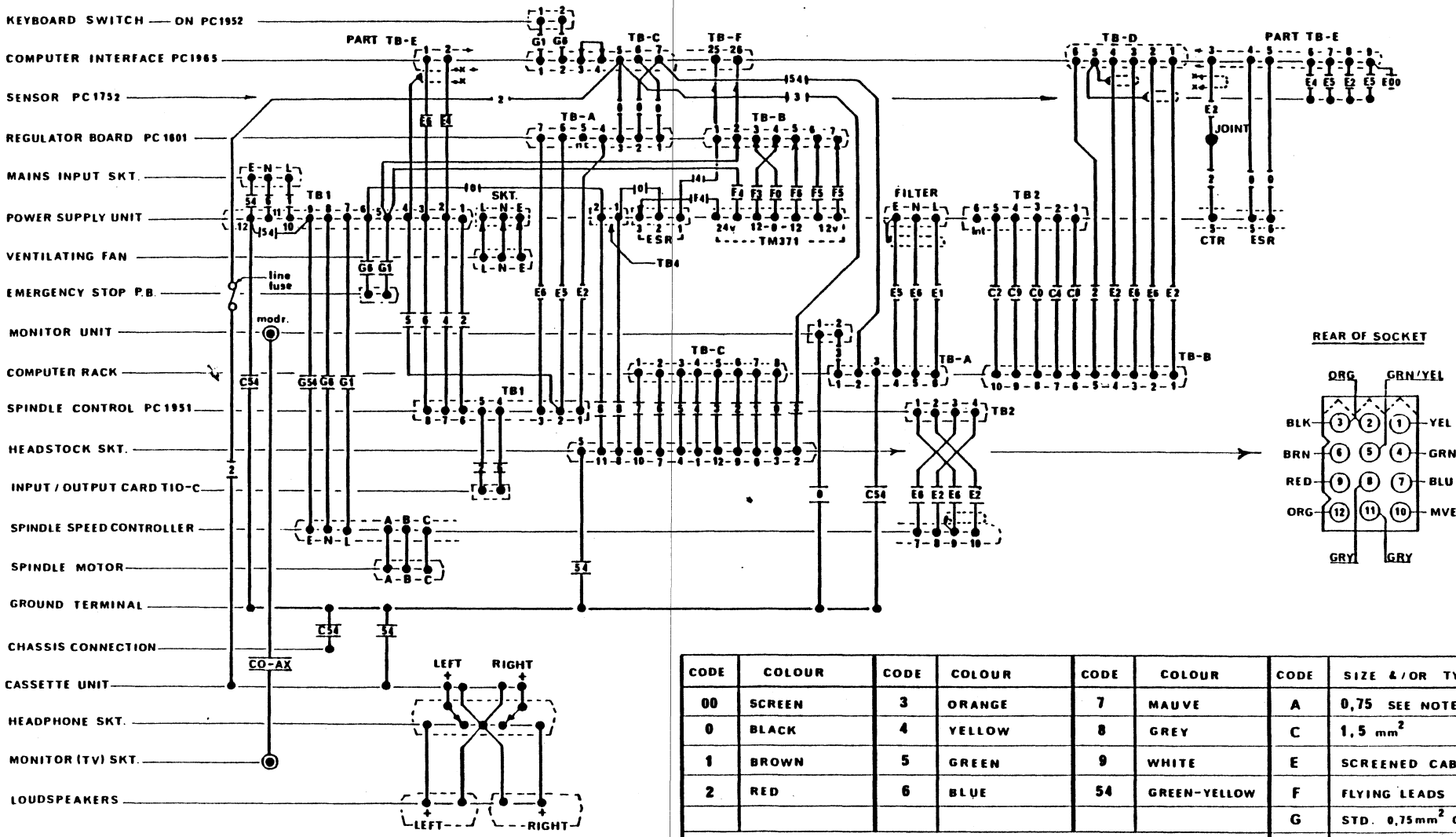
UPDATED 12.5.86 — RED. SCALE

TITLE: ORAC 85: WIRING INTERCONNECTIONS

14.8.85

GSH ELECTRICAL CONTROLS LTD.
WITCHAM WORKS, QUEENS MILL ROAD, HUDDERSFIELD
W. YORKS HD1 3QJ
Phone 0484-511147

DRG No. M2050



CODE	COLOUR	CODE	COLOUR	CODE	COLOUR	CODE	SIZE &/OR TYPE
00	SCREEN	3	ORANGE	7	MAUVE	A	0,75 SEE NOTE
0	BLACK	4	YELLOW	8	GREY	C	1,5 mm^2
1	BROWN	5	GREEN	9	WHITE	E	SCREENED CABLE
2	RED	6	BLUE	54	GREEN-YELLOW	F	FLYING LEADS
						G	STD. 0,75mm^2 CABLE
NOTE! ALL CABLES ARE CODE A UNLESS SHOWN OTHERWISE							

REVISIONS

TITLE

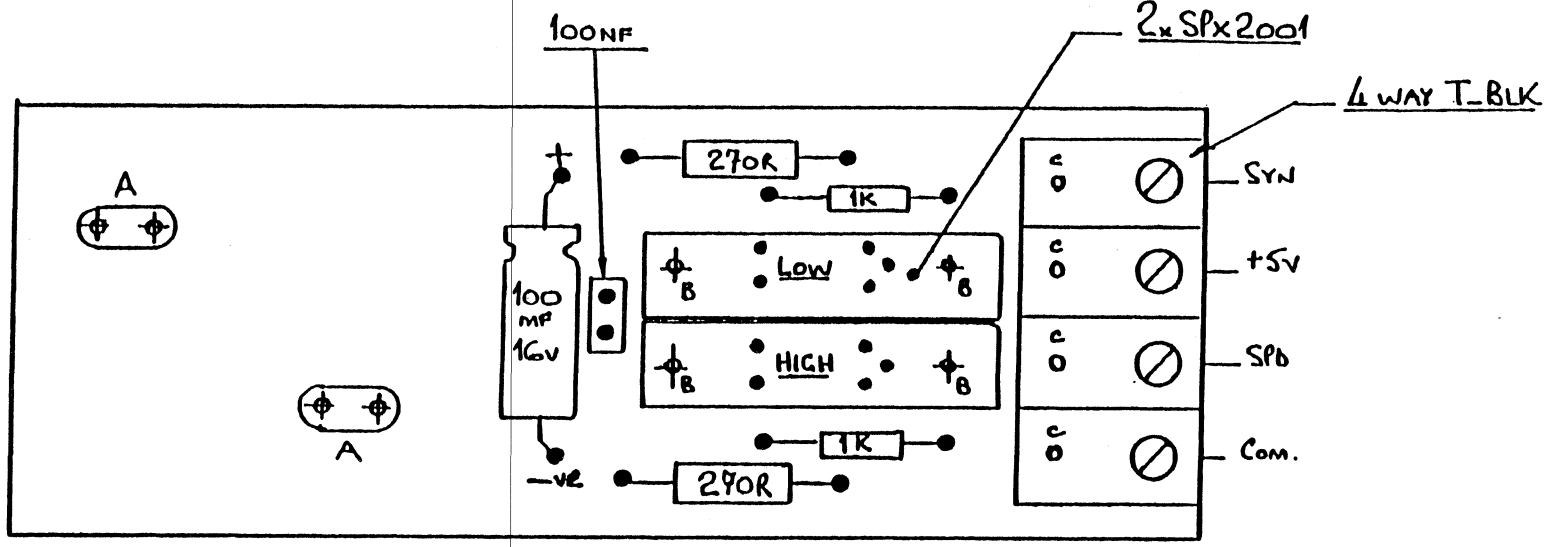
ORAC 85 :- MAIN INTERCONNECTION DIAGRAM __ CABLES.

JOB	
CODE	
DRN.	PLP
CKD.	
DATE	23·6·86

GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PG
Phone: 0484 38101/2

DRG. No.

M2119



Drilling Details.

Holes 'A' — Drill 2x Nº 26 Then Slot. — 2-off

Holes 'B' — Drill Nº 30 — 4-off.

Holes 'C' — Drill Nº 54 — 4-off.

Remainder — Drill 0,9 mm. — 22-off.

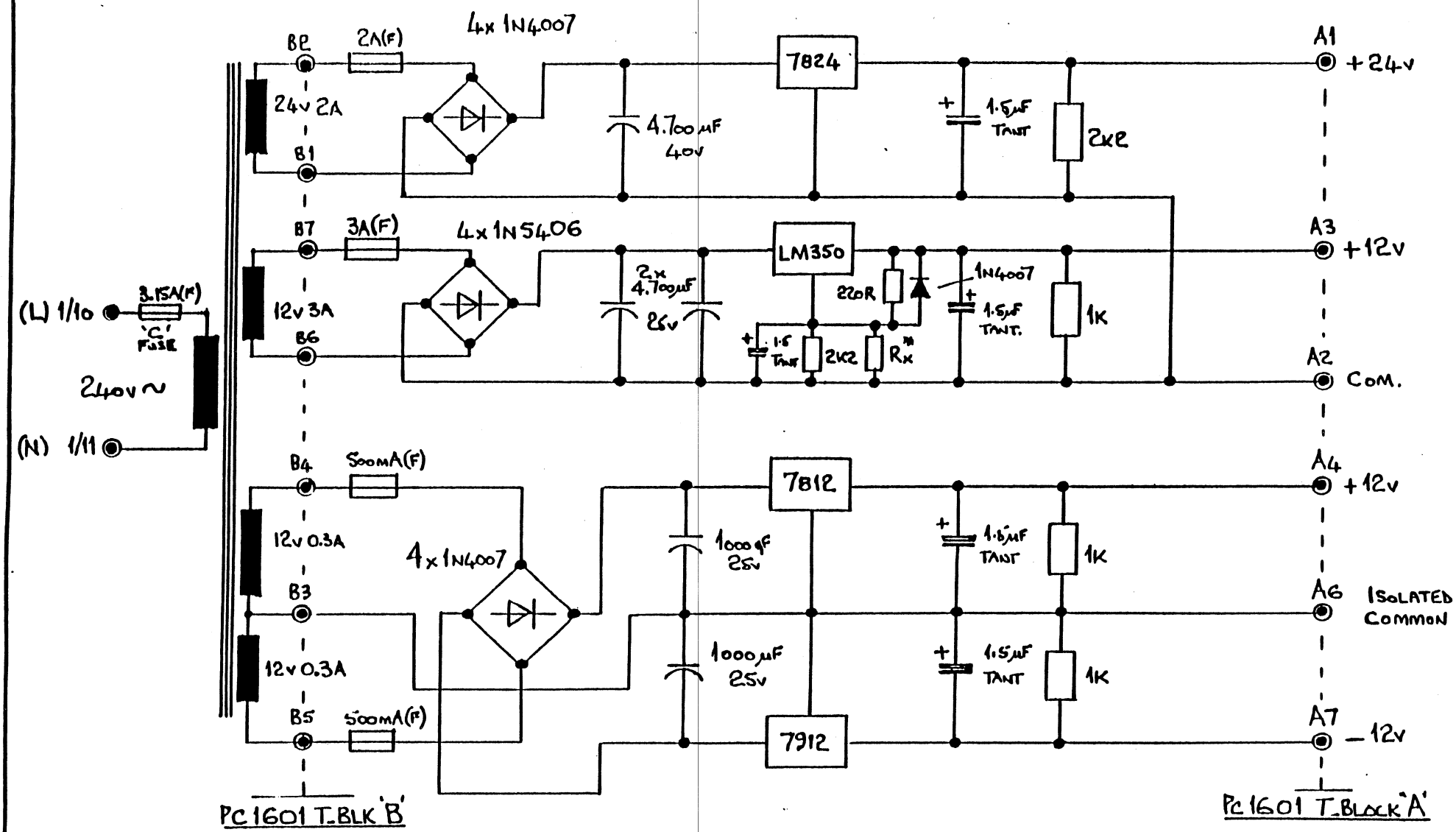
Sensor Fixing.

"Low":- 2 off M3 x 10mm CH. HD screws + Plastic Nuts.

"High":- 2 off M3 x 12mm CH. HD. Screws with 4 BA Nuts as spacers, secured with Plastic Nuts.

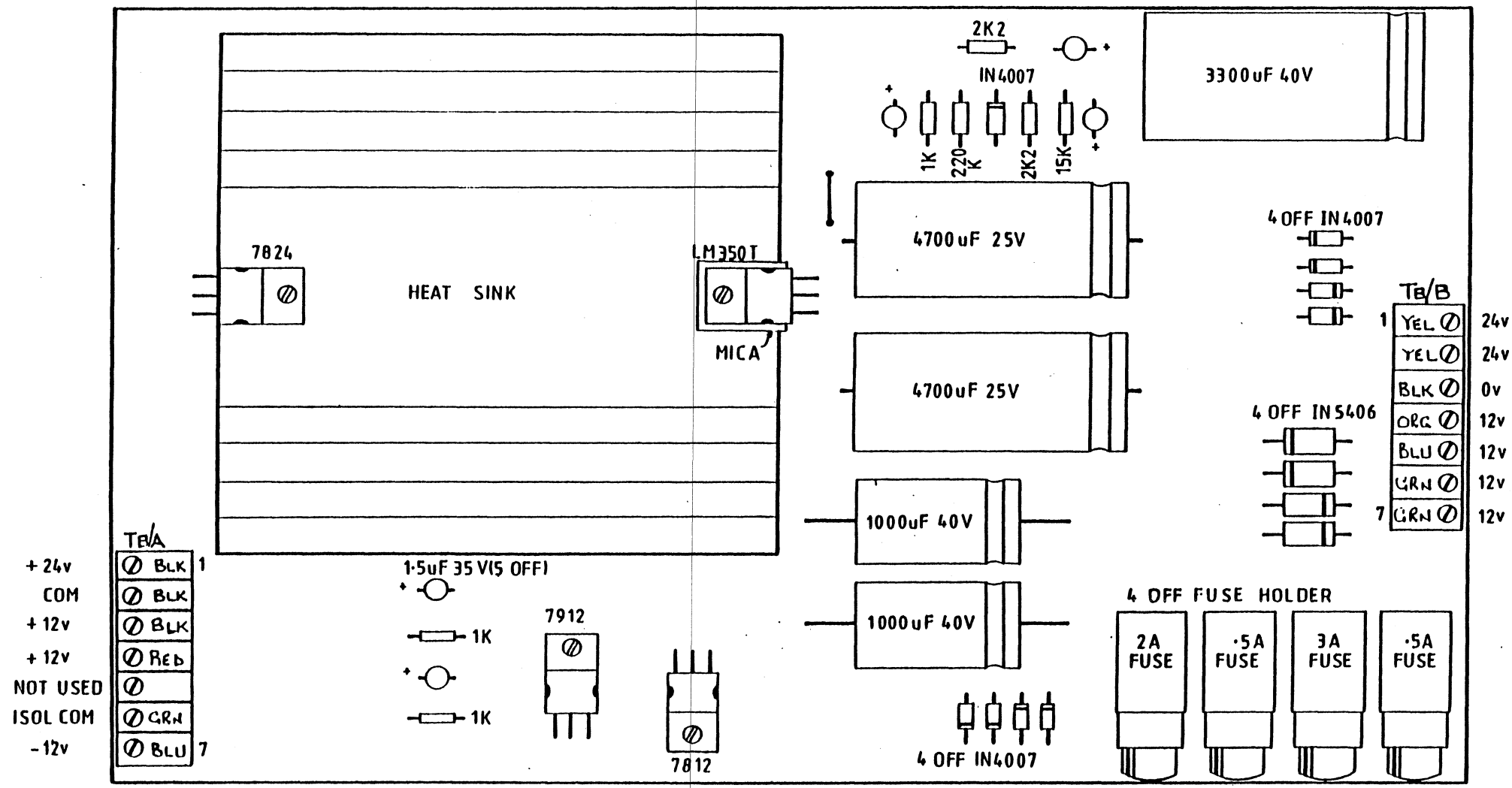
Scale :- 2x Full Size.

REVISIONS		JOB		GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PB Phone: 0484 38101/8	DRG. No. S2120
TITLE ORAC 85:- Component Layout & Drilling Details For Opto-Sensor Board — PC1852.		CODE			
		DRN.	Pep		
		CKD.			
		DATE	24.6.86		

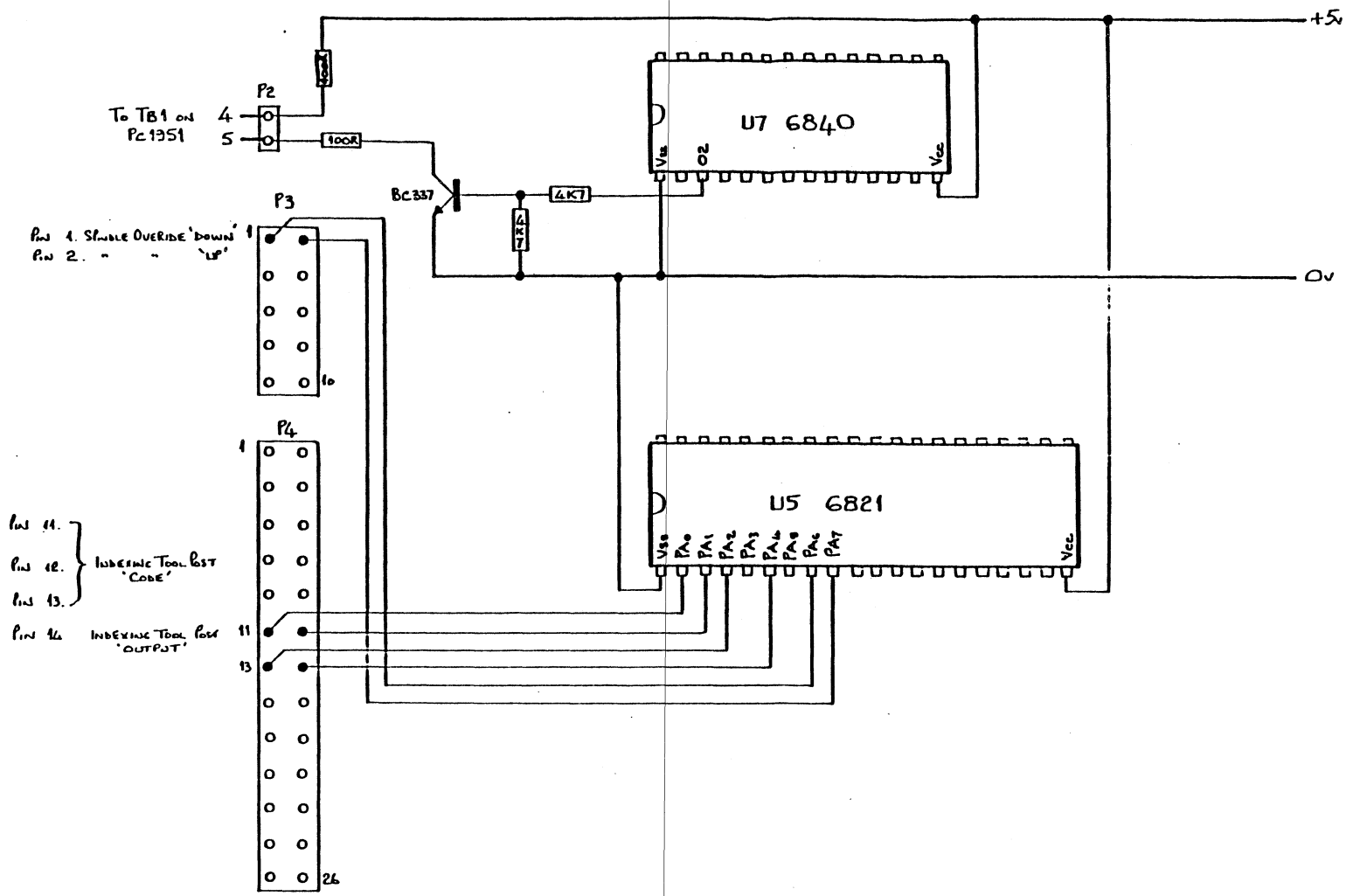


*NOTE! Rx IS A TRIMMING RESISTOR — NORMALLY 15K

REVISIONS	JOB	GSM-SYNTEL LTD.	DRG. No.
	CODE	VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PG Phone: 0484 38101/2	S2098
TITLE: ORAC 85 :- PC1601 PSU REGULATOR BOARD — CIRCUIT	DRN.		
	CKD.		
	DATE	14.5.86	



REVISIONS	JOB		GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PG Phone: 0484 38101/2	DRG. No. S2074
TITLE COMPONENT LAYOUT FOR ORAC 85 PC1601	CODE			
	DRN.	P.P.A.		
	CKD.			
	DATE	24.2.86		



REVISIONS

TITLE

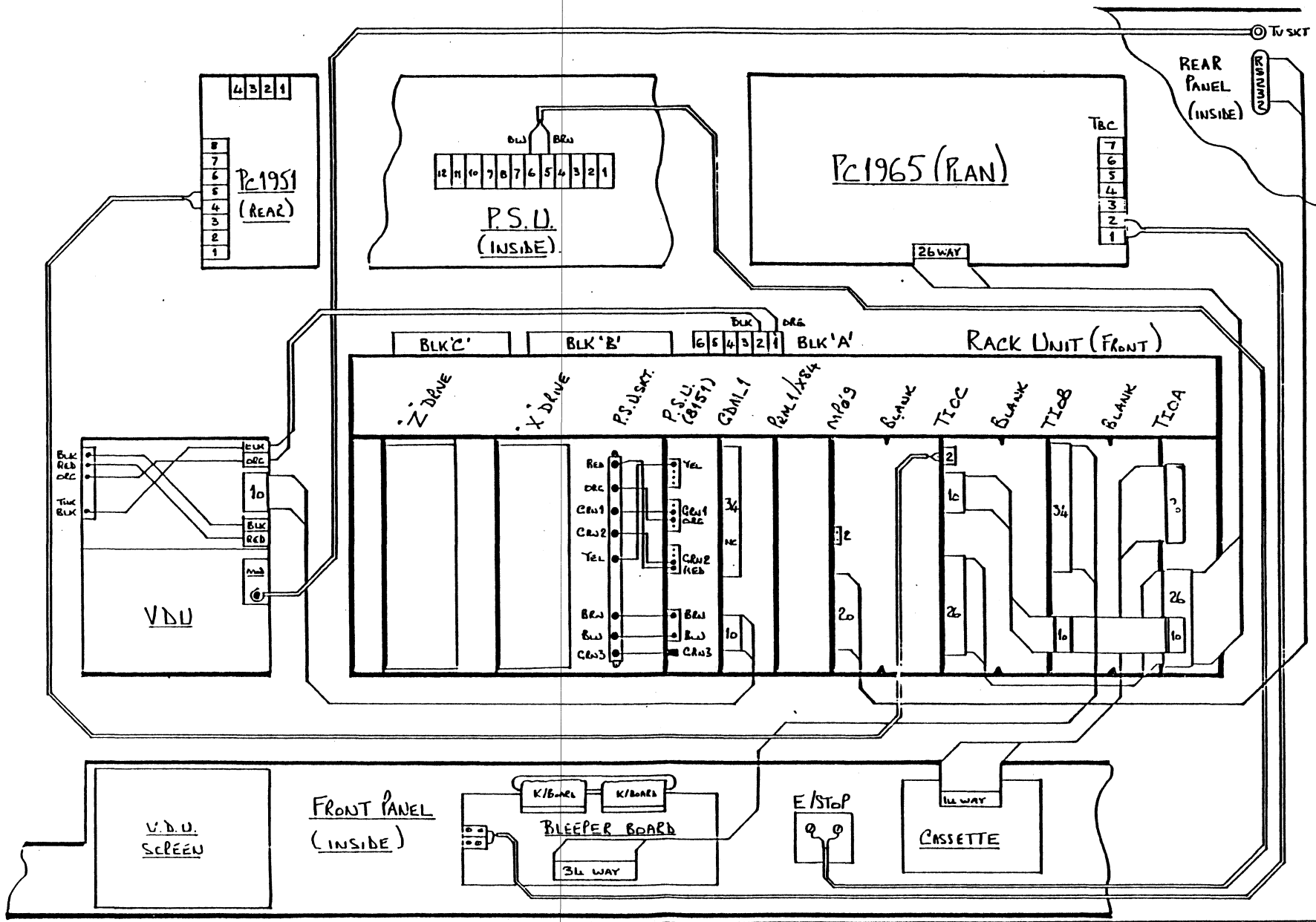
ORAC 85: TIOC _ CIRCUIT DIAGRAM.

JOB	
CODE	
DRN.	AKJ
CKD.	
DATE	22-5-86

GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PB
Phone: 0484 38101/2

DRG. No.

M2107



REVISIONS

TITLE

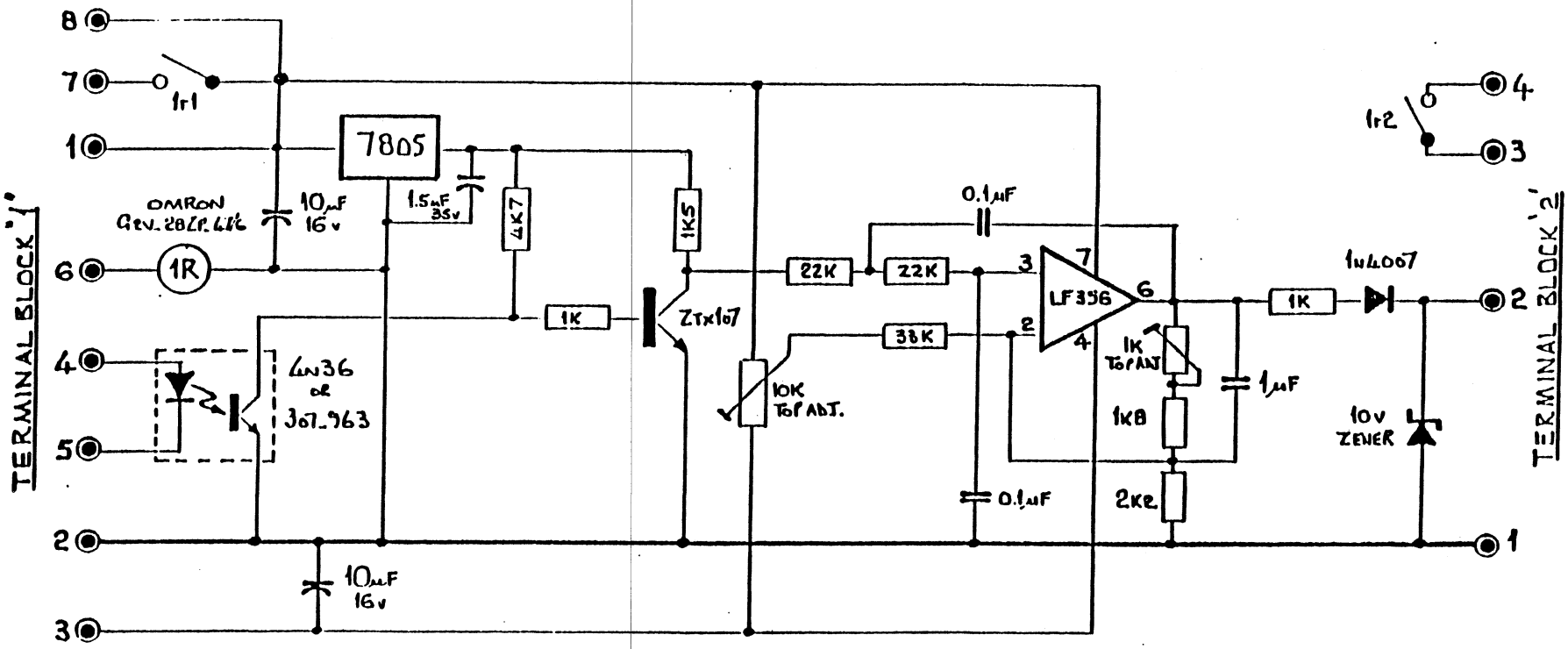
ORAC 85:- RIBBON CABLE INTERCONNECTIONS ETC

JOB	
CODE	
DRN.	PRD
CKD.	
DATE	21.5.86

GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PG
Phone: 0484 35101/2

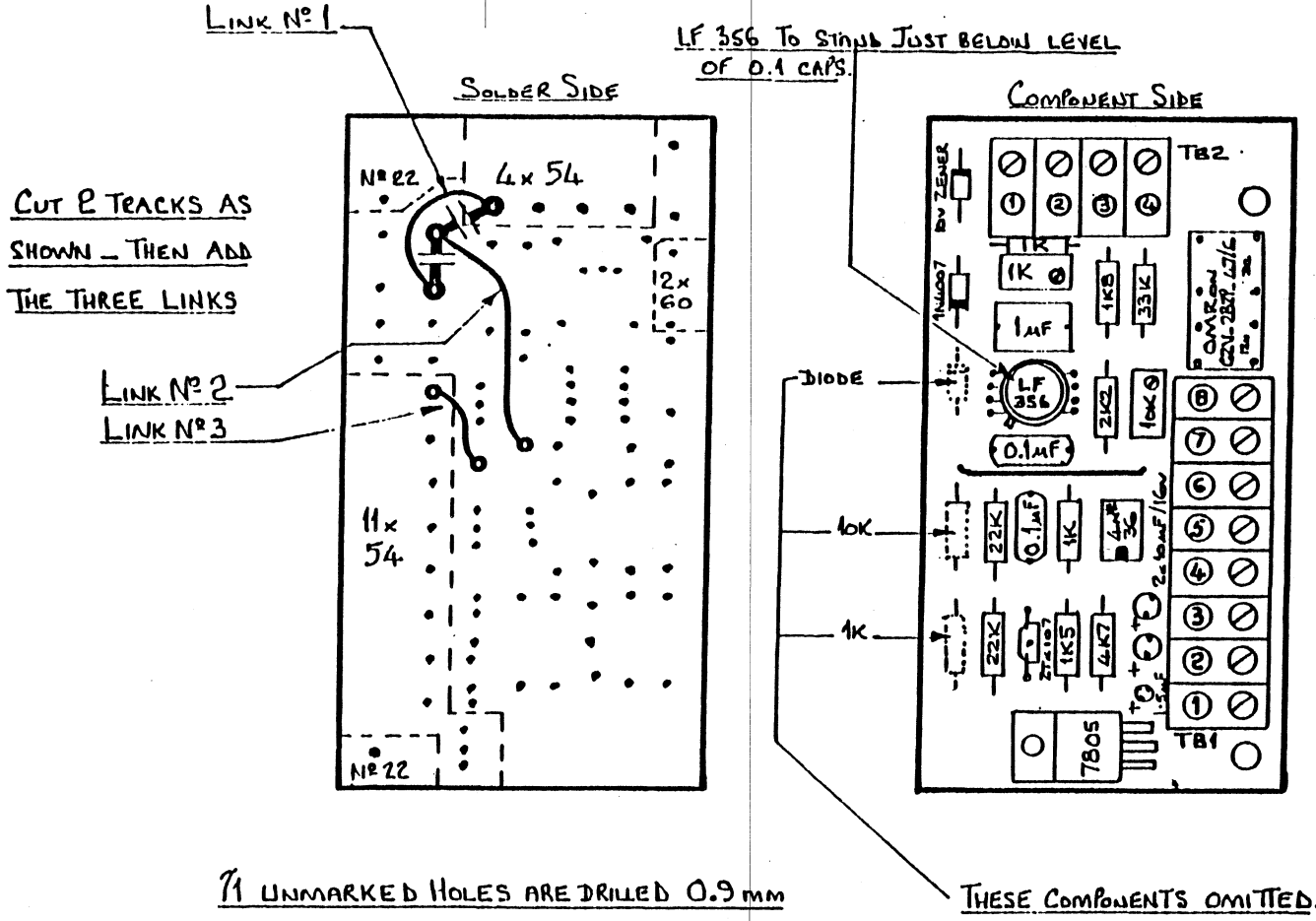
DRG. No.

M2105



SEE DRG. S2109 FOR COMPONENT LAYOUT

REVISIONS	JOB		GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PB Phone: 0484 38101/2	DRG. No. S2108
TITLE: DRAC 85: SPINDLE CONTROL UNIT_PC 1951_CIRCUIT DIAG.	CODE			
	DRN.	PKD		
	CKD.			
	DATE	23.5.86		



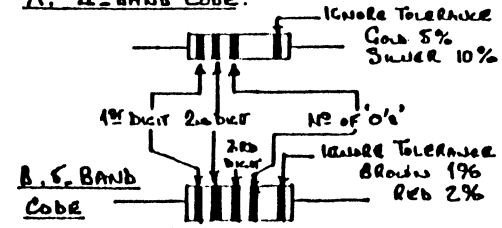
71 UNMARKED HOLES ARE DRILLED 0.9 mm

THESE COMPONENTS OMITTED.

* RS 307-963 IS ALTERNATIVE TO 4N36

RESISTOR CODES

A. 4-BAND CODE.



A

VALUE	BAND 1	BAND 2	BAND 3
1K	BRN	BLK	RED
1K5	BRN	GRN	RED
1K8	BRN	GRY	RED
2K2	RED	RED	RED
4K7	YEL	MVE	RED
22K	RED	RED	ORG.
33K	ORG.	ORG	ORG

B.

VALUE	BAND 1	BAND 2	BAND 3	BAND 4
1K	BRN	BLK	BLK	BRN
1K5	BRN	GRN	BLK	BRN
1K8	BRN	GRY	BLK	BRN
2K2	RED	RED	BLK	BRN
4K7	YEL	MVE	BLK	BRN
22K	RED	RED	BLK	RED
33K	ORG.	ORG	BLK	RED

REVISIONS

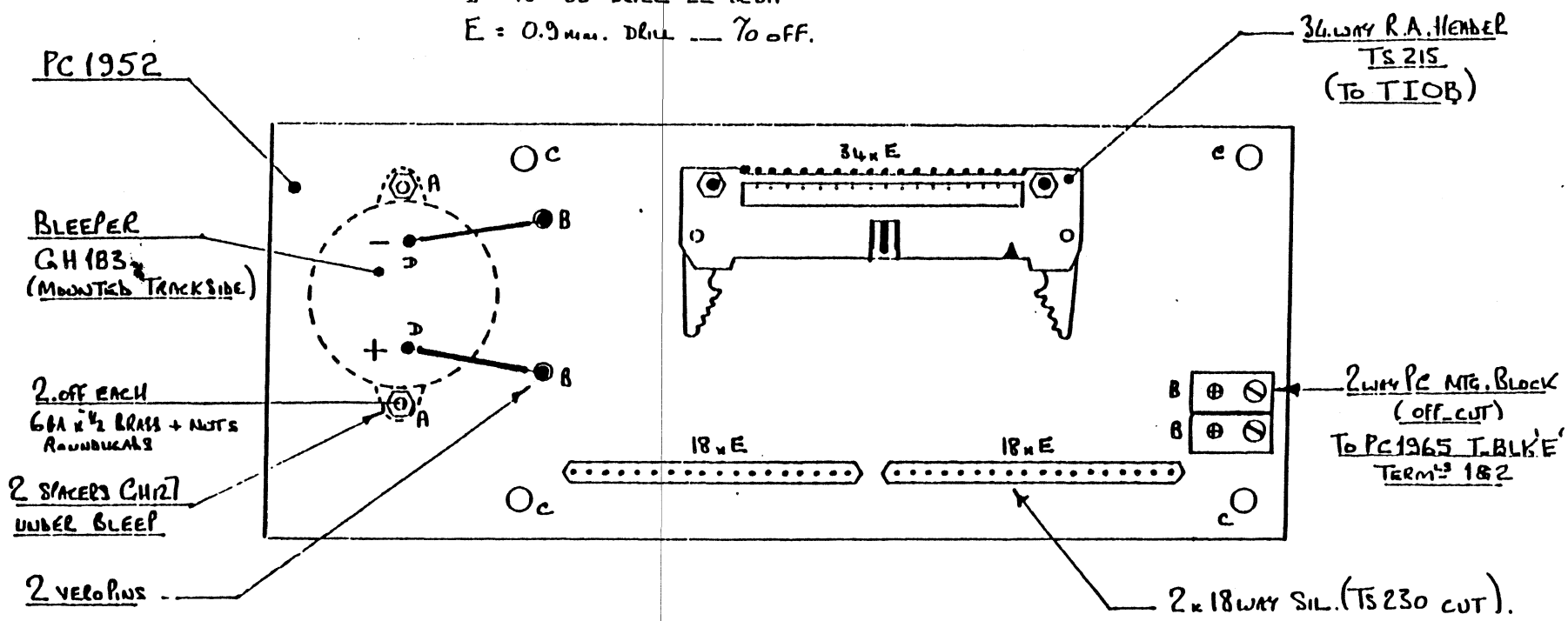
TITLE
ORAC 85: DRILLING DETAILS & COMPONENT LAYOUT OF PC 1951
SPINDLE CONTROL P.C.B.

JOB	
CODE	
DRN.	PRP
CKD.	
DATE	23·5·86

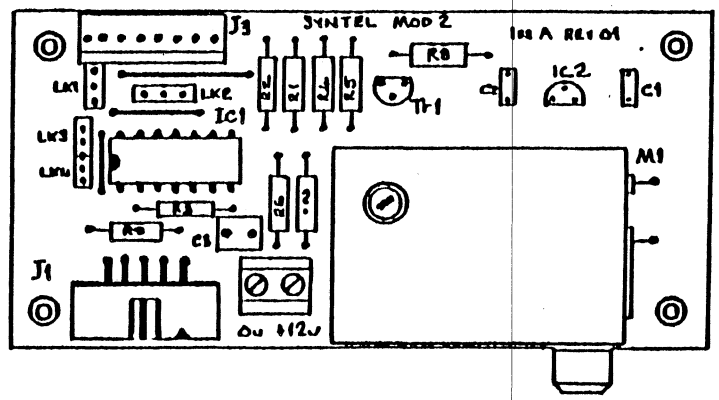
GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PB
Phone: 0484 38101/2

DRG. No.
S2109

DRILLING DETAILS:— A = N° 39 DRILL — 2 off.
B = N° 54 DRILL — 4 off
C = N° 20 DRILL — 4 off
D = N° 50 DRILL — 2 off
E = 0.9 mm. DRILL — 70 off.



REVISIONS	JOB		GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PG Phone: 0484 35101/2	DRG. No. S2097
TITLE ORAC 85 :- PC 1952 _ BLEEPER BOARD _ COMPONENT LAYOUT & DRILLING DETAILS.	CODE			
	DRN.	PRD		
	CKD.			
	DATE	14-5-86		



ITEM	DESCRIPTION OR VALUE.
J1	10 WAY R.A BOXED HEADER.
J3	8 WAY SIL. STR. MALE LATCHING CONN.
R1	4K7 ¼ WATT RES. ± 1% 50PPM
R2	10K ¼W ± 5%
R3	560R ¼W ± 1%
R4	4K7 ¼W. ± 1% 50PPM
R5	100R ¼W ± 1% 50PPM
R6	820R ¼W ± 1% 50PPM
R8	560R ¼W ± 1%
R9	470R ¼W ± 1% 50PPM.
C1	100N S CAPACITOR CERAMIC ?
C2	—— DITTO ——
C3	0.47μF 10% 63V
IC1	SN 74 136 N
IC2	MC 78L05 CP
TR1	BC 182 LB
M1	ASTEC UM 1233 E36 MODULATOR
R?(?)	470R ¼W ± 1% 50PPM

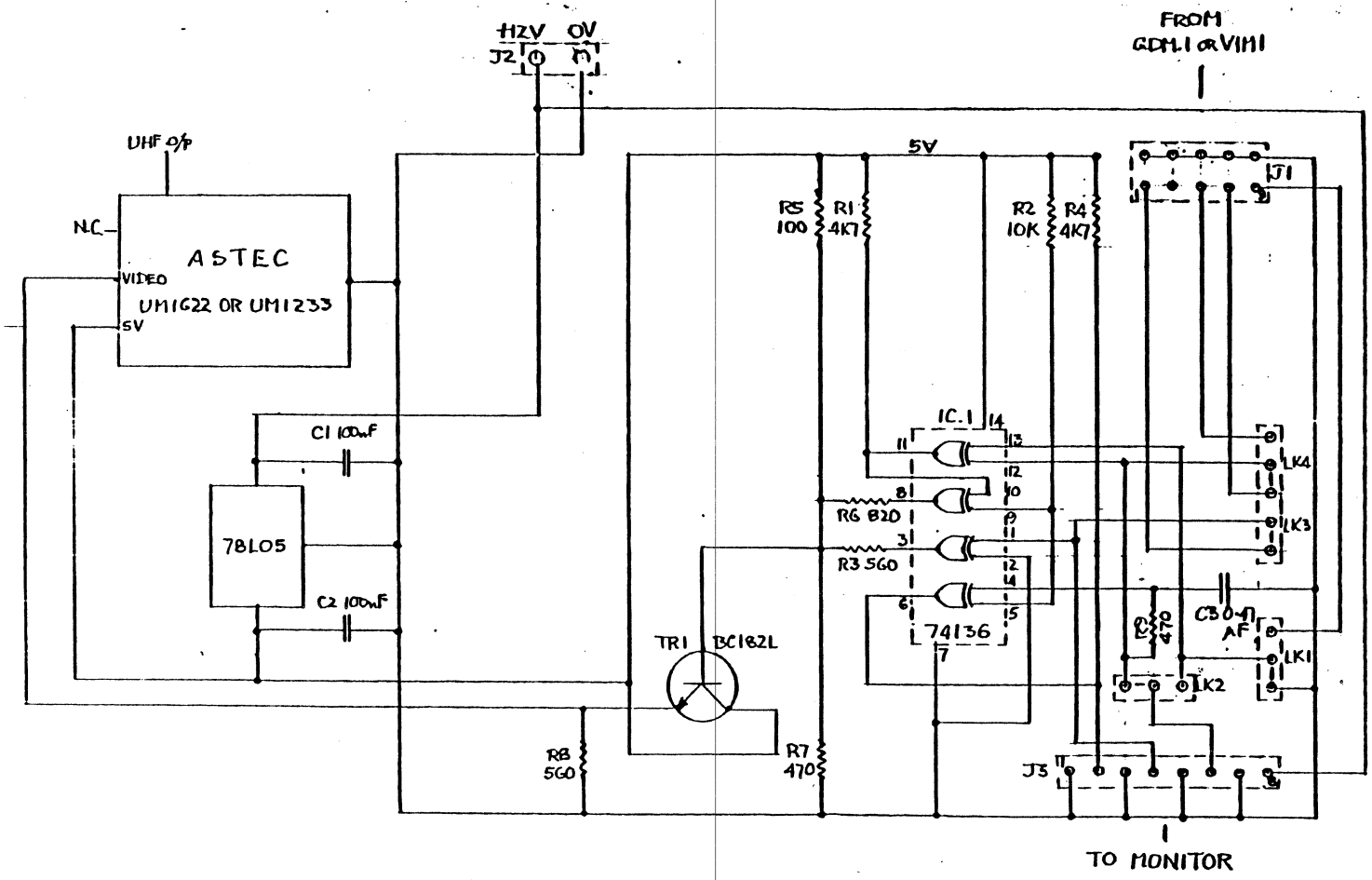
REVISIONS

TITLE
DRACS MKIII & 85:- MODULATOR FOR NEVIN 7"_ COMPONENT LAYOUT.

JOB	
CODE	
DRN.	PRB
CKD.	
DATE	15.5.86

GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PB
Phone: 0484 38101/2

DRG. No.
S2099



J1 CONNECTIONS		
PIN Nº	LINKS AS SHOWN	ALT. LINK CONN'S
1	VIDEO	N.C.
3	N.C.	N.C.
5	N.C.	VERT. SYNC.
7	COMP. SYNC.	VIDEO
9	N.C.	HORIZ. SYNC.
2,4,6,8,10	Ov	Ov
	FOR GDM.1	FOR VIM.1

REVISIONS

TITLE

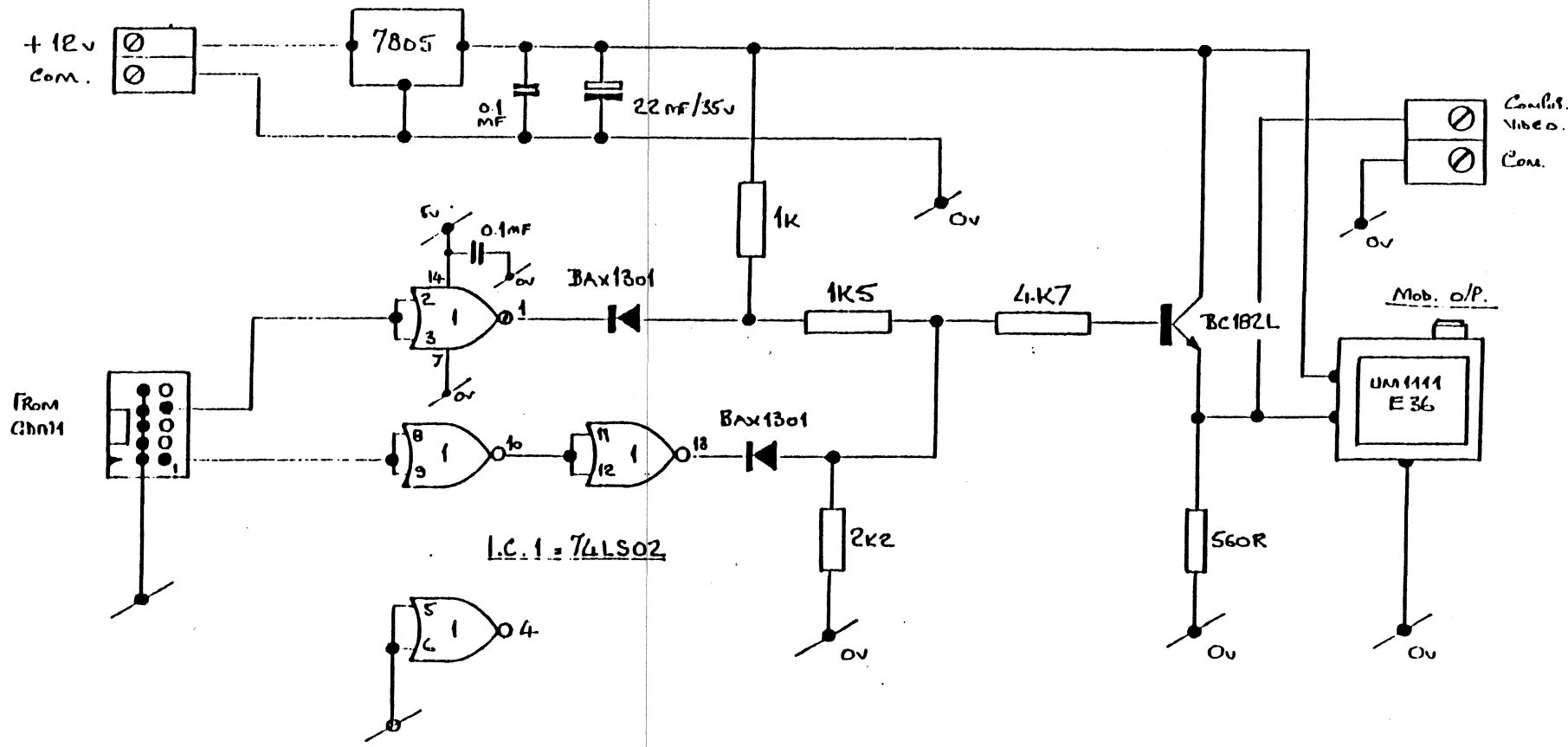
CIRCUIT DIAGRAM FOR 'NEVIN' MONITOR MODULATOR BOARD.

JOB	
CODE	
DRN.	S.B.
CKD.	
DATE	5.12.84

GSM ELECTRICAL CONTROLS LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD.
W. YORKS. HD1 3PJ
PHONE 0484 351012

DRG. No.

M1958



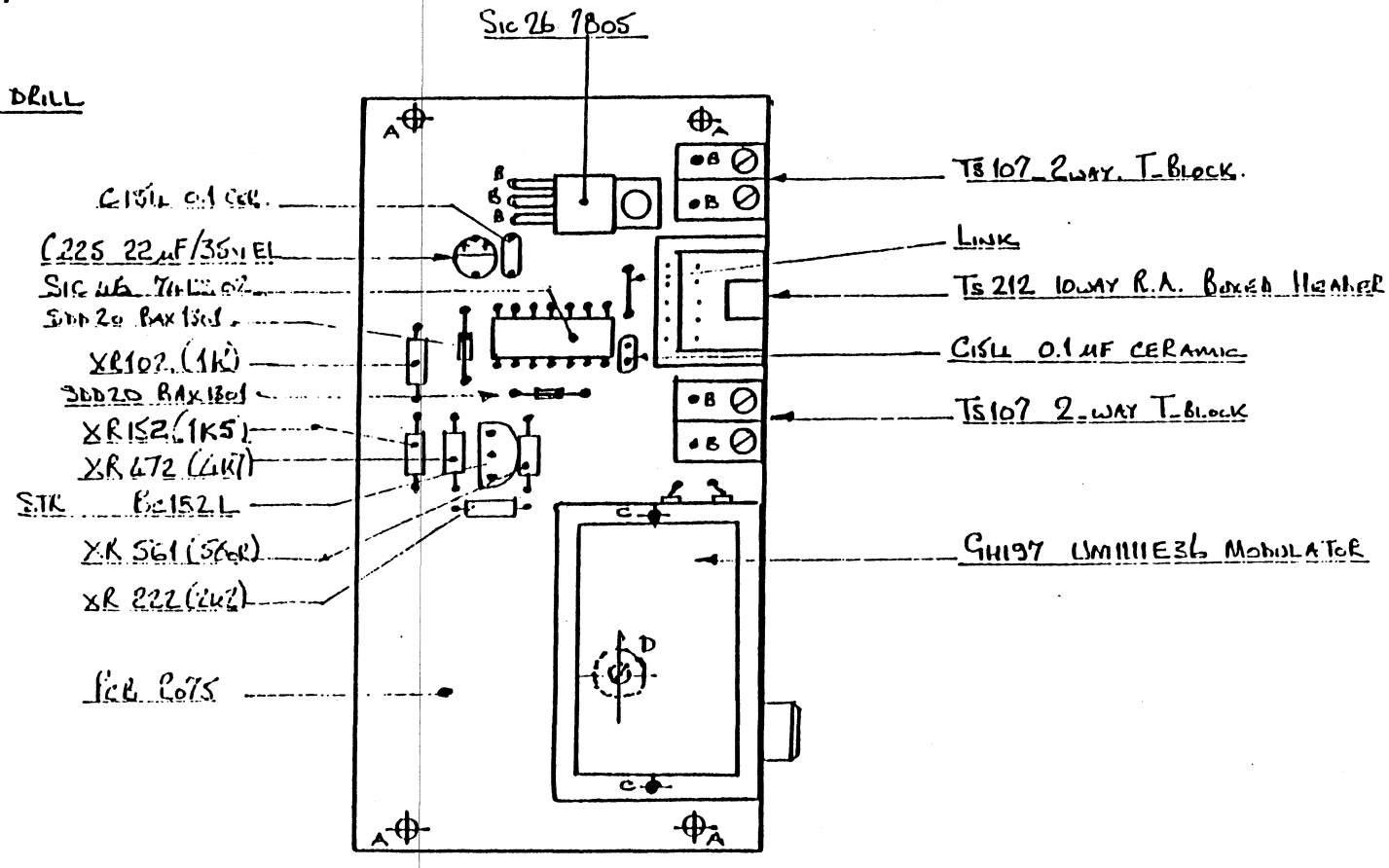
SEE DRG. S2076 FOR COMPONENT LAYOUT.

REVISIONS	JOB		GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PG Phone: 0484 38101/2
	CODE		
TITLE: TO SUIT KME MONITOR. ORAC:- CIRCUIT DIAGRAM OF MODULATOR PC 2075 (COMPOSITE VIDEO). '85	DRN.	PKJ	DRG. No. S2077
	CKD.		
	DATE	10.3.86	

Hole Sizes:-

A = Nº 29 DRILL — 4 off.
B = Nº 54 DRILL — 7 off
C = Nº 52 DRILL — 2 off.
D = Nº 1 DRILL — 1 off.

Remaining Holes — Nº 60 DRILL

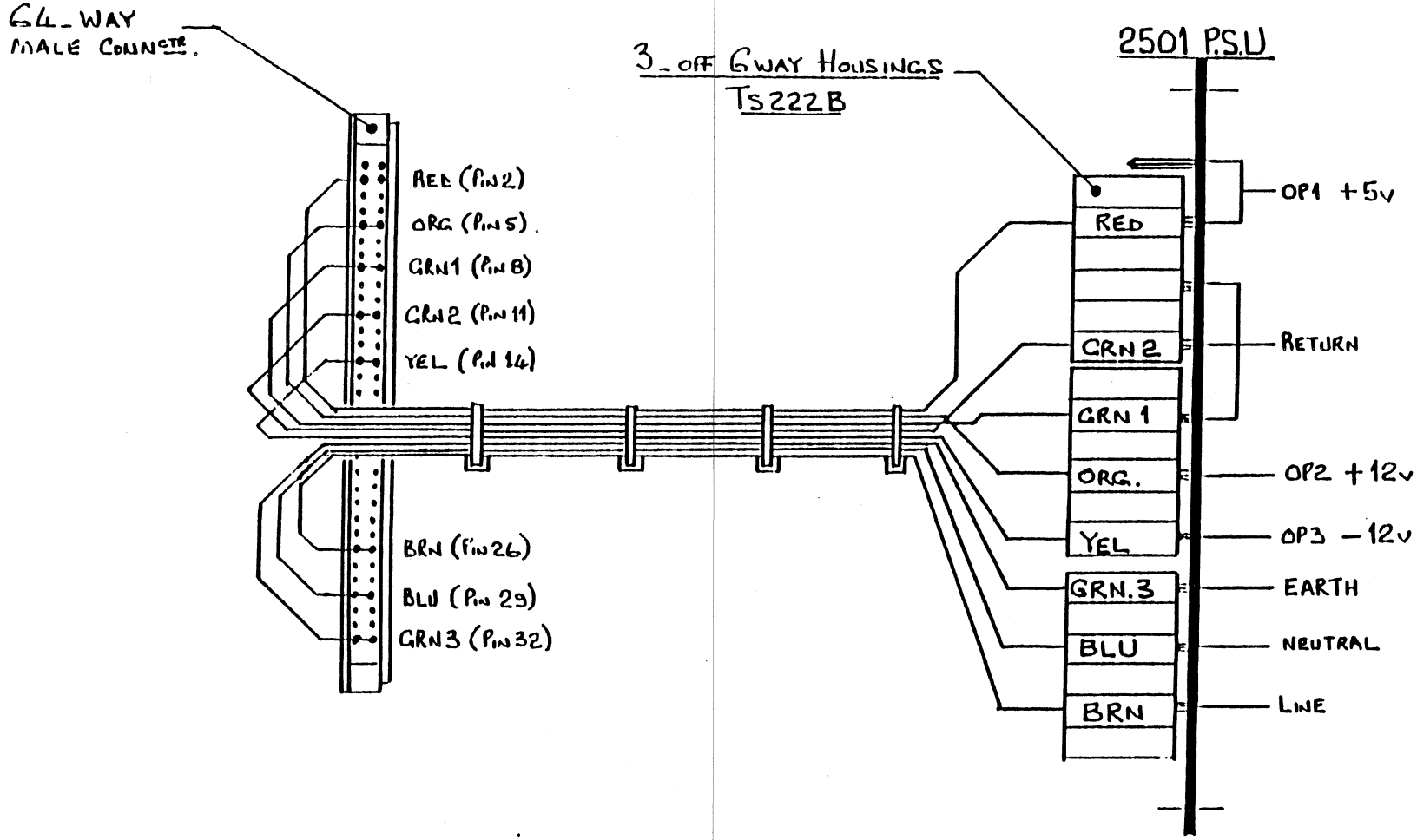


SEE DRG. S2077 FOR CIRCUIT DIAGRAM.

REVISIONS	JOB	
	CODE	
TITLE To suit KME Monitor	DRN.	PRD
"ORAC":- Revised Modulator PCB — Component Layout & Drilling '85'	CKD.	
	DATE	7.3.86

GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PG
Phone: 0484 35101/2

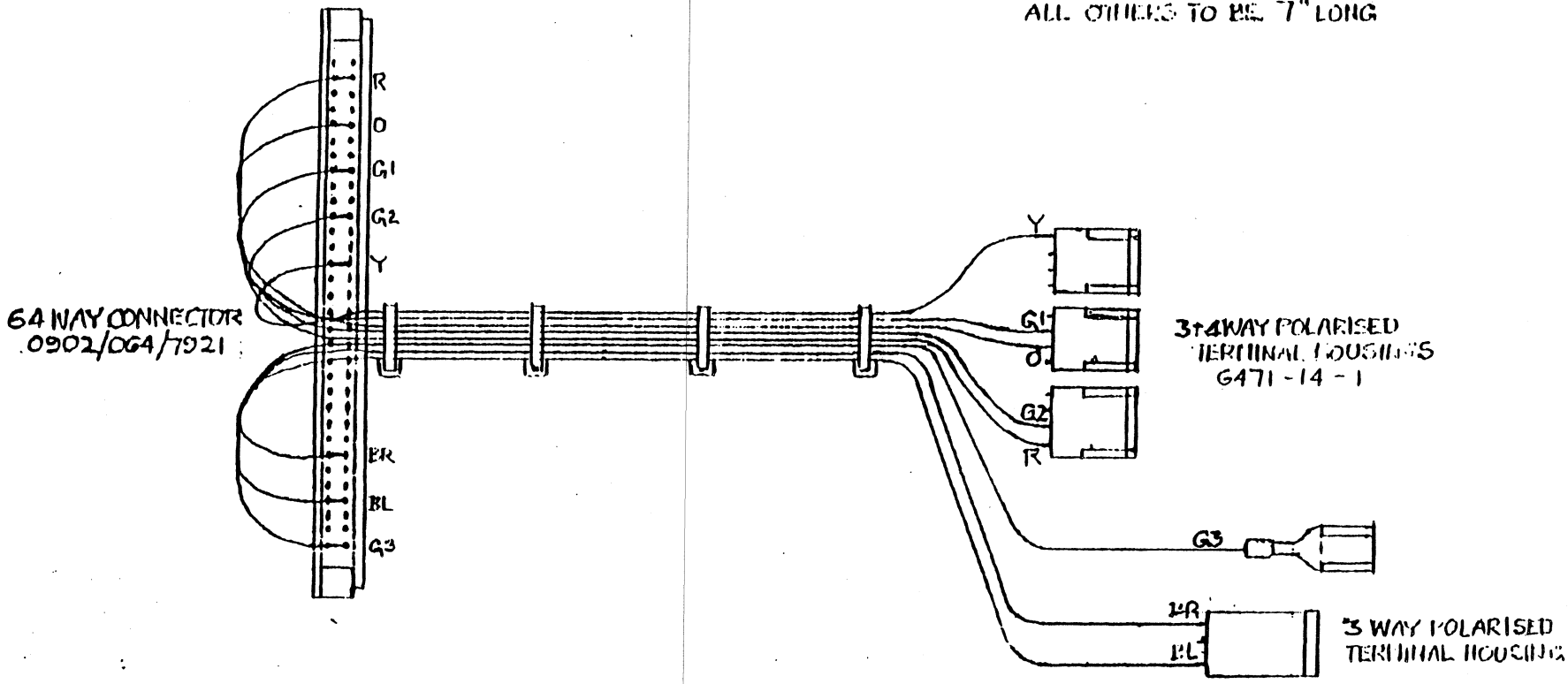
DRG. No.
S 2076



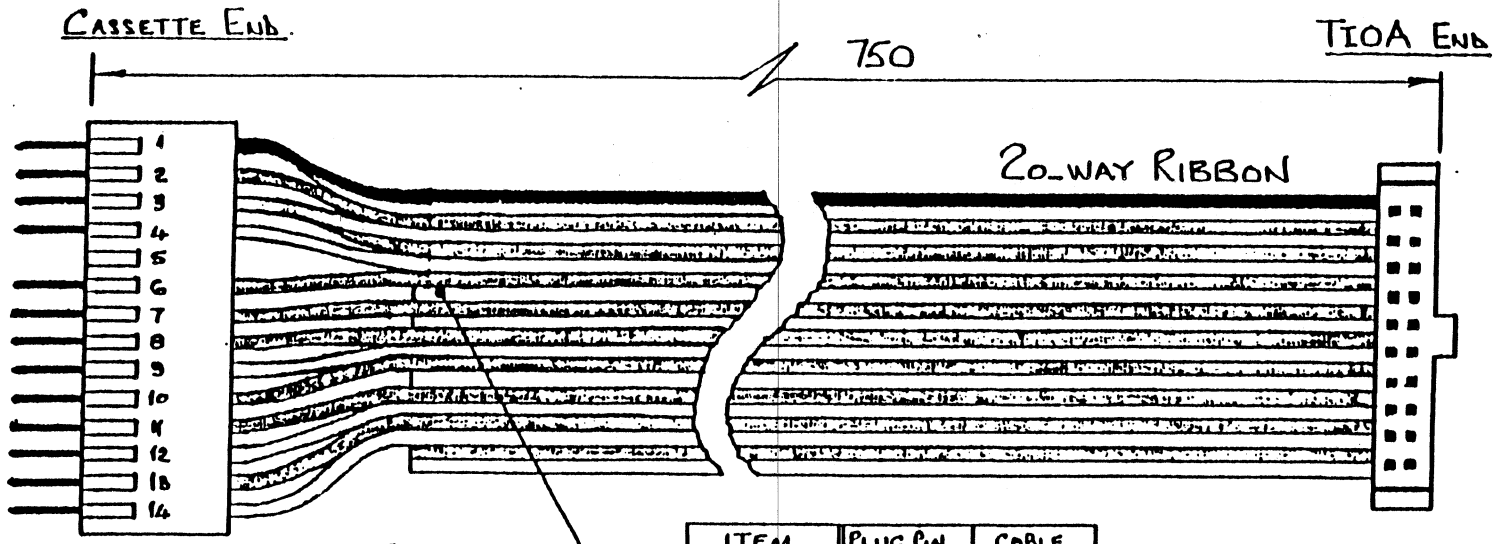
REVISIONS		JOB		GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PG Phone: 0484 38101/8	DRG. No. S 2123
TITLE ORAC 85 — 2501 Power Supply Unit Connector From P.S.U. To Rack.		CODE			
		DRN.	PCP		
		CKD.			
		DATE	25.6.86		

NOTE

BLUE, BROWN & G3 - 9" LONG
ALL OTHERS TO BE 7" LONG



REVISIONS MOD. ARR.	JOB		GBM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PG Phone: 0484 38101/2
TITLE Ref. B151 ASTEC POWER SUPPLY MODULE RACK CONNECTOR FOR 'ORAC' MKIII & '85'	CODE		DRG. No. S1861
	DRN.	P.B.	
	CKD.		
	DATE	4.4.84	



14-WAY IN-LINE PLUG
PIN 5 OMITTED

ITEM	PLUG PIN	CABLE
+12v	1	1 & 2
COM. GND	2	3
" "	3	4 & 5
" "	4	6
KEYWAY	5	
$\overline{WDA}$	6	7
$\overline{BET}$	7	9
$\overline{WCD}$	8	11
$\overline{REV}$	9	12
$\overline{FWD}$	10	13
$\overline{RDC}$	11	15
$\overline{RDA}$	12	16
$\overline{CIP}$	13	17
$\overline{WEN}$	14	18

20-WAY MOLEX
CONNECTOR

REVISIONS

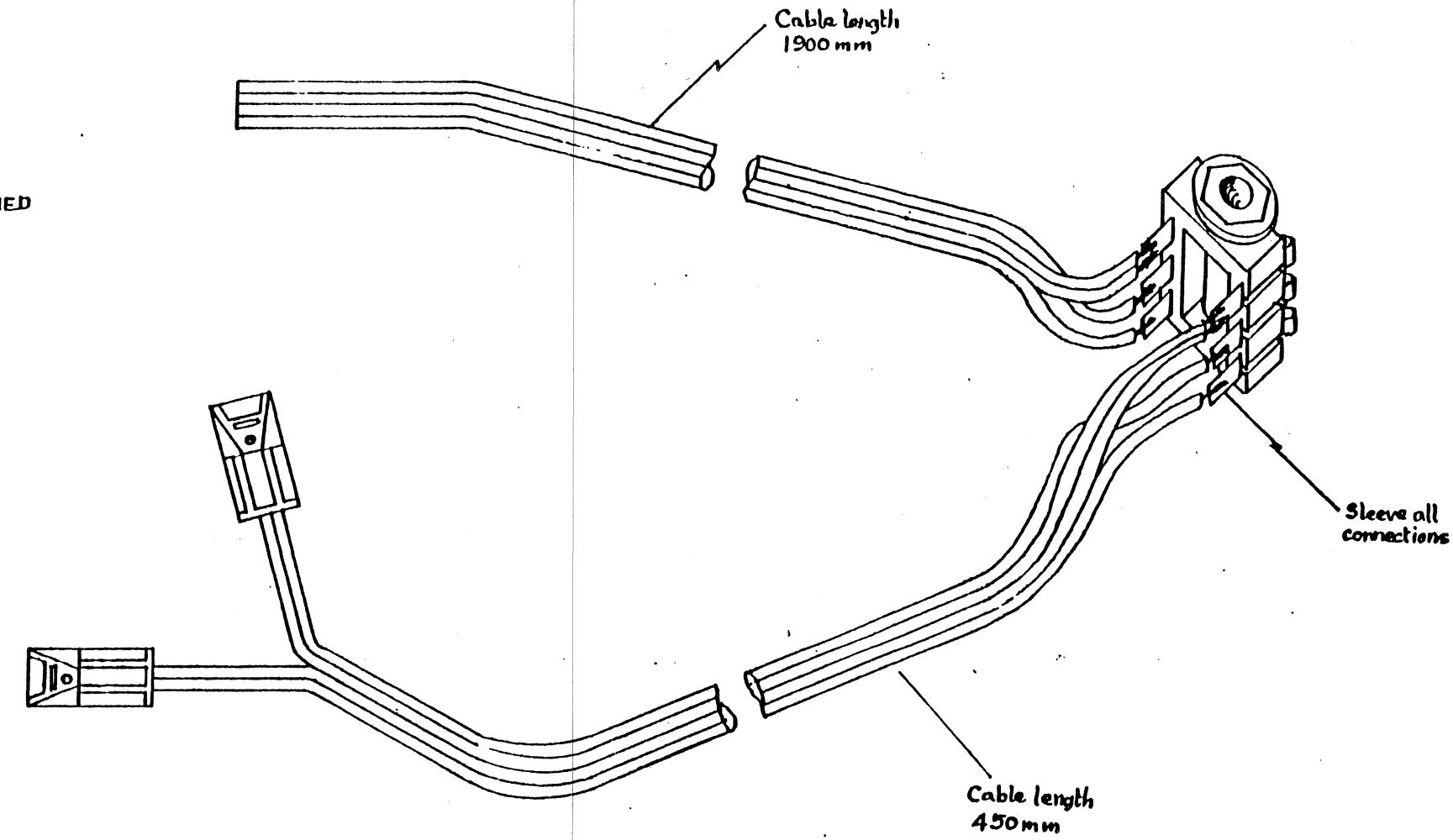
TITLE
ORAC 85 :- TIOA/DATA CASSETTE RIBBON CABLE DETAILS.

JOB	
CODE	
DRN.	RDT
CKD.	
DATE	19.5.86

GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PB
Phone: 0484 38101/8

DRG. No.
S 2100

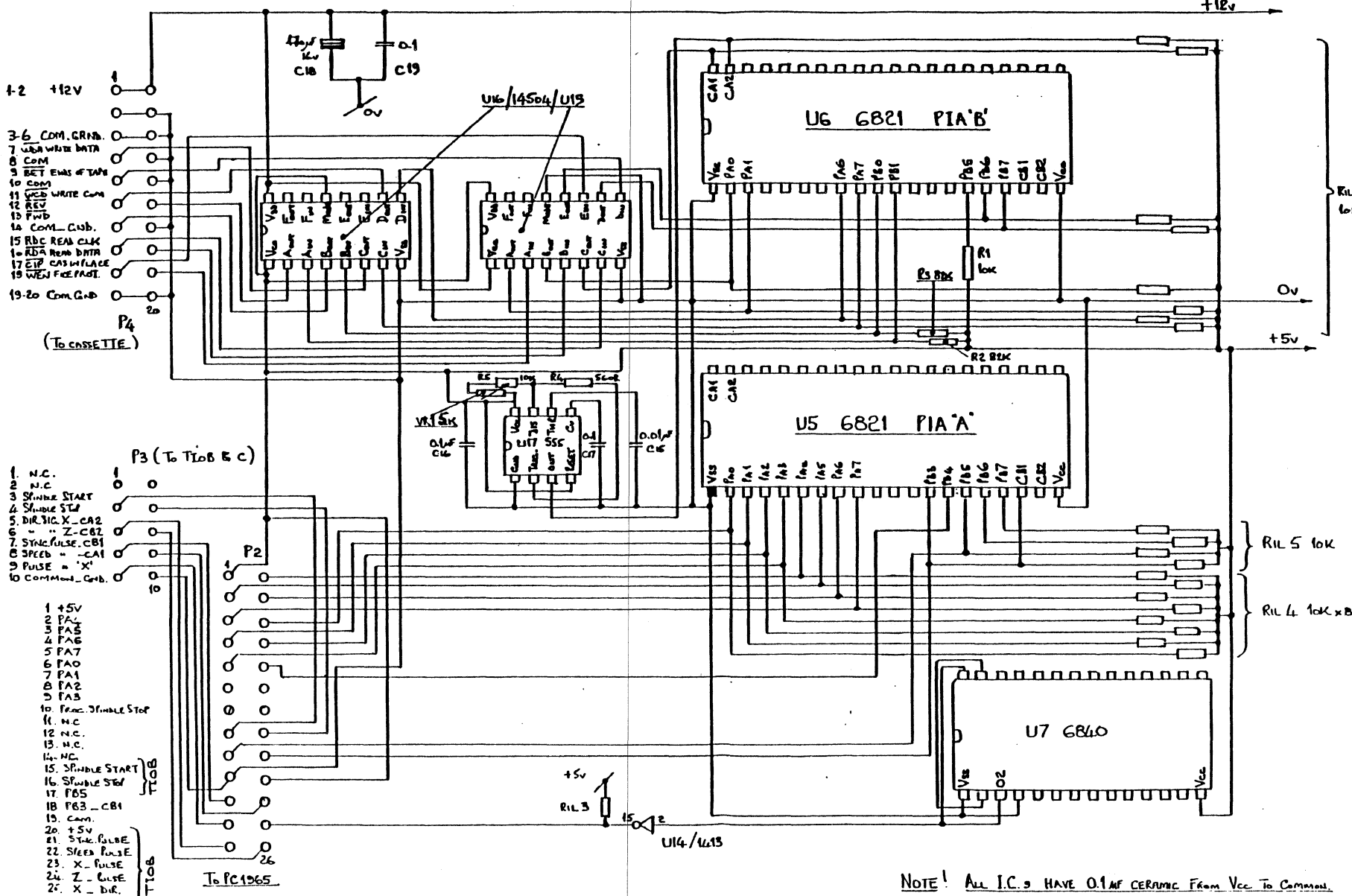
CABLE SUPPLIED
WITH SHARP
CASSETTE



REVISIONS	JOB		DRG. No. S1632
TITLE JACK SOCKET CONNECTION DETAILS ORACS MK III /85 ETC	CODE		
	DRN.	A. C. H.	
	CKD.		
	DATE	18. 11. 82.	

GSM ELECTRICAL CONTROLS LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD.
W. YORKS. HD1 3PJ
PHONE 0484 35101/2

JOHN H. WARD 15150/77



REVISIONS

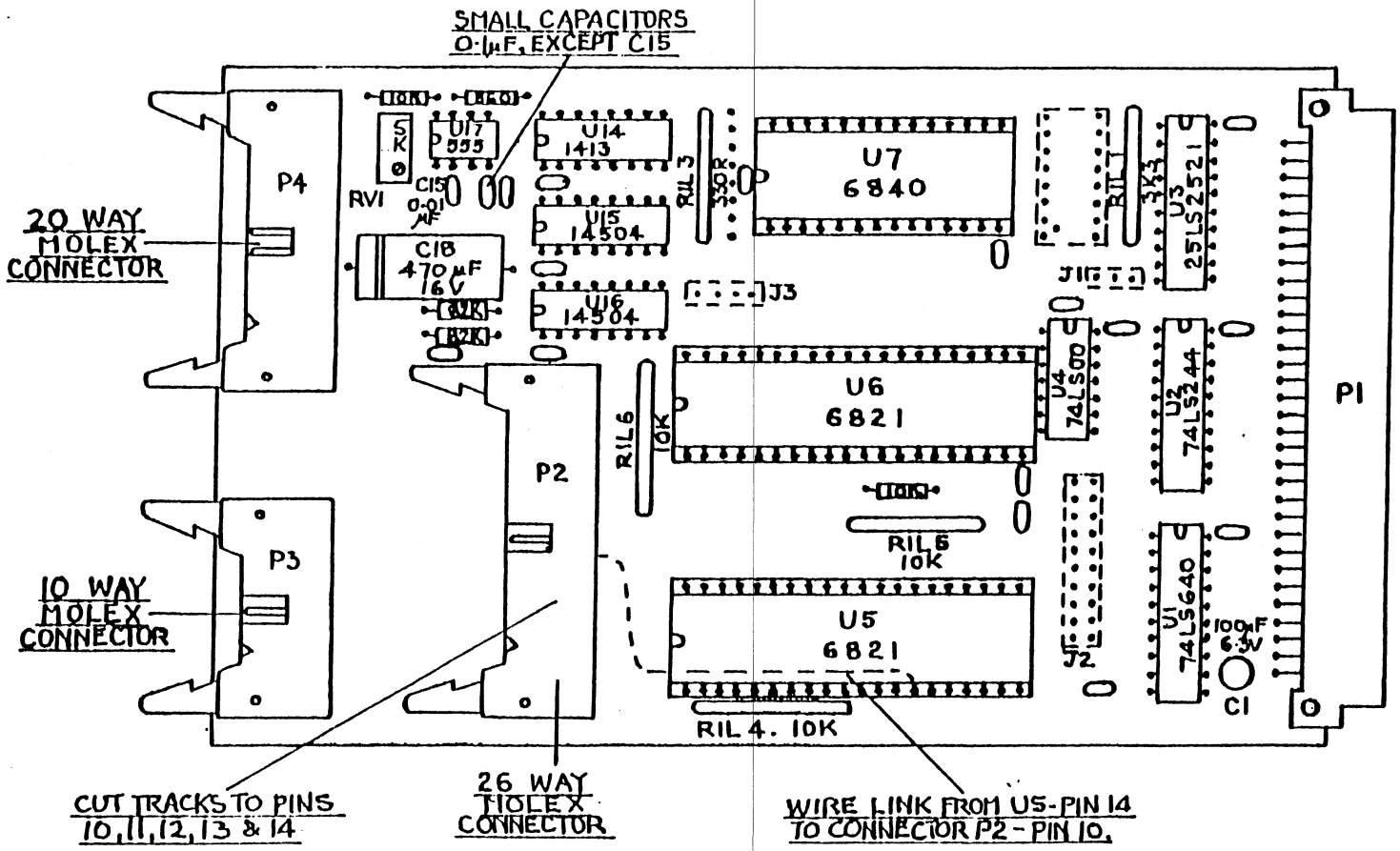
TITLE

ORAC 85: TIOA BOARD_CIRCUIT DIAGRAM.

JOB	
CODE	
DRN.	PRJ
CKD.	
DATE	20.5.86

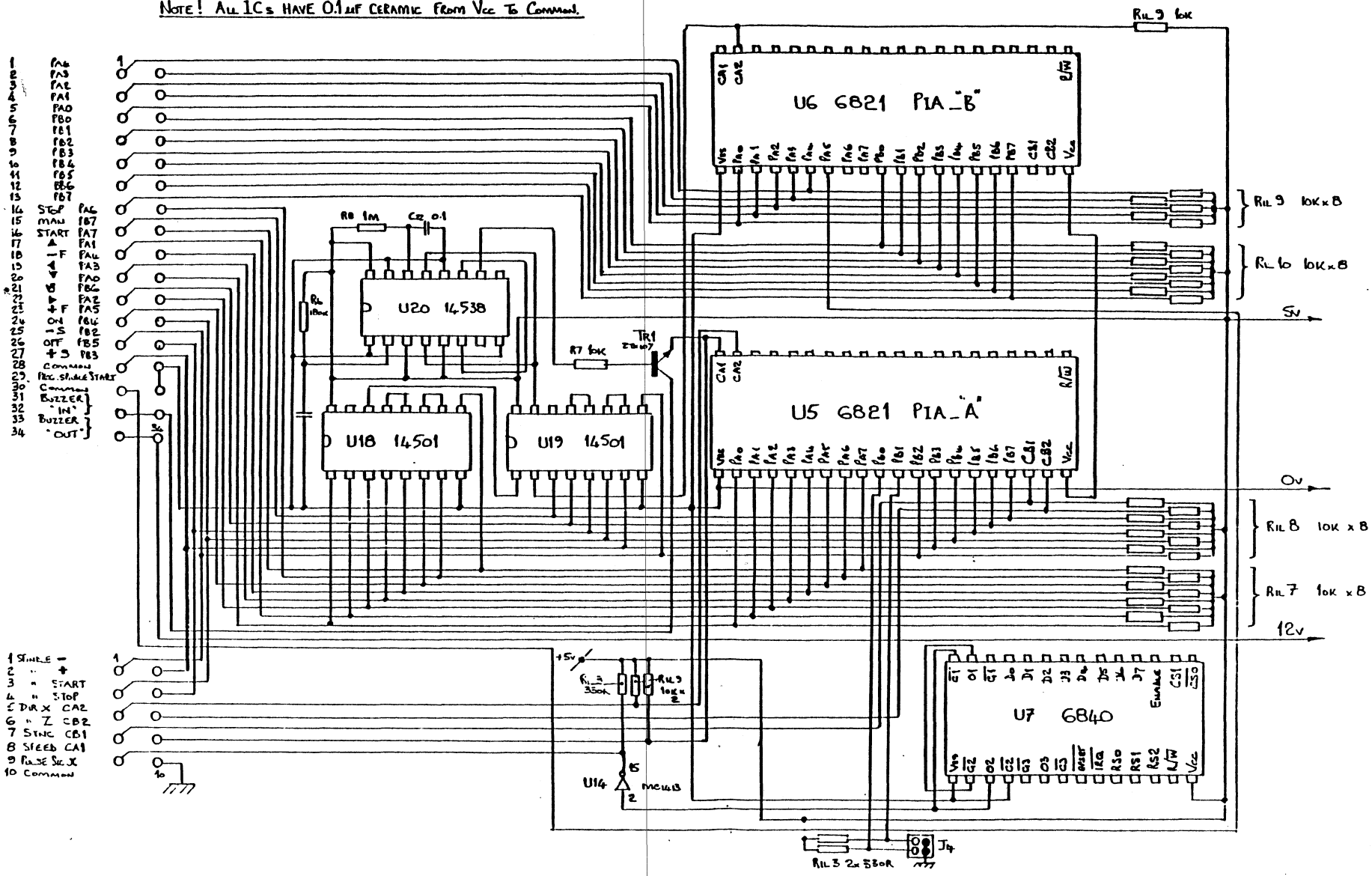
GBM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PB
Phone: 0484 38101/2

DRG. No. M2102



REVISIONS	JOB		DRG. No.
TITLE	CODE		S 2016
COMPONENT LAYOUT FOR T10-A TIMER MODULE -'ORAC 85'	DRN.	L.B.	GSM ELECTRICAL CONTROLS LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD. W. YORKS. HD1 3PJ PHONE 0484 35101/2
	CKD.		
	DATE	6.3.85	

KEITH WARD



REVISIONS

TITLE

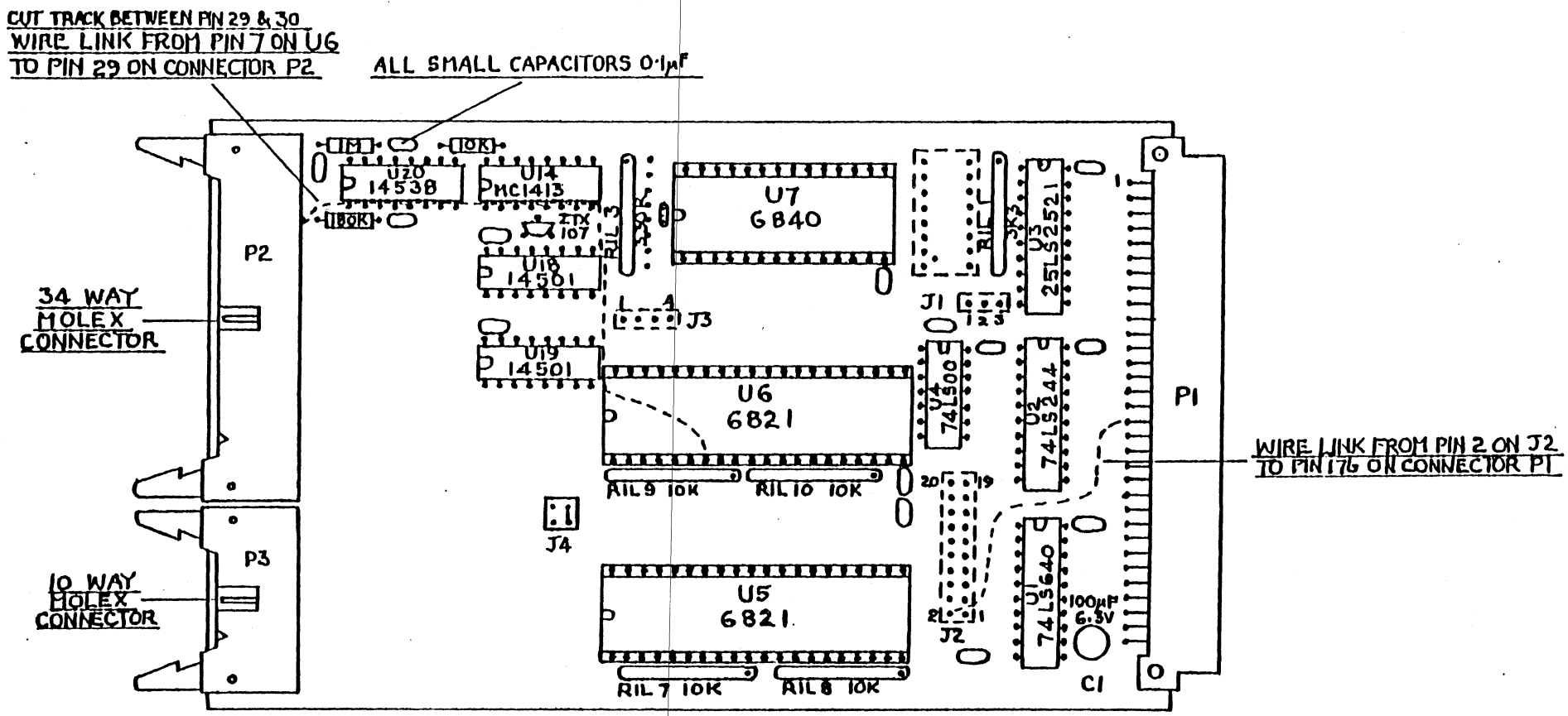
ORAC 85 :- T10B _ CIRCUIT DIAGRAM.

JOB	
CODE	
DRN.	PRT
CKD.	
DATE	20.6.86

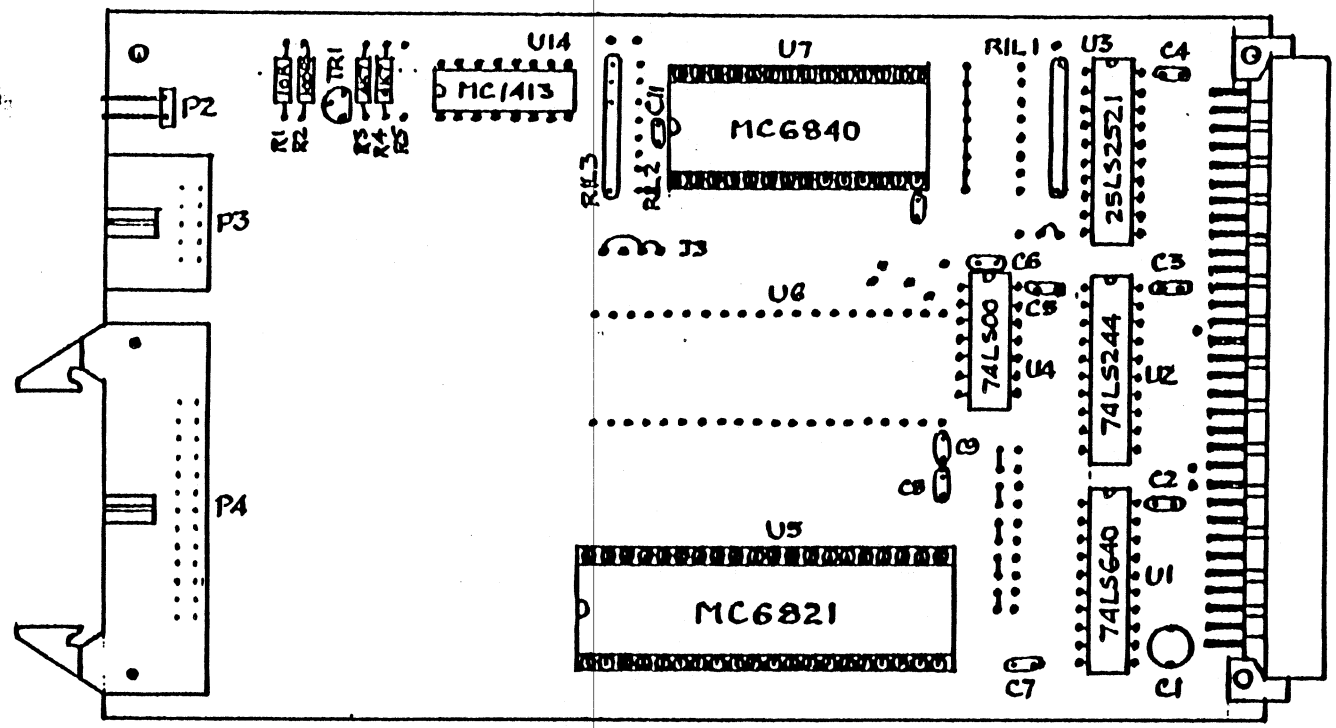
GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PS
Phone: 0484 35101/2

DRG. No.

M2103



/15	JOB		DRG. No. S 2013
TITLE: COMPONENT LAYOUT FOR T10-B TIMER MODULE -'ORAC 85'	CODE		
	DRN.	S.B.	GSH ELECTRICAL CONTROLS LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD. W. YORKS HD1 3PJ
	CKD.		
	DATE	6.3.85	

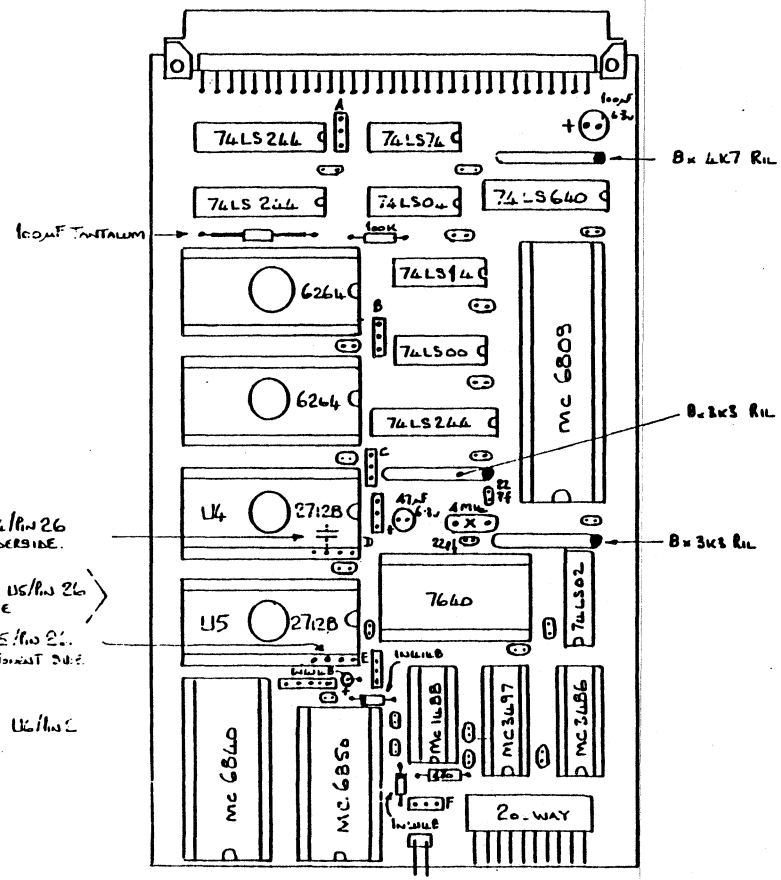


REVISIONS	JOB	
	CODE	
TITLE	DRN.	P.B.
ORAC 85: COMPONENT LAYOUT FOR TIO.C MODULE	CKD.	
	DATE	31.7.85

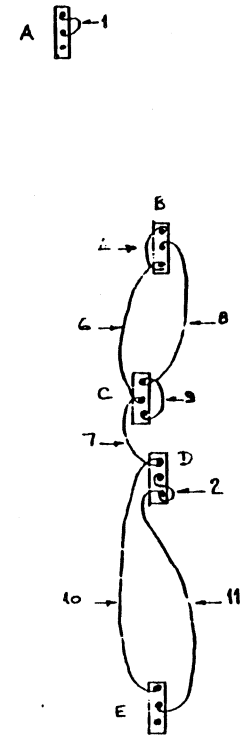
GSM-SYNTEL LTD.
VICTORIA WORKS,
QUEENS MILL ROAD,
HUDDERSFIELD,
W. YORKS. HD1 3PB
Phone: 0484 38101/2

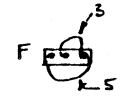
DRG. No.

S 2044

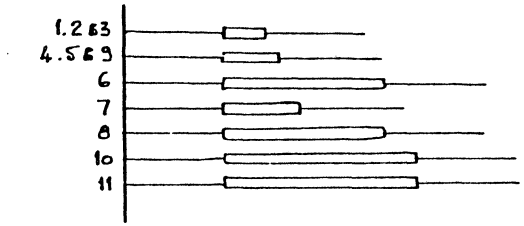


ALL CAPACITORS ⊖ ARE 0.1 uF CERAMIC
UNLESS OTHERWISE STATED





LENGTHS

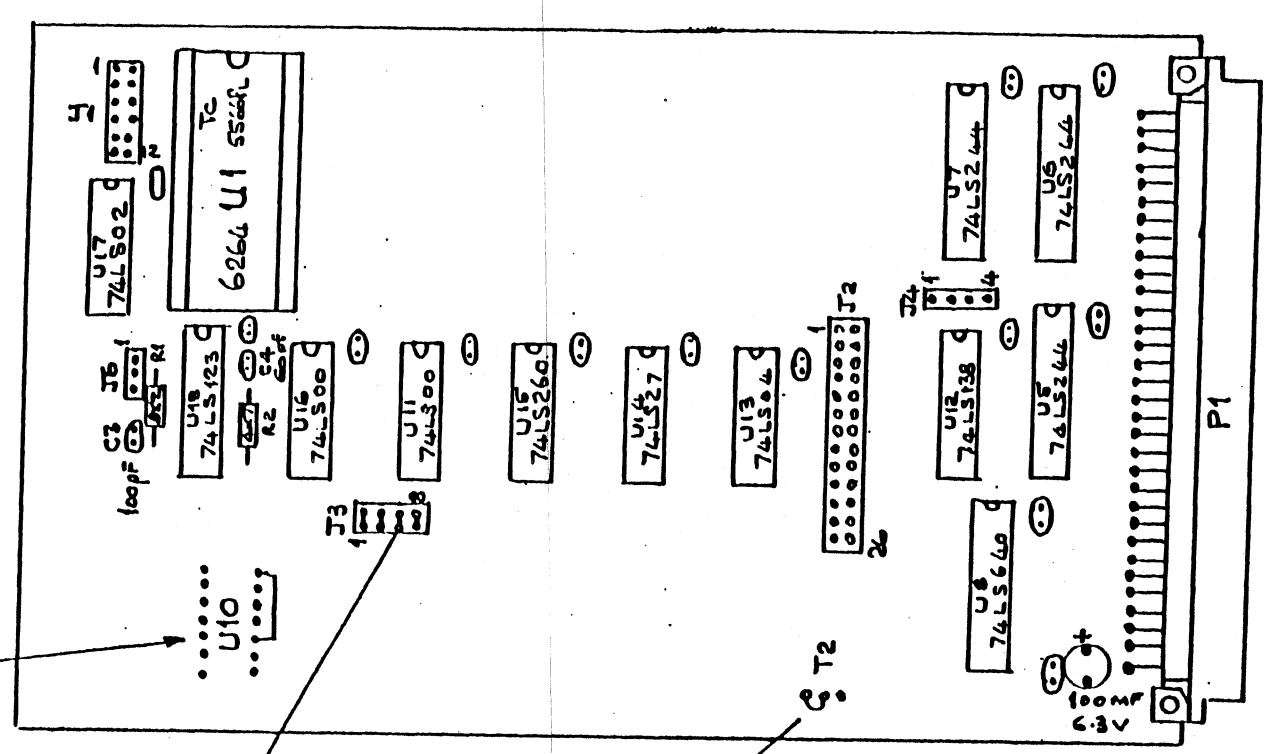


NOS. 1.2.3.8 & 11 ARE BLUE
NOS. 4.5.6.7 & 9 ARE RED.

DETAILS OF WIRE-WRAP LINKS.

REVISIONS		JOB		GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PG Phone: 0484 38101/2	DRG. No. M2104
TITLE		CODE			
ORAC 85 :- MP09 PROCESSOR BOARD — COMPONENT LAYOUT ETC.		DRN.	RJH		
		CKD.			
		DATE	21.5.82		

ALL CAPACITORS ARE 0.1 NF CERAMIC EXCEPT WHERE SHOWN.



LINK PINS 10, 14 ON U10

LINK PINS 1-2, 3-4, 5-6 & 7-8 ON J3 USING 1/0.25 mm WIRE

LINK T2 AS SHOWN

LINKING

J1

PINS 1-3-5-9-11 & 2-4-6-10-12

J2

PINS 1-3-5-7-9 & 11-14 & 13-15-16-17 & 19-21-23-25-26

J3

(AS SHOWN)

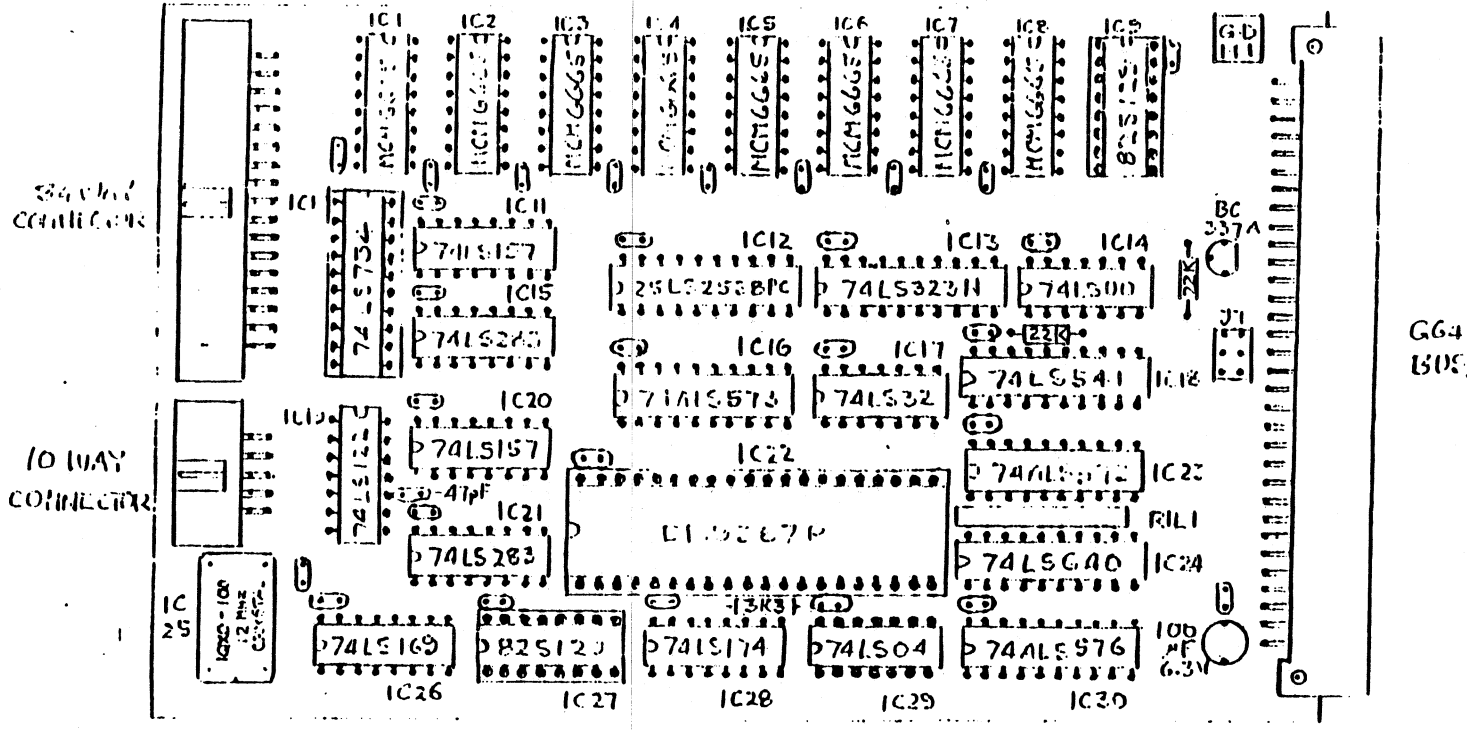
J4

PINS 3 & 4

J6

PINS 1 & 2

REVISIONS	JOB		GBM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PB Phone: 0484 38101/8	DRG. No. S 2101
TITLE ORAC 85: DEDICATED PRM-1 BOARD REF^en X84	CODE			
	DRN.	PRJ		
	CKD.			
	DATE	20.5.86		



ALL CAPACITORS 0.1μF, EXCEPT WHERE MARKED

REVISIONS IC10 CHANGED TO 74LS734-31.10.85	JOB		GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PG Phone: 0484 35101/2	DRG. No. S0061
TITLE COMPONENT LAYOUT FOR SYS 6DM MODULE.	CODE			
	DRN.	J.J.		
	CKD.			
	DATE	23.2.84		

J. H. WARD 9070/83

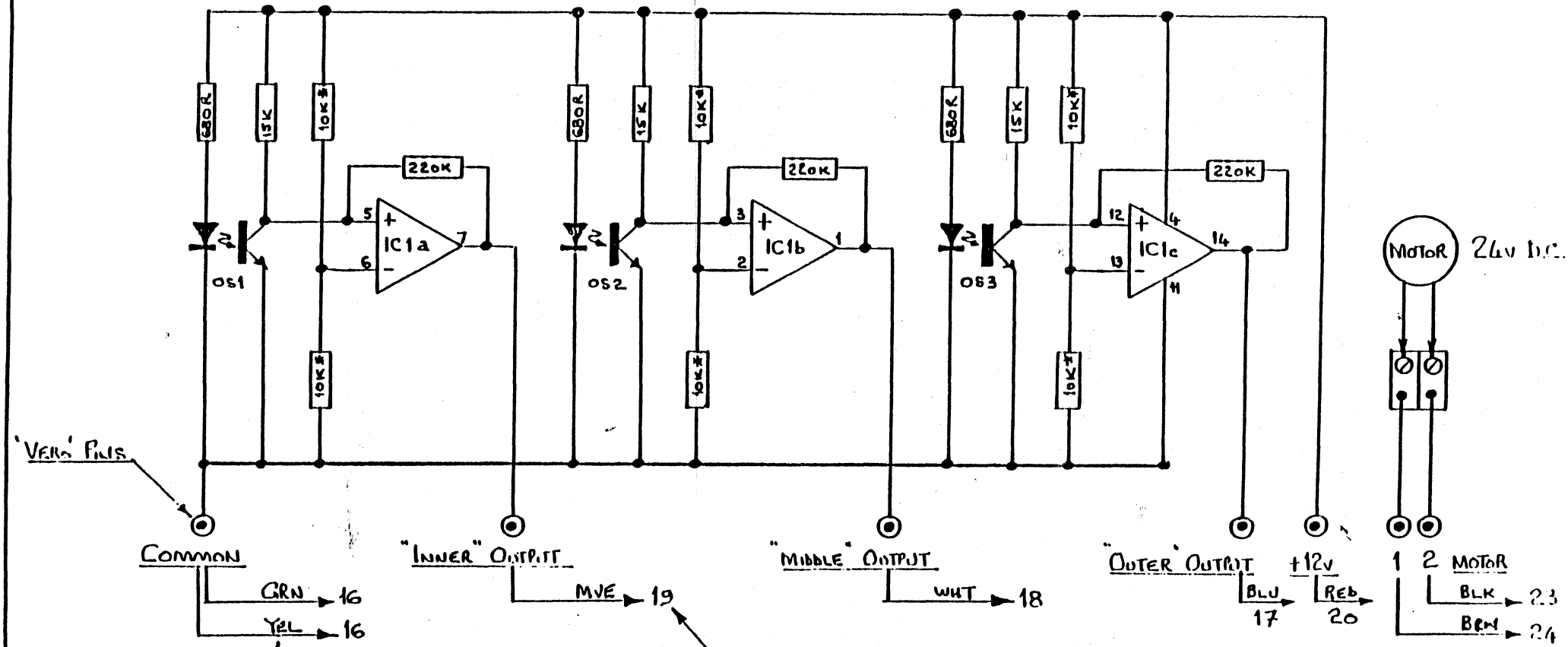
SEMICONDUCTORS.

IC1 — RS TYPE 34B (QUAD 741).

OS1_3 — RS REFCE 307_913 (REFLECTIVE OPTO SWITCH).

* THESE PAIRS OF 10K RESISTORS REPLACE 10K MULTI_TURN POTS ON EARLIER VERSIONS

680R RESISTORS ARE 1/2 WATT, REMAINDER ARE 1/4 WATT.

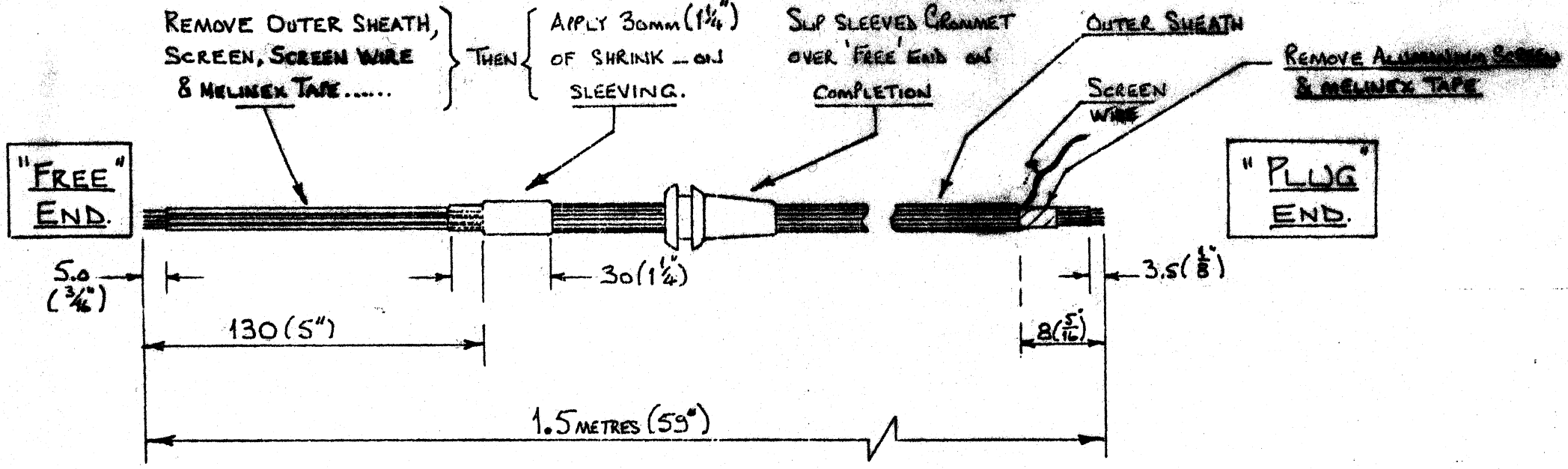


NOTE! COLOURS ARE THOSE OF CONNECTING CABLE CORES. NOS ARE THOSE OF TERM^L BLK. 'F' OF PC 1965 (SEE DRG. M2106).

SEE DRG. S2121 FOR COMPONENT LAYOUT.

REVISIONS	JOB	GSM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PD Phone: 0484 38101/2	DRG. No. S2124
TITLE ORAC 85:- CIRCUIT DIAGRAM ETC. FOR PC 1928 — SENSOR BOARD FOR INDEXING TOOL POST.	CODE		
	DRN. PKP		
	CKD.		
	DATE 25.6.86		

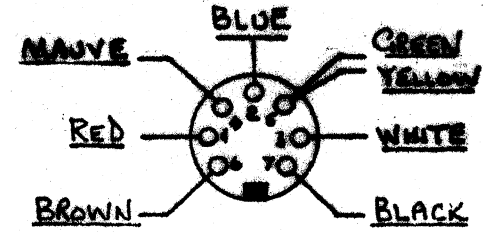
IMPORTANT! FIRST: STRIP 8mm (5/16") FROM BOTH ENDS AND CHECK THE LAY OF COLOURS. SELECT THE 'PLUG-END' AS THAT WHOSE COLOUR SEQUENCE MATCHES THE REAR VIEW OF PLUG BELOW. THE OPPOSITE END THEN BECOMES THE 'FREE END' AND CAN BE STRIPPED TO 130mm (5") TOTAL AS SHOWN BELOW.



NOTES

1. DIMENSIONS IN MM. (INCHES) — INCH DIMENSIONS ARE NEAREST 'ROUND FIGURE'.
2. AT 'PLUG' END — STRIP CABLE & ASSEMBLE PLUG PER INSTRUCTIONS IN THE PACK.
3. FOR EASE OF ASSEMBLY OF PLUG :~
   a) ENSURE ALL LENGTHS ARE ACCURATE.
   b) USE A BASE-BOARD-MOUNTED SOCKET AS A HOLDING JIG WHEN SOLDERING WIRES TO PINS — INSERT PINS PRIOR TO SOLDERING.

PLUG REF. L1304A/7/FP (FARNELL).



REAR VIEW OF PLUG

REVISIONS			
	JOB		GBM-SYNTEL LTD. VICTORIA WORKS, QUEENS MILL ROAD, HUDDERSFIELD, W. YORKS. HD1 3PB Tel: 0484 35101/2
	CODE		
TITLE 'ORAC': INTERFACING TOOL-POST :- TOOL-POST CONNECTING CABLE.	DRN.	IRB	DRG. No. S1937
	CKD.		
	DATE	4.10.84	