A high resolution electro-mechanical actuator for automated skiving

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Abstract

A High Resolution Electro-Mechanical Actuator for Automated Skiving

by M.O.Newton

M.Sc Thesis 1994

This thesis describes a step by step approach to the design, assembly and final testing of a high resolution electro-mechanical actuator which will be an integral part of an automated skiving process used in the shoe manufacturing industry. It is referred to as a skiving machine in this thesis.

The thesis provides the necessary background information as to the reasons for replacing a previous machine and then investigates the features considered suitable for incorporation into the new skiving machine. An investigation is carried out into the desired objectives of the new design and the components to be used. A discussion then follows into the most desirable design systems to be considered for the skiving machine. It is concluded that a system comprising of:- actuating pins, levers, transmission wires and solenoids has the most appropriate combination of characteristics for a satisfactory machine. A detailed description of the completed design and its parameters is given in relation to the initial objectives. There follows a description of the manufacture and assembly based upon the design principles. The thesis then describes the performance of the machine and evaluates its skiving capability. Finally, suggestions for future improvements and further integration of the automation process in shoe manufacturing are made.

A High Resolution Electro-Mechanical Actuator for Automated Skiving

by

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A thesis submitted in fulfilment of the requirements for the degree of Master of Science

School of Engineering and Computer Science

The University of Durham

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DECLARATION

The work contained in this thesis has not been submitted elsewhere for any other degree or qualification and unless otherwise referenced it is the authors own work.

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ABBREVIATIONS AND NOMENCLATURE

ASCII	American standard code for information interchange
BUSM	British United Shoe Machinery Co. Ltd.
C	Coil Ratio of a spring (ratio of springs diameters)
E	Young's Modulus or Modulus of Elasticity
F	Applied Force (N)
G	Torsional Modulus (used for spring steel calculations)
G.A. drawing	General Assembly drawing
I	Second moment of area
k	Radius of Gyration
M	Bending Moment
M68000	Motorola microprocessor
n	Number of active coils of a spring
(sp_o)	Previously used spring.
(sp_n)	New or recent spring.
S	Stiffness of a spring
SDB	Tms34010 Software Development Board
Tms34010	Texas Instruments Graphics Systems processor
VIA	Versatile Interface Adapter circuits used in the M68000 Motorola microprocessor
Z8000	Zilog 16-Bit microprocessor
σ	Bending stress which is dependant on the Bending moment
α	Angular Acceleration

CHAPTER 1

Introduction

1.1 Main Theme

The main theme of the research project described in this thesis is an investigation into the design of a high resolution Skiving Machine, which is to be integrated into an automatic process. The process of skiving involves the machining of pre-cut leather components used in the manufacture of footwear. At present skiving is still carried out by manually operated machinery. It would therefore be a potential breakthrough and an economic advantage if it were to be automated.

1.2 The Aim of Skiving

The skiving process is part of the manufacture of shoe uppers. Skiving is a shoemaker's term for paring leather where it is to be joined so as to maintain uniformity of thickness. Leather shoe uppers are assembled from a number of individual pre-cut leather components. The first stage in shoe upper manufacture is to cut the hide to the predefined shapes, necessary for its assembly. The shapes of the components relate not only to their relative position in assembly, but also to the mechanical function within the shoe during its use. Therefore different shapes are cut from certain areas of the hide to give the required specific properties [R1]. For this reason, components for a particular footwear may be cut from different leather types [R2].

The cutting is manually or semi-automatically performed using shaped dies, and processed in medium sized batches. Identical components may not necessarily be cut in sequence because a single hide of leather is a source of a large number of individually shaped components. It would therefore be impractical to switch hides for the purpose of cutting the same shape or storing similar shapes together.

The cut components need to be separated and identified by hand. After cutting, the components are usually split to produce uniform thicknesses. Different thicknesses are required for different parts of the shoe upper, depending on its function within the overall shoe construction. The extent to which the splitting takes place depends on the quality intended for the final product.

To assemble the shoe upper it is necessary to cement and stitch the leather components. If two component edges are joined together then the resulting overlap will be the sum of the two thicknesses. This is an undesirable feature which detracts from the shoes appearance and level of comfort.

Figure 1.1 shows the necessary thinning of the adjoining regions to eliminate this effect. The shoe making process which is used to achieve this is called Skiving. Skiving is the localised thinning of leather components and it is usually applied up to 50% of the component thickness. It may be assumed that a reduction of this degree would weaken the strength of the leather component. This is not true because most of the strength is contained at 0.1 to 0.3 mm [R3] below its upper surface, which is the outside of the leather. The joint produced is rigid and tolerant to fatigue.

Skiving is required for other reasons, such as decorative folding, joints using folding, and for the connection of the shoe upper to the sole. This is because the projection due to the thickness of the shoe upper would result in discomfort in use. Examples of skiving are shown in figure 1.1. To achieve reliable joints of the shoe it is necessary for the components to be subjected to a roughing process. If the edges are skived, they are automatically roughened [R4] for this purpose. It is noted that skiving may be carried out as a decorative effect, although this is not common in the shoe manufacturing industry.

1.3 Existing Method of Skiving

The current manually operated skiving machines used in the shoe manufacturing industry, all utilize the same basic mechanism. This consists of a

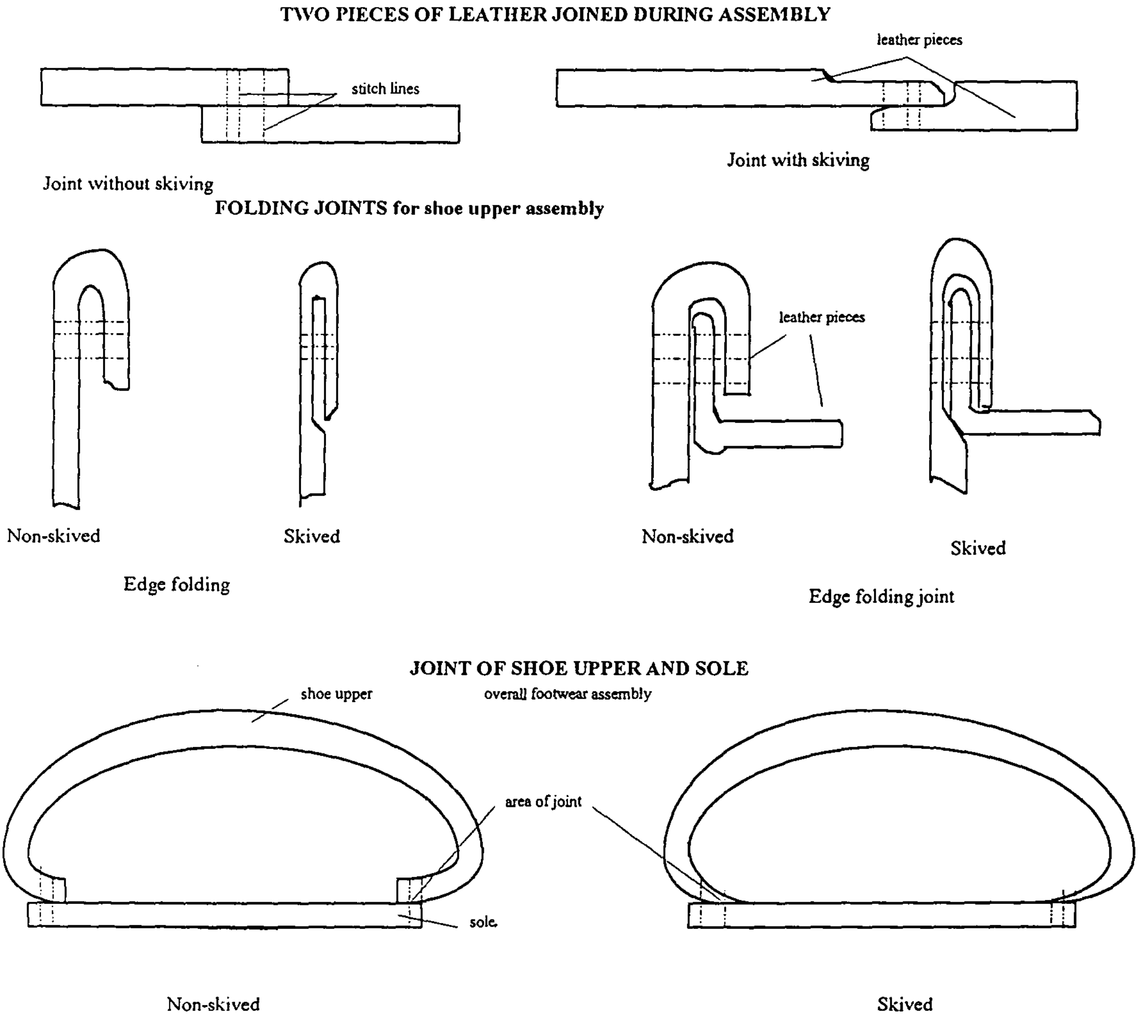


FIG 1.1 *Shows the necessity of skiving for adjoining regions during shoe assembly.*

continuously rotating sharp disk or knife and a suitable metallic guide which is shown in figures 1.2 and 1.3. Figure 1.4 shows a variety of skived leather and figure 1.5 indicates how the skived components are assembled to produce the shoe upper. As can be seen from figure 1.3 the operator adjusts the position of the components as they are passed through the guide and knife. The component is therefore skived along the edges. The guide is adjusted so that the gap between the knife and the guide is less than the thickness of the leather. Therefore when the leather is passed through the guide it is reduced to the thickness of this gap and the leather is skived. This is a relatively skilful process for the operator because it depends on the edge of the shape being manipulated through the guide. The result is a difficult skive along the end of the leather. These machines can also restrict the depth and the width of skive. It is therefore necessary that components should be carefully selected prior to skiving in groups, to minimise tool change and machine settings. i.e. for different thicknesses and physical properties of leather. Manual Skiving Machines have been improved in recent years with respect to tool changes and settings. In some machines there are electronic controls for rapid tool changes and pre-set settings for various types of leather. It is mainly in this area of machinery design that industrial development had been concentrated.

Another type of manually operated Skiving Machine is used to skive the edges of leather belts [R4]. This mechanism uses a splitting machine in conjunction with adjustable metallic jigs which press the edges of the belt against the knife of the splitter. The advantage of this machine is that the jigs can be adjusted so that different skive profiles are produced. The belts have to be presented to the machine at a particular orientation and the length of the skive is not adjustable. It could not perform skiving as required for shoe components.

The process using the basic disk knife Skiving mechanism which is shown in figure 1.2 is a semi-skilled operation.

Fig. 1.2 The basic disk knife based mechanism, in all existing skiving machines (by permission BUSM Ltd).

Fig. 1.3 The manual skiving operation (by permission BUSM Ltd).

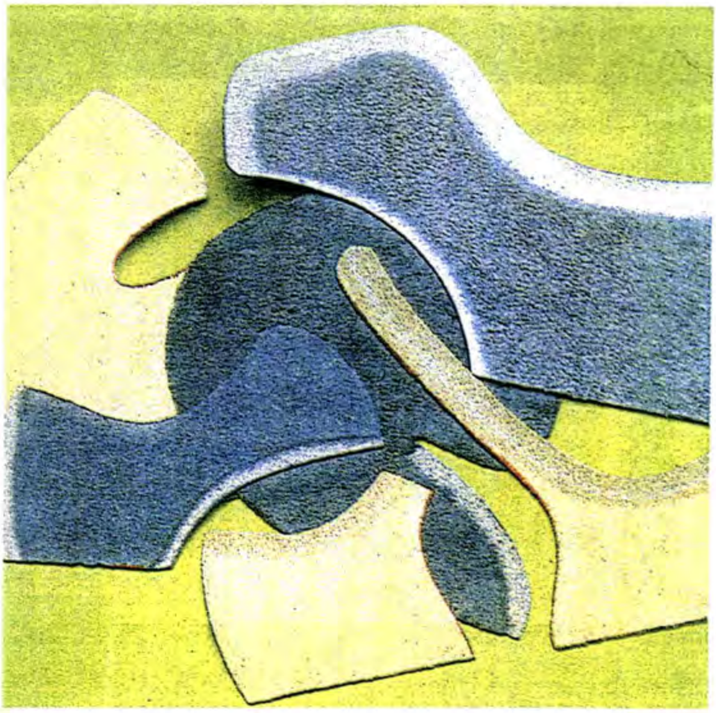


Fig 1.4 A typical example of skived components (by permission BUSM Ltd).

Fig 1.5 The assembly of a shoe upper, comprising a number of skived components (by permission BUSM Ltd).

1.4 Need for Automation in Shoe Machinery

From the considerations pointed out in sections 1.2 and 1.3 it can readily be concluded that an automated skiving system will have the following benefits:-

a) The elimination of the requirement of grouping the components after the cutting process.

b) The termination of a tedious, semi-skilled manual operation.

c) The reduction in labour, tooling, overhead and maintenance costs.

d) A reduction in the present number of skiving process devices required.

e) There would be no requirement for supervisory management.

f) There is the additional flexibility which enables the automation system to be used after normal working hours. Therefore a stock of skived components could be built up. This would be extremely useful if the system needed to be stopped for maintenance or for other reasons during normal working hours.

g) The introduction of a more highly competitive and profitable industrial product.

h) The possibility of linking this automation system with other processes and creating a multiple operation station.

1.5 The Research Background of the Skiving Process

It is important to point out the relevance of the Skiving Machine in relation to the automated system. The development of the automated skiving system was co-linked to two previous research projects which were sponsored by BUSM, and situated at the University of Durham. The first project was concerned with another shoe manufacturing process of stitch marking [R5] which is the marking of the shoe upper to enable it to be stitched. It was the development of the hardware required for this process that was later utilised for the automated skiving process. This system depended on recognising the shape of the shoe upper and then marking it by using an electronically controlled printer. This was done on a conveyor system and hence it was possible to adapt this process to skiving.

The first study relevant to the process of skiving was carried out by M. Saadat [R.2] and was also sponsored by BUSM (British United Shoe Machinery Co Ltd)

This study was into the process of milling to perform skiving, and to identify the material properties and operational characteristics of leather. It was suggested during this research study that automation of skiving could be achieved by the method of pin matrix or dynamic matrix skiving, although it was not researched in depth.

It must be noted that for the purpose of this thesis the reference of pin matrix or dynamic matrix skiving refers to the depression of leather by a forced pin so that a knife machines or cuts the leather.

It was at this stage of research that an earlier Skiving Machine was developed. This was designed by the author of this thesis whilst under a temporary working contract with the University of Durham. The design of this mechanism will be described in the next chapter.

The next study of research was by S.K.Topis [R.6] and this was into pin matrix skiving. This study went into greater depth on the requirements for automation of skiving. The study was principally related to the mechanical and electrical integration of the Skiving Machine and the hardware developed for the stitch marking process. There were additional developments, such as the introduction of upper and lower conveyor belts to feed the components into the Skiving Machine. It was at this stage of research that it was felt to be necessary to develop a new Skiving Machine.

1.6 The Current Automated Skiving System.

It is important to briefly describe the automated Skiving process at the stage when the new Skiving Machine was being considered.

The mechanical aspects of the skiving system comprised of a vision rig, splitting machine, twin belt handling mechanism, driving stepper motors and Skiving

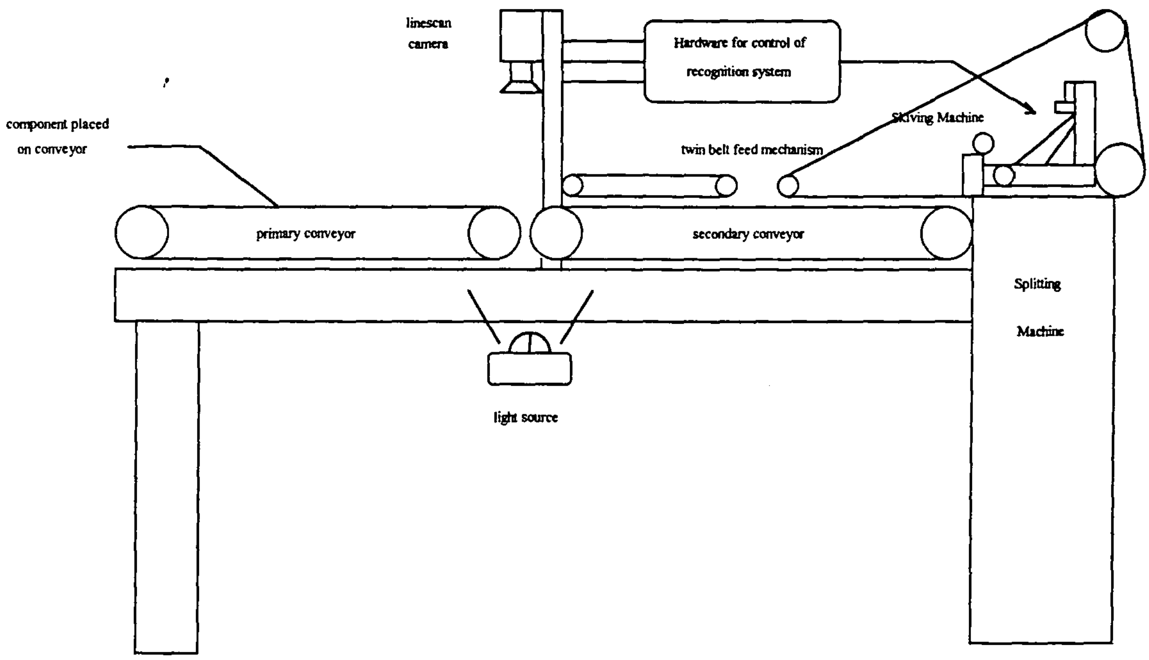


FIg 1.6 ***Shows a schematic diagram of the automated skiving system.***

Machine. The schematic diagram of figure 1.6 shows the overall mechanical structure of the system. Figure 1.7 shows the appearance of the skiving system.

The component is placed onto the moving primary conveyor. The conveyor moves it to the camera. The component is then scanned by the camera and recognised by the hardware system . It then continues to move onto the twin belt secondary conveyor system. This feeds the leather into the splitting machine. Then the hardware system activates the pin matrix on the Skiving machine which is mounted on the splitting machine. The pins press the leather onto the knife of the splitting machine. A shape is then skived on the recognised leather component.

1.7 The Specification for the Research Project

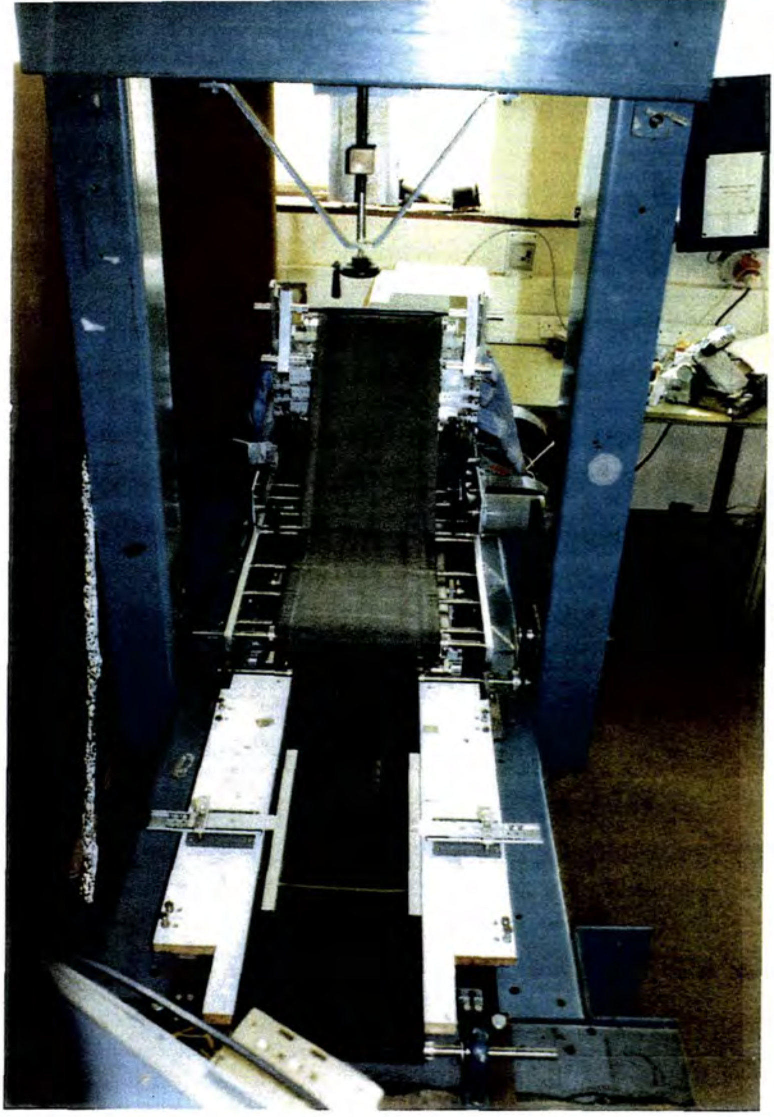
The relevant academic and industrial co-ordinators of this project have established guidelines as to the expectations of the new Skiving Machine. One of the expectations was that the project should be of research value rather than development. It was however apparent that the specification could also define a commercial product. The main specifications of this project had to be the following:-

1) The spacing between the pins of the pin matrix had to be of a smaller pitch to improve the resolution of the skived components. It was apparent that the old skiving machine had produced a stepping effect which was due to its large pitch. This effect is described further in this thesis,(see Chapter 2 section 2.7.)

2) The new machine had to be located in the same position as the previous machine. It was also a requirement that it should be adaptable for a new, larger splitting machine that would enable the skiving system to skive shoe uppers with a width of up to 400 mm.

The lower level specifications to the system can be summarised in the following statements:

a) During the skiving process it would be necessary for the pins to return to their starting position at a quicker rate then the pins of the old Skiving Machine.



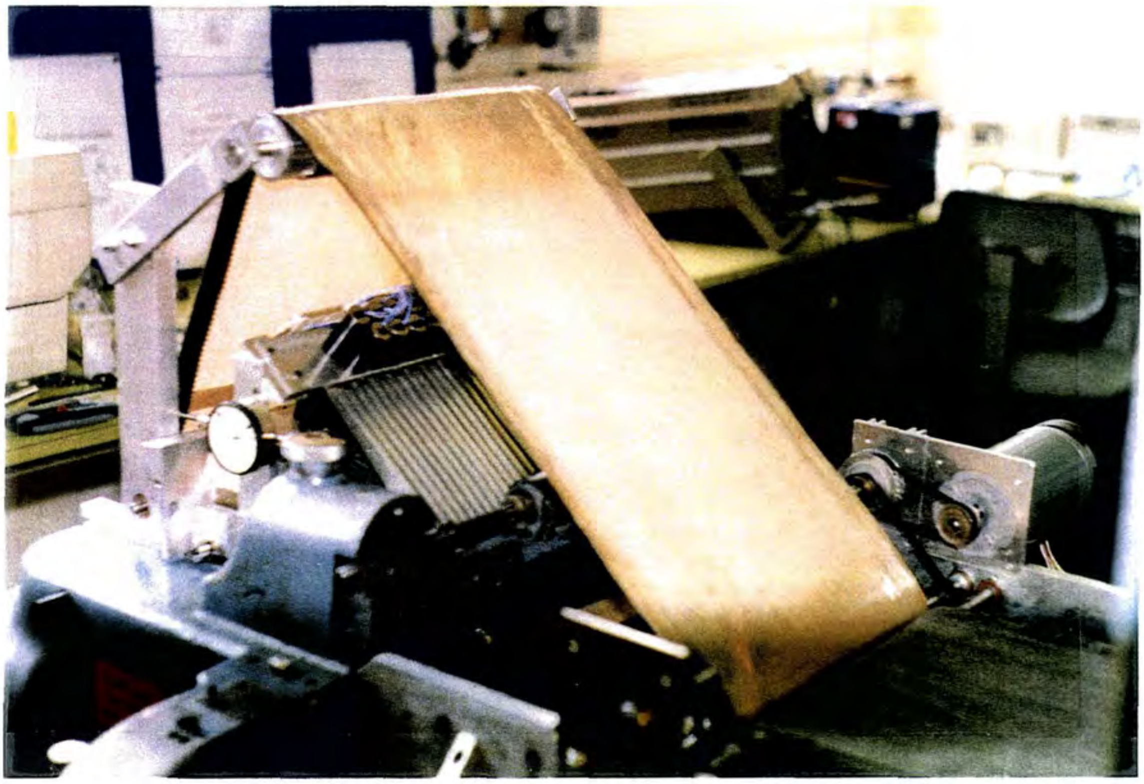


FIG 1.7 *Shows the appearance of the skiving system.*

b) The force required for skiving had to be increased to compensate for additions of added conveyor belts.

c) The new skiving machine had to include all the advantages of the old machine.

With respect to the last statement it is desirable to start the second chapter of this thesis, by discussing the design and performance features of the previous Skiving Machine.

CHAPTER 2

Analysis of the Previous Machines Design

2.1 **Introduction**

The purpose of this chapter is to enumerate the features of the original Skiving Machine which have influenced the present design.

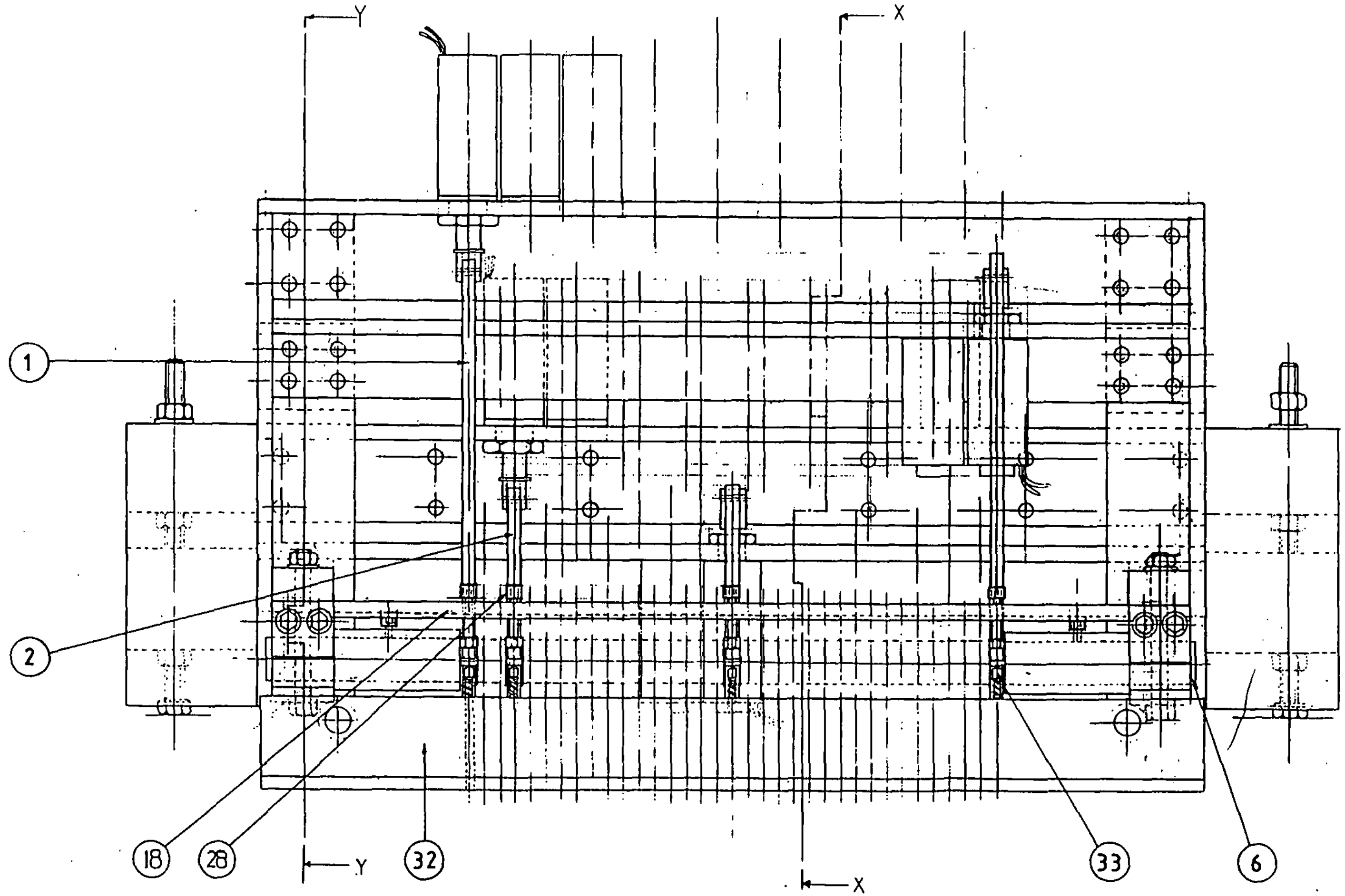
Figures 2.0 and 2.1 show the front and side elevations taken from the General Arrangement drawing which is titled `Solenoid Mounting Assembly'. For the purpose of this thesis, this machine be referred to as the "old Skiving Machine". A copy of the complete G.A. drawing is in the Appendix A5 enclosed at the back of this thesis.

The old Skiving Machine was designed, by the author, for the University on a previous project. The following gives a description of the machines operation.

The leather was fed between the feed roller and the press bar (Item 19 Figure 2.1). As the leather passed above the knife, the pins situated on the skive plate (i32,f 2.0/2.1) of the press bar, pushed the leather onto the knife. The knife splits or cuts the leather around the surface area of the pin. (i33,f2.0) The shaft (i6,f2.0/2.1) was located onto a base support bar (i4,f2.1) which held a series of solenoids. The clevis of the solenoids were connected to the ends of the levers (i1/2,f2.0/2.1) and therefore moved the pins. The pins returned due to the force of the leather and a spring located on the pin (i35,f2.1). This also pushed the solenoid plunger out after being energised (i37,f2.1). The skived leather was then pushed through, underneath the mechanism.

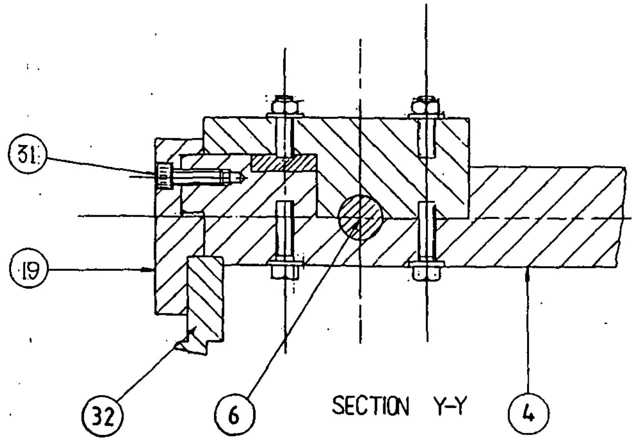
The development of the Skiving Machine is based on a Leather Splitting Machine which was obtained from BUSM (British United Shoe Machinery Ltd) for this project.

ITEM NO.	DESCRIPTION
1	UPPER CRANK LEVER
2	LOWER CRANK LEVER
6	SHAFT.
18	STOP BAR
28	SCREW
32	SKIVE PLATE
33	PIN ASSY.

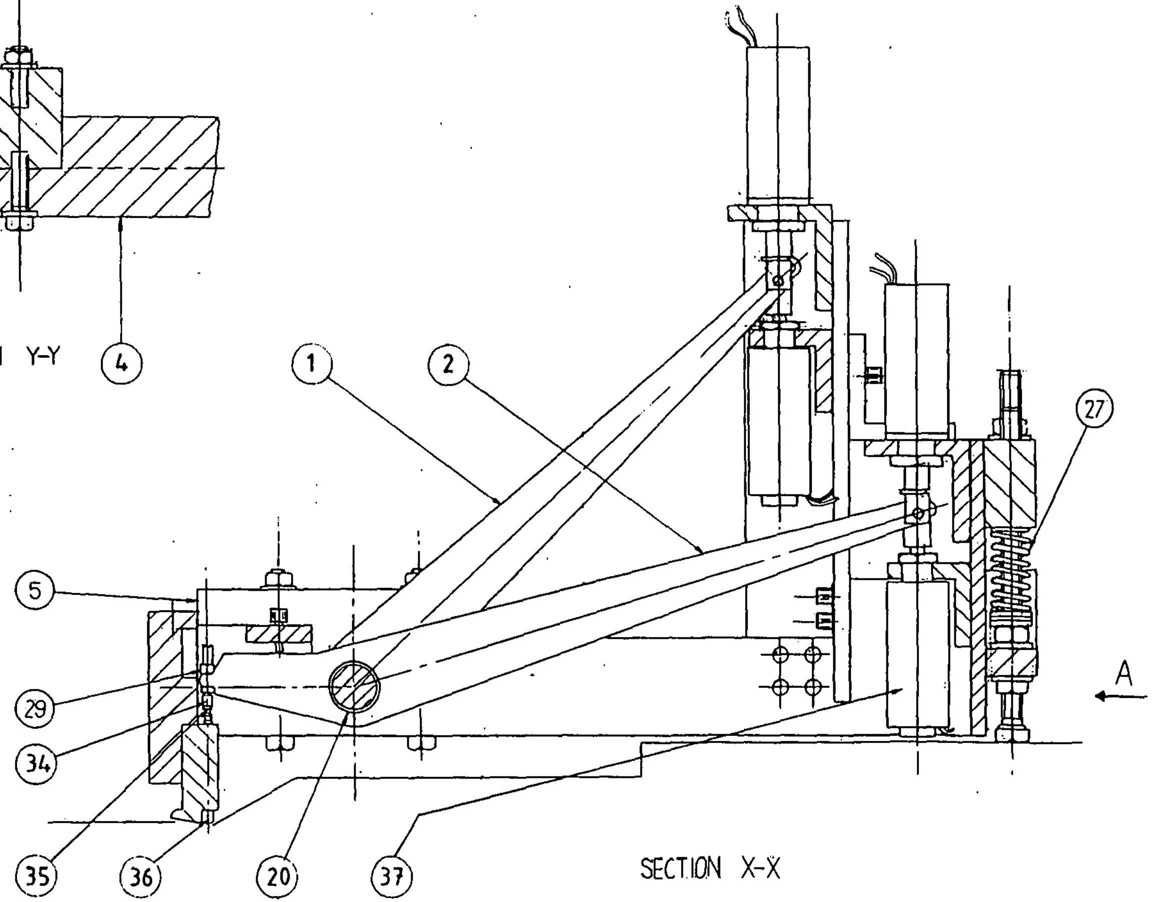


FRONT ELEVATION

FIG. 2·0 Drawing taken from G.A drg. titled SOLENOID MOUNTING ASSY.



ITEM NO.	DESCRIPTION		
1	UPPER CRANK LEVER	27	ADJUST. MECHANISM
2	LOWER CRANK LEVER	34	CAP
4	BASE SUPP.T BAR	35	SPRING
5	SHAFT MOUNTING	36	PIN STEM
6	SHAFT	37	SOLENOID
19	PRESS BAR		
20	BEARING		
29	NUT/SCREW		
31	SCREW		
32	SKIVE PLATE		



SIDE ELEVATION

FIG.2.1 Drawing taken from G.A drg. titled SOLENOID MOUNTING ASSY.

2.2 **Depth of Skive**

Figure 2.2 shows the leather splitting machine and the components which make up the press bar mechanism.

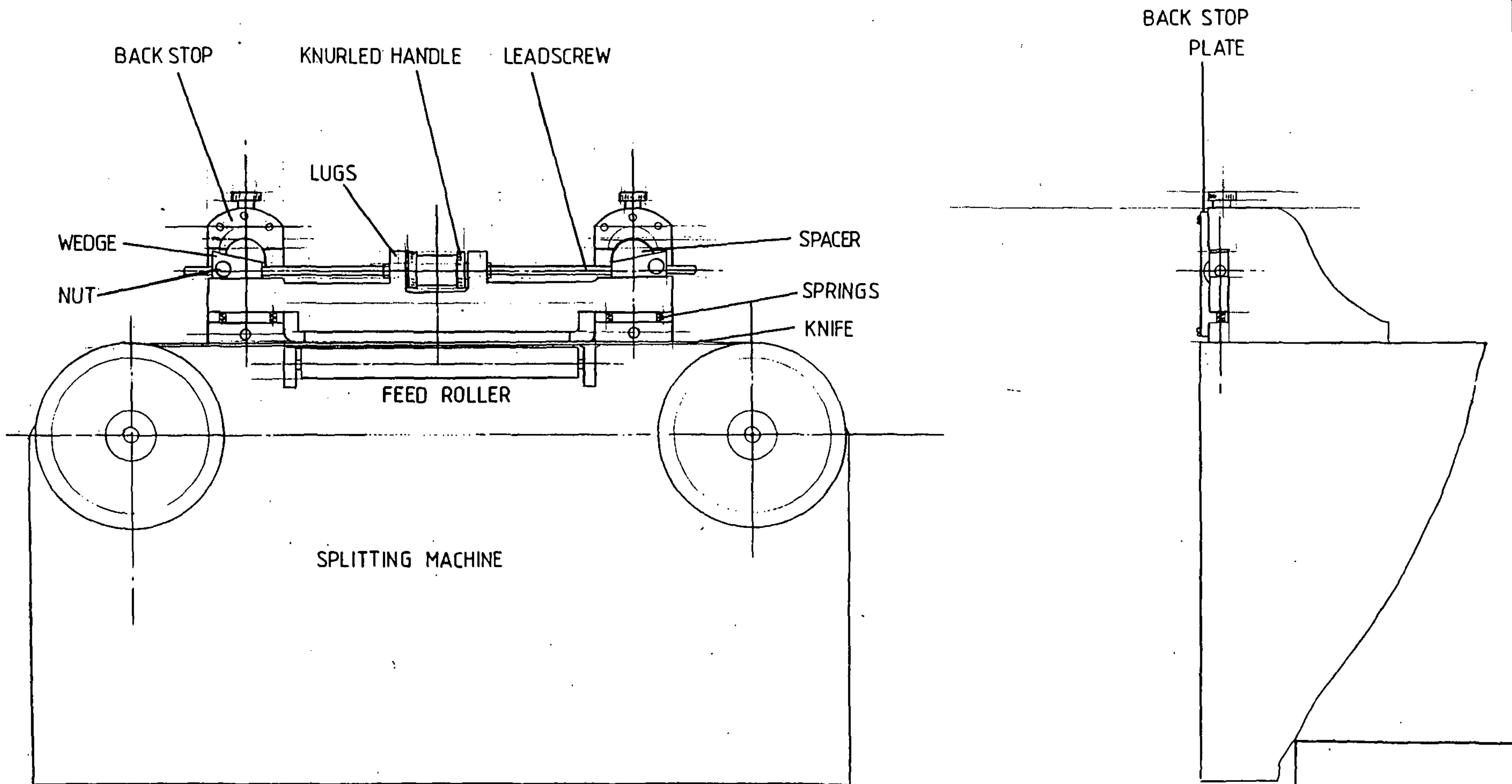
The splitting machines press bar controls the pressure and depth of skive. The leather was skived by the knife when pushed between the feed roller and press bar. The depth of the press bar was determined by a mechanism which is mounted directly above the bar. The bar rests on two springs situated on each back stop of the splitting machine. There are two wedges engaged onto a lead screw, the left wedge (i2,f2.3) is on a right hand thread and the right is on the left thread. A knurled handle (i4,f2.3) is cottered to the lead screw (i3,f2.3) and centred on the two lugs of the press bar. The two springs push the wedges against a semi-circular spacer which is in contact with the back stop. When the handle was turned the wedges moved and the press bar is raised or lowered. This mechanism allowed the bar to be lowered level to the knife and the back stops allowed an accurate dimensional reference point. Plates can also be fitted onto the back stops to secure a permanently fixed position which is free from vibrational errors.

Fig 2.3 shows the rear view of the press bar. The bar was manufactured using a series of high tolerance machining and grinding processes and is subsequently dimensionally accurate in its vertical and horizontal regions. It was therefore advantageous to build the skiving machine onto the press bar and this made it accurate with reference to the splitting machine's knife. The skiving machine was then able to produce accurate and consistent skives of leather.

2.3 **Pin Design and Performance**

The skive plate (i32,f2.3) is connected to the press bar, which has a raised front edge that allows incoming leather to have a degree of clearance and angular movement. This plate had been modified to hold a number of pins (i33,f2.3). The resolution of the skive was determined by the pitch between each pin. It was decided to make a pin resolution or pitch of 5 mm and a pin diameter of 3 mm. This gave an

FIG.2.2 Shows leather splitting machine and PRESS BAR MECHANISM



adequate smooth skive. The width or span required was set at 170 mm which is equivalent to thirty five pins.

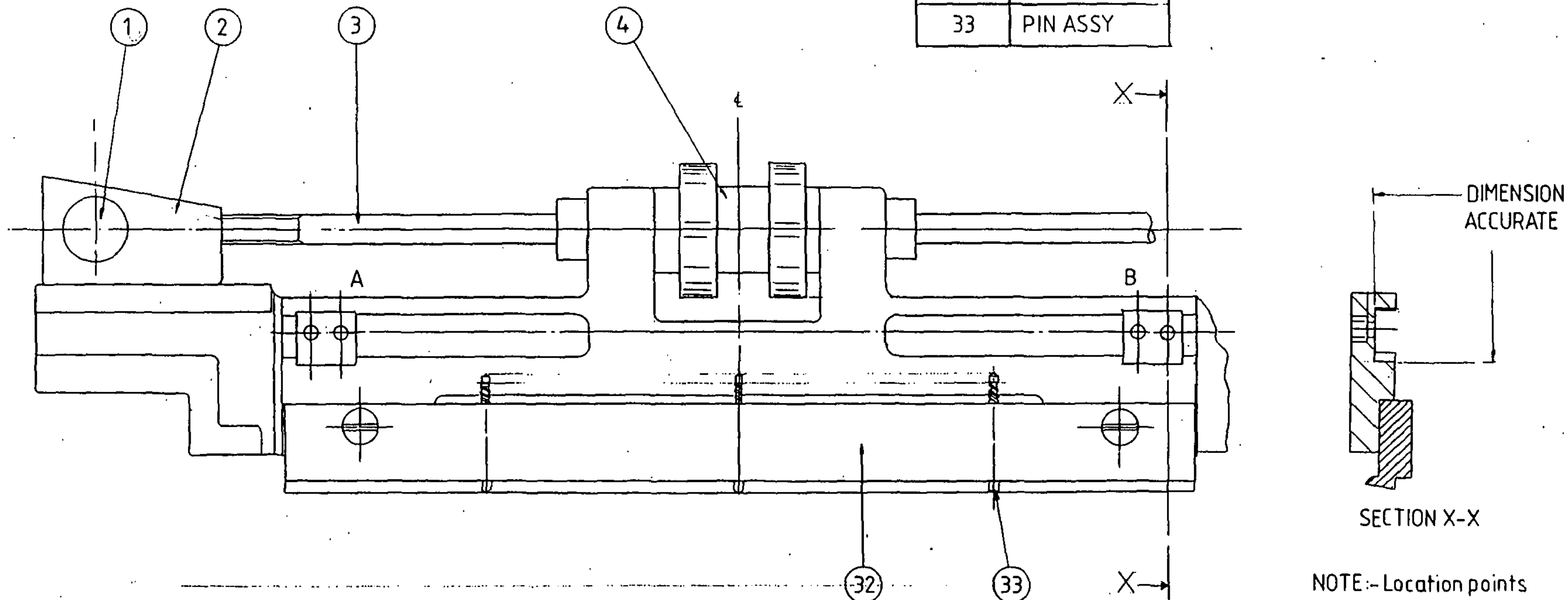
The design of the pin was a very important feature for the performance of the machine. The pin is housed in the skive plate and required a clearance fit to allow it to move freely and centralise its position. The pin must also be free enough to allow the spring force to return the pin to its start position. The start position had be the same for all the pins along the span of the skive plate. The pin end or skiving point is domed in profile and this allowed the skived shape to have a smooth cut. The plate was counter-bored and the pin stem (i36,f2.1) was reduced in diameter and threaded. The depth of the counter-bore or the length of the reduced diameter determined the maximum permissible movement of the pin. A compression spring (i35,f2.1) is used to return the pin to its original position, as well as to push the connecting levers up. A cap (i34,f2.1) was screwed onto the pin stem to secure the spring in position.

All the pins were produced to the same dimensional setting and later measured with reference to the underside of the skive plate.

The force of the spring or stiffness is an important factor and was affected by a combination of factors related to the forces produced in the machine. The desired rate of return of the pins is a function of the created forces and the stiffness of the spring. A high rate of return, which is desirable, could be caused by an excessive force generated by the pull of the solenoids and a stiff compression spring. However if the applied forces exceeded the spring's capacity and its maximum deflection is surpassed, then no additional return force is produced. When a small force was applied by the solenoids the deflection of the spring and the rate of return was reduced. The forces generated will not be constant because the force required for leading edge skiving will vary from interior skiving.

"Leading edge" skiving is the term describing the skiving operation on the edge of the component that is facing the pin row, as the components proceeds towards the skiving area. "Interior" skiving is the simplest and easiest form of skiving and occurs in the regions away from the edges. Also the term "trailing edge", refers to the edge

ITEM NO	DESCRIPTION
1	NUT
2	WEDGE
3	LEADSCREW
4	HANDLE
32	SKIVE PLATE
33	PIN ASSY



NOTE:- Location points A and B are premachined, therefore(during manufactum accurate with respect to each other.

FIG. 2·3 Shows rear view of PRESS BAR.

exactly opposite to the leading one, i.e. the edge of the component last to leave the skive area.

Topis [R6] gives more information on the difficulties of skiving on a leading edge of a leather component which tended to cause jamming if the pins were activated. This introduced the requirement of an upper conveyor belt to assist in directing the leather to the knife and to reduce its distortion during the skiving process. This thesis describes the difficulties of component handling during the transfer process and the necessity of the upper and lower conveyor belts to prevent any lateral movement.

The additional thickness and rigidity of the conveyor belt also creates a greater force to return the pins and levers. The conveyor's handling system allowed the speed of the skiving process to be increased to the customer's requirements of 185 mm/s and enabled the skiving process to be computer controlled. This was achieved by enabling stepper motors to drive the belts and allow the process to be integrated with a visual recognition system.

The development of the visual recognition systems is given in Tout [R5] and describes the general processes required for the automation of shoe manufacture. This thesis gives details of the recognition system in a Stitch marking system used in the manufacture of shoes. This project was sponsored by BUSM, and the system was adapted for the skiving process.

The recognition system comprises of a Linescan camera, edge detection and encoding boards, Slave Z8000 microprocessor, Master Z8000 microprocessors ,Compaq 386, Tms34010SDB and an additional conveyor belt. The camera generates pulses as the component passes over a gap between the recognition conveyer and the handling conveyers of the skiving system. These pulses are converted into edge co-ordinates of the scanned shape and the orientation and position is calculated by the slave Z8000. The system uses the handling conveyors to prevent the component from moving out of position during transfer. The Compaq compares the shape with stored information in its database and generates the required output signals from the Tms34010SDB, changed later to the Motorola M68000 microprocessor, to activate the solenoids to skive the stored shape onto the leather. The Master Z8000 controls the stepper motors and counts the signals so the camera is synchronised scan the shape. It also interrupts the control programs until the required number of counts from the stepper motor is completed to activate the skive.

2.4 **Conclusion**

It was evident from the stepping effect, shown on the skived components, that the skiving machine required further development (see fig 2.4). However these components also showed the desirable feature of a uniform depth of cut along the width of the leather. This signified that the dimensional accuracy of the press bar and its mechanism used to adjust the depth of cut was accurate with reference to the splitting machines knife. It also showed that an effective pin movement of 1mm was adequate for the requirements of skiving. From this evidence it was concluded that the new skiving machine must be dimensionally accurate, have a method to adjust the depth of cut and to have an effective pin movement of 1mm.

The skived components showed, see fig 2.4, that there was a fault in the appearance of subsequent diagonal cuts. Rather than creating a diagonal line, a series of steps would appear. This was apparent when the diagonal line trails the direction of the skive, as shown in figure 2.4. This was due to a low resolution and a slow rate of return of the pins. The slow rate of return was principally caused from a low return force and is a function of the skiving machine's operating forces, see section 2.3. It was apparent from the comparative large dimensions of the levers that a lot of weight or mass is contained on its crank arm (or the long arm side of the pivot). Figure 2.5 shows the old skiving machine. Therefore the levers of the mechanism create high moments of inertia and subsequently produce a low angular acceleration and a low rate of change in momentum. As a result of this, the rate of return of the pins was slower than their rate of descent and therefore a longer skive or stepping effect was observed.

This effect is described by Topis [R6] who discusses how the skive profile is dependent on the rate of pin insertion and retraction.

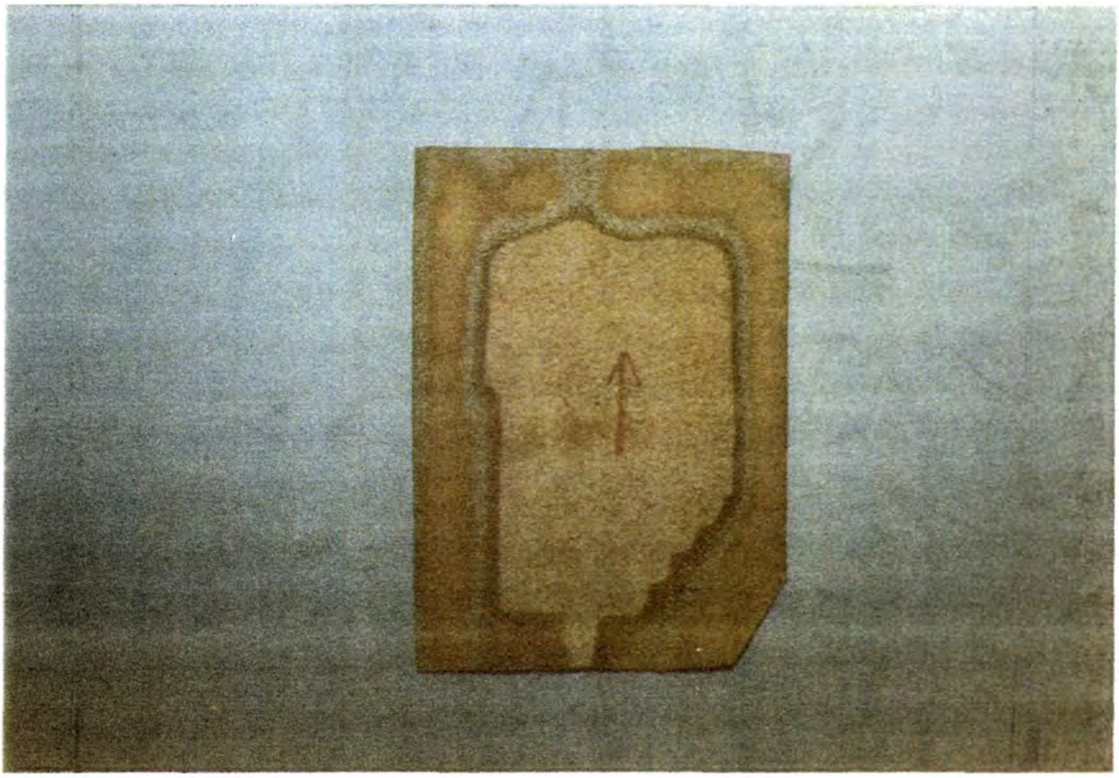
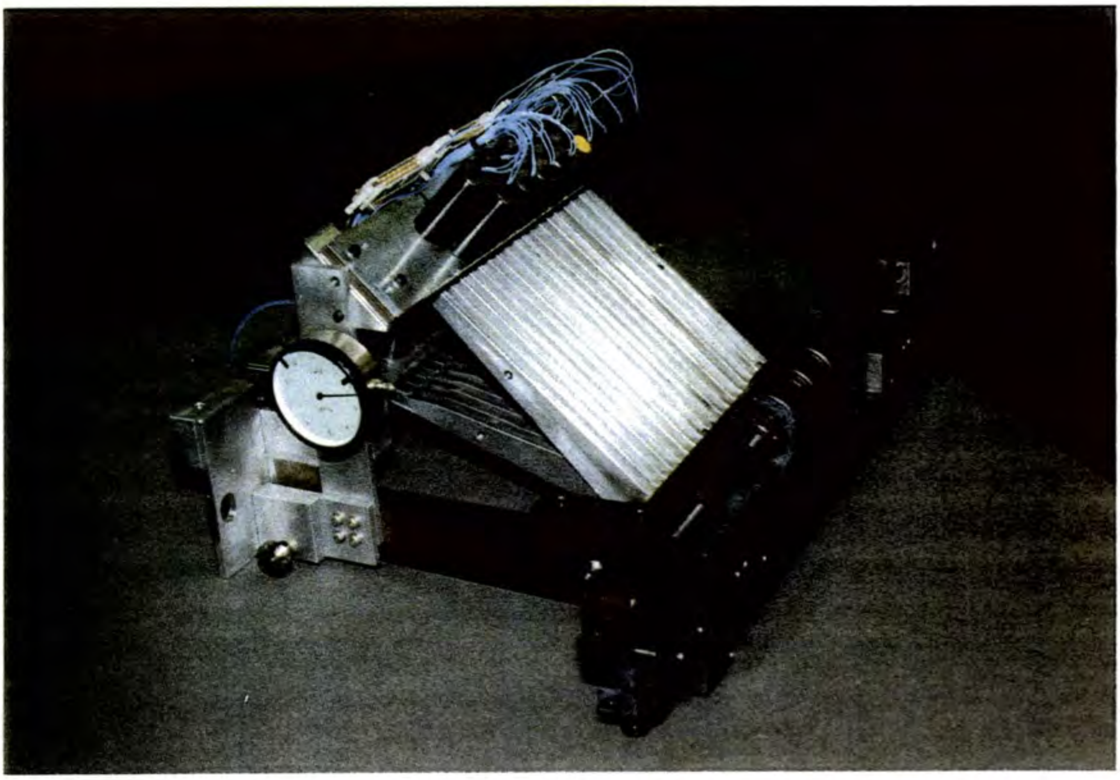


Fig. 2.4 Shows the stepping effect on skived leather for the old skiving machine

The low resolution (a pitch of 5mm between pins) meant that larger and more noticeable steps were produced. Therefore if the pitch was reduced then each pin would skive smaller areas of the leather and therefore create smaller steps. This would assist in improving the appearance of the skived edges.

In addition to the above performance defects there also tended to be buckling of the pins. This was principally due to the momentum generated by the motion of the conveyor and the leather as they push against the front of the pins during the skiving process. Therefore any deflection or damage would reduce the free movement between the pins and the skive plate. This effect would become more apparent on the low return force of the pins stroke. This effect is shown in figure 2.4 where a pin does not return and therefore skives a line to the end of the leather component.

Ultimately it was concluded from these performance defects of the old skiving machine that further steps needed to be taken to improve the rate of return, the resolution and the pin design of the operating process.



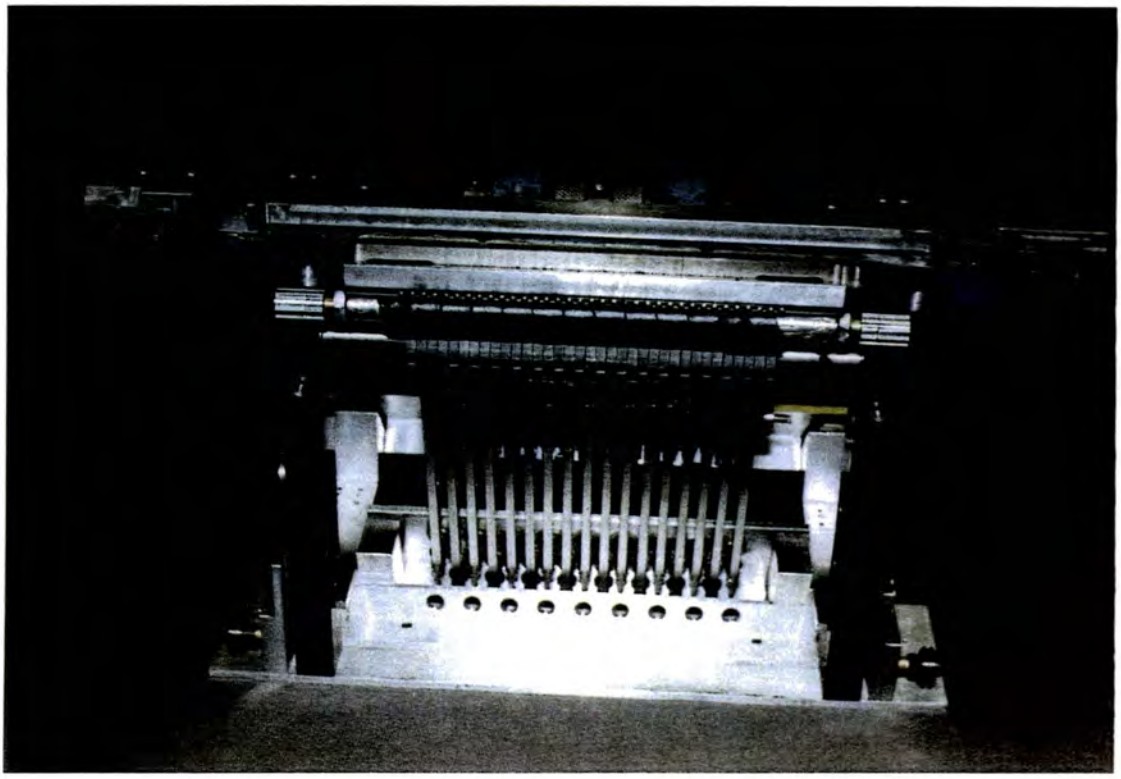


Fig. 2.5 Shows the old skiving machine

CHAPTER 3

A General Outline of the requirements for the New Machine

3.1 Introduction

One of the major objectives in the design of the rig was to make the machine as flexible and adjustable as possible, so it could be adaptable for different experiments and other purposes. This was a requirement for the machine in its research role, rather than for commercial use.

As was discussed in the previous chapter the major objective of this design was to produce a high resolution Skiving Machine. This implied that the pins on the new machine would have a closer pitch spacing than the old machine. This would overcome the problem described in the previous chapter of the `stepping effect' produced when skiving leather.

Figure 2.5 shows the diagonal portion of the skived shape having a stepping effect caused by the pins on the old machine.

It is the purpose of this chapter to determine the necessary changes to the design caused by this major objective. The following gives a list in order of priority of the most desirable design features for the Skiving Machine:-

a) A high resolution of skive, which is determined by a low pitch spacing of the activating pins. At this stage of the design it had not been decided on the spacing distance between the pins required and therefore this needed further investigation.

b) To fit the current dimensional criteria and the additional requirements of the customer. The machine needed to be fitted under the twin belt handling system which restricted the dimensions of the design. The customer BUSM, also required the design to be fitted onto a new splitting machine.

c) The minimum pin movement must be approximately 1.0mm. This amount of pin movement was equal to the effective pin movement of the old Skiving Machine which performed satisfactory in producing the required depth of cut. The pins must also be level and dimensionally accurate with reference to the knife. This was necessary to produce a cut of uniform thickness across the width of the leather component.

d) A higher rate of return of the pins was needed. This would therefore reduce the length of the cut trailing behind the pin's skiving position. For the previous machine the rate of return was dependent on the pull force generated by the solenoid and the stiffness of the compression springs located on the pins. The springs were used to push the pins and the levers back to their start positions. It was therefore desirable for the new machine to have a high pull force generated by the solenoids. However, as described in the previous chapter's conclusion, the old skiving machine had relatively large and heavy crank levers. Consequently for the new machine there must be a reduction in the comparative weight and dimensions of the levers. This would therefore decrease the moment of inertia of the lever and hence increase its rate of return.

e) The design of the machine must be adjustable and flexible. It would be desirable to adjust as many performance parameters of the machine as possible so that the best quality skive could be achieved. For instance, if the pin movement was adjusted then the depth of cut would be altered. The construction of the machine must be flexible so that the positions of the components can be moved or altered to provide an easier assembly and installation.

3.2 **Pin Resolution**

A number of skiving tests were carried out on leather using a series of pins at a pitch of 2 mm. These pins were located in a slotted plastic holder and connected to the back stops of the splitting machine. The plastic holder was lowered to the required skiving position and the leather passed under the conveyor belt between the knife and the pins. The pins were forced down and a pattern was skived as shown in fig 3.0. The picture shows that there is no `stepping effect' on the skived leather and therefore the 2 mm pitch resolution was adequate for the new machine.

Having decided on a pitch of 2 mm it was now necessary to investigate the feasibility of incorporating this into a successful design. The old Skiving Machine's pin design included a pin stem, compression spring and cap. If these were reduced in size to the new resolution, the following problems could be identified.

a) When the pin stem (Item 36 Fig 2.1) was manufactured its diameter was reduced and threaded so that the cap (i34,f2.1) could be easily located onto its end. With a pitch of 2 mm the diameter of the pin stem would have to be less to allow for a clearance fit and to allow for space between the holes of the skive plate (i32,f2.1). It would be difficult to reduce the diameter of the stem and then to add a thread that would have the necessary purchase. Also it would be difficult to machine to the same tolerance accurately for all the pins.

b) The holes to be drilled in the skive plate would have a pitch of 2 mm but also must have support material of 0.5 mm between the holes. This was required in the drilling process as it would be difficult, with the equipment available, to maintain consistently vertical boring without misalignment or convergence of the holes. There was also the additional problem of the material flexing on the fixture bed due to the cutting stresses induced.

c) A reduced pin diameter would subsequently mean a reduction in the diameter of the compression spring (i35,f2.1). As a result of this the length of the spring would have to be increased to maintain the same spring stiffness [S] as for the previous machine. Therefore the required spring length for the new machine could be determined by the following equation[R7].

Stiffness [S] = $G*d/8*n*C^3$ Eqn 1 .

The stiffness [S] is defined as the force applied divided by the deflection of the spring. The coil ratio [C] is defined as the outer diameter divided by the diameter of the wire

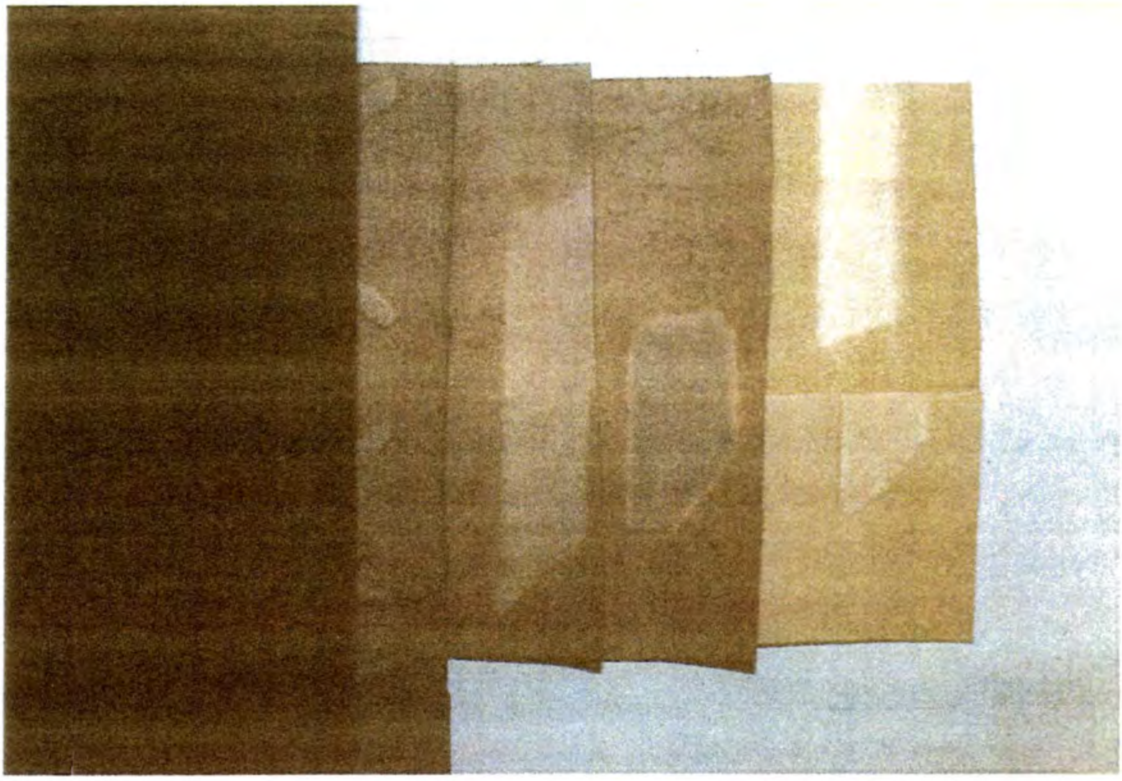


FIG 3.0 *Shows the Skiving tests done to prove that the required resolution pitch was 2mm and the skived leather with no stepping effect.*

used for the spring. Let G be the torsional modulus for the spring steel and d the diameter of the spring wire. For both springs the variables G, S and d remain constant. It is therefore apparent, from eqn1, that the number of active coils [n] will determine the overall length of the spring.

If eqn1 is equated for ;- S for old spring(sp_o) = S for new spring(sp_n).

Then from knowing the above conditions ;-

$[n*C^3]$ for (sp_o) is equal to $[n*C^3]$ for (sp_n)

$[n*(D/d)^3]$ for (sp_o) $=[n*(D/d)^3]$ for (sp_n)

D is the outer diameter of the springs. It must be noted that D for the previous spring is 5mm and for the new spring will be 2mm. This is due to the increase in resolution.

n for (sp_n) = $(5/2)^3*$n for (sp_o)

Therefore the length of the new spring would be 16 times longer than the previous spring length. This would mean that the overall length of the pin would be increased to house the spring. Consequently the pin would be more susceptible to damage and bending.

Experience with the earlier machine had indicated that pin buckling might be encountered. This effect is likely to increase with the pin diameter being reduced from 5 mm to 2.0 mm and length being increased for the new spring. A new design of pin was required to reduce the tendency to buckle. Figure 3.1 shows the design for the new pin.

The pins were made from 1 mm wide brass plate which was cut to a width of 8 mm. The tip of the pin is a dome ended bar of diameter 2 mm which was slotted onto the plate and soldered in position. These pins were then located in a slotted block of plastic with a 2 mm pitch. The pins were prevented from falling out of the slots by an additional plate secured by four screws.

This design did not include a return spring and consequently the pins returned by the combined force of the leather and conveyor.

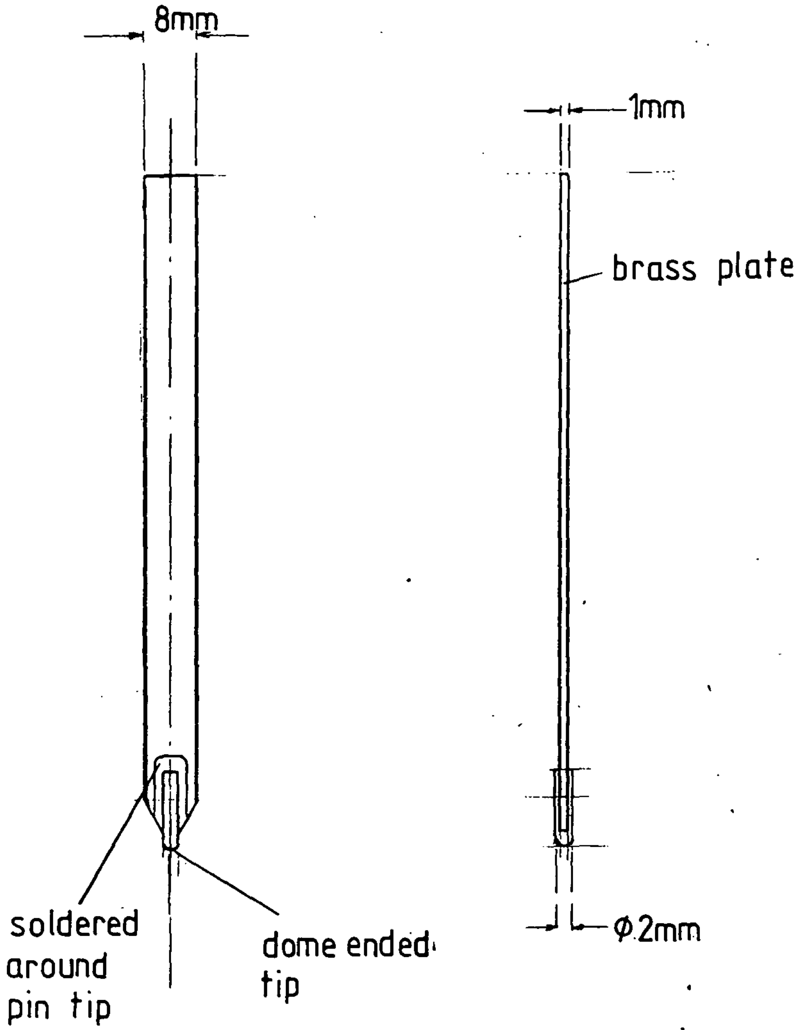


FIG 3·1 Shows experimental pin.

It was apparent by using these pins they could withstand more force and bending stress than the equivalent of the old designed pin. To prove this, a comparison was made of the stresses on both types of pins. The bending stress exerted was due to the force created by the momentum of the conveyor hitting the front of the pins. The new brass pin had a rectangular section and a larger second moment of area [I], as shown below.

For brass pin $I = b*d^3/12 = 42.7 \text{ mm}^4$

Let d represent the depth which is 8mm and b represent the breadth or thickness which is 1mm of the new pin.

For circular pin $I = \pi*d^4/64 = 0.79 \text{ mm}^4$

Let d represent the diameter of the old design of pin which is 2mm.

It was assumed that the bending moment [M] would be the same for both pins during normal working conditions. Let σ(sigma) represent the resultant bending stress and y the distance from centroid of the pin's section to the position of the force. Therefore for the circular pin, y is half its diameter, which is 1mm, and for the brass pin, y is half its depth, which is 4mm. The following is taken from basic stress theory [R8];-

The bending stress [σ] divided by the distance from the centroid or stress free position [y] is equal to the bending moment [M] divided by the second moment of area [I].

Hence $\sigma/y = M/I$ Eqn 2

However, the bending moments for both pins are the same.

If eqn 2 is equated for $\sigma*I/y$ for circular pin = $\sigma*I/y$ for brass pin

σ for brass = $0.073*\sigma$ for circular pin.

As can be seen from the above equations the brass pin has a greater second moment of area (I) and therefore a lower bending stress. Therefore the bending stress for the new pin would be 14 times less than that for the old designed pin.

Therefore a new lever mechanism was needed, so that the brass pins were able to transmit movement accurately. A novel solution was to connect the lever into a

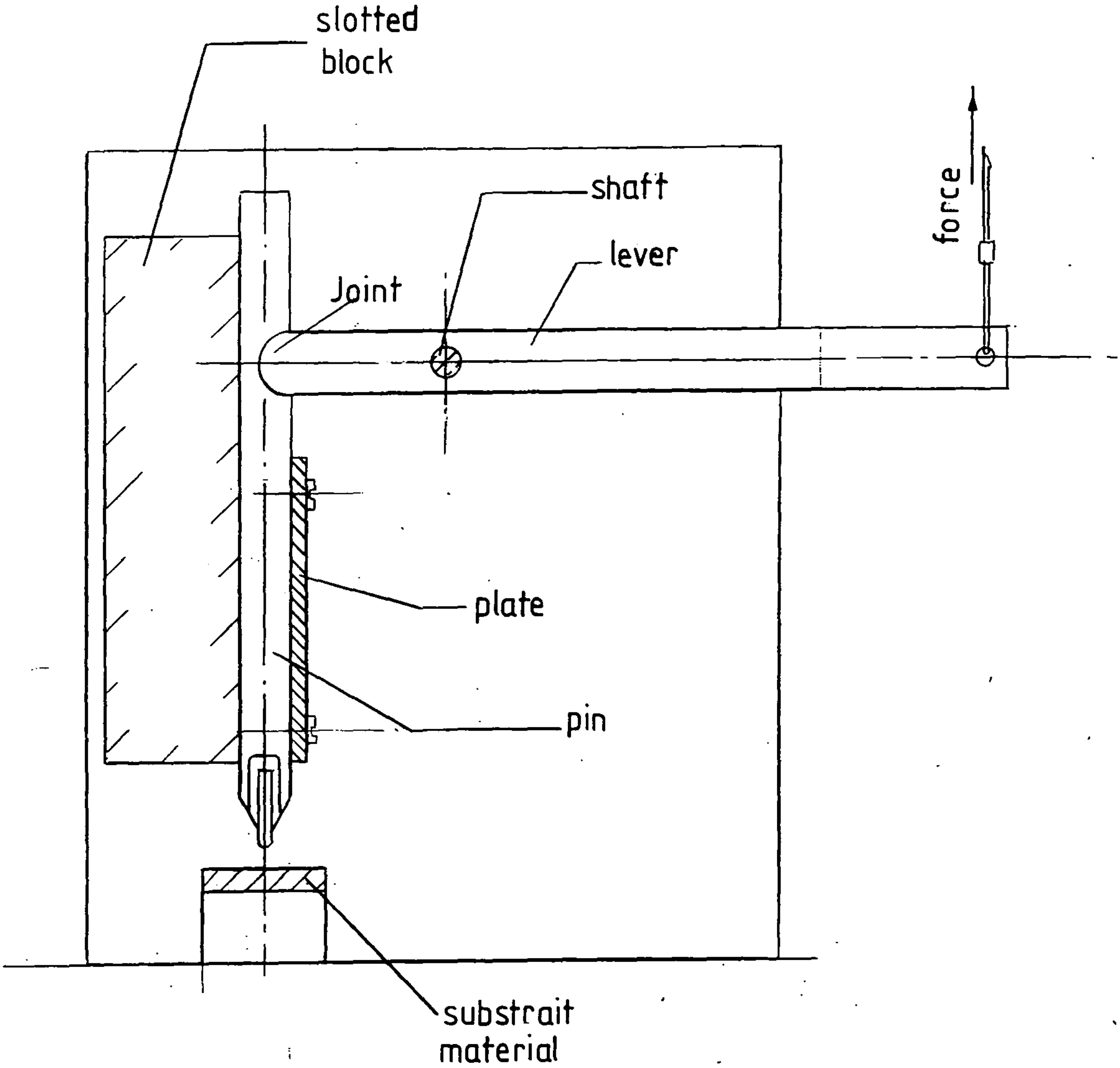


FIG 3·2 Shows the lever and pin joint mechanism semi circular joint in the pin. This was contained within the slot which held it in place. see fig 3.2.

3.3 **Dimensional Criteria**

The specified requirement for the new machine was that it must fit under the conveyor belt on the old splitting machine, and also to require little modification when transferred to the new splitting machine.

Figures 3.3 and 3.4 show the old and new splitting machines.

There were other dimensional factors that needed to be considered about the new design :-

a) The high resolution design, with a 2mm pitch pin spacing, would require 120 pins for the old splitting machine and 175 pins for the new machine. Therefore the components must be adjustable for when the skiving machine needed to be installed into the new splitting machine. This meant that the skiving machine needed to be wide enough to accommodate the 175 pins.

b) The Skiving Machine required 120 actuators and levers to be located under the conveyor belt and this meant that there would be limited space available for maintenance or adjustment.

c) The pins would be located in the best skiving position and be adjustable for depth of cut. Therefore adjustment mechanisms would be provided to achieve the best skiving position.

d) The pin movement would exceed 1 mm of stroke and this would give a minimum movement of 3mm of the solenoids plungers.

e) Friction in the mechanism should be low enough to allow the pins to return to their starting position.

The only way to address these factors was to draw a scale drawing of the conveyor and splitting machine, then to dimension the known requirements.

3.4 Materials and Stress Considerations

As mentioned earlier in the discussion about the stress induced in the pin assemblies, there are other stresses involved in connecting the components which are affected by the high resolution.

It was assumed that the levers would pivot on a shaft such as in the old machine. Therefore there would be a hundred and twenty levers spanning 240 mm and connected to a hundred and twenty solenoids. Although the Skiving Machine is research equipment and therefore it does not need be operated to its full capability, the condition where all the solenoids being activated at the same time must be taken into account. This would create a very strong bending moment uniformly distributed alone the shaft. If the shaft was supported at both ends so the maximum deflection would occur in the centre and the levers are at a pitch of 2 mm and the thickness of each is 1 mm. Then additional washers must be added to keep the alignment and free movement of the levers. If there was a slight permanent deflection of the shaft then levers and washers could jam or buckle. The old design was therefore altered in the following way:-

a) Increase the shaft diameter to the maximum allowable. This must be a compromise between the space available and the strength required for the levers. A hard rigid tool steel was selected.

b) Separate supports were incorporated at various points on the shaft to reduce any deflections.

The minimum number of supports was calculated as three (for calculations see Appendix A1). These were evenly spaced along the shaft and were 1 mm thick.

3.5 Adjustability and Flexibility

One of the aims of the design was to be as flexible and adjustable as possible. The following is a list of adjustments that are available in the new Skiving Machine:-

1) The amount of pin movement.

Fig. 3.3 Shows the old splitting machine and conveyor

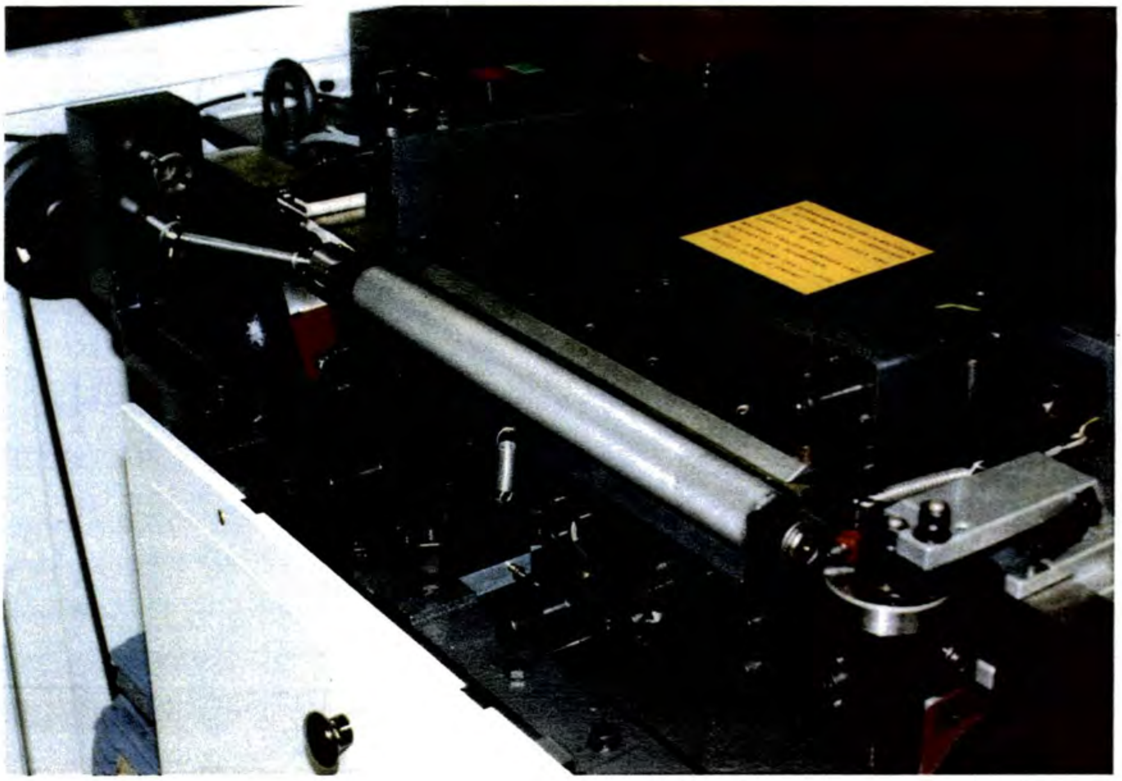


Fig. 3.4 Shows the details and dimensions
of the new splitting machine

2) The amount of movement and force of the activators.

3) The force exerted on the pins to return to their start position.

4) The adjustment of the actuators position, in three directions, relative to the lever.

5) The height of the Skiving Machine with respect to the back stops.

6) The forward movement from the back stops to achieve accurate skiving.

7) The height of the Skiving Machine with respect to the position of the pins.

8) The height of the roller positioned behind the pins.

9) The adjustment of the solenoids to allow for the height of the conveyor.

The above adjustments were able to cope with any variations in the machines dimensions. These were found because the old splitting machine is a cast steel structure and not symmetrical in its dimensions.

3.6 Investigation into Different Actuator Designs to Satisfy the Necessary Criteria

The new design of pins gave a resolution of 2mm pitch pin spacing by employing brass plate pins located in slots. These were operated by levers which engaged the pins via a joint mechanism.

This was the starting point of the actuator design and different mechanism designs were based on this taking into account the restriction due to the space available on the splitting machine. If the old machine's design was considered and only levers were used, there would be a problem with space. Consequently, alternative designs were considered.

Pneumatic devices are commonly used actuators which are available at the required force and stroke. To use a pneumatic device requires the additions of valves, a single acting spring return cylinder, and a series of air pipes. This would cause difficulties because of the limited space available. Also there would be a gradual

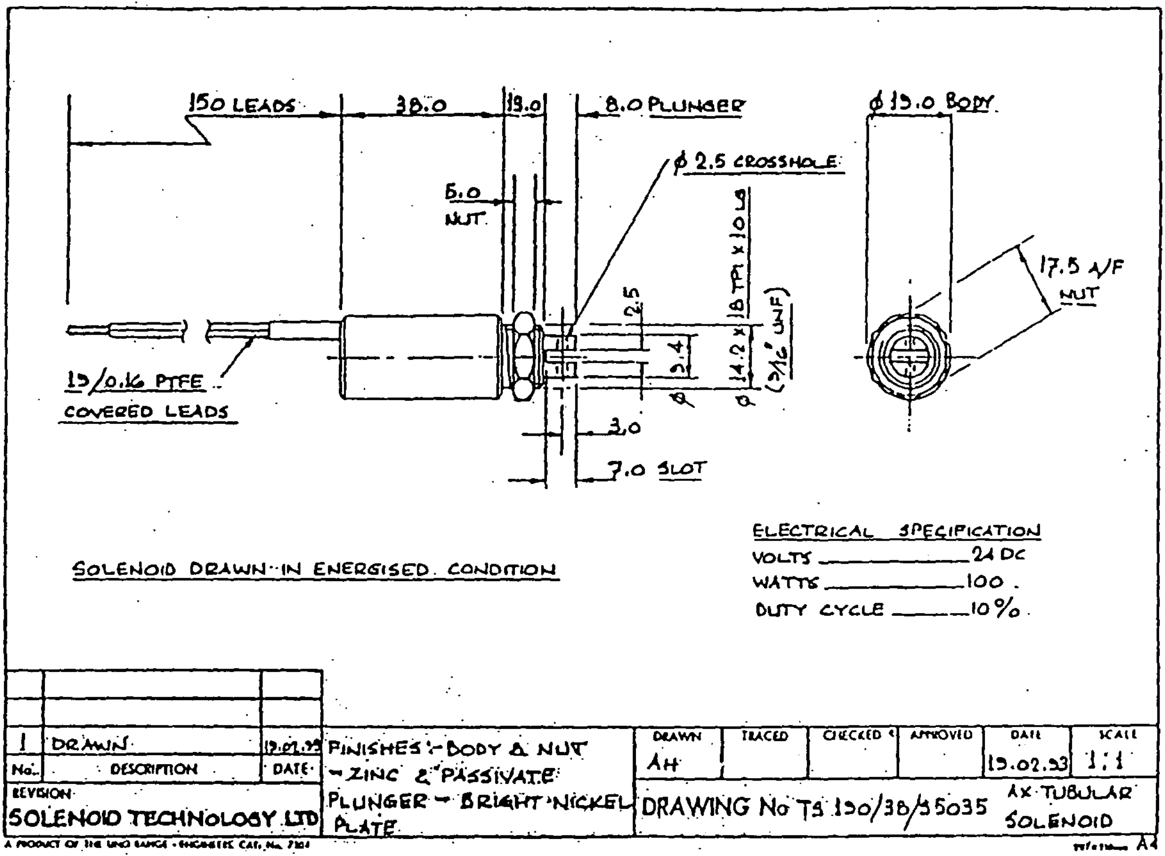


Fig. 3.5 Shows the details and dimension of the new solenoid

increase in force when the pin is actuated. This would cause a slow and gradual increase in the profile of the skive cut.

Solenoids were the best option due to the compact size and the high rate of force applied. It was decided to use solenoids similar to the old Skiving Machine but exerting greater forces. The dimensions of each solenoid could then be used to determine the spaces available and how to transmit the forces to the pins.

Figure 3.5 shows the dimensions of the solenoids to be used for the new skiving machine. The solenoids were supplied by Lisk (UK) Ltd [R9]. As there needed to be a hundred and twenty solenoids a number of configurations were investigated. The only method of transmitting forces discovered, in the space available, was to use wires.

The wires would need to be connected between the solenoids and a lever. Consequently they could be diverted around a series of pulleys to accommodate for the lack of space. The use of wire for transmitting forces in the skiving machine was principally due to the restriction in space available between the solenoid and the lever. However the introduction of the wires also enabled a high rate of return for the pins to be achieved. In section 3.1, of this chapter, it was decided that the rate of return could be improved by a greater pull force from the solenoids (which will be achieved by the new solenoids mentioned above) and a reduction in the size of the lever. (However there is no restriction on the size of the new lever because it is connected to a transmission wire rather than a solenoid).

It is shown by eqn. 3, that if the mass [m] and the radius [k] of the lever was decreased then the moment of inertia [I] for the lever would be reduced. Therefore the angular acceleration [α] of the lever would be increased by the return force [F] of the pin.

The following gives the general equation of motion used when considering the rate of return[R10]. The sum of the moments of all external forces [F] is equal to the mass moment of inertia [I] multiplied by the angular acceleration [α] about a fixed point.

$F = I*\alpha$ Eqn. 3 and $I = m*k^2$ where k is the radius from mass to fixed point.

It is evident from the above considerations that the rate of return could be increased if the design of the new lever was restricted to a minimum in size. Unfortunately the use of wires to transmit the forces meant that an investigation into the type of wires to be used and the method of connection must be undertaken. This was because the wires would stretch by various amounts and this would mean that a method of adjustment needed to be introduced.

Figure 3.6 shows the operating system of the wire moving the lever from being operated from the solenoid.

The evaluation and tests are detailed in the next chapter.

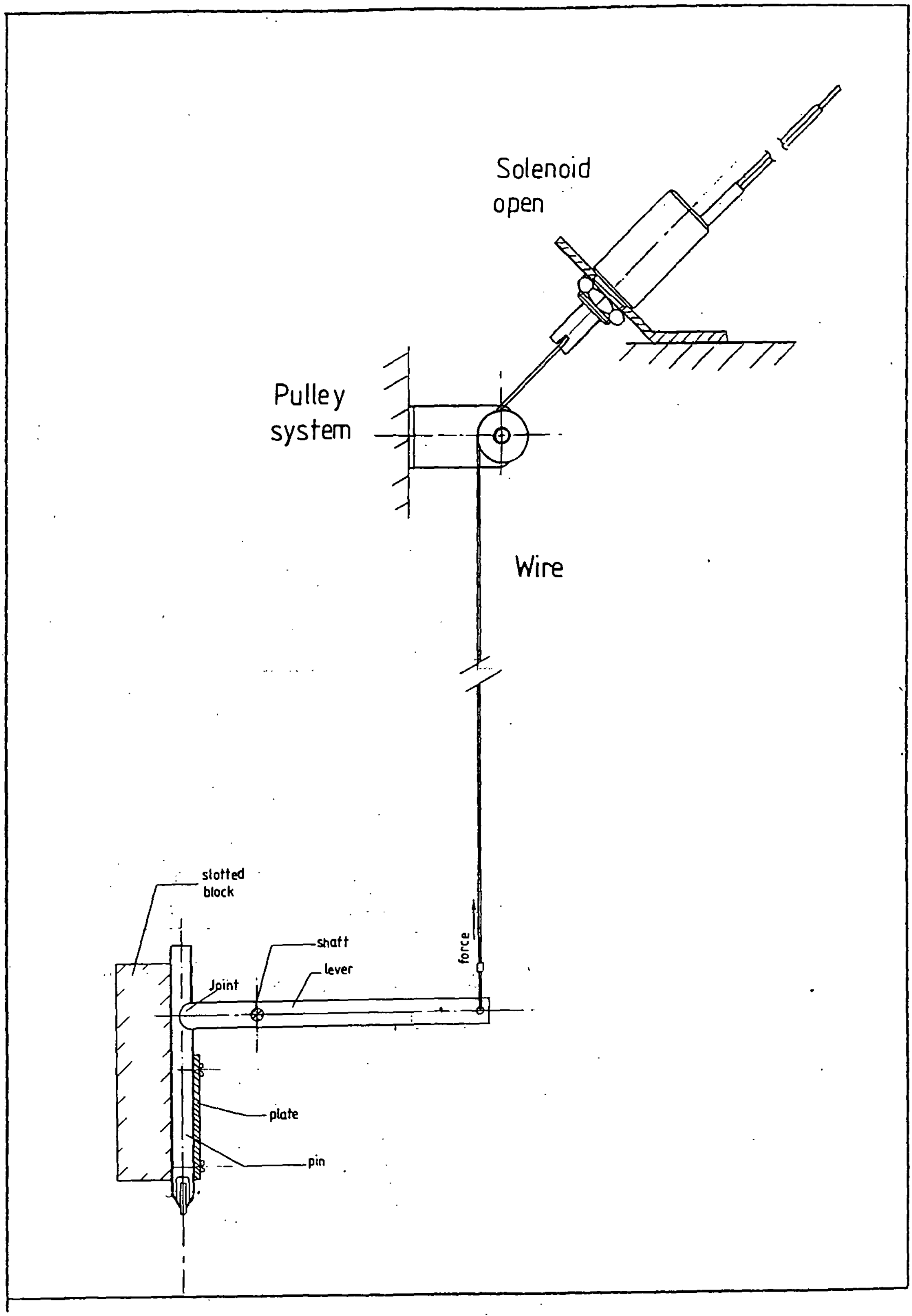


FIG 3·6 Shows the operating system

CHAPTER 4

Evaluation and Tests of Components

4.1 Introduction

The design objectives described in the previous chapter give a guideline of the requirements necessary for the new Skiving Machine. Before the General Arrangement drawing was produced it was necessary to carry out experiments on the individual components of the machine, the pins, levers, wire and solenoids, to establish that the operative properties were correct for the overall specification.

4.2 Solenoids

The new solenoids had a rating of 24 VDC and a power of 100 watts, pulse duty. The solenoids had to be evaluated on their performance. For these experiments the solenoid was energised at 12 Volts because of restrictions on the amplifier boards used for the old machine.

For the first experiment the apparatus consisted of a power supply, transistor, solenoid, pulley and weights. The solenoid was connected through a pulley onto a weight hanger by using wire. Weights were added in increments of 200 gms and the weight of the hanger was 114 gms. When the solenoid was energised weights were carefully placed onto the hanger until the plunger of the solenoid came out. The amount of the current input to the solenoid was increased from 0.4 - 1.5 AMPS.

Figure 4.0 shows a gradual increase in force until it reaches 1.2 amps where the electromagnetic saturation point occurs giving the maximum amps/turns of coil [R11,R12]. This showed that there was no need to apply a higher current knowing that the force would be the same. At a current of 1.5 amps the force was 5.5 kg or 55 Newtons.

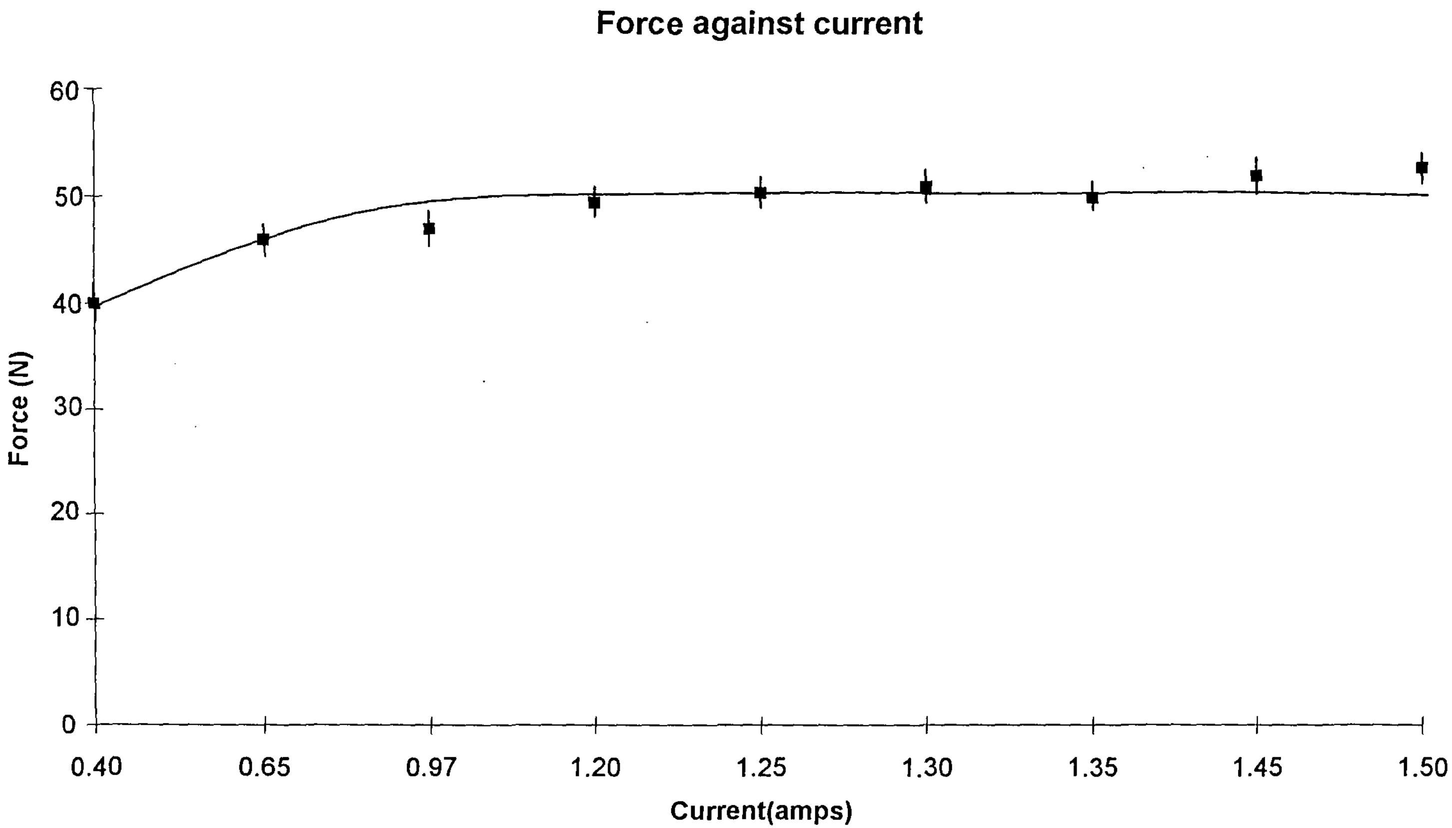


FIG 4.0 Shows the variaton in force with new solenoids

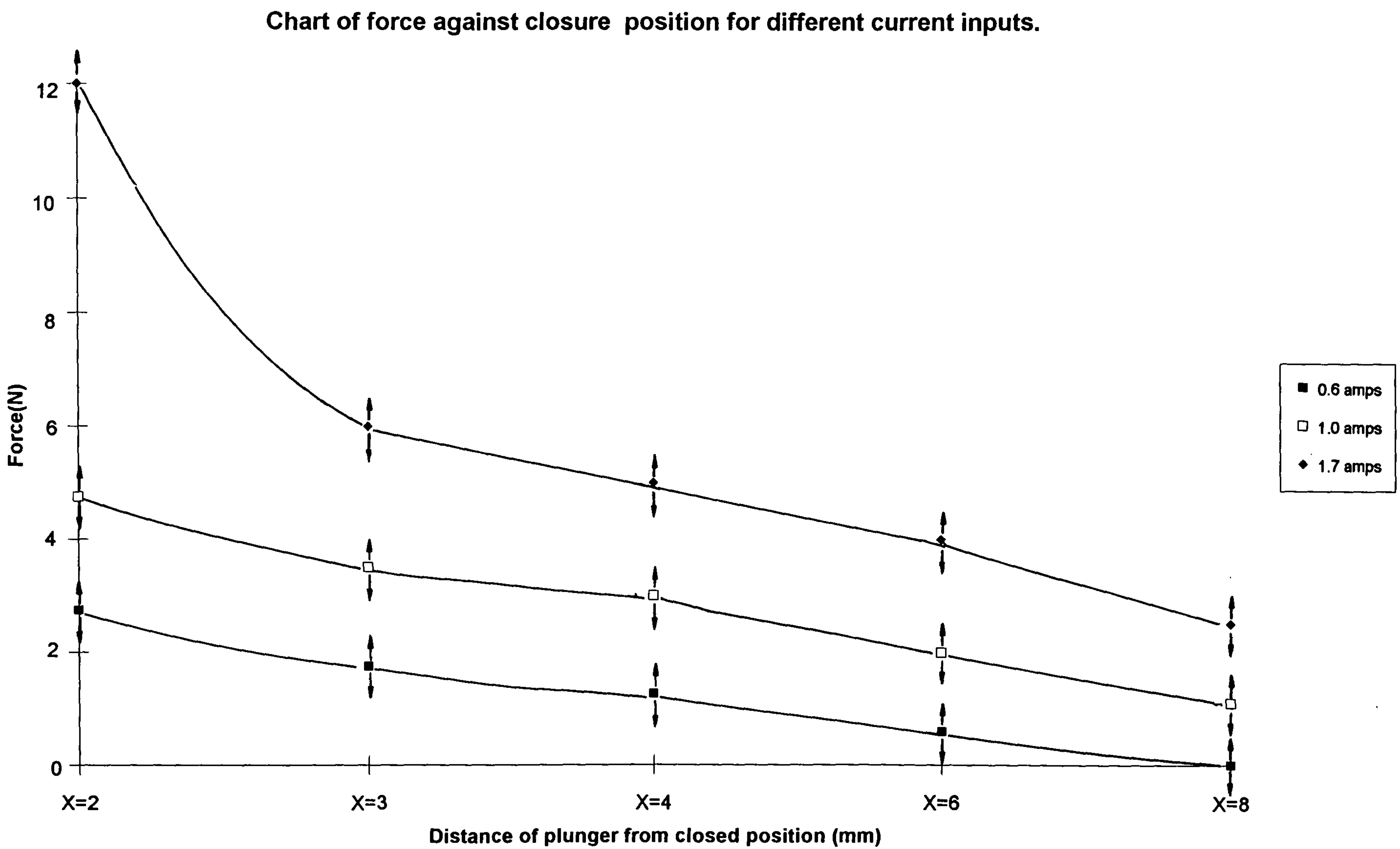


FIG 4.1 Shows force characteristics of new solenoids

This was considerably greater than the force generated by the old machine solenoids which was 19 N. This meant that at 12 V, 1.5 amps the maximum force the pin would exert was 165 N due to the mechanical amplification of the lever.

During the process of testing it was discovered that there was a residual magnetism effect apparent in the core of the solenoids. This effect prevented the plunger from being released after energisation. It was discovered that the residual force was equal to 2.5 N and this remained constant for variations in current.

This effect had not been noticed on the old Skiving Machine and it was necessary to do tests on an old solenoid to compare the results. It was found that a residual force of 1.5 N was also present in this solenoid. Unfortunately, this meant that the new Skiving Machine will have difficulty in obtaining sufficient rate of return of the pins because of its lack of spring return. As mentioned earlier in the previous chapter it was hoped that the forces generated by the two conveyor belts and leather being cut would enable an adequate rate of return for the pins.

In the experimental tests done by Topis [R6] it was shown that static experiments on the tri-layer system (substrate, leather, superstrate) proved there was a return force of 20 Newtons created for 1.5 mm of pin displacement. This effect did not appear in the previous machine due to forces being generated by compression springs on the pin assembly.

An experiment was performed on a modified solenoid to try and reduce the residual force. A hole was drilled into the rear of the solenoid to remove part of the core, see fig 4.2. This reduced some of the contact area after the plunger was energised and therefore increased the effective air gap.

For this experiment the apparatus consisted of a power supply, ammeter, transistor, pulse generator, solenoid, and spring balance. The ammeter was accurate to ± 0.1 AMPS and had a zero error of 0.4 AMPS. The spring gauge was accurate to ± 20 gms.

The adopted method was to measure distances of 2,3,4,6 and 8 mm from the closure position of the plunger. The plunger was then connected to the spring gauge

PULL-SHOWN DE-ENERGIZED

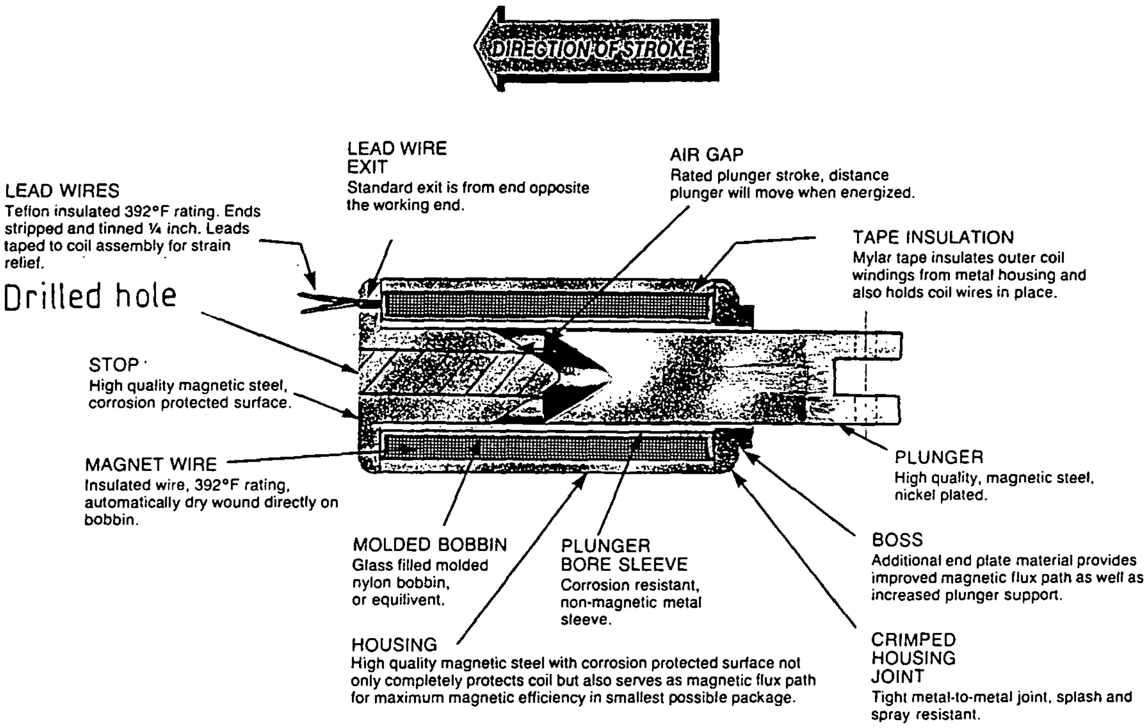


FIG 4.2 Shows hole drilled in solenoid

Taken from Supplers catalogue.
Lisk (uk) Ltd.

by a wire. The voltage on the power unit was set at 12 Volts and the current was increased in increments of 0.1 amps from 0.4 amps to 1.5 amps. When activated the plunger was moved in to the first distance, which was 2 mm, so the force of the spring gauge was equal to the force exerted by the solenoid. This held the plunger of the solenoid in equilibrium. It was necessary to turn the solenoid off regularly because the coil resistance increases with the heat of the solenoid and hence this reduces the force exerted. The manufacturers [R13,R.9] specify a reduction of 65% if it reaches a temperature of 350 F.

The force was recorded and the process repeated for the other distances and different currents. The results are shown in fig 4.3. As can be seen from the chart there is an exponential decay curve and a reduction in force at the close position. Unfortunately there was only a small change in the residual force which was 2.2.N. It was decided that the modification was not desirable to achieve such a small reduction in residual force.

Other methods were considered such as adding a washer or spring to the plunger. The washer would effectively produce an air gap while the spring would push the plunger out after energisation. The disadvantage was that all the plungers would have to be machined and a circlip added to hold the spring or washer in position. The addition of springs would also add more friction to the movement of the plunger. An alternative method would be to add springs onto the levers. The springs would have to be very small in diameter to allow for a pitch of 2 mm.

The above experiment was repeated for an unmodified solenoid. Figure 4.1 show the results obtained. The results show that as expected the force does not increase uniformly with the plunger adjustment. As the plunger moves towards its closed position the force is increased due to the additional magnetic flux density, as the air gap reduces. If these results are compared to those obtained from the modified solenoid, shown in figure 4.3, it can be seen that there is an overall reduction in the level of forces exerted by the modified solenoid, as expected.

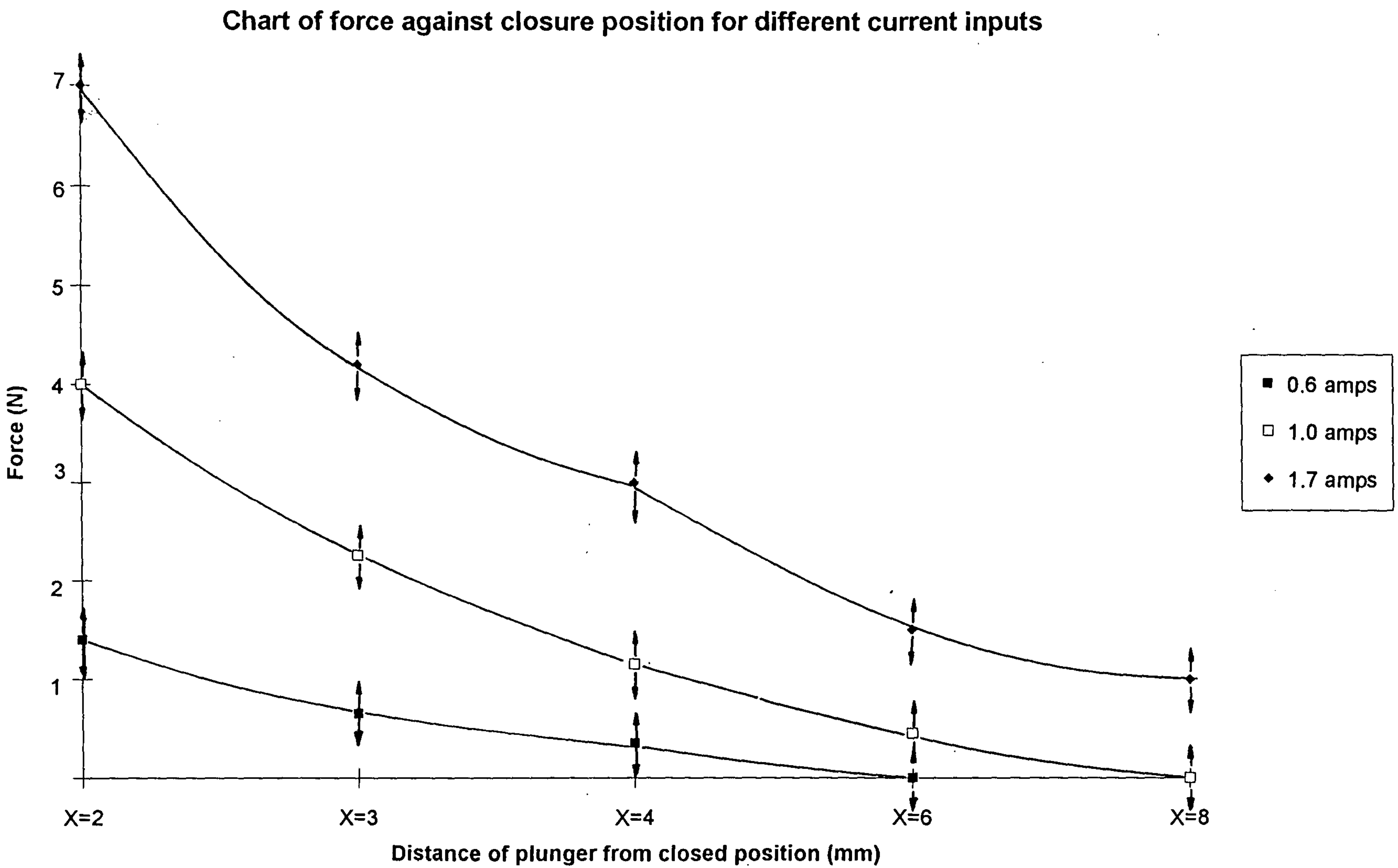


FIG 4.3 Shows force characteristics of modified solenoid

The objective of this experiment was to determine the maximum allowable stroke of the plunger which would allow full movement of the pins.. This meant that the force generated at a distance of 8 mm had to overcome the friction of the mechanism and forces of the conveyor belt. If the force was less than this, then the solenoid would not activate. The stroke of the plunger also determined the pin movement, it was necessary to allow a stroke of 6 mm minimum because of a 3 to 1 ratio of the levers.

It was important to consider the response time or actuation time of the solenoids as this has an effect on the operation of the skiving machine. The response time of the solenoid is defined as, the time between the application of power to the time when the plunger reaches the end of its design stroke. There are two main factors which contribute to the overall response time. The first is time taken for the current to overcome coil inductance and develop the required magnetic flux field. The other was the time taken for the plunger to actually travel the stroke distance. From the information supplied by catalogue [R13], the flux build-up normally takes approximately half of the total response time. Therefore it is possible to estimate an approximate response time given that the required stroke of the plunger is 6mm and the force exerted by the magnetic flux is 4 N at this position. It is evident that the curve shown in fig 4.1 also represents the acceleration of the plunger at various stroke positions and therefore the effective acceleration can be found. Consequently, by knowing the mass of the plunger (22gms), the time taken to travel the stroke length was determined. Hence, from the above considerations the response time was found to be approximately 9 milliseconds. This result was also to within the specified response times detailed in the suppliers catalogue.

4.3 Actuation Wires and Wire Connections

The choice of the actuation wire was significant in the new design and the performance of the machine was dependent on the following physical properties of the wire:-

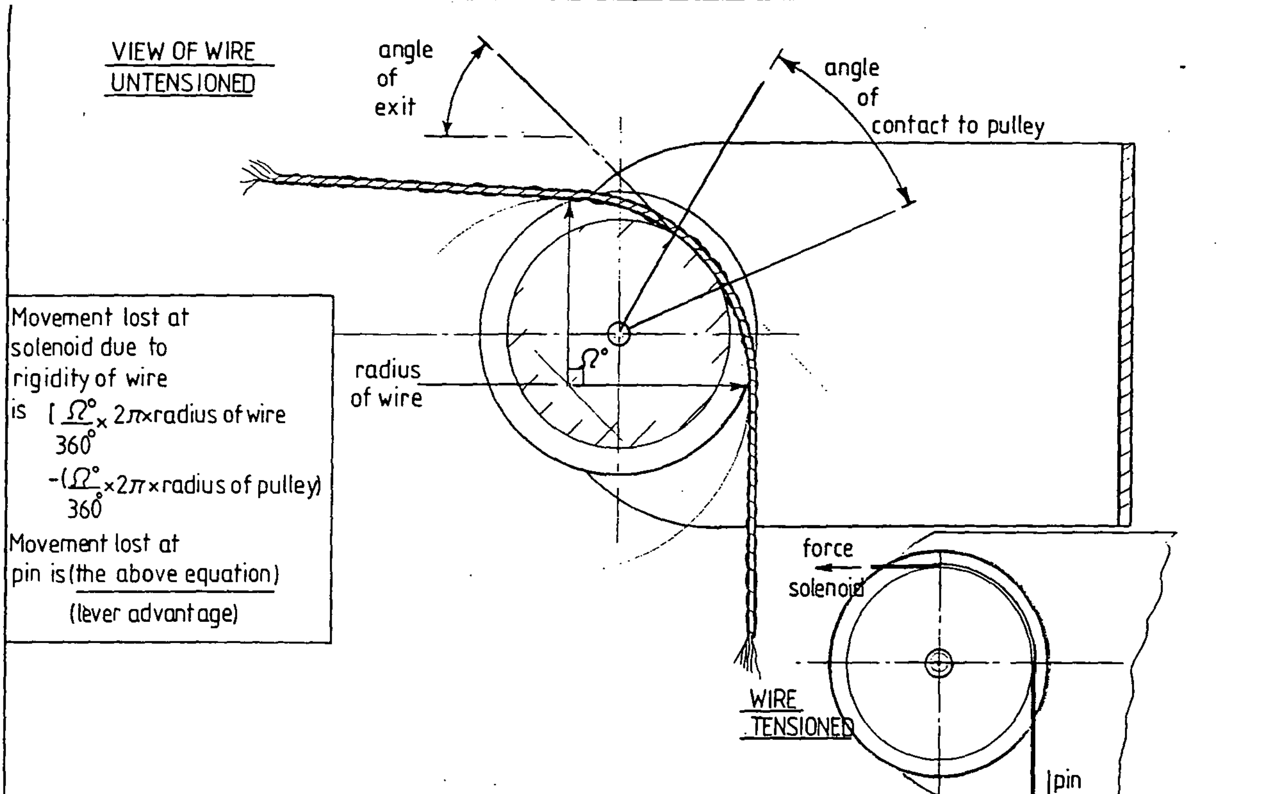


FIG 4.4(a) Shows the pin movement lost due to the high rigidity of the wire

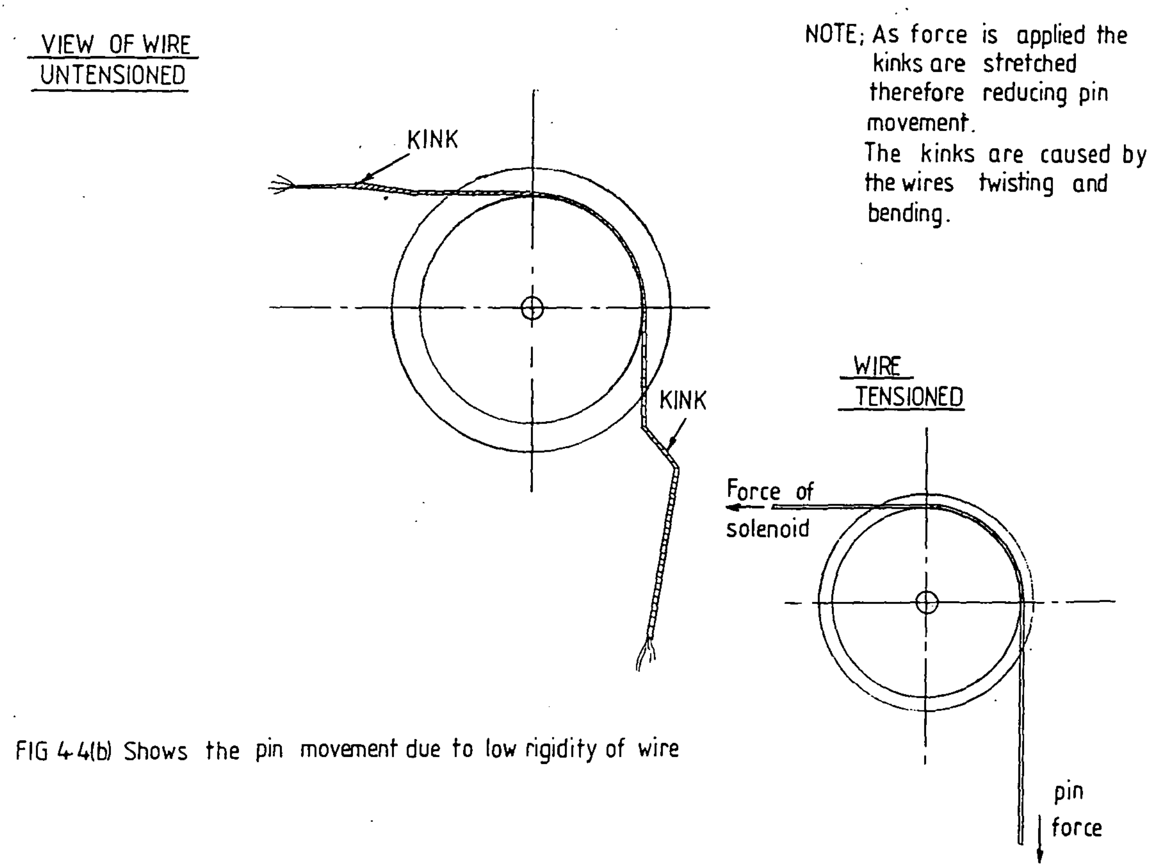


FIG 4.4(b) Shows the pin movement due to low rigidity of wire

a) Breaking force.

b) Maximum extension at maximum force.

c) The rigidity and flexibility of the wire.

The maximum breaking force is the limiting factor in the design as the wire has to withstand the force exerted by the solenoid. The maximum force exerted by the solenoid was 55 N, see previous section.

If we allowed a safety factor of 2 on the wire then we can allow a breaking or ultimate force of 110 N. The factor of safety is equal to the ultimate stress divided by the working stress required [R.7].

The maximum extension is also very important because the amount of adjustment for the tensioning of the wires will be limited. The extension expected under working conditions had to be determined and an adequate adjustment introduced to compensate.

The rigidity and flexibility was significant because the wire passes around pulleys. If the rigidity of the wire is high then a large angle is created, see fig 4.4 (a), and the wire does not conform to the shape of the pulley. The equation shown in fig 4.4(a) gives the amount of movement lost at the pin end if the rigidity of the wire is too high. Under these conditions when the force was applied the movement would be reduced at the pin end. If however the rigidity of the wire was low then `kinking' could occur due to twisting and this would also reduce the movement of the pin, see fig 4.4 (b). A number of steel type, seven strand wires were tested as previous experiments on the solenoids suggested they provided good flexibility and low extension.

Two types of wires were tested, items A and B. Item A had a thickness of 0.4mm and a manufacturers rated break force of 13 kg (fishing tackle leader wire). Item B had a thickness of 0.27mm and a break force of 9 kg (fishing tackle tracer wire). The wires were cut to lengths of 250 mm and passed around pulleys. One end was connected to a lever and the other fixed to a rigid support. The wire was marked in two positions (perpendicular from each other) before and after the pulley see fig

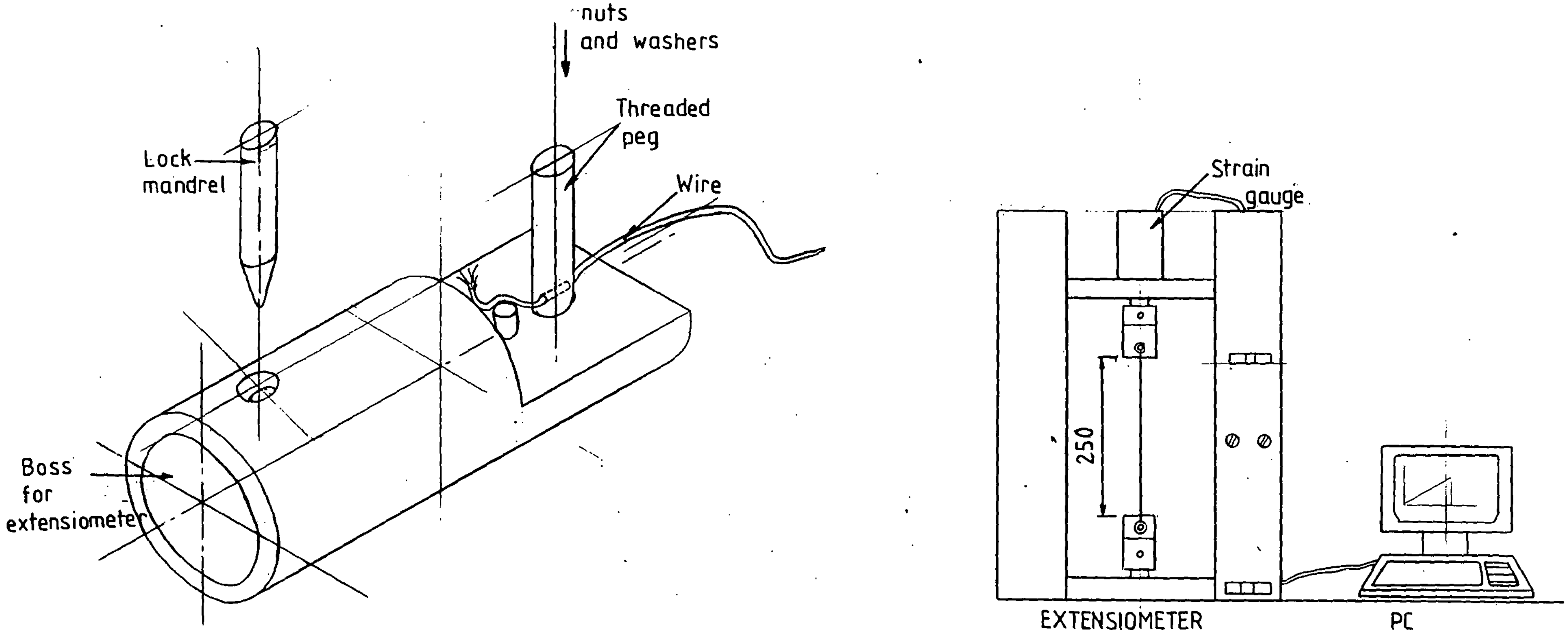


FIG 4.5 Shows method of connecting wire to extensiometer

4.4(a). It must be assumed that the angle Ω, shown in the equation of fig 4.4(a), was equal to 90° and from measuring the distance between these marked positions the radius of the wire could be determined. The objective of this experiment was to compare the rigidity of the two wires and to determine the amount of movement lost during the machines operation. Consequently both wires were measured and, by using the equation, the following results were obtained. For item A the movement lost due to rigidity of wire was 60 mm, therefore lost movement at the pin was 20mm. For item B movement lost due to rigidity of wire was 17 mm, therefore lost movement at the pin was 5.7mm.

These two wires were then connected to an extensiometer in the method shown in fig 4.5 and a series of tests were carried out. The force was applied to the wire and recorded accurately on a personal computer using the standard software. The software gave charts of extension against force and shows the maximum breaking force as can be seen from the results obtained, see fig 4.6(a),.

Item A gave an extension of 3.1 mm for a force of 143.1 N.

Item B gave an extension of 3.6 mm for a force of 90.3 N.

These results were repeatable to ± 10%.

For this experiment the wire was clamped tightly. It was necessary to do experiments on different types of connections which may be used for the new design.

Figure 4.6(b) shows six samples which were connected to the peg of the extensiometer.

The wire termination connections in the new design consisted of a `U' tube and a collar, made from 1mm Ø annealed stainless steel, because it was necessary to protect the wire from contact with the solenoid's roll pin. The following description outlines the different methods of connection:-

a) Sample 1 gave an extension of 5.18 mm at a breaking force of 91.55 N. The collar was crimped twice by using clippers. Therefore the crimps were deep and deformed the wire inside the collar. When the force was increased the wire deformed and spread through a bottleneck. The wire broke at the top crimp. This may have been due to the crimp depth as strands of wire may have been cut during the crimping process.

b) Sample 2 gave an extension of 6.01 mm at a breaking force of 94.9 N. The collar was crimped by using standard crimping pliers which gave two crimps with a wider profile. This provides more area contact with the wire. There was also less likelihood of cutting any strands of wire. However the graph showed similar characteristics as for sample 1.

c) Sample 3 gave an extension of 12.4 mm at a breaking force of 81.54 N. The collar was crimped once in the middle and by crimpers so there was a wide profile. During extension the collar slipped three times as seen from the chart.

d) Sample 4 gave an extension of 27.3 mm at a breaking force of 97.7 N. In this case the collar was not crimped and a knot was tied directly behind the collar. It was a difficult process to adjust precisely to the length required. As force was applied by the extensiometer the knot was reduced in size and pushed into the collar. This caused a lot of extension as the knot tightened. Eventually the knot slipped through the collar and into the U tube, this is shown in the chart of wire slip. The wire than showed the same characteristics as previously and extended uniformly until it broke. It is unusual that the wire did not break at the U tube but in the centre, with the ends showing no sign of fraying as previously. This suggested that the fraying was caused by the crimping process spreading and separating the wires. The clean break of the wire also suggested that the wire had fewer weak points which was shown by the high break force.

e) Sample 5 was a different wire from that previously used. This gave an extension of 15.2 mm at a breaking force of 61 N. The collar was crimped twice with crimping

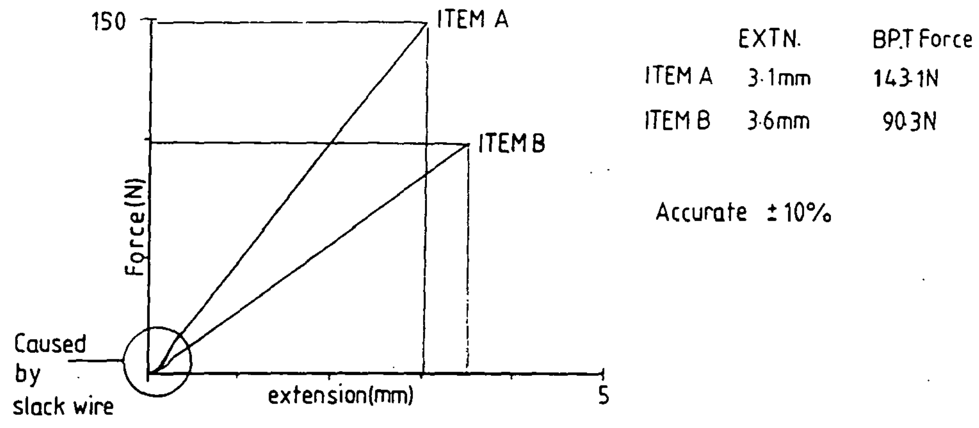


FIG4·6(a) Shows extension results for items A and B.

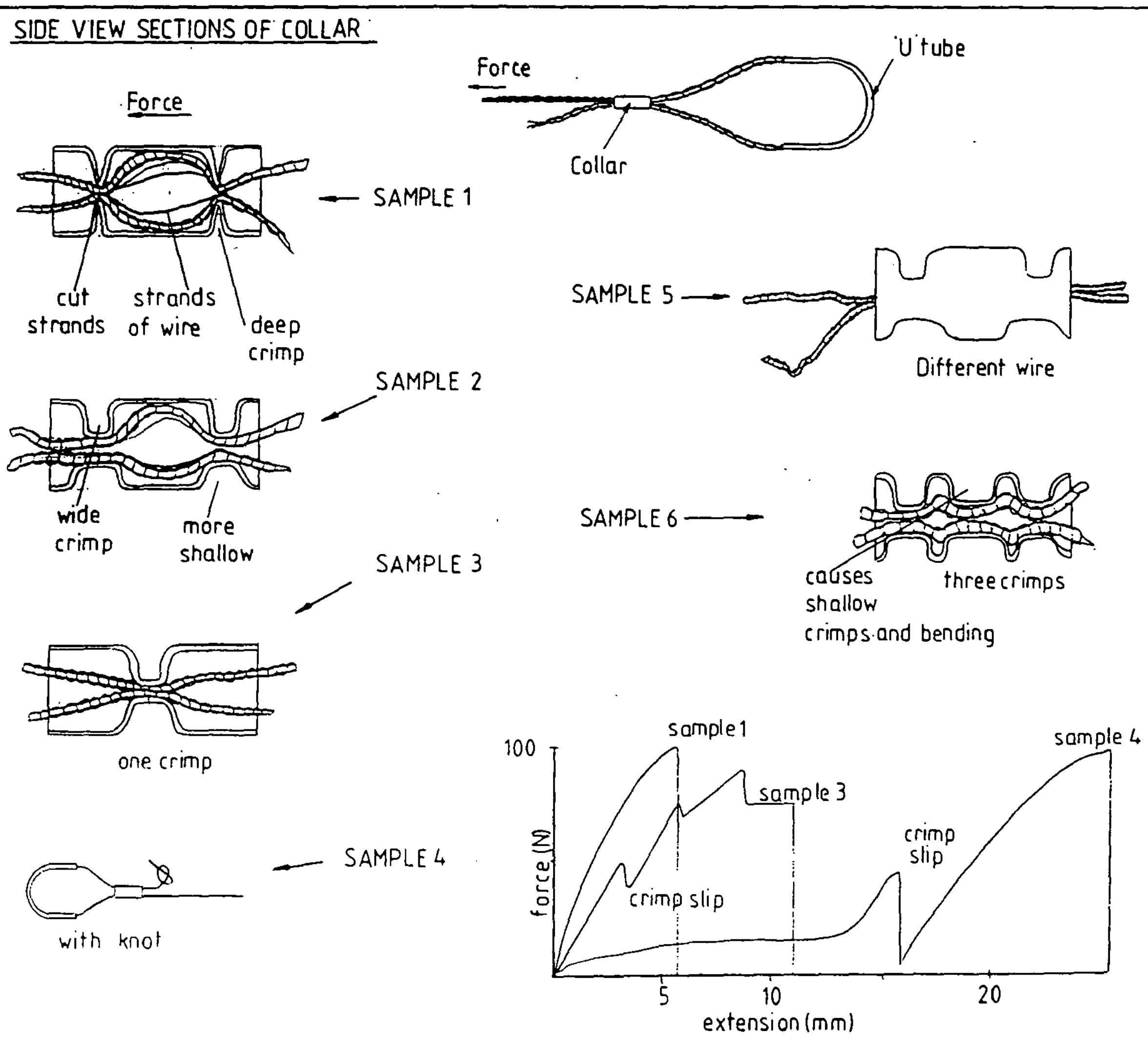


FIG4·6(b)Shows different types of connection tested for the new design pliers. The wire had a very course feel and was kinked. The graph showed similar characteristics as for sample 4.

f) Sample 6 gave an extension of 6.4 mm with a force of 84.2 N. The collar was crimped by crimping pliers three times, two at the ends and one in the middle. The crimps were slightly shallow and wide in profile. It was found that if the collar was crimped to any depth it would bend and alter the orientation of the wire. The graph showed similar characteristics as for sample 1.

The results of the above tests shows how different methods of connecting the same wire can affect its performance.

4.4 **Overall lever actuation**

The overall lever actuation includes the movement of the pins, levers, wire, pulley and the plunger of the solenoid.

The mechanism was assembled and the operation was observed. The apparatus described in the previous chapter was used which comprised of a slotted block of plastic, brass pins, levers connecting wire, pulley and supported solenoid. The pins were placed onto leather to provide the return forces. It was discovered that as the brass lever was pushed by the solenoid it tended to bend about the pivot shaft. This was due to there being 165 N of force being applied to the lever. It was necessary to redesign and strengthen the lever to cope with the forces exerted. Also it was apparent that the lever did not completely return to its start position after actuation.

4.5 **Discussion on the results**

The results showed that the solenoids provided sufficient force for the new skiving machine and had the following design implications. A residual force was present after the solenoids energisation, however this characteristic did not affect the rate of return because of a high return force. The solenoids gave sufficient force at the required stroke to activate the mechanism and a low response time which was necessary for a specified skiving speed of 185 mm/s, which requires an actuation time of 11 milliseconds. However this response time is for a solenoid without any load or weight on the plunger. Consequently when the plunger is connected to the levers and the pins the response time will increase due to the increase in inertia. The stroke or pin movement is therefore dependent on this feature, and to the time for the plunger to return to its start position. Consequently it can be seen from the chart in fig 4.1, that if the mass of the mechanism increases the stroke of the solenoid must decrease to maintain the correct force and actuation time. This was an important consideration when designing the new machine.

From the results obtained it can be seen that item B was the wire that came close to the safety factor limit of 2 and gave a low extension (of 3mm). Item A was stronger but tests on the rigidity suggested that the wire was too rigid to be passed around a pulley. Item B therefore had the required properties, such as a low rigidity and a reluctance to `kink' during its assembly, see fig 4.4(a),(b). The amount of movement lost due to its rigidity as it passed around the pulley was also less than item A. The results obtained from these experiments on the rigidity lead to the design requirement for pre-tensioning the wire before actuation of the pins to reduce the amount of lost movement. From the results obtained on the different connections it can be seen that sample 2 had the greatest advantages. The two crimps on the collar allowed the wire to be trapped in a `bottleneck' type of connection and to buckle between crimps. Therefore the strands of the wire would separate and deform thus giving a better connection. The crimps were not deep enough to cut the strands of the wire and the crimping pliers allowed better control of the crimping process. However this method allowed the wire to creep and extend when in a state of tension, unlike those wires being clamped to the extensiometer. This was an unfavourable requirement because the wire would extend and become slack during the skiving operation. However, it was difficult to clamp the wire on the new design because of the limited amount of space between the levers.

From the observations made during the experiment on the overall lever actuation it was discovered that the the mechanism did not completely return. This was due to the friction created by the movement between the levers and its pivot shaft.

4.6 **Conclusion**

It is evident from the above considerations that the new design should have the following properties. The skiving machine must incorporate adequate adjustment to allow for the extension of the wires. The levers must be strengthened to allow for the additional increase in force used for the skiving machine. The inertia of the mechanism must be as low as possible so that a high rate of actuation and return for the pins is achieved. The wires must be pre-tensioned to improve the transmission of movement around the pulleys. The wires are to be connected by adding collars around the ends and then compressed with crimping pliers. The levers must have a means of ensuring that they return to their original start positions.

In this chapter the type of wire, the method of connection to the lever and the performance of the solenoids have been investigated. The next stage of the work was to use this information in the design of the new skiving machine.

CHAPTER 5

The Design of the New Skiving Machine

5.1 Introduction

The following chapter gives a brief description for the design of the new Skiving Machine. A more detailed account is given in Appendix A3 entitled "the new Skiving Machine", at the back of this thesis. This refers to the General Assembly drawings and details of individual components, used in the machine. Please note that, for this chapter, any references to sections or figure numbers, will be found in Appen. A3.

To start drawing the high resolution skiving machine it was important to follow a procedure related to the findings previously determined, (by experiment and calculation). The high resolution effect of the pins had already been investigated and shown to work satisfactory in manually operated experiments. It had been proposed that the primary system of operation was to be pin, lever, wire, pulley, and solenoids. Consequently, these dimensions were used as a starting point in designing the machine. The drawing procedure is described in section A.1, Appendix A3.

For the design of the machine it was essential to include the objectives discussed in Chapters 3 and 4. Therefore, it was necessary to incorporate in the design, a means to adjust the machine's performance. This was achieved by adding a series of mechanisms, which were easily accessible for adjustment. A detailed description of how the mechanisms work on the skiving machine, is given in Section A.3.

During the design it was necessary to redefine and alter some of the components, due to their dimensional and strength limitations. These factors, and the procedures taken to modify them, are discussed in more detail in Appendix A3.

5.2 **The new Skiving Machine's operation.**

The skiving machine's operating system is detailed in Section A.2. This describes the method of the skiving process, in which the movement of the solenoids is transmitted to activate the pins.

The machine was designed so that its performance could be altered by a number of adjustments (see section A.3). This was achieved by the following:-

a) A mechanism to adjust the stroke of the plunger in the solenoid, as shown in Section A.3, fig.A.2. The length of plunger stroke was altered by moving the plunger adjust bar (i31,fA.2). This was used to set the amount of movement required for the actuation of the pin. The charts in chapter 4, figures 4.1/4.2, show the variation in force with respect to the stroke length of the plunger. Therefore, the stroke of the plunger determines the force exerted by the pins and the rate of actuation. This was discussed previously in chapter 4.

b) The pulley adjustment mechanism, shown in fig.A.3, allowed the pulley to move in and out. It was required because the wire needed to be kept in tension otherwise the required transmitted movement was not achieved at the pins. This ensured that the wires were in a pre-tensioned state, before the actuation of the pins, which removed any permanent deformation (such as kinking). The pulley adjustment mechanism, see fig.A.3, was also used to accurately adjust the closure position for the solenoid. This was achieved by preventing the plunger of the solenoid from reaching its final closure position or energisation point. This created an air gap, which reduced the effect of the residual magnetism of the solenoid and allowed the plunger to return to its start position. Consequently, there was an improvement in the time taken for the levers and pins to return to their stop positions.

c) A mechanism to adjust the return of the levers to their stop positions, as shown in fig. A.4. This was used in conjunction with the above mechanism, to alter the amount of magnetic attraction exerted on the levers. This allowed the wires to be pre-tensioned in their stop positions.

d) The shaft mounting and support mechanism, shown in figure A.5 . This was used to strengthen the shaft of the skiving machine, see the calculation in Appendix A.1.

Section A.3 describes the other mechanisms which were used to assist in the assembly and the adjustment of the skiving machine. These will be discussed further in the next chapter.

5.3 **Changes to the design and dimensional considerations.**

Figure A.6 shows the changes to the G.A drawing made during the designing process. These included changes made to strengthen the structure of the machine. Spacers, (see fig. A.7), solenoid support bars (i27,A.2) and supports (i2,A.6) were added or modified to make the structure more rigid. The modifications to the solenoid support bars allowed the positions of the solenoids to be moved and this prevented fouling of the wires. The supports also assisted the plunges to fall out of the solenoids after actuation. This was achieved by supporting the solenoid support bars while they were tilted at an angle. The top lever adjust bar (i10,A.6), was an additional component, which was used to limit the amount of movement of each lever. Section A.4, also lists a number of other functions of lesser importance.

Section A.5 gives a detailed description about the dimensional and accuracy requirements for the skiving machine. Figures A8/A9 gives the relation of the activated pin to each individual solenoid.

5.4 **Features of the Design required for the new splitting machine.**

It had been mentioned previously that the design had to be adaptable so it could be used on the new splitting machine, see Fig A.4. It was impossible to design the machine to fit both splitting machines without some modifications or new components being manufactured. The new splitting machine required 175 actuating pins therefore it was necessary to manufacture components. This was principally due to the dimensional restriction of the back stops (i2,fA.0) on the old splitting machine. However if installation was to take place only 2% of the overall components would have to be re-manufactured. It must be noted that the increase in the number of activating pins was to allow a wider span; if this was not required then the Skiving Machine could be transferred without alteration. The following components had features to allow for future expansion. The front brackets (i63,fA.0), the front plate (i10,fA.0), the solenoid support bar, the spacers (i14,fA.6), the tie bars (i13,fA.6), and the pulley adjustment bar (i42,fA.3)

5.5 Standardisation for Cost and Ease of Assembly

It was necessary to reduce the cost of manufacture and assembly to a minimum. This had to be incorporated in the design. It was decided to use as many standard mass produced components as possible as the cost to manufacture `in house' would have been excessive. Standard items were specified where possible to speed up assembly and to reduce complicated machining processes in manufacture. There were over a thousand components in the design, and a hundred different component types. The majority of these components were nuts, screws, washers, circlips which were `off the shelf' items. In particular, pulleys and brackets were bought in as standard items, although some vibration resulted from the low quality of the support brackets. Therefore an additional support was added to the pulley adjustment bar. The design of the machine was initially based on aluminium sections with standard dimensions to reduce the cost and speed up the manufacturing process.

This showed that although the machine was designed for research purposes it was accepted that cost should be an objective.

CHAPTER 6

The influences of the Design on the Manufacture and Assembly

6.1 Introduction

The following chapter describes the design of the new Skiving machine and the affect on its manufacture and assembly. In the previous chapter, the design was discussed with reference to the machines operation and the process of its development. The description below details the factors discovered, during the manufacture of the design, which affected the machine's performance.

6.2 Manufacture of the Skiving Machine

The large quantities of components such as the levers and pins, were manufactured by outside suppliers to detailed drawings. The accuracy of the drawing was extremely important as any faults in the drawings would affect the batch of components produced. This was more important with reference to tolerance specifications. On some occasions suppliers could not meet the design requirements and therefore design modifications were necessary. If modifications or changes had to be carried out on one component drawing then alterations were needed for connecting parts. For 'off the shelf' items such as the pulleys, these were ordered directly from the suppliers. Some components were manufactured in-house in the University. This assisted in reducing the overall time requirement for component manufacture. The drawings which required the largest number of components were sent to the suppliers first. This allowed for time in the manufacture of larger quantities. This meant that as the drawings were being issued to the suppliers and the University Machine shop, manufactured components were being completed and returned to the University. Therefore when all the drawings were completed, the assembly of the parts could take place. The organisation of this strict time schedule, and the production of drawings in the correct sequence was crucial in planning the assembly of the machine.

6.3 Method of Assembly

The sequence of assembly was determined by the time that parts were received from the suppliers. This did not follow the plan as perceived by the designer. It was fortunate that some sub-assemblies could be built out of sequence.

As discussed earlier, when the G. A. drawing was produced the author had an idea of how components could be assembled and had allowed for this in the design. But because this is an original prototype machine there was no way of determining other problems unforeseen by the designer. The sequence of assembly could therefore be altered and it was a case of 'trial and error'. The design of the machine was also changed due to the requirements identified during assembly. The first items to be assembled were the sub-assemblies.

The first sub-assembly to be assembled was the magnetic holder which is used to adjust the return of the levers and to pre-tension the wires. This comprised of fifteen permanent magnets secured to an aluminium bar with a pitch spacing of 20 mm. The use of fifteen circular magnets was not the ideal requirement for the Skiving Machine because the bar would exert greater magnetic force at the centre of a magnet than at the circumference. Therefore, some levers would experience less force than the others. This could be overcome by using a single long magnet as it would give an even magnetic force on all the levers. Regrettably, a magnet could not be manufactured to the required length of 300 mm and at a reasonable cost.

The solenoids were located into their support bars and labelled with reference to the position of their offset, see fig 5.8 and 5.9. Additional electrical wiring was fitted along the channel section of the support bar, see fig 6.0. This was to prevent mechanical interference with the actuating mechanism and was achieved by drilling holes in the bar next to each solenoid and pushing the colour coded extended wires through the hole and along to the end of the bar. After this was done the solenoids

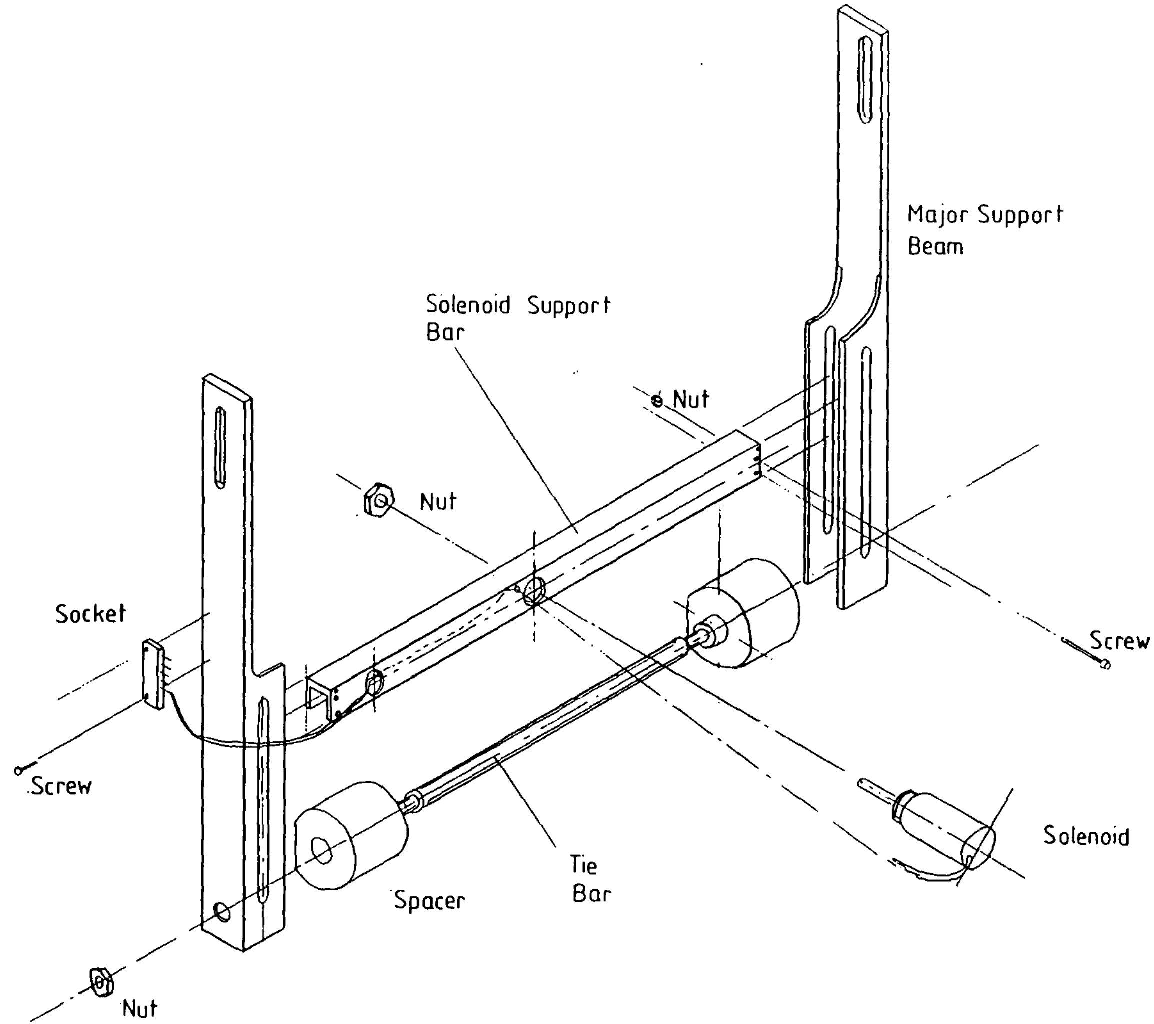


FIG 6·0 Shows assembly of Major Support Beam Assy.

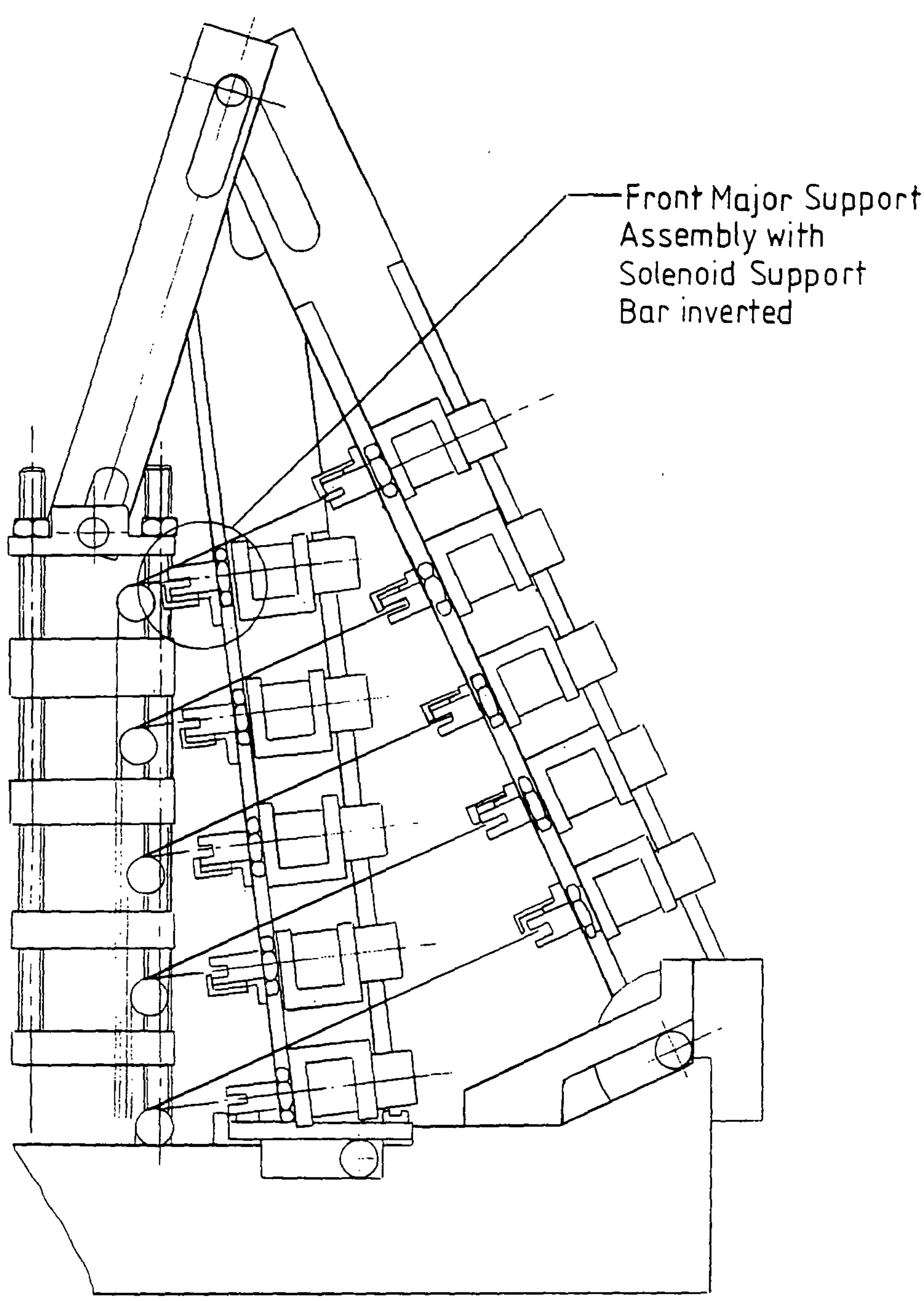


FIG 6.1 Shows inverted Solenoid Support Bar
to allow more space

were secured and connected to the mounting support beams. The bars were secured into the beams and the height could be adjusted by loosening the nuts and screws.

It was found necessary to invert the front solenoid support bars; this was because the position of the solenoids was not in the middle of the bar length. This meant that if both the front and the rear solenoids bars were inverted then the mechanical transmitting wires from the rear solenoids to the pulleys would interfere with the plunger adjust bars of the front solenoids. Fig 6.1 shows that this arrangement allowed more space.

The levers were made by laser-cutting 1 mm thick mild steel and then machining to give a good tolerance and a smooth contact finish. This was necessary to ensure that the levers were straight and they did not catch or foul each other in operation. The washers and shaft supports were located between levers on the shaft. The design required that one shaft support to be added after every thirty eight levers and the washers had been ground to satisfy necessary tolerance requirements.

The slots located in the pin holding bar needed to be of an accurate depth and width to allow the pins a clearance fit. However, it was not possible to achieve the required tolerance because of the induced stresses created by cutting the slots in the plastic bar. Consequently, this caused the orientation of the pin holding bar to become slightly warped. During the design stage this effect had been anticipated and the bar was sandwiched between the front plate and thrust plate. This straightened the plastic holder and the pins were dropped into the slots. The pins were made free moving before continuing to the next stage.

The shaft and levers were located onto the two crossbars and the shaft support mechanism was added. The mounting block and rear plate were connected, see fig 6.2. The assembly was then inverted and the two dowels of the crossbar were located into the thrust plate. The two dowels was a necessary design feature because it allowed the crossbars to be positioned vertically. The levers were pointed downwards to avoid contact with the pin holder, see fig 6.2. This was necessary due to the difficulty in engaging all the levers into the slots while the crossbar was being located.

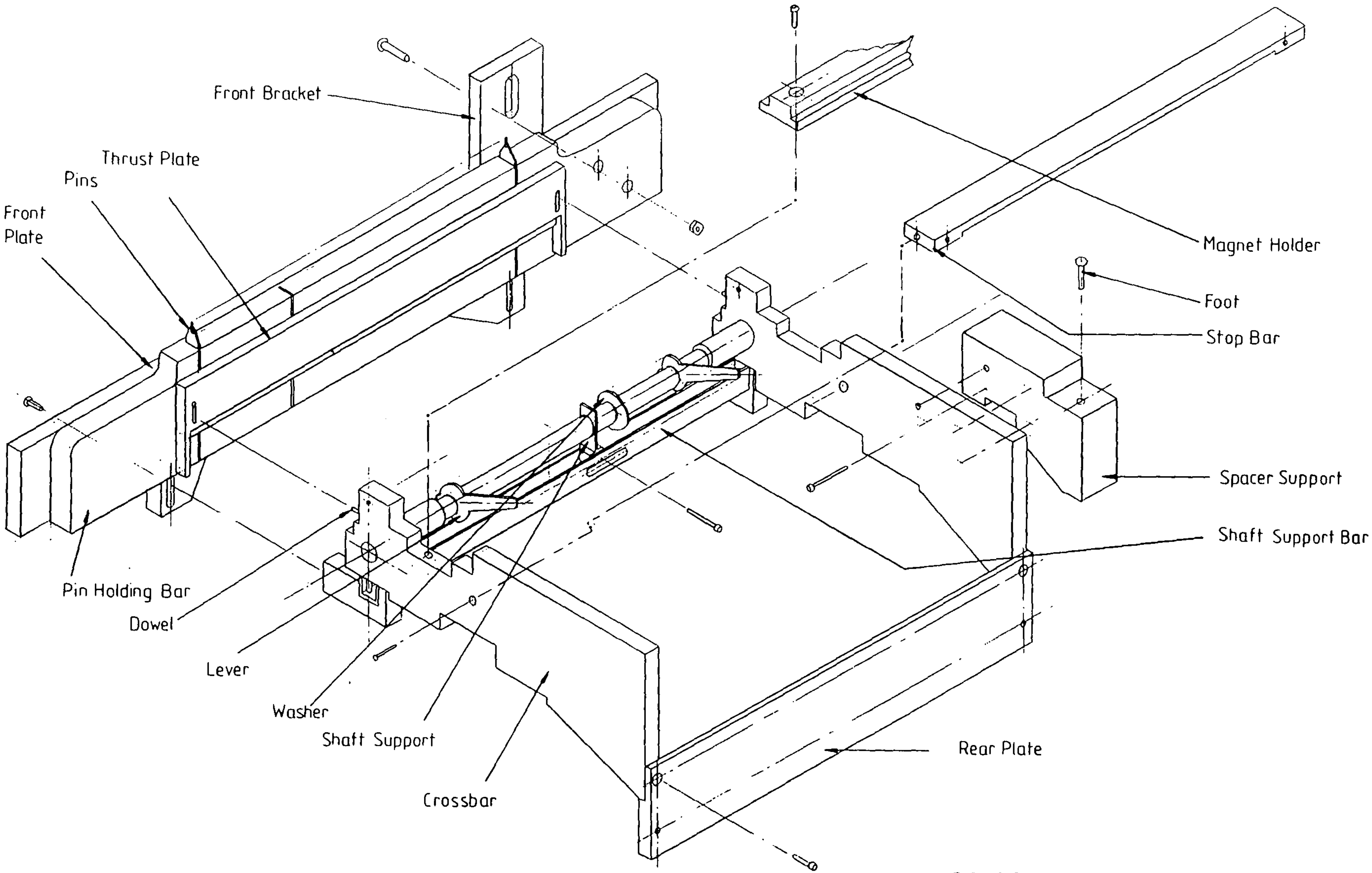


FIG 6·2 Shows method of assembling Crossbar and locating Pins/Levers.

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ROW NUMBER	FRONT or BACK	ACTUAL LENGTH from G.A. DRAWING(mm)	ESTIMATED SAFE LENGTH(mm)
1	B	132	158
1	F	40	48
2	B	153	184
2	F	80	96
3	B	156	206
3	F	100	120
4	B	206	272
4	F	132	158
5	B	217	260
5	F	167	200

NOTE;- The Estimated Safe Length = Actual Length from G.A drawing + 20 %

Length= Distance from end of plunger clevis to the lever hole.

The additional length is required for the connections to the lever hole and plunger clevis.

Fig 6.3 ***Shows the wire lengths required for the Skiving Machine.***

The front plate was secured to the mounting block and crossbar. The levers were engaged one at a time because the walls of the slot had to be pushed apart to allow access into the semi-circular pin joint. If there was a pin and lever engaged next to it then the slot wall would not deflect. The design of the steel levers and brass pins allowed an easy free moving contact. The magnetic holder and roller assembly were located. The roller assembly was adjusted to a height that allowed for the movement of the conveyor.

The Skiving Machine had also been designed for the new splitting machine which required a greater height from the knife position to the base of the crossbar. Therefore, the pin height was altered by adjusting the position of the stop bar, this set the position for the machine to skive. The front and rear mounting beam's assemblies were then located onto the crossbars and their positions were marked and recorded. These reference marks were important to the design because they set the degree of angle for the mounting beam assemblies and the lengths of wire for each bank of solenoids. The beams were then removed for the next stage of assembly.

The assembly was mounted to protect the pins from damage and the wires were connected to the levers. This was done in sequence of rows of solenoid support bars as specified by fig 5.9. Therefore the pins or levers which would be activated by the solenoid support bar labelled '1 B',(note that the '1' signifies the bottom row and the `B' signifies the back mounting support beam), would be pin numbers 1, 11, 21, 31, etc. After all the levers of row `1 B' had been connected the next row `1 F' was connected to pin numbers 6, 16, 26, etc. This process was continued until all the levers were each connected to a wire. Each wire was identified, measured and cut so their lengths were the same as the G.A. drawing. Fig 6.3 shows the lengths with reference to the row and the estimated safe length required for the connections of the wire. The wires were connected to the levers using a crimped collar, as recommended in chapter 4. The open wire had a length of 5 mm to allow for the crimp slip during tension and operation. On the other end of the wire a collar was added and then a 'U'

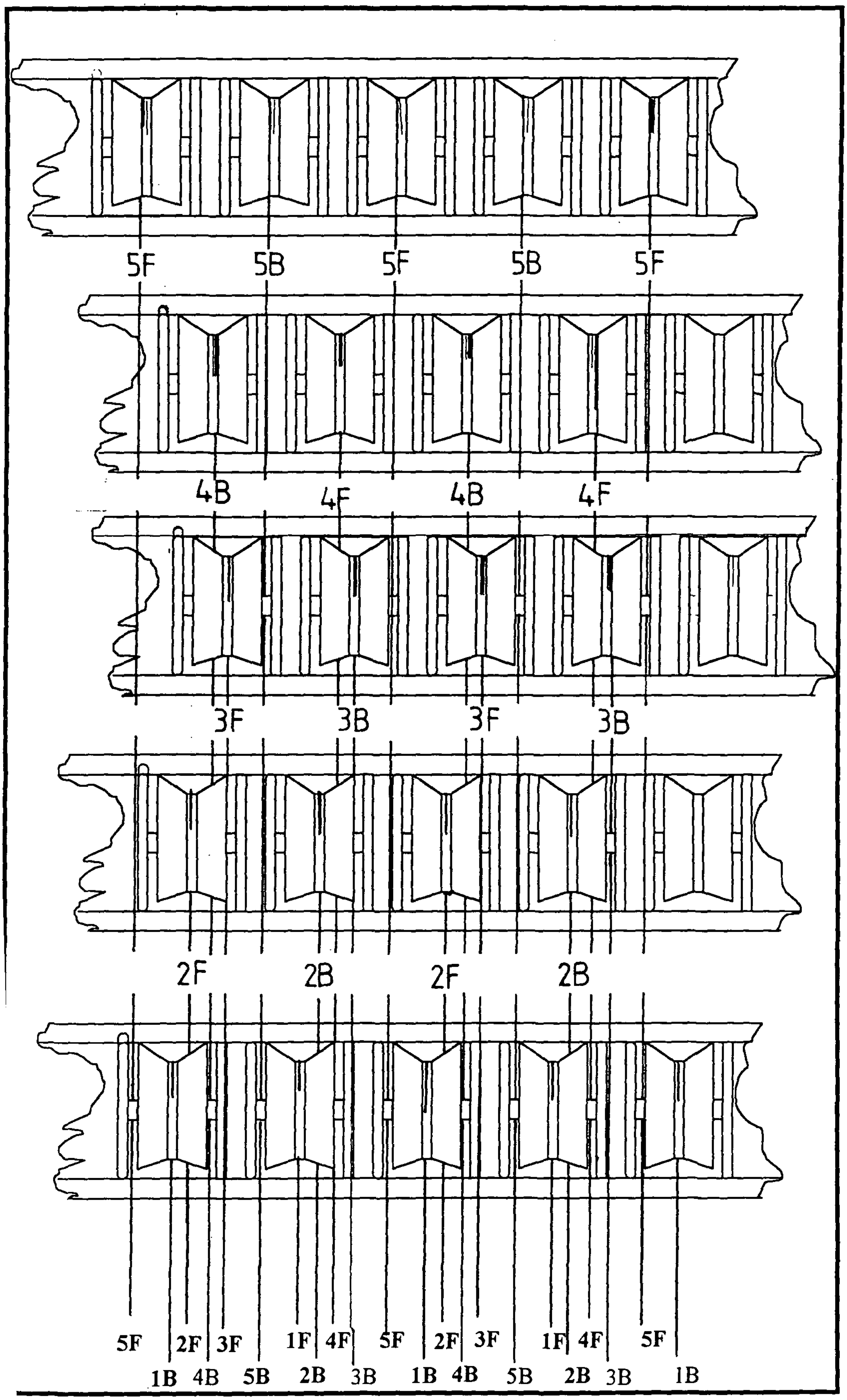


FIG6·4 Show the positions of the wires as threaded through pulley brackets tube was threaded onto the wire. When all the wires were connected then the next important stage of the assembly was begun.

The front mounting support beam assembly was then located on the assembly. The rear mounting support beam assembly was then located behind and secured by tightening the tie bars and by locating the pivot blocks. The pivot blocks only secure the position of the spacers and the tie bars secure the angles of the support beams. This was a necessary design feature as it allowed movement of the mounting beam assemblies during the wiring process. The first pulley adjustment beam was located onto the crossbars and the wires were threaded through its pulley brackets. Fig 6.4 shows the positions of the wires as they were threaded through the brackets of each of the five adjustment beams. It was important that the wires should not catch or foul the sides of the pulley brackets during operation. Therefore the pulley adjustment bars were designed so their positions could be altered, see fig 6.5. The front mounting beam assembly was located in the premarked position. The ends of the wires were then connected in plunger of the solenoid.

The rear mounting assembly was positioned to the recorded markings and the wires were tensioned around the pulleys. The collar was then crimped in this position. There was difficulty with this process because when the wires were connected to the solenoids there was not enough space to allow access to locate more than one plunger at a time. This was overcome by locating every plunger behind the front mounting assembly and hence allowing access for the next plunger to be connected. The design of the rear mounting assembly allowed it to pivot backwards and therefore for the upper solenoids this allowed greater access, see fig 6.5. This process was repeated until all the wires were connected to plungers. The rear plungers were then connected to the solenoid support bars of the rear mounting beam assembly. The front and the rear mounting beams were then secured tightly because any minor vibration could alter the settings required.

When all these factors had been set then it was necessary to start the various testing procedures and any minor adjustments.

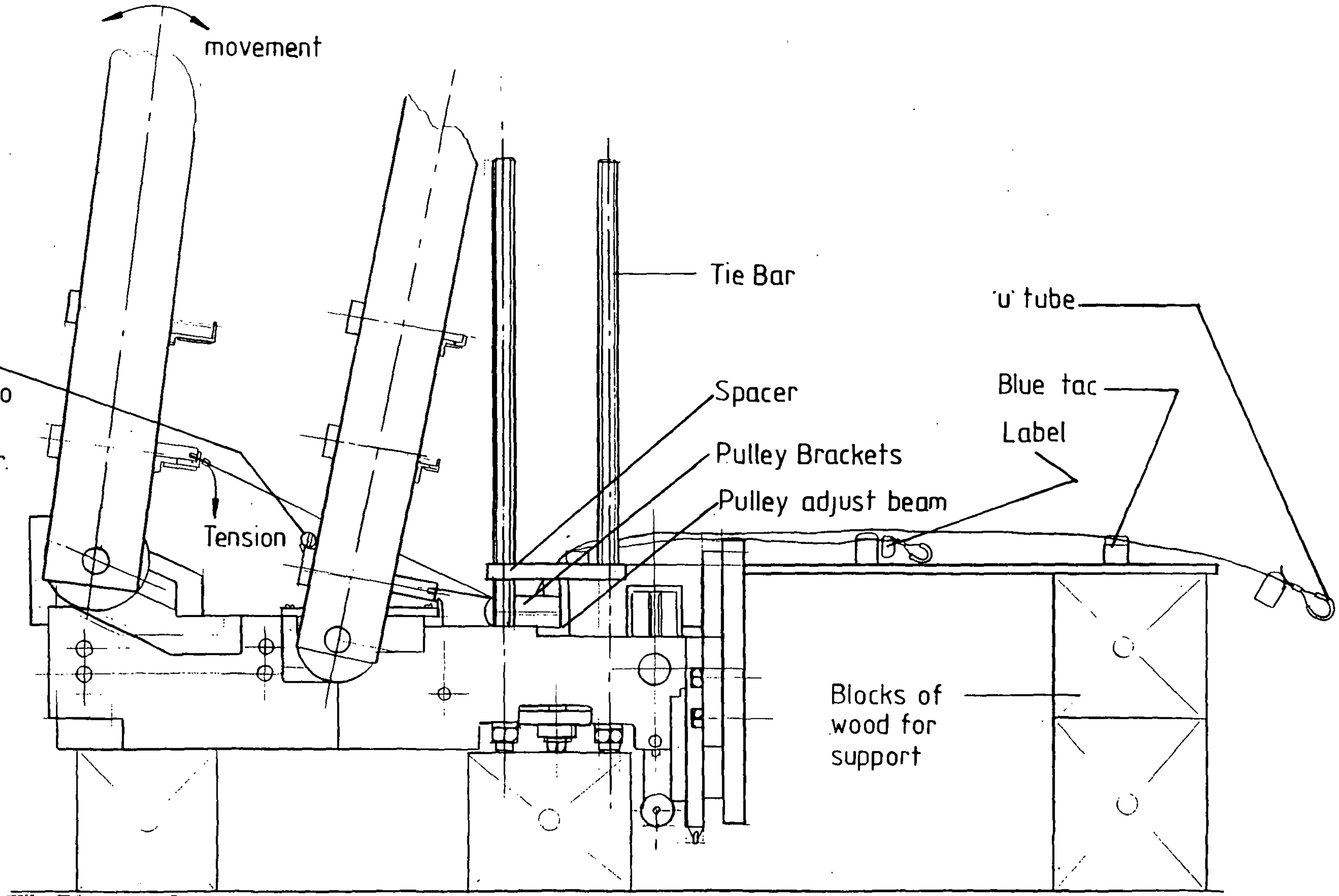


FIG 6·5 Shows the procedure for connecting wires

It can be seen from the above description that the design had been proved to be a success in achieving some of the initial objectives of this report. These objectives were to ensure that the machine had the flexibility and was assembled to the required dimensional parameters.

CHAPTER 7

Testing of the Machine

7.1 The Hardware and Software Required to test the Machine

It was necessary to test the Skiving Machine while it was still located on the bench, to evaluate the machine's performance before its location onto the splitting machine. The hardware system that was required to activate the Skiving Machine comprised of the following:-

a) A Motorola M68000 Microprocessor which used Versatile Interface Adapter (VIA) circuits. Each VIA port was used for the input or output of signal voltages. For the operation of actuation of the solenoids on the Skiving Machine the VIA ports provided an output signal of 5 Volts and an 8 bit output. Fig 7.0 shows the output port addresses. There are eight output lines which are numbered from 0 to 7 as shown along the top of the table. Each of these givesan output signal to control the thrust pins. The table gives the respective thrust pin for each port and line. It can be seen that there were twenty eight ports available and only fifteen were used. This was because the microprocessor had been designed so that additional thrust pins could be added for the new splitting machine or at a later development stage. Each 8 bit VIA port was outputted by a 20 way flat cable connector arranged as alternate signal and ground. The M68000 comprised of four cards which were numbered from 0 to 3. All 8 ports on cards 0, 1, 2 were configured as outputs. Card 3 with ports 0, 1, 2, 3 were output, while ports 4, 5, 6, 7 were input ports. There were also buffers which could be set and this meant that outputs were inverted. The microprocessor had four registers of 16 bits each which could be programmed to divide the clock (1.25 ms period) and optionally control an output. This requirement was not needed for the testing procedure. Fig 7.0 also shows the inverted Binary Line number which addresses each output line.

Binary Line No.	FE	FD	FB	F7	EF	DF	BF	7F
VIA Output Port Address	**Output Line 0**	**Output Line 1**	**Output Line 2**	**Output Line 3**	**Output Line 4**	**Output Line 5**	**Output Line 6**	**Output Line 7**
74601	1	2	3	4	5	6	7	8
74603	9	10	11	12	13	14	15	16
74621	17	18	19	20	21	22	23	24
74623	25	26	27	28	29	30	31	32
74641	33	34	35	36	37	38	39	40
74643	41	42	43	44	45	46	47	48
74661	49	50	51	52	53	54	55	56
74663	57	58	59	60	61	62	63	64
74681	65	66	67	68	69	70	71	72
74683	73	74	75	76	77	78	79	80
746a1	81	82	83	84	85	86	87	88
746a3	89	90	91	92	93	94	95	96
746c1	97	98	99	100	101	102	103	104
746c3	105	106	107	108	109	110	111	112
746e1	113	114	115	116	117	118	119	120
74701	*	*	*	*	*	*	*	*
74703	*	*	*	*	*	*	*	*
74721	*	*	*	*	*	*	*	*
74723	*	*	*	*	*	*	*	*
74741	*	*	*	*	*	*	*	*
74743	*	*	*	*	*	*	*	*
74761	*	*	*	*	*	*	*	*
74763	*	*	*	*	*	*	*	*
74781	*	*	*	*	*	*	*	*
74783	*	*	*	*	*	*	*	*
747a1	*	*	*	*	*	*	*	*
747a3	*	*	*	*	*	*	*	*

Note: symbol * signifies that port addresses are not used.
Grey indicates Pin numbers.

TABLE 7.0 *Shows which VIA ports control activating thrust pins on the mechanical activator.*

b) Amplifier boards and a power unit were used to increase the 5 volt signal to 12 volts, with a current value sufficient to activate the solenoids. The amplifier boards outputted the solenoid voltage through a 34 way connector with 16 bits of information.

c) A switch box was used to re-route signals from the M 68000 to the Skiving Machine. It was necessary to have a switch box because the solenoid support bars activated the thrust pins in an interval sequence of ten. For example, solenoid support bar, 1 B activated thrust pins 1, 11, 21, 31 etc. It was therefore necessary to route the signals so that the output lines 0-7 on the ports of the M 68000 activated thrust pins 1, 2, 3 etc. respectively. It was possible to perform this function by a different software addressing mode. However, the switch box had the following advantages. It was flexible for easy upgrading to the new Splitting Machine which required 175 thrust pins. The switch box replaced a connection box which was necessary to connect the 34 and 40 way cables. The time and cost for the assembly of a switch box was the same as for a connection box. The switch box contained additional on-board connections to accommodate extra solenoids. It was therefore an easy procedure to connect up extra cables, and wires were re-routed to simplify any solenoid addressing in the software.

Fig 7.1 shows the connection between the Motorola M68000 microprocessor and the solenoids of the new Skiving Machine.

The Motorola M 68000 was interfaced with a UNIX Computer System. The UNIX system had a cross-assembler and editor which allowed updating of the software for the M68000.

It was necessary to write the software to activate individual thrust pins in sequence for the testing process. This program was designed to test the following:-

a) Actuation of the pins.

b) The amount of pin movement.

c) The return of the levers to the stop bar.

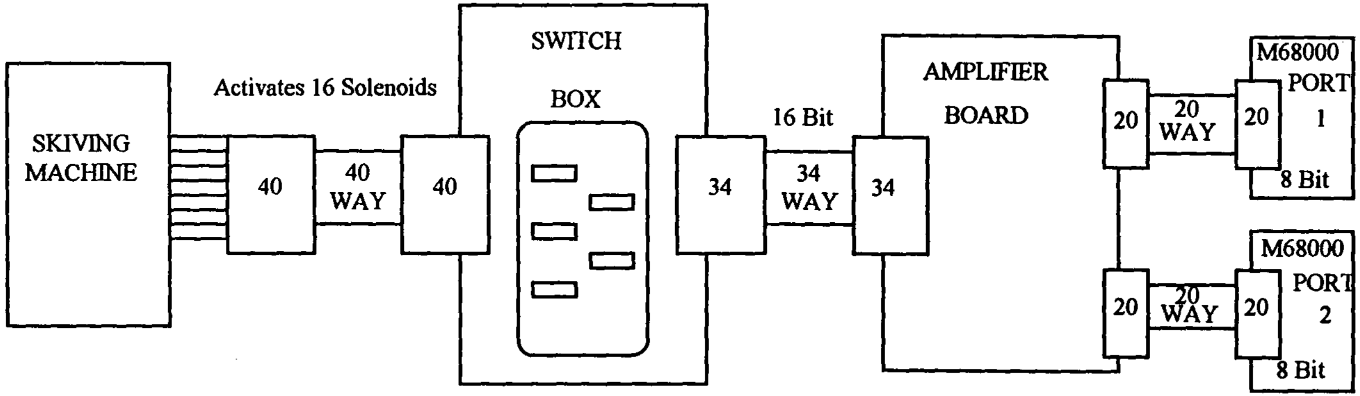


FIG 7.1 ***Shows the communication between the Motorola M68000 microprocessor and the new Skiving Machine.***

d) The speed or rate of activation.

This program activated each pin for a period of one second.

A second program was written to activate the levers eight times with a time period of one second. This program was used for the following reasons:-

a) It allowed time to adjust the wires and improve the performance of each actuation.
b) It allowed a testing of the strength of the crimps on the wires.

These two programs are shown in Appendix A2 at the back of the thesis under the titles of Test Program 1 and Test Program 2.

7.2 Adjusting the Machine for Maximum Performance

The programs were used to adjust the machine and this was done by the following procedure:-

The upper lever adjust bar was adjusted for the maximum amount of lever travel.

The first program was then set to run through the sequence to activate every thrust pin from numbers 1 to 120. From the rear of the Skiving Machine the motion of the wires pulling the levers was observed to determine the levers with the minimum amount of movement. When this had been discovered, then the upper limit bar could be adjusted to limit all the levers to obtain a consistent amount of pin movement and to improve the return of the levers to the stop bar.

After subsequent testing, it appeared that the machine required the following adjustments to improve its performance.

It was evident that the residual magnetism effect, which was present after the solenoids de-energisation, prevented the plunger from returning to its open position. During the design of the machine, this effect was considered and the following alterations were introduced. The magnetic holder mechanism was adjusted to increase the attraction on the levers. The upper lever limit bar was lowered; this caused the levers to hit the bar earlier than before and prevented the plunger reaching closure position in the solenoid. However, some plungers did not return due to the wires

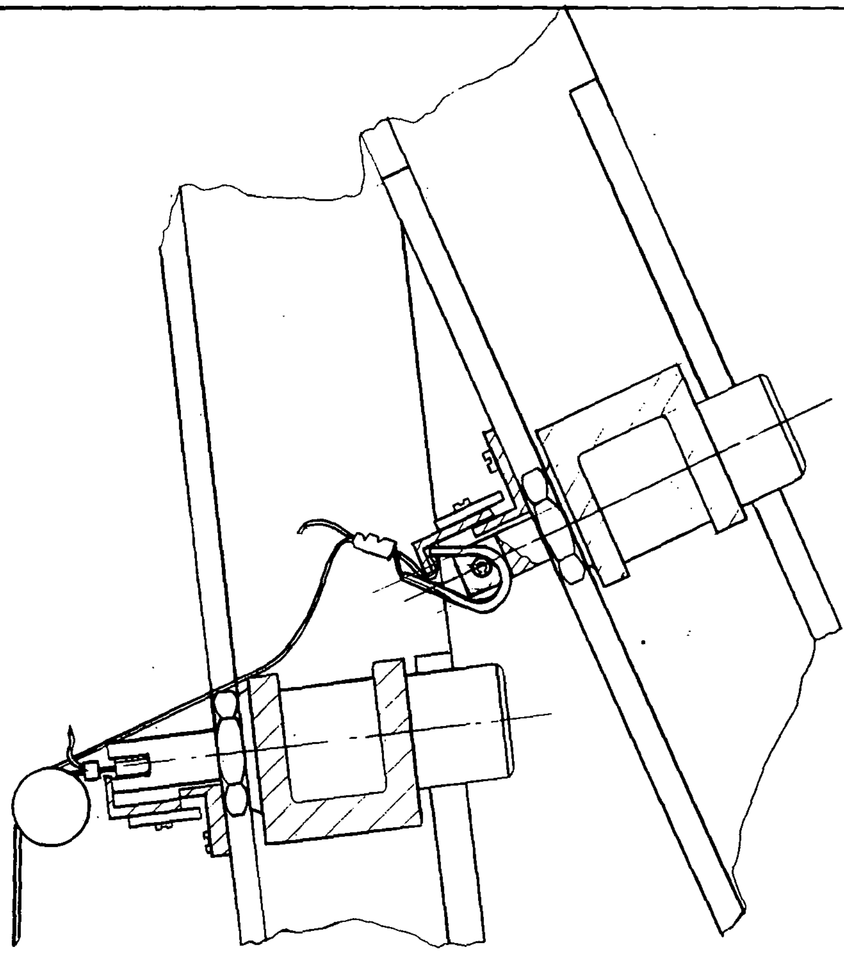


FIG 7·2(a) Shows 'u' tube jammed under the adjust bar.

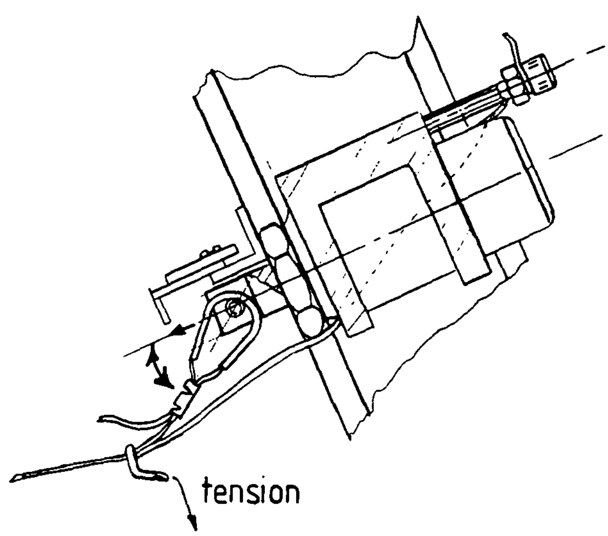


FIG 7·2(b) Shows wire pushing 'u' tube away from bar.

stretching and energising in the solenoid. This was due to the differences in the length of wire for each pin and this resulted in different extensions. Consequently, two layers of substrate material was inserted under the upper lever limit bar to provide a spring effect to push down onto the levers. This pulled the wire and the plunger out of the solenoid and all the levers returned to their start position.

The addition of the substrate material also improved the rate of return of the pins. However, it was evident that the pulley adjust mechanism needed to be adjusted to remove any slack in the wire. This enabled the wire to transmit the force of the solenoid without any loss in movement. Consequently, this meant that the wire could be accurately adjusted to provide optimum amount of pin stroke and rate of return. To ensure that the wire connections had been bedded into a permanently fixed condition, it was necessary to do repeated tests using program 1. This had the effect of tensioning the wire and removing any connections which were not secure or tended to extend.

Program 2 was then started and each wire was adjusted in turn. This was to check that each pin produced the same performance across the span of the machine. The maximum pin movement was adjusted for an input power of 12 V and 1.5 amps per solenoid. If the power input is changed, this would result in a change in performance of the mechanism and the wires would have to be re-adjusted.

However, it was observed that during the testing there was need for additional modification to the Skiving Machine. The 'U' tubes on the solenoids at the rear mounting beam assembly tended to latch or jam under the plunger adjustment bar, as shown in fig 7.2. This caused the pins to remain in an actuated position and would produce an unwanted skive. It was therefore necessary to connect additional wires on each of the rear solenoid support bars. The wires exerted a force on the roll pin of the plungers clevis which was perpendicular to the movement of the solenoid. This force was exerted on the return stroke of the operation and turned the 'U' tube so it went under the plunger adjustment bar. The tensioned wire was connected from the right hand side of the solenoid support bar to the left hand side with two screws and nuts.

The tension of the wire could be adjusted by turning the screws. If too much tension was applied to the solenoid wires then the plungers could be pulled under the plunger adjustment bar and fall out. Therefore, care was taken when exerting tension on the wires. With the addition of this wire it was necessary to re-adjust the mechanism. When all the adjustments had been completed then the Skiving Machine was installed into the splitting machine.

The Skiving Machine was then ready to skive and for results to be obtained, see figures 7.3 and 7.4.

The performance and accuracy of the results will be discussed in the next chapter.

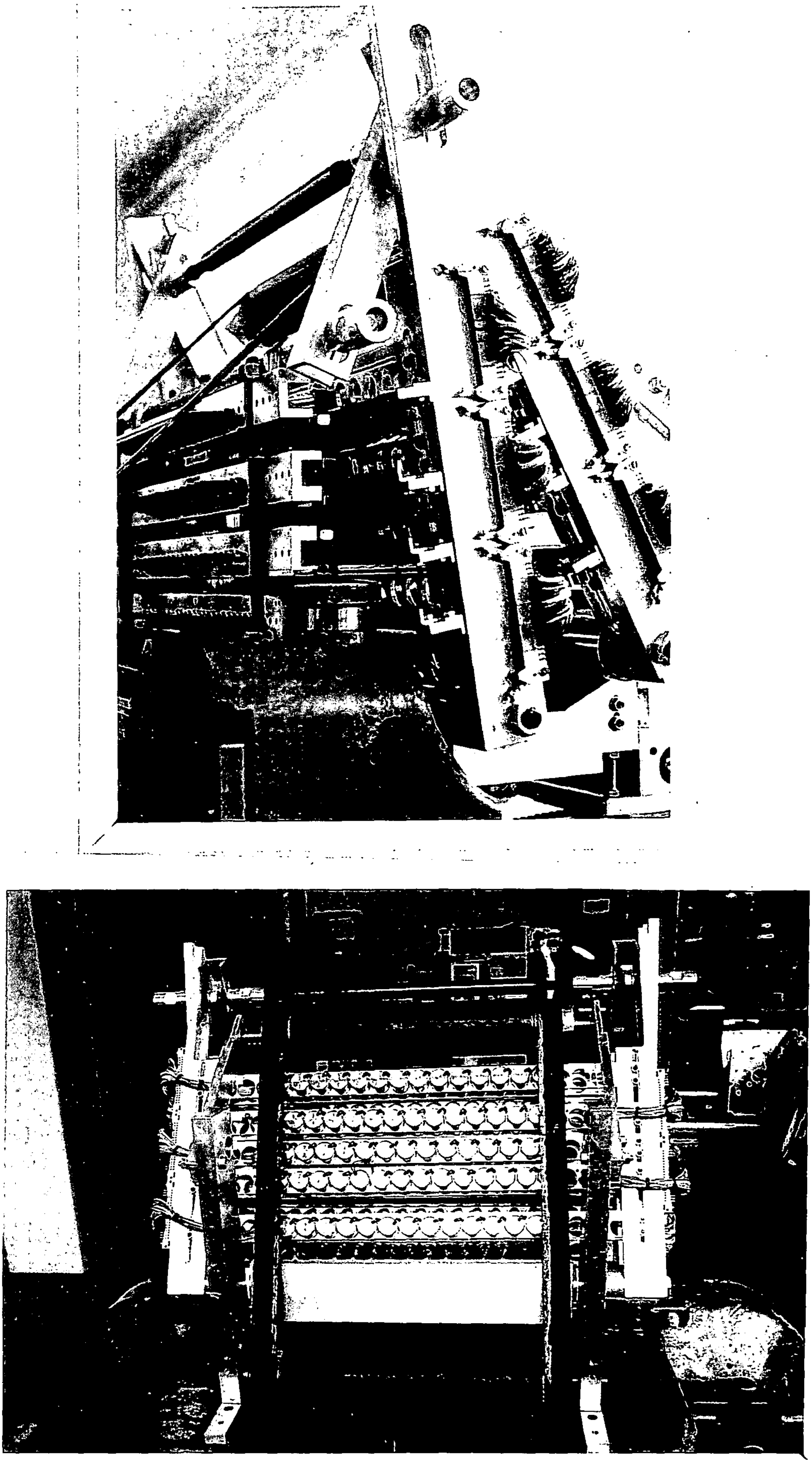
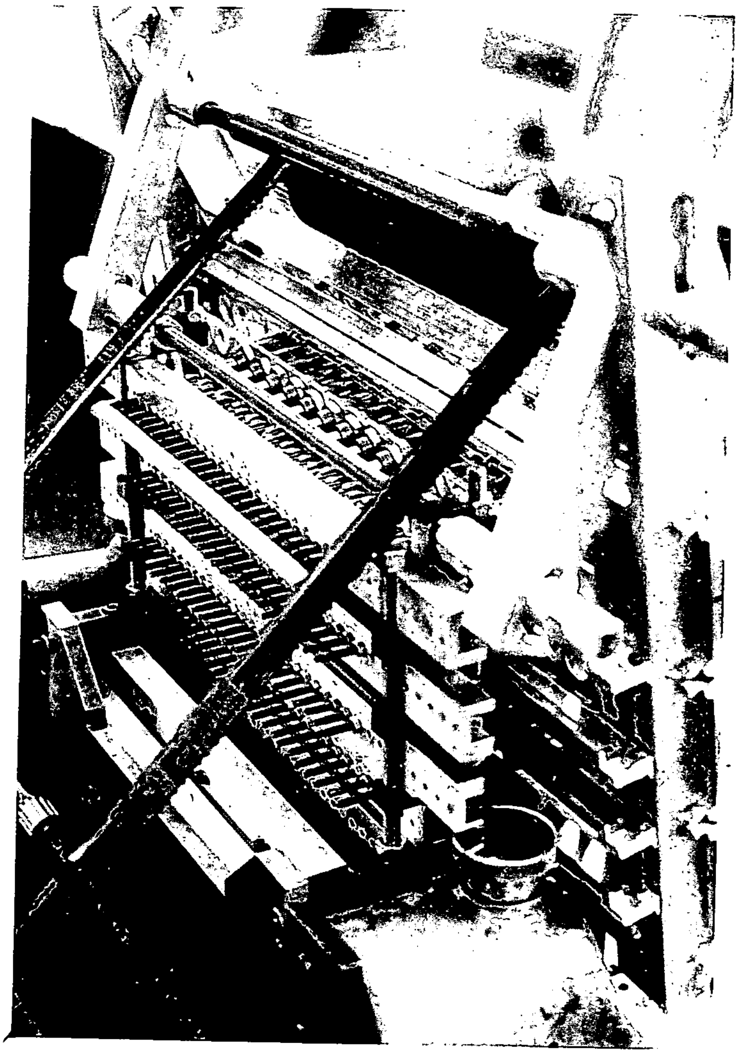


FIG 7.3 *Shows Skiving Machine with stepper belts located under the Tie Bar.*



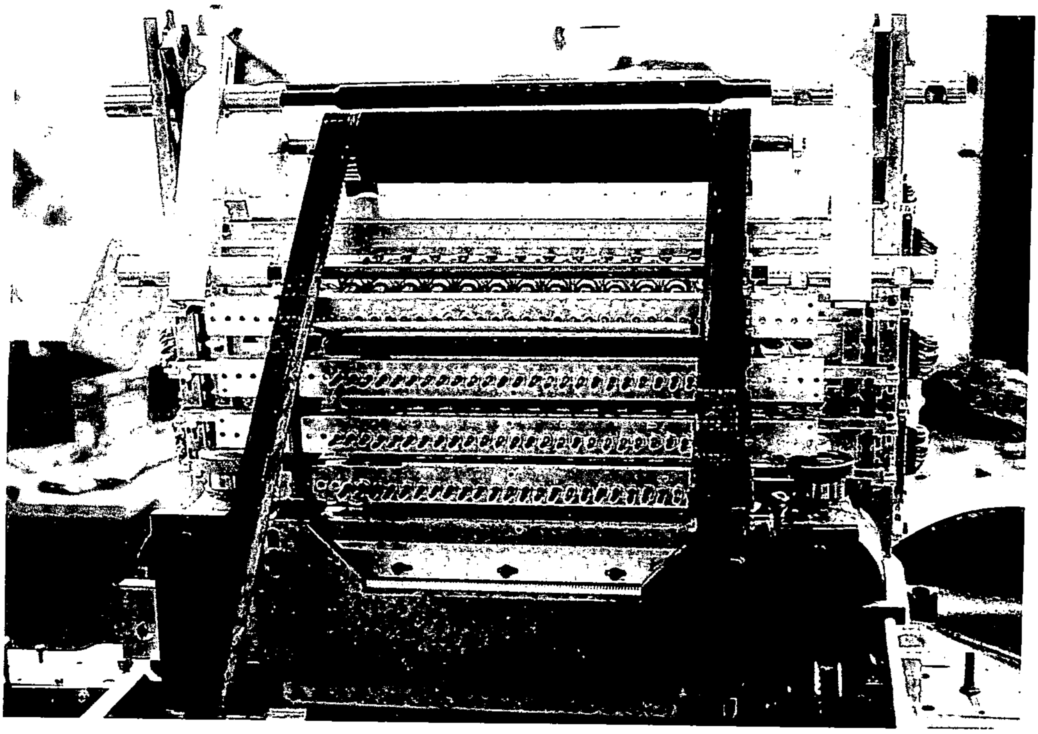


FIG 7.4 *Shows Skiving Machine with protective strip on adjust screws.*

CHAPTER 8

Performance tests on the new skiving machine

8.1 Introduction

The purpose of this chapter is to evaluate the performance of the new skiving machine. This was determined by producing skived components and analysing the quality of the cut. The performance tests were carried out in four stages;-

1) To analyse the quality of the skived components produced.
2) To compare the depths of cut produced by operating the solenoids at different voltage levels.
3) To compare a series of shapes, on the same strip of leather, which were alternating in sequence, from a full depth skive to a variable depth skive.
4) To evaluate the accuracy of the process used to control the depth of cut.

The first stage considers the original performance objectives for the machine and compares these with the acquired results.

The other stages are not related to the initial objectives of the machine and form an additional investigation into another performance feature, which will prove useful for future development.

8.2 First stage: analysis of the quality of the skived components.

To achieve the results it was necessary to control the parameters which most affected the performance of the skiving process. The following describes the influence of the parameters on the results.

The upper and lower conveyors were used to transport the component into the skiving area and therefore they determined the speed of the component whilst being cut. The actuation time for each pin was determined by altering the time delay in the control program used to actuate the skive. This controlled the resolution of the shape in the direction of the conveyor's motion. Consequently, at a constant conveyor speed, if the delay loop was reduced, then the overall length of the skive was also reduced. The position of the Skiving Machine, in relation to the knife edge, was adjusted to achieve the best skive. The knife had to be as sharp as possible and this was indicated by the appearance of the cut leather. If the skived component showed uneven cut edge, then the knife required sharpening.

It was important to control these parameters during the process of taking results, so that an understanding for the reasons for certain quality related characteristics could be determined.

8.3 Description of the experiment

The apparatus comprised the following hardware: a Motorola M 68000 microprocessor, amplifier boards and a switch box (which has already been described in chapter 7) a Unix editor and assembler, which was accessed through a monitor, and two heavy duty car batteries. The batteries were connected in a series circuit to the amplifier boards and supplied 40 amps of current at 24 volts dc. This enabled the solenoids to provide maximum power output. Cables were connected to the switch box, the Skiving Machine, the M 68000 microprocessor ports and the batteries, in the sequence as it was described during operational testing in chapter 7. Additional cooling fans were added to the amplifier boards to reduce any excessive heating effect caused by the transistors during operation. The system of communication between the Motorola M 68000 microprocessor and the new Skiving Machine is shown in figure 7.1.

The control program used is called "program test 3" and is shown in appendix A4 at the back of this thesis. This program produced a skive by activating only 32 of the 120 pins on the Skiving Machine. A series of skives were produced with a width of thirty two pins or (64 mm) and with no restriction on the length of the shape.

The experiment was to produce a skive of an isosceles triangle. The program was altered to skive a triangle and set to run on a repeated cycle. The skiving position was also adjusted to observe its effect on the results to be obtained. The speed of the upper and lower conveyors was recorded with a tachometer and while the solenoids activate, leather was fed into the twin conveyor system. As the leather passed under the pins, it was pushed onto the knife to produce a skived pattern of a triangle. This procedure was repeated for differing conveyor speeds and program delays. The quality of the skive was examined at four different speeds of 35,70,105, and 160mm/s. The skive quality of different types of leather was also examined. The results and any functional problems or observations were recorded.

Figure 8.0 shows some of the results obtained from this experiment.

8.4 Analysis of the first stage results

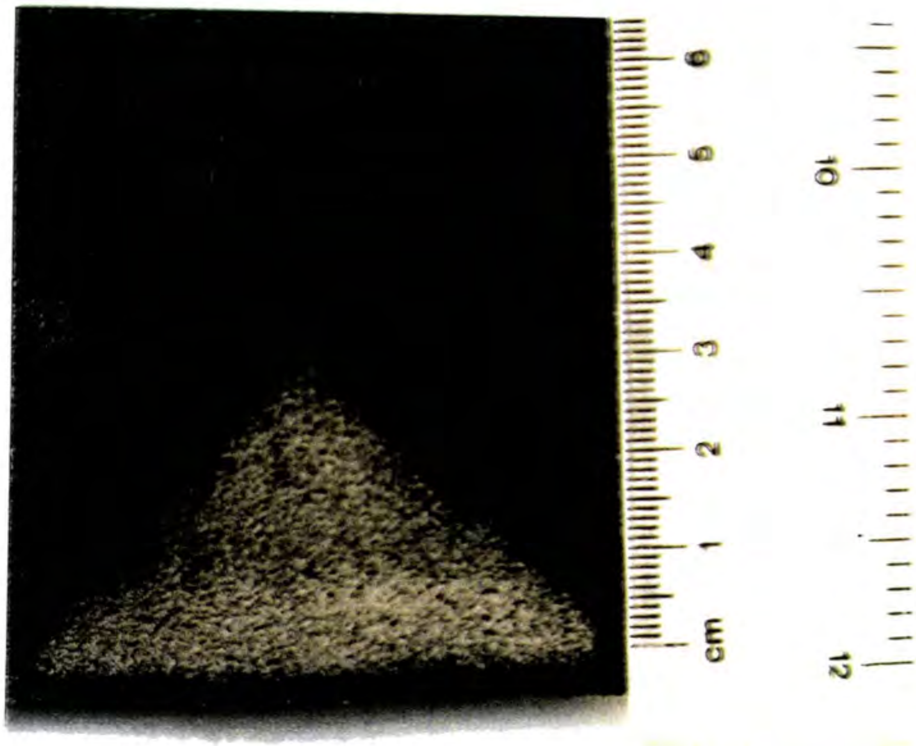
The main objective of the work described in this thesis was to design a skiving machine to eliminate the stepping effect, which was apparent when skiving a diagonal edge on the old skiving machine.

It can be seen from Figures 8.0 and 8.1 that the profiles of the skived diagonal edges of the triangles show no sign of this stepping effect, which suggests that the main objective had been achieved..

Figure 8.2 shows the leather skived at different speeds and figure 8.3 shows the versatility of the process in skiving different shapes.

The dimensions of the skived shapes were examined to determine the improvement in the quality produced. It would be expected that the height of the

Direction of skive



Direction of skive

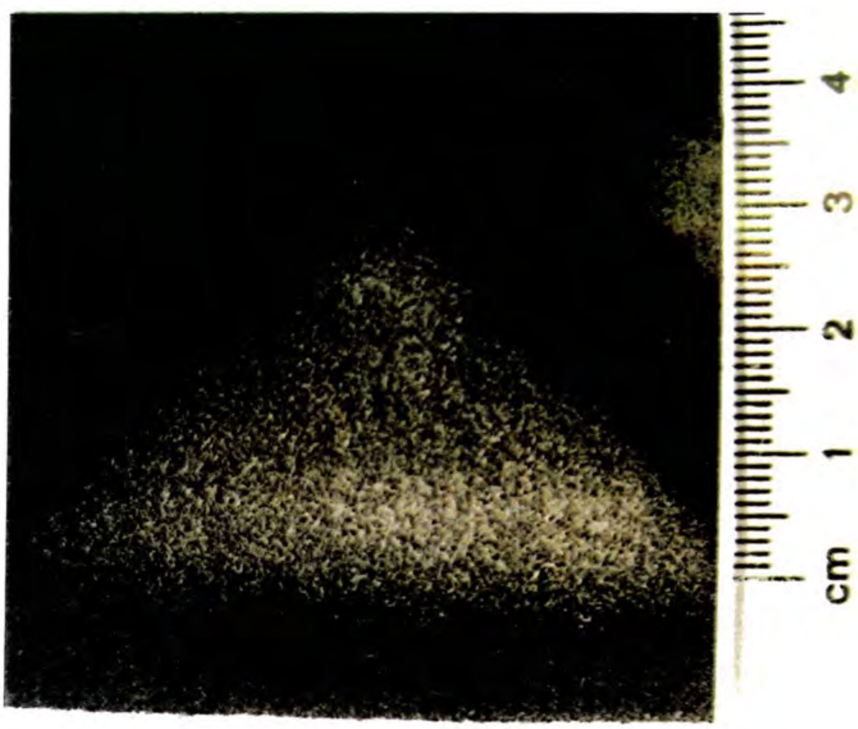


Figure 8.0 shows that the profiles of the skived diagonal edges of the triangles show no sign of the stepping effect.

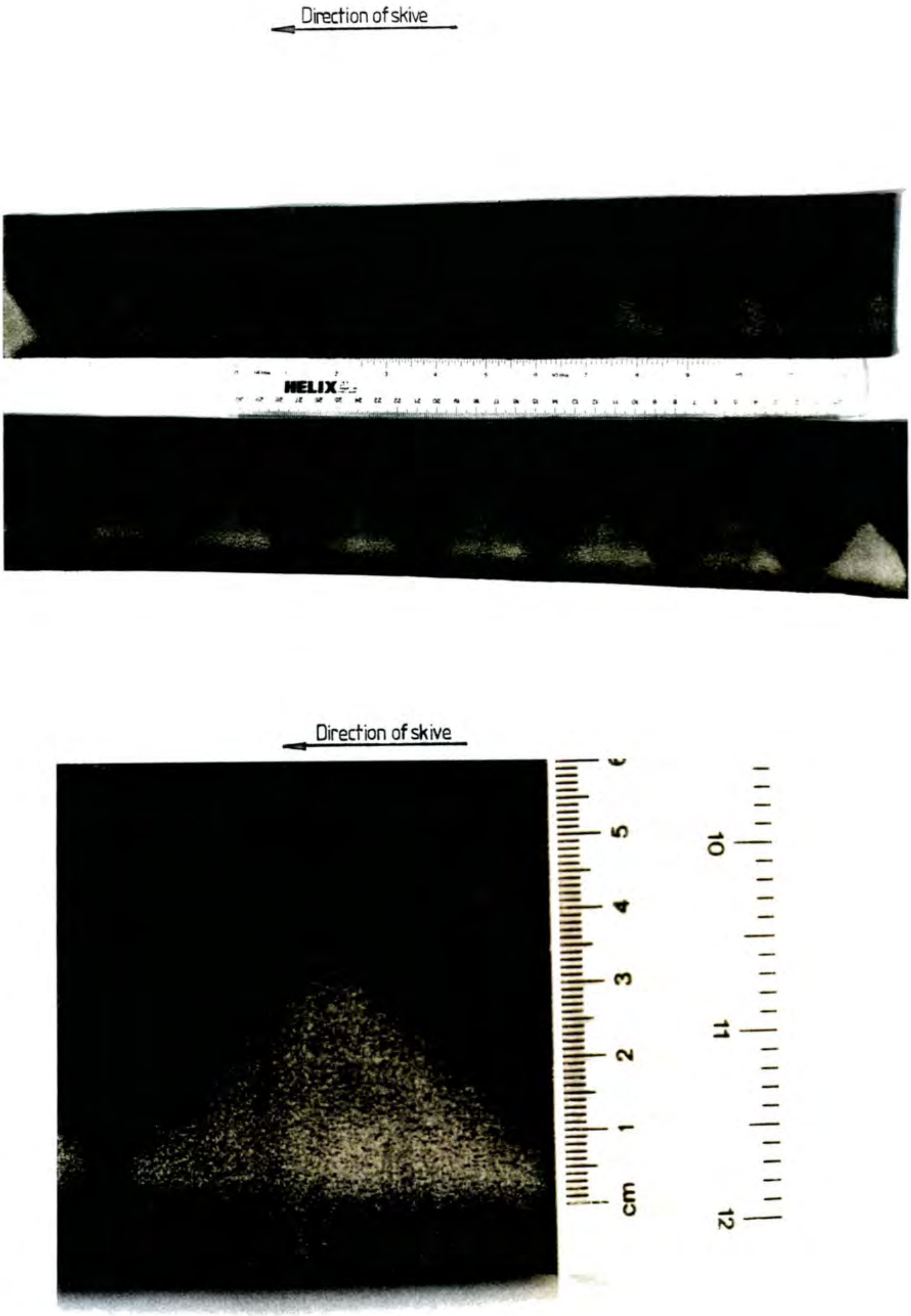
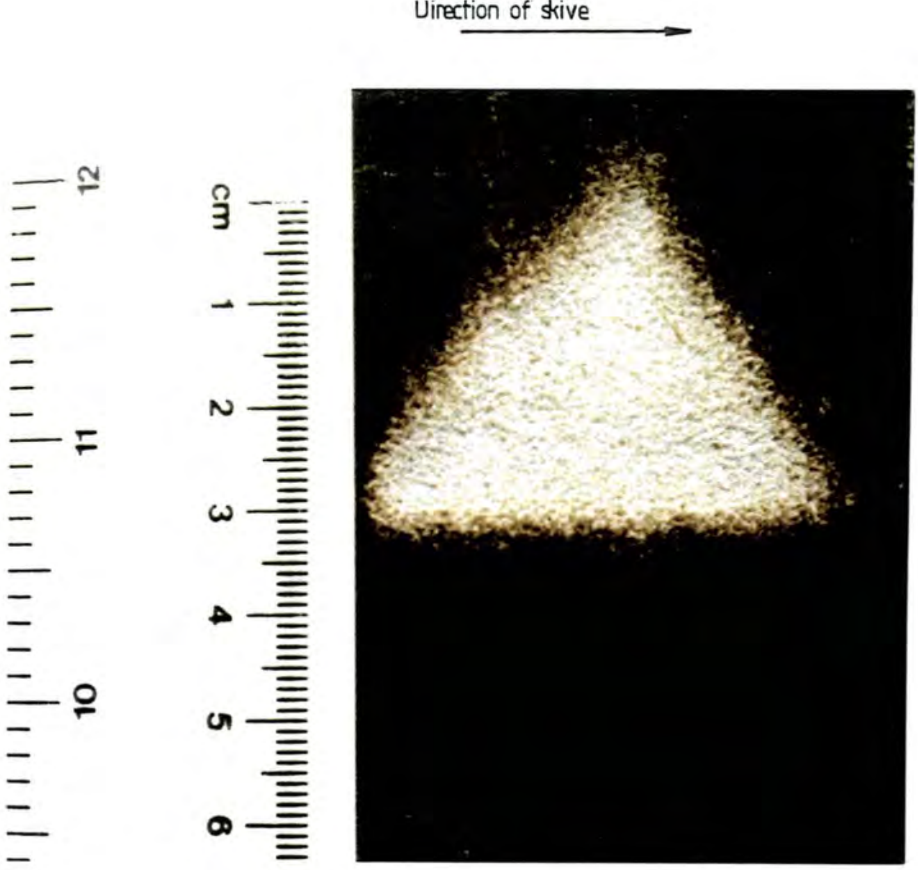


Figure 8.1 shows that the profiles of the skived diagonal edges of the triangles show no sign of the stepping effect.



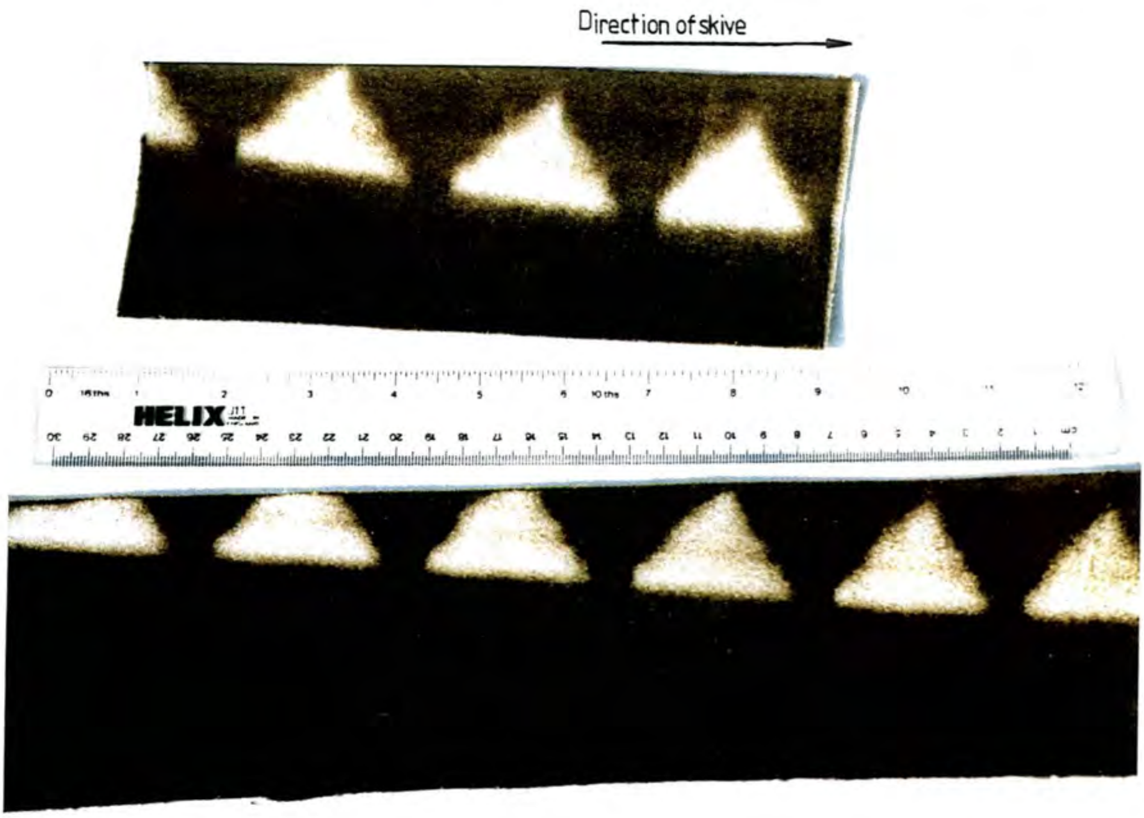
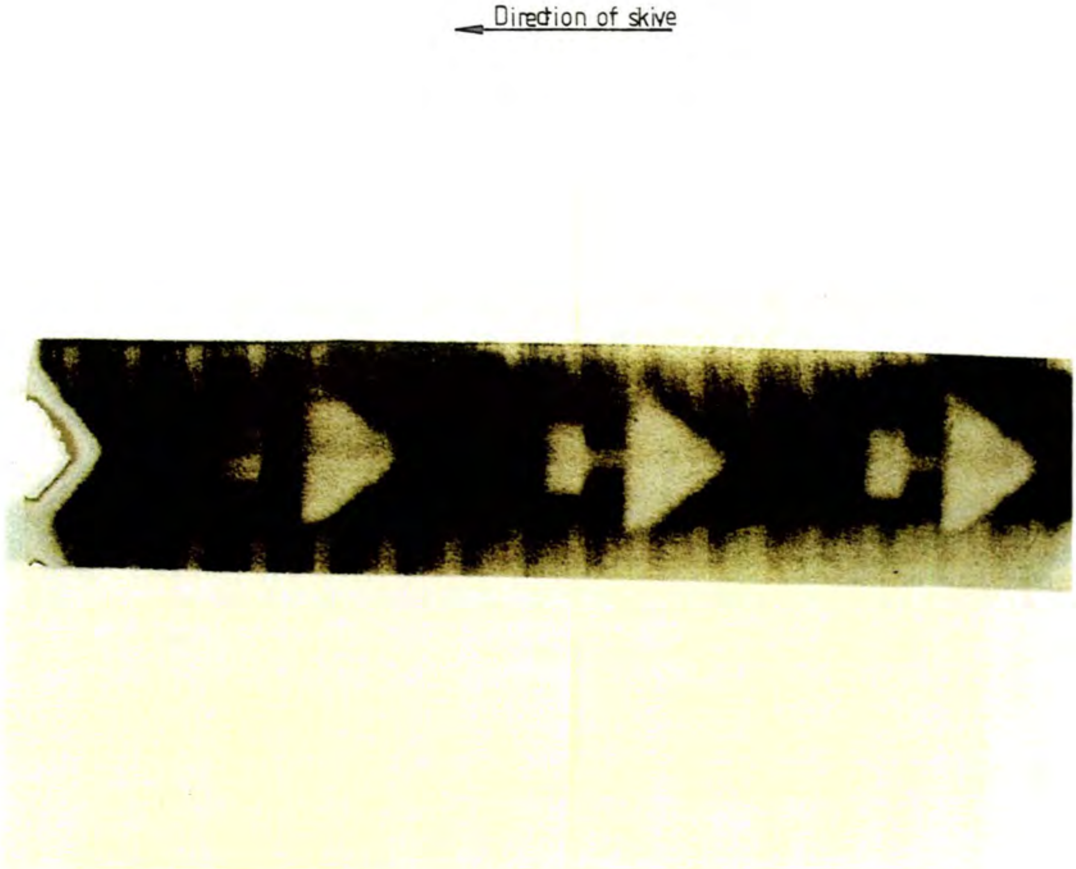


Figure 8.2 Shows the effect on the leather being skived at different speeds.(160mm/s, 105mm/s and 75mm\s) The top photograph, shows a shape that had been skived at a speed of 75 mm/s. The bottom photograph shows shapes skived at 105mm/s and 160mm/s respectively.



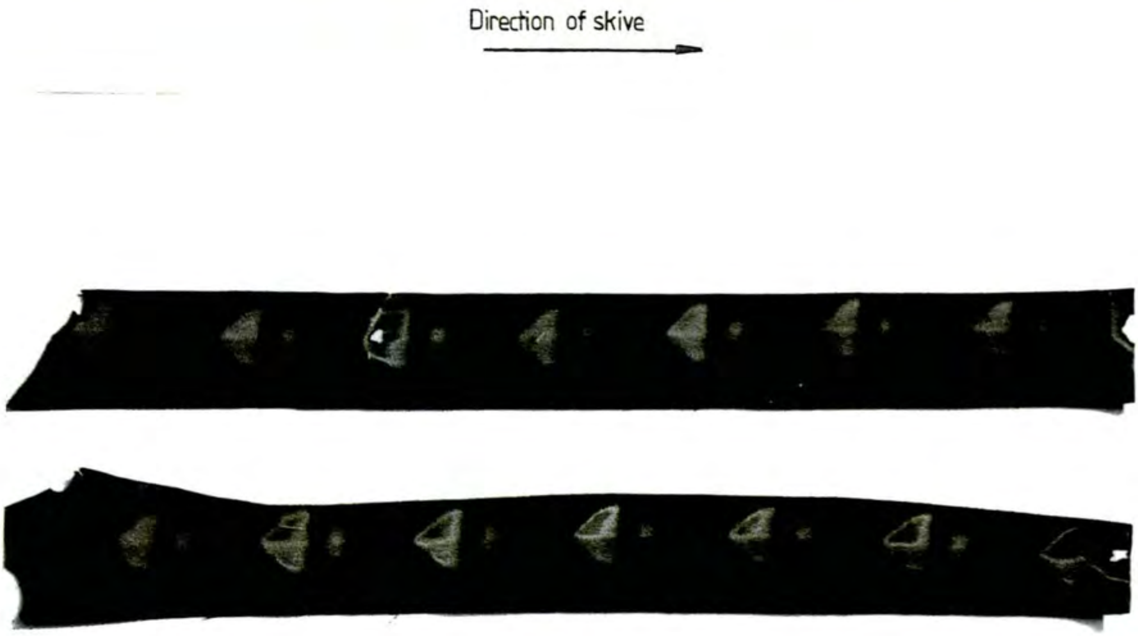


Figure 8.3 shows the versatility of the process in skiving different shapes (christmas trees)

skived shape would remain constant at 32mm. This was because the triangle had a maximum height of 16 pins when it was set up in the control program.

The following gives a description of the method used to determine the dimensions of the samples in figure 8.4(a). The dimensions shown give the height, the calculated or ideal shape, (which was based on the height and the base length), and the co-ordinates of six skived triangles plotted on an x,y axis. The y axis is positioned at the centreline and the x axes at the base of the triangle. The distances for the x values at four step intervals of y, from 0 to 32 were measured. These measurements were taken to the skived outline of the shape. The dimensions were compared to the equivalent of the ideal triangle. The shapes of the six randomly selected samples were traced on tracing film paper. These dimensions, when compared to the ideal shape indicated the success of the transfer of information between the image of the program and the skived shape. Hence, this gives an indication of the accuracy of the skiving process.

Figure 8.4(b) shows the traced samples (at full scale) and the accuracy of the dimensions when compared with the ideal shape. The shapes were traced to a depth of approximately 0.25mm. It must be noted that the shaded areas represent the unskived region between the skived shape and the ideal triangle. The figure also gives the direction of skive which indicates which side had been cut first.

The speed of the conveyor and the time delay between activating pins were kept constant for these results. In practice the dimensions were also dependent on the thickness of the leather component. The leather was not of a uniform thickness and therefore a variation in dimension of the skived area would be expected.

The six samples were skived at a conveyor speed of 35 mm/s and a pin actuation time of 0.06 seconds. Figure 8.4(b) shows that in all six samples the length of the base is not equivalent to the ideal triangle. As shown in figure 8.4(a), there is a reduction of 3.3mm from the front and 5.5mm from the back of the skived shapes.

		Skived shape coordinates for the x axes(-ve) when the y value is				Skived shape coordinate for the x axes(+ve) when the y value is			
SAMPLE	**HEIGHT of sample(mm)**	**0**	**8**	**16**	**24**	**0**	**8**	**16**	**24**
1	32	-26	-22.5	-15	-6	27	22.5	15	7.5
2	32	-30	-22.5	-15	-7.5	25	25	15	9
3	32	-25	-22.5	-15	-6	24	22.5	15	7.5
4	32	-22	-23	-15	-7.5	24	24	15	7.5
5	32	-27	-22.5	-15	-6	22	22.5	15	7.5
6	32	-30	-22.5	-15	-6	27	22.5	15	7.5
Average	32	-26.7	-22.6	-15	-6.5	24.8	23.2	15	7.8
Coordinates of ideal triangle	32	-30	-22.5	-15	-7.5	30	22.5	15	7.5
Deviation	0	3.3	-0.1	0	1.0	-5.2	0.7	0	0.3
Loss of area	0	26.4	-0.8	0	8	-41.6	5.6	0	2.4
% of unskived area inside ideal triangle		=7.9%				% of skived area outside ideal triangle			=0.9%

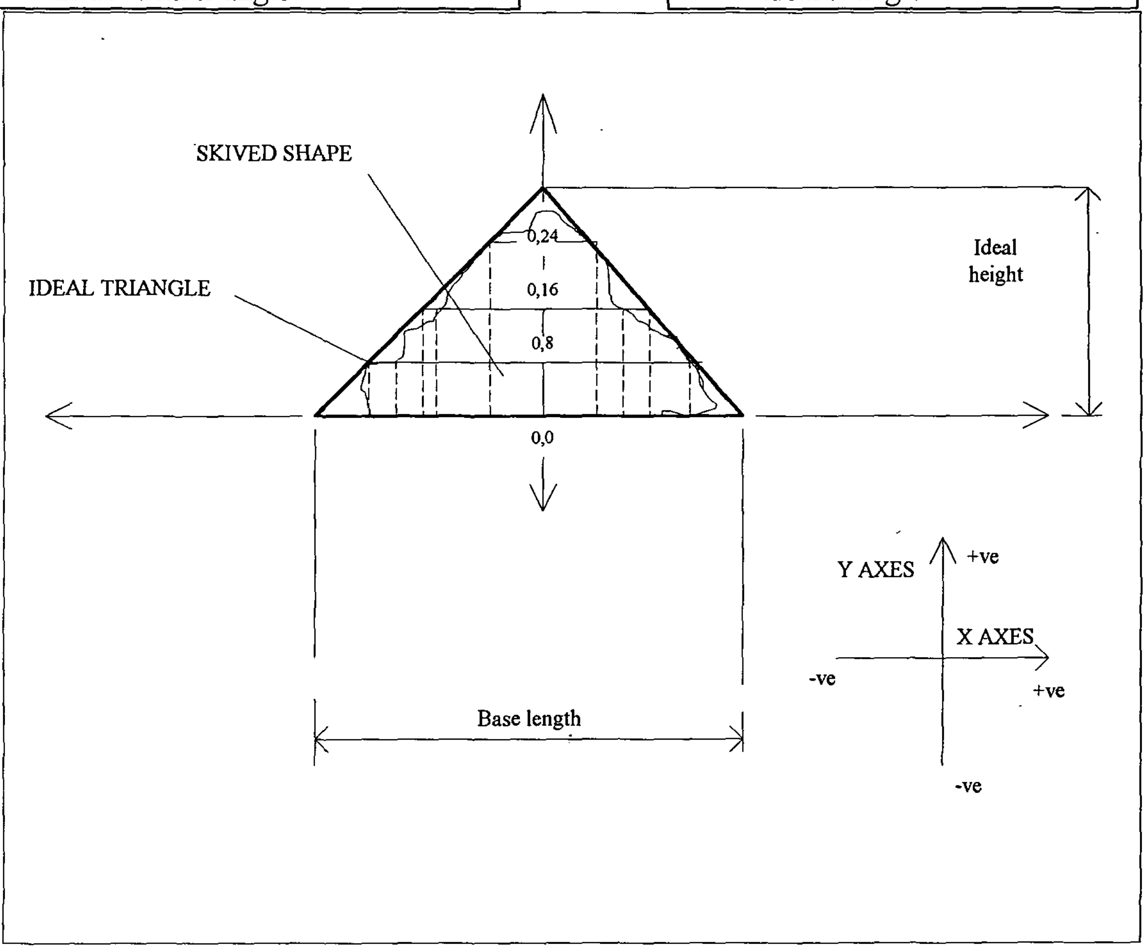
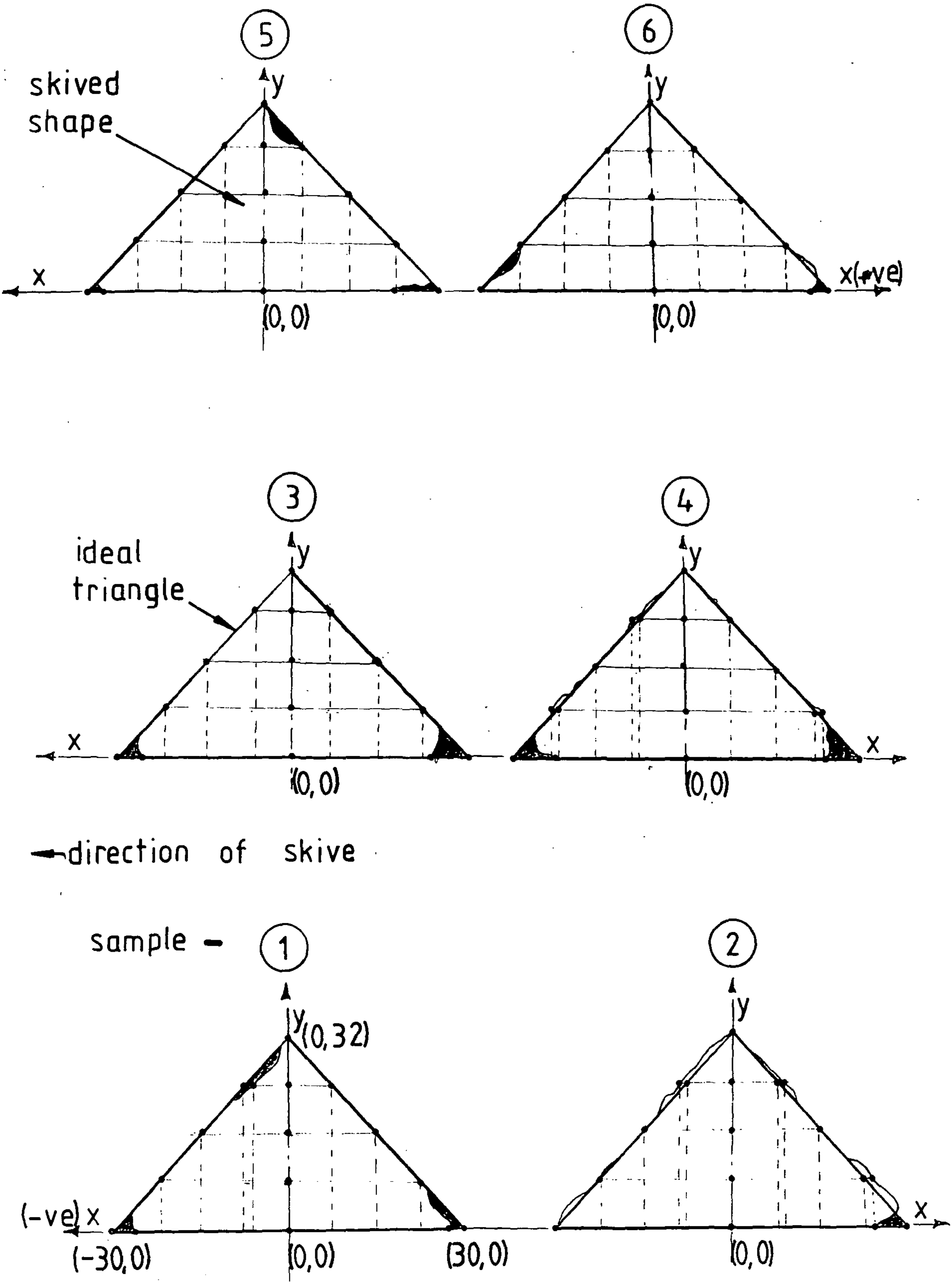


FIG 8.4(a) *Shows the dimensions of the six sample results and compares them with the ideal triangle.*

fig 8·4(b) show the six samples(full scale)



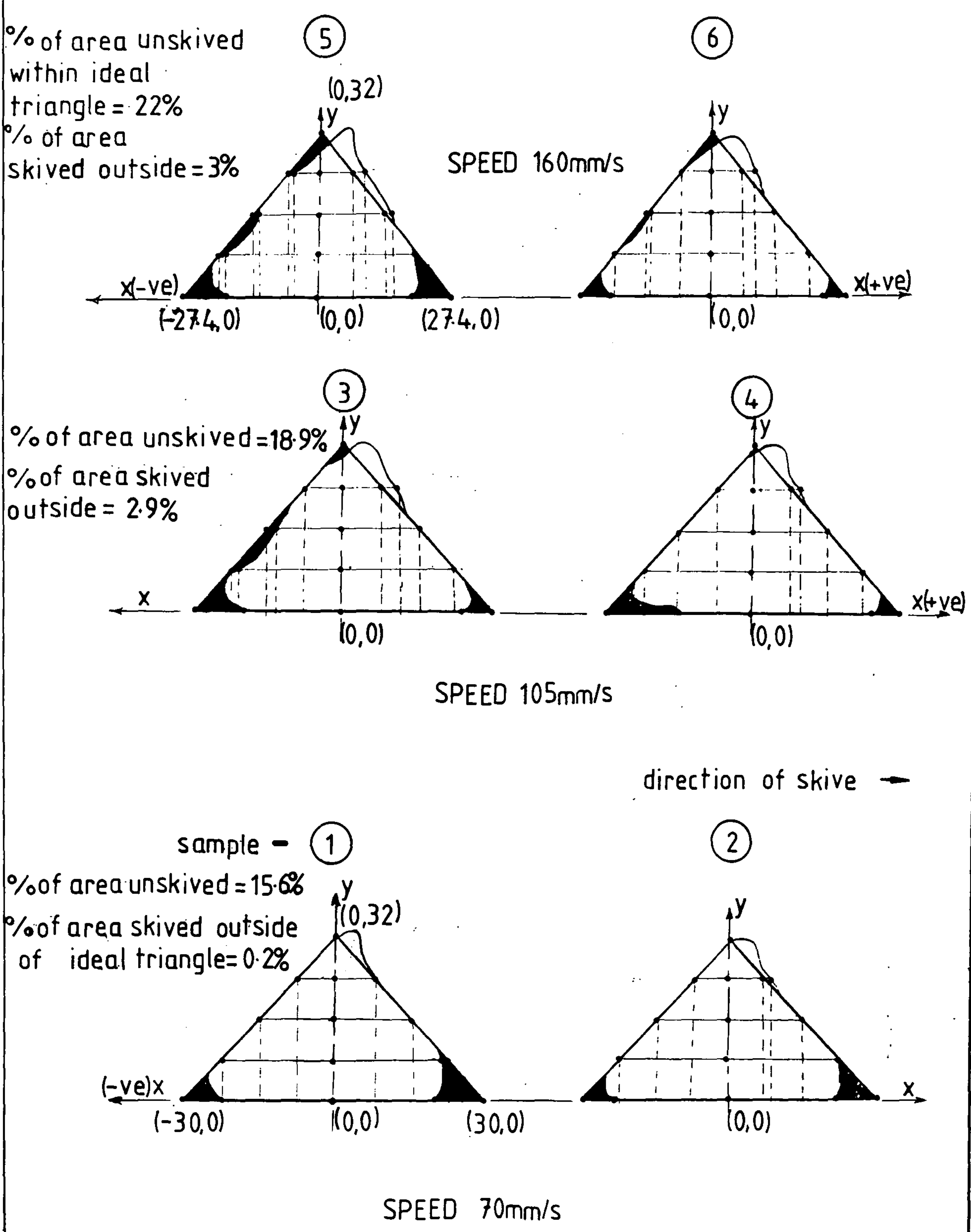
This effect is due to the force, exerted by the first activated pin, not being sufficient to skive. Therefore, as preceding pins are actuated, a greater pressure is applied to the leather. Therefore, the length of cut for the first pin is comparably reduced. The comparison between the edges of the skived shape and the ideal triangle show that it is accurate to 0.1mm. The results shown in figure 8.4(a) are measured to an accuracy of +-0.5mm. Consequently, the maximum variation between the diagonal edges of the skived and ideal triangle will be 0.6mm.

The accuracy of the skived shapes was obtained by determining the average of each co-ordinate for the six samples. The averages were subtracted from the co-ordinates for the ideal triangle and the area loss was calculated. The accuracy could be analysed by two features of the skived shape: the area unskived within the ideal triangle and the area skived outside the ideal triangle. The percentages of the area unskived inside and skived outside, divided by the area of the ideal triangle, was a measure of the dimensional deviation created by the skiving process. Figure 8.4(a) shows that the percentages for these features were 7.9% and 0.9%. This is an acceptable accuracy for the diagonal edges and proves that there is no stepping effect caused by the pins.

In addition to the above, the skived shapes also had straight, smooth, diagonal edges which were not achieved with the previous skiving machine and this effect was due to the high resolution of the pins.

Figure 8.5 shows six shapes skived at different conveyor speeds. Samples 1 and 2 were taken at 70mm/s, samples 3 and 4 at 105mm/s and samples 5 and 6 at 160mm/s.

The objective was to measure the deterioration in shape caused by an increase in conveyor speed. This was done by adjusting the control program in relation to the increase in speed. Therefore the co-ordinates of the ideal triangle remained the same. The speed of the skive was limited by the power provided by the stepper motors used fig 8·5 shows the effect of speed on the shapes



to drive the conveyor system. Consequently, this resulted in a maximum speed of 160mm/s which was less then the customer's specification of 181mm/s. However, the control program was adjusted to provide a pin actuation time which would be necessary to skive at 181mm/s. This proved that the skiving machine would skive at this rate. As a result, the ideal triangle length being skived at 160mm/s was reduced to 54.8mm. The accuracy of the skived shapes for each speed was determined by calculating the average of each co-ordinate from the samples. Consequently, by using the previously described method, the following results were calculated.

Figure 8.5 shows that samples 1 and 2 have an unskived area of 15.6% and an area skived outside the triangle of 0.2%. Samples 3 and 4 have an unskived area of 18.9% and an area skived outside the triangle of 2.9%. Samples 5 and 6 have areas of 22% and 3% respectively. It is therefore evident that as the speed increases, the accuracy of the skive decreases. Figure 8.5 shows that, as the speed increases there is a reduction in the base length and the peak of the skived shape deviates forward from the ideal triangle. There is a greater force exerted on the movement of the conveyor belt by the pins as the speed increases. The low stiffness or slackness of the conveyor belt material, towards the centre of its width, allows an amount of movement in the opposing direction. Therefore, as the conveyor speed and pin force increases the opposing movement also increases. The loss in movement at the centre of the belt, reduces the speed of the leather component, whilst the rate of actuation of the pins remains constant. Consequently, as the centre of the conveyor belt moves, the top of the triangle is skived forward of its required position. To improve the accuracy of skiving at high speeds the conveyor belt material must be less flexible towards its centre. This can be achieved by tensioning the width of the conveyor belt which increases the rigidity. Despite this, the accuracy of the samples skived at 160mm/s were satisfactory and achieved the customer's specifications to skive at high speed.

8.5 Second stage: to compare the depth of cut by varying the pin force

The objective of this experiment was to determine whether there was a variation in the depth of cut by altering the power to the solenoids. It had become apparent, during the above experiment, that the increase in temperature led to an increase in coil resistance, so the applied force and the depth of cut was reduced. This was due to the force created by the solenoids being balanced by the return force. It can therefore be concluded that as the force of the solenoids is reduced there is a reduction in the pin movement.

The experiment was set-up as detailed above. The speed of the conveyor was set at 35mm/s and the control programme was set to skive a triangle, as previously outlined. The hardware used for the experiment was alternated between a 12volt power unit at 70amps, and the 24volt batteries at 40amps. These two power supplies provided skived components at 12v and 24v. During the experiment it was important to record the duration of each operation. This was due to the temperature of the solenoids increasing during their operation and reducing the actuated force. The results were taken in an alternating sequence of 12volt, 24volt, 12volt respectively. This gave a comparison of consecutive results which eliminated the influences caused by the heating effect. The sequential method was repeated on the following day so the repeatability of the results could be examined. During the experiments, it was important to ensure that the leather was inserted at the same position on the conveyor belt and the pins were actuated at the same time. The batteries were constantly charging during the experimental period and the conveyor was frequently checked for variation in the speed. The knife was not sharpened and its position in relation to the pins was not altered. The strips of leather were cut horizontally across the width of the hide in one metre lengths and one hide a day was used over the two day period. It was necessary to keep these factors constant and limit the influence of any variables on the results. During the taking of the results, each skived strip of leather was marked with an item number and six of the cut shapes were marked with a shape number from 1 to 6. All the experimental parameters and observations were recorded during the testing period.

Figure 8.6 shows the equipment used to determine the thickness of the skived leather and the following outlines the procedure.

The leather strip was placed onto the x,y adjustment table and secured in position. The dial indicator was set to zero with reference to the table surface and its accuracy was checked to be satisfactory by taking repeated measurements. Six samples, marked with shape numbers 1 to 6, were measured from each strip of leather. The overall pre-skived thickness, which was positioned above each skived shape, was measured. Item 1 in fig. 8.6, shows the measured thicknesses in positions A, B, C and D and these results were recorded for all six samples. Results were taken for skived strips of leather for item numbers A17 to A27 and then for item numbers A28 to A38 (second day results). From these results the average thicknesses for each position of A, B, C and D were obtained and, from these averages an overall average thickness was calculated for each item number, or skived strip of leather.

Figures 8.7 and 8.8 are graphs which show the overall average skived and unskived thicknesses for item numbers A17-A27 and A28-A38 respectively. The graphs indicate the relationship between the results obtained from a 12 and 24 volt power supply. The two lines give an approximate indication, from the points plotted on the graph of the general trend of an increase with the working time.(This was due to the temperature of the solenoids increasing and reducing the applied force to the skive) The comparison of the graphs show a larger diffusion of plots in fig.8.7 compared to fig 8.8. This was due to a greater variation in the unskived thickness of the leather components. Consequently, this creates variable skiving forces during the cutting process and effects the depth of cut. The results shown in fig. 8.8 have a lower diffusion of plots which was due to a uniform thickness of leather. Item A30 was

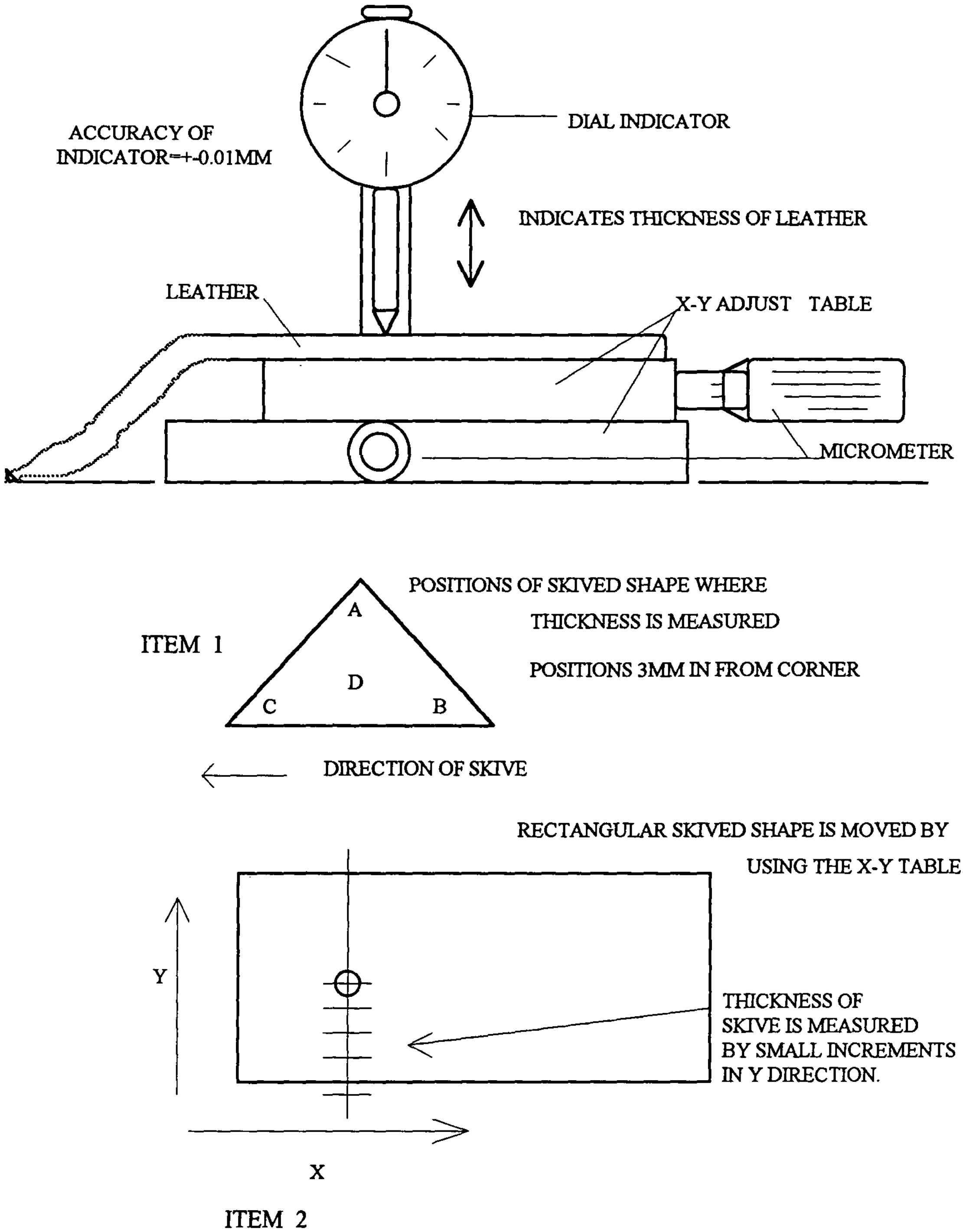
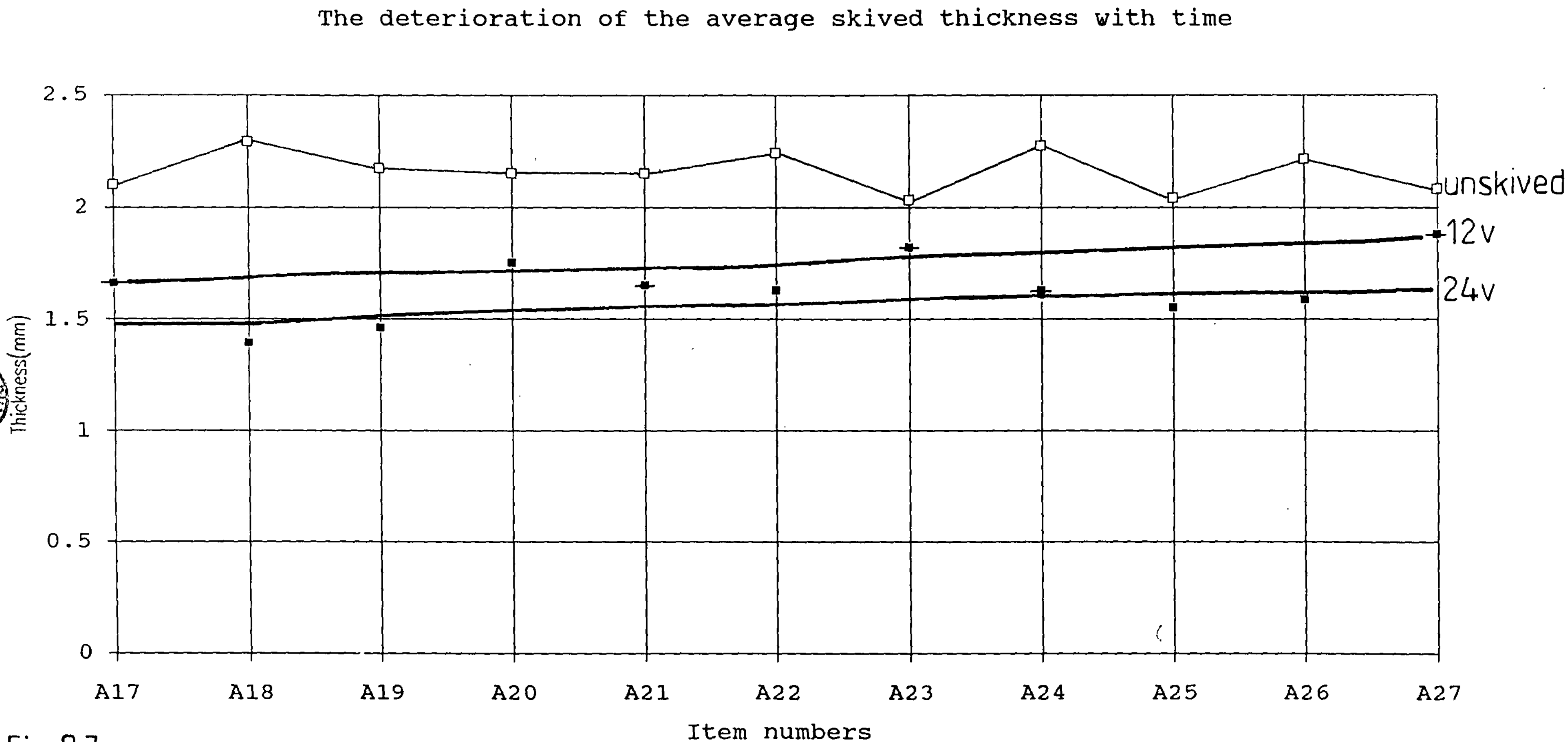


Figure 8.6 shows the equipment and method used to determine the depth of cut.



The deterioration of the average skived thickness with time
2.5
2
1.5
1
0.5
0
Thickness(mm)
A17
A18
A19
A20
A21
A22
A23
A24
A25
A26
A27
Item numbers
unskived
12v
24v

Fig 8.7

The deterioration of the average skived thickness with time.

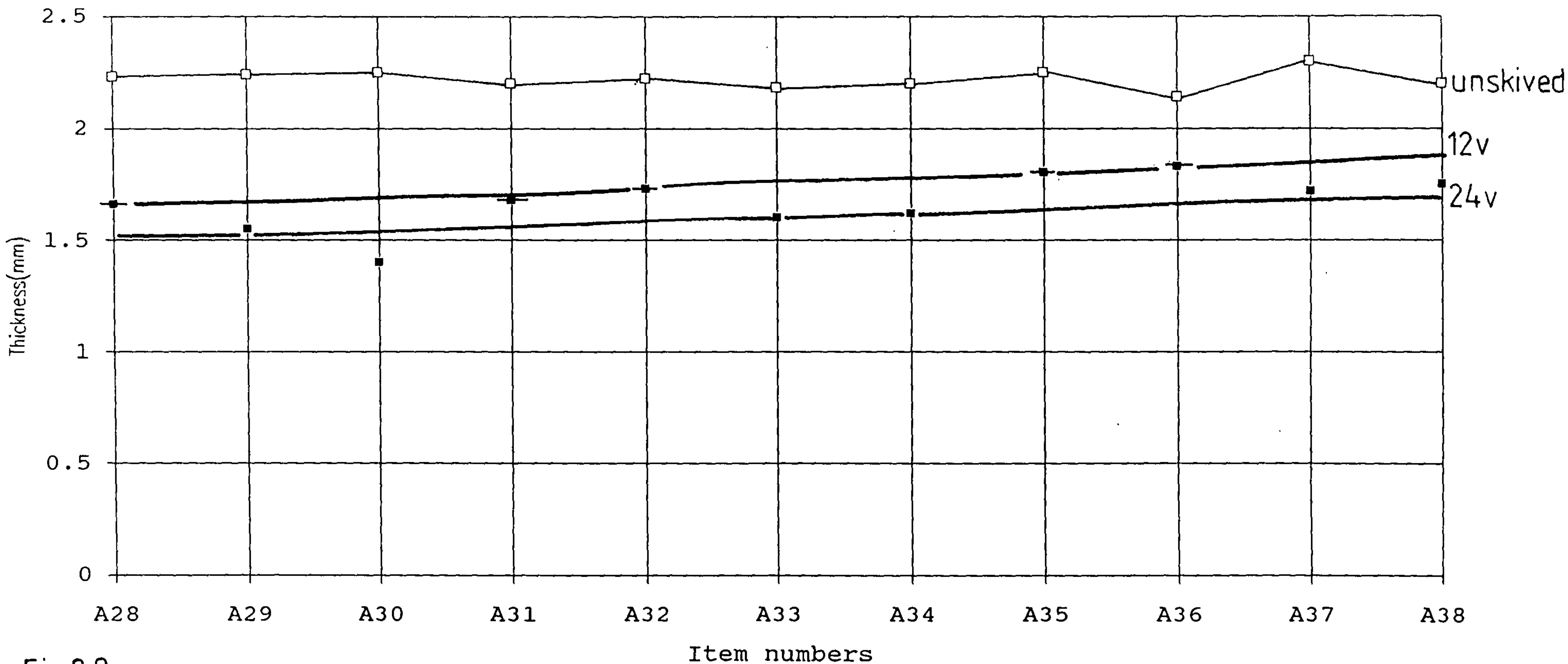


Fig.8.8

skived in a different position on the conveyor belt, this resulted in an increase in skiving forces and hence was skived at a greater depth. It is deduced that the forces created during the skiving process determines the depth of cut. The graphs indicate that the depth of cut increases by an average of 0.13mm when the inputting voltage is doubled from 12v to 24v.

Figure 8.9 shows the deterioration in the average skived thickness at region C compared with the unskived thickness. Region C is the first position of the triangle to be skived. This graph shows that in this position there is an average difference of 0.22mm between the 12volt and 24v inputs. Regions A, B, and D have average differences of 0.06, 0.2 and 0.04mm respectively. The regions C and B represent the front and rear base of the skive, as shown in fig. 8.6. Therefore, the same pins are used to skive the front and the rear of the shape. Consequently, the difference in the depth of cut between power supplies of 12v and 24v deviates by 0.02mm across the skived length of 70mm. This proves the depth of the pin at 12volts can be held in position for the duration of the skive, by the balance of forces between the solenoid and the spring return effect.

Figure 8.10 shows the variation in skived thickness for positions A, B, C, and D for the shapes on sample item number A34. Shape 1 was the first triangle to be skived on the strip of leather and shape 6 the last. The graphs show the fluctuation in the skived thickness as the strip of leather passes through the machine. The thicknesses of A, B, C, and D are not equal. This was due to a physical and mechanical feature which was related to the splitting machine. However this effect remained constant and therefore did not influence any of the results obtained. The graphs show an increase in thickness from shape 1 to shape 6 and this was due to the increase in temperature of the solenoids during their working duration, which reduced the applied force. The fluctuations of the points indicate the variation in the skiving forces as the leather strip passes through the conveyor belt. This indicates that the

The deterioration in the thickness at region C compared to the unskived thickness

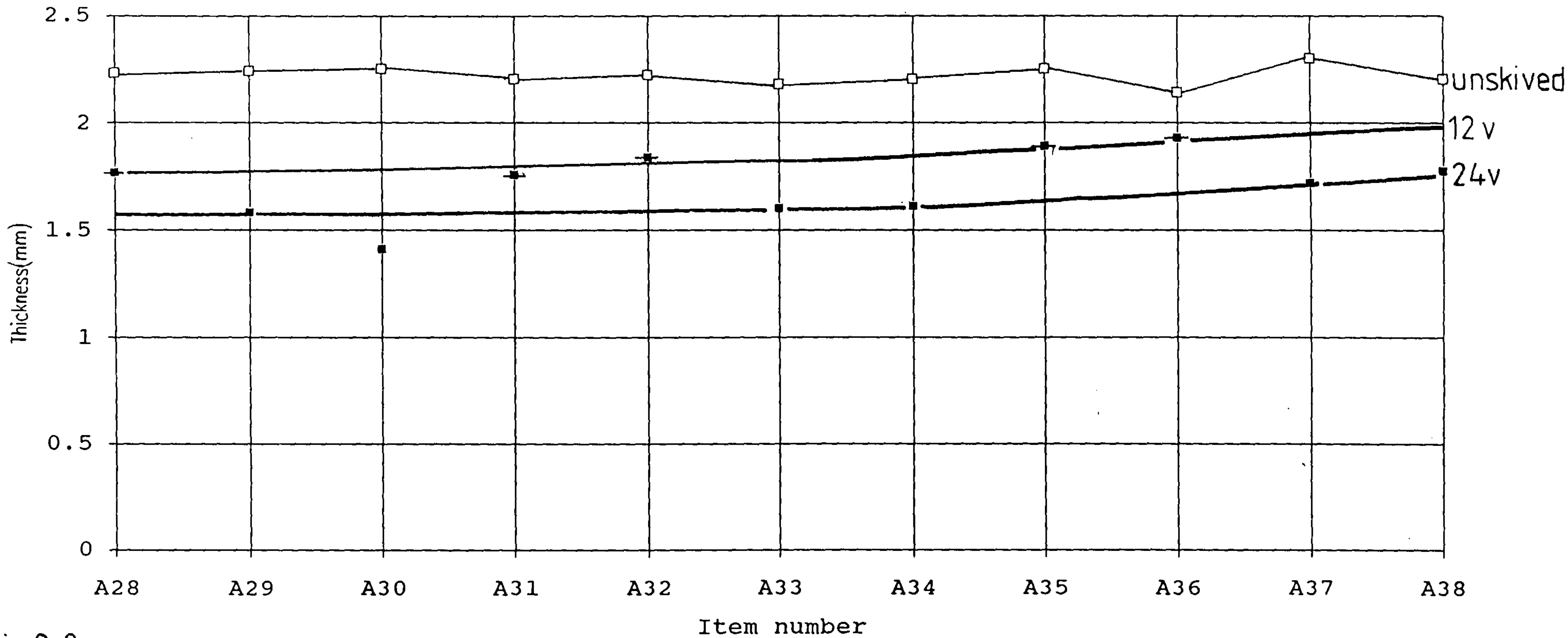
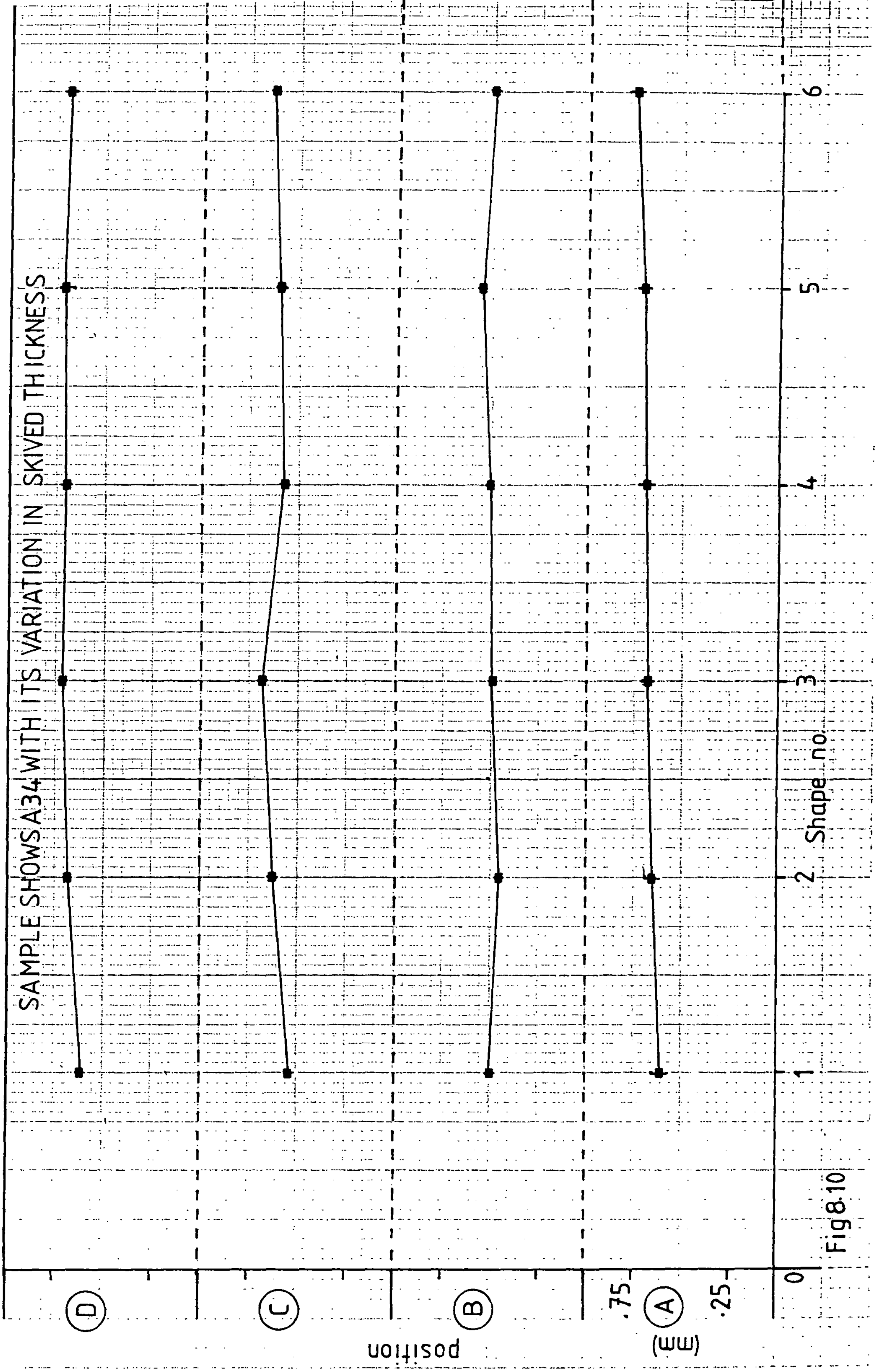
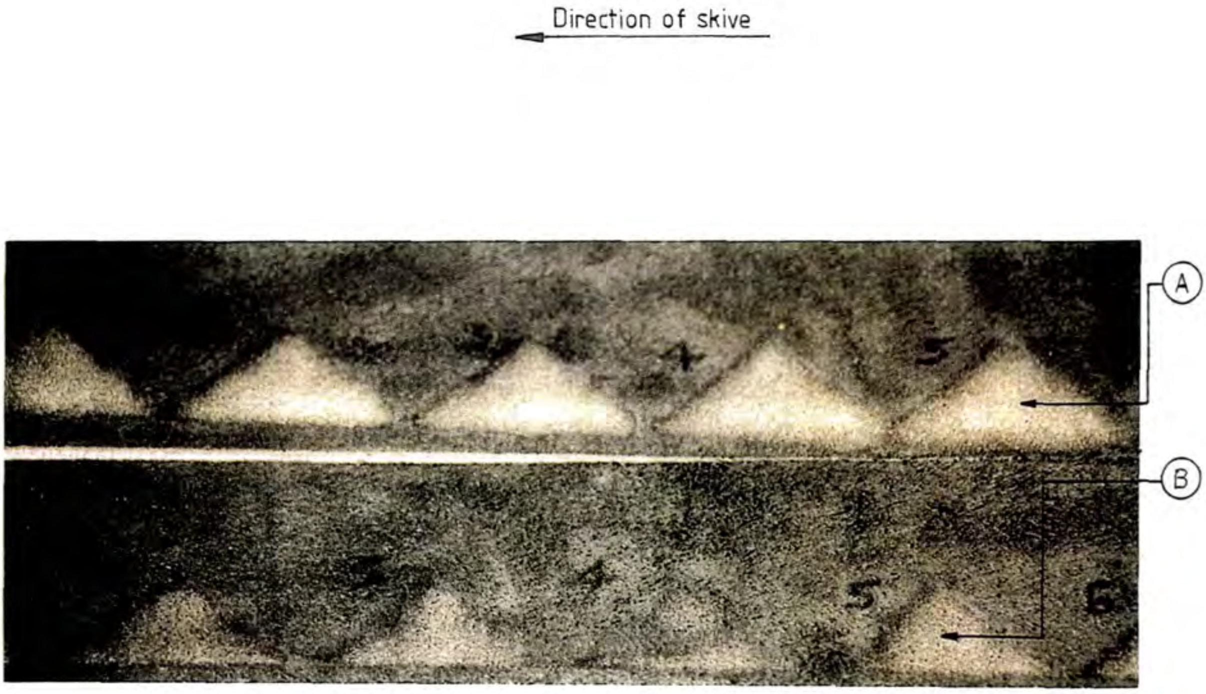


Fig 8.9


SAMPLE SHOWS A34 WITH ITS VARIATION IN SKIVED THICKNESS
Shape no.
0
1
2
3
4
5
6
position
(mm)
.75
.25
A
B
C
D
Fig 8.10



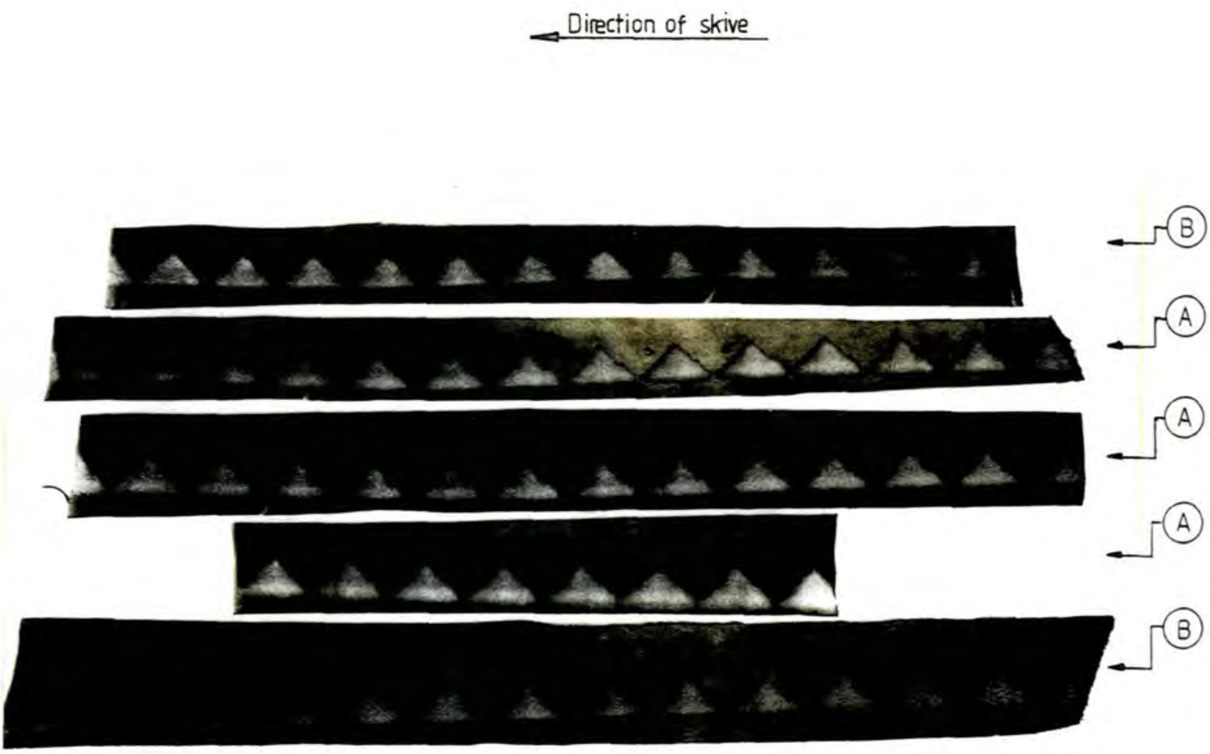


Figure 8.11 Shows the comparison of the skived strips of leather with the input voltages of 12v and 24v. The top photograph is a closer view and shows that the skives labelled A have been skived at 24v, whilst the skives labelled B have been skived at 12v.

forces are random in different positions of the skived shape. Figure 8.11 shows the skived strips of leather.

8.6 Third stage: to compare full and variable depth skives, alternating on the same strip of leather.

The control program had to be altered so that a full depth shape and then a variable depth shape could be skived repeatedly on the leather component. This was achieved by introducing subroutines that initiated a sequence where the output of the microprocessor was repeatedly switched on and off. The consequence of this was that a pulse or mark and space was produced. The mark and space output provided a variable current produced by the smoothing effect, which in turn was created by the inductance of the coil in the solenoids. In the control program, the mark and space was controlled by delay loops preceding the switch on and off commands. These delays were altered to produce a mark and space equal to 0.1milliseconds. It had been proved in a previous test that at this input frequency the solenoids did not vibrate during operation. These commands were in a loop which provided a number of mark/spaces for each actuated pin. The number of cycles of the loop determines the actuation time for each pin skiving the triangle. The counter statement in the loop (which determined the number of cycles in the loop) was therefore adjusted, so the length of the triangle produced was equal to the length of the full depth triangle. The control program switched from a full depth skive to a variable depth skive continuously. This process created the variable voltage required for variable depth. The variable depth triangle was set to half the power of the full depth so that it was compared to the previous results for a 12volt power supply.

The procedure for taking results was the same as detailed above and the skived strips of leather were marked with item numbers from B1 to B10.

Figure 8.12 shows the appearance of the skived strips of leather with shapes at full depth then variable depth. The full depth skive is a complete triangle and the variable skive is incomplete.

For each of the leather strips, the skived shapes were measured, as previously shown in item 1, fig. 8.6. The average thicknesses for each position of A, B, C, and D were obtained for full and the variable depth skived shapes. The overall average thicknesses were determined for each skived strip of leather (or item number).

Figure 8.13 shows a graph of these results and indicates that the full depth skive is 0.19mm deeper than the variable depth skive. This is approximately the same as the results obtained for different input voltages. The graph also shows that when the unskived thickness, decreases the resultant skived thickness increases. Consequently, item number, B5, has the lowest depth of cut and the thinnest leather, whilst, B2, has the thickest leather and the deepest cut. It must be noted that there was an increase in the skive depth for item numbers B1 to B5, owing to the batteries not being charged to their full capacity. From item numbers B5 to B7, the batteries were in the process of being charged and therefore an increase in the depth of cut was achieved. From item numbers B7 to B10 there was an increase in the skived thickness and this was due to an increase in temperature which lowered their applied forces. These results were obtained from using 24volt batteries.

Using the new modified control program it is possible to vary the depth of cut of the skives by altering the time delays for the mark and space ratio. Consequently, if the mark and space are equal then the variation is as shown in fig 8.13. If the mark delay is twice the space delay, then the difference will be halved.

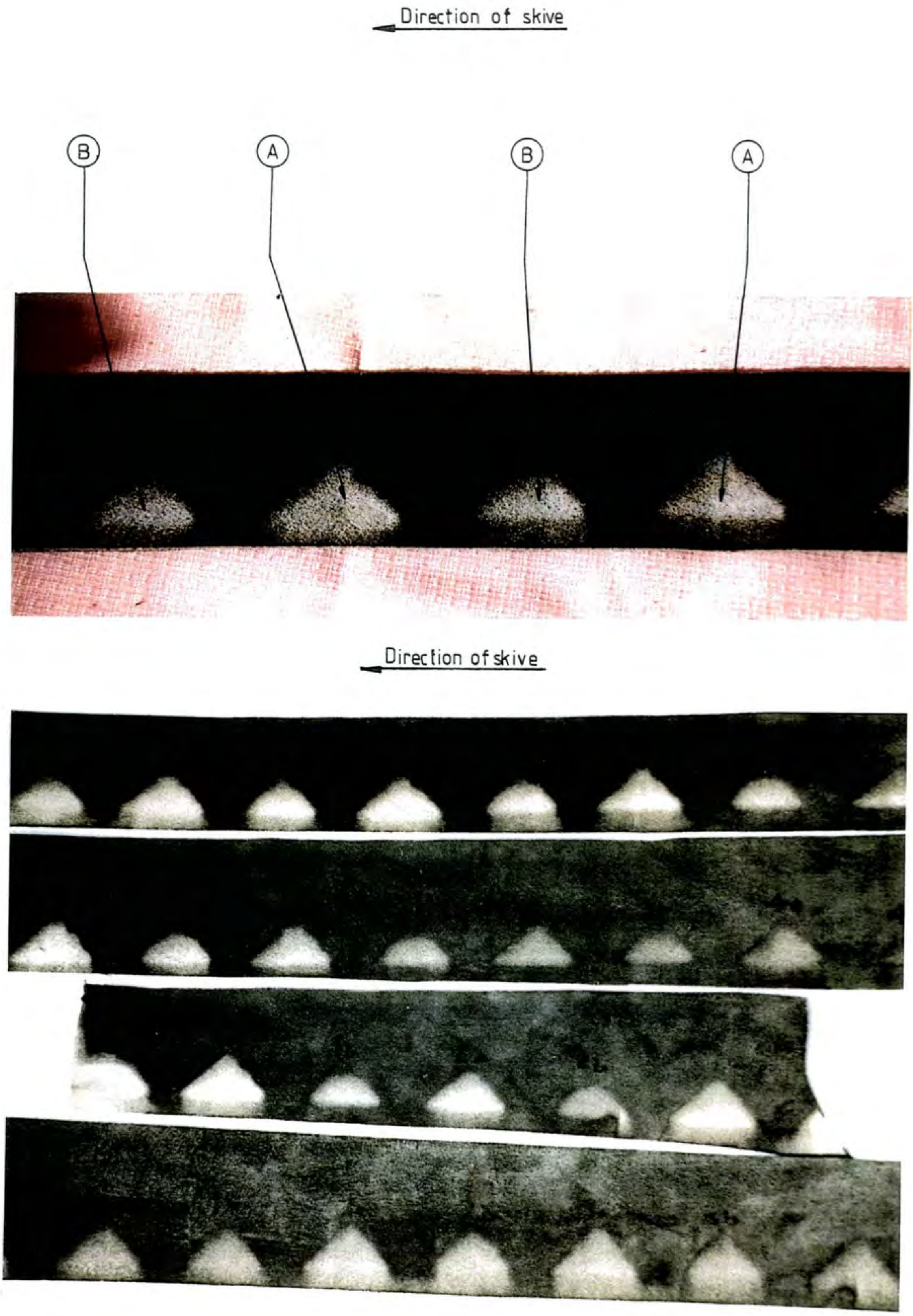


Figure 8.12 Shows the appearance of the skived strips of leather with shapes at full depth and at variable depth. The top photograph shows a closer view, note that item A is a full depth skive and item B is a variable depth skive.

The deterioration of the average skived thickness with time

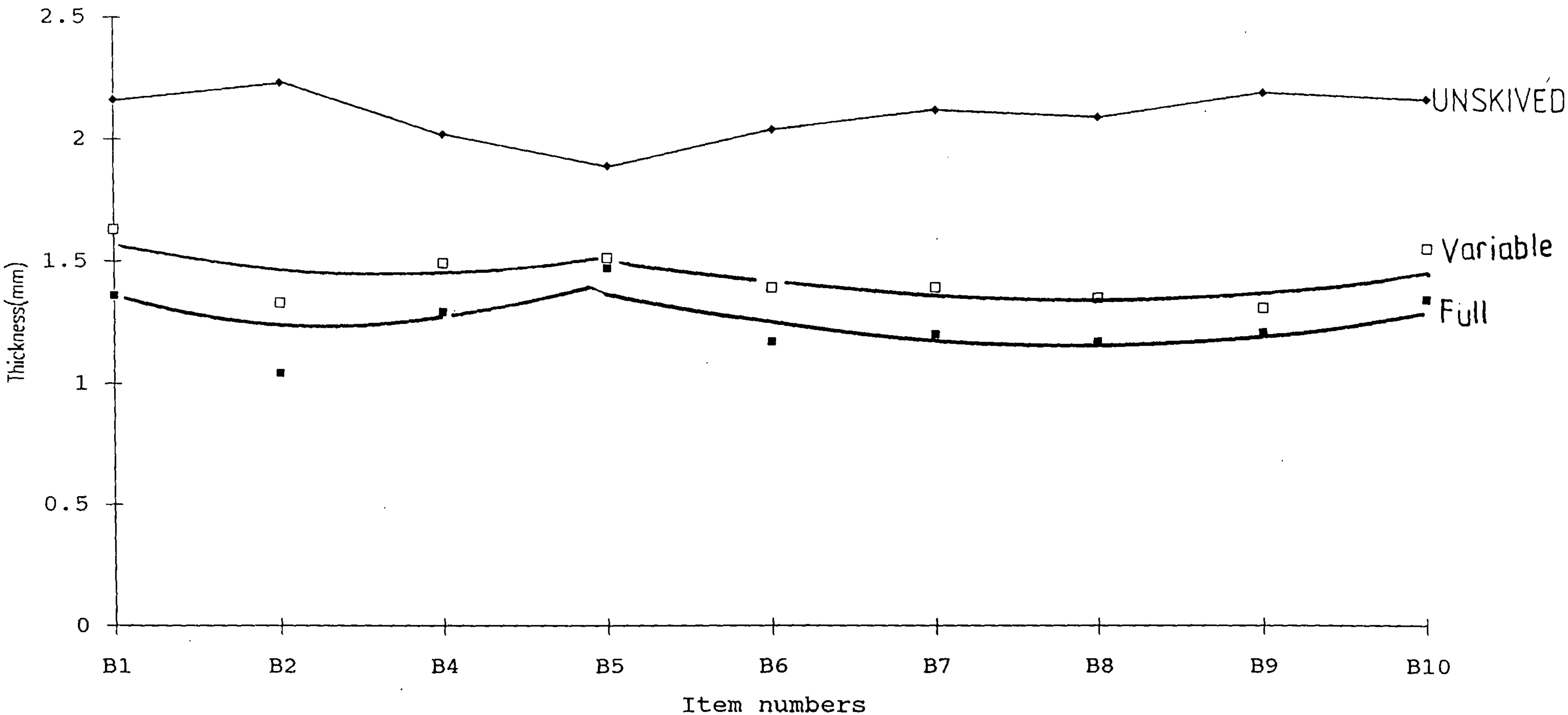


Fig. 8.13

8.7 Fourth stage: to evaluate the accuracy of the process used to control the depth of cut.

The objective of this experiment was to vary the depth of cut by controlling the displacements of individual pins. It was decided that the profile of the skived thickness would be tapered. To achieve this the control program was altered. This was accomplished by removing the loop delays used for the control of the mark/space ratio and by including in the loop, which determines the number of cycles for a pin actuation, a shift bit to the right, command. This command moved a zero into the right side of a 32 bit word, with each bit controlling the actuation of a pin. The shifted zero therefore represented a space, or switch off command for the pin. At the end of each loop the command shifted another zero into the 32 bit word. This created marks and spaces which represent a wedge type profile. As a result each actuated pin was displaced a different amount, thus producing a taper. The control program alternated between skiving a full depth shape and tapered depth shape.

This experiment was set-up and controlled in the same manor as for the previous test. The shape of the skive was changed from a triangle to a rectangle, as shown in fig. 8.6, item 2. This was to allow the depth measurements of the profile to be taken more than once. Figure 8.6, item 2, shows the method used for measuring the depth of skive. The x,y table was adjusted in increments of 1mm across the width of each skive and the depth measurement was recorded. This procedure was repeated in different positions on the same skived shape and an average for the depth for every incremental measurement was calculated. These measurements were plotted on a graph as shown in fig 8.14. Three types of skived shapes were measured: a full depth skive, a tapered skive with the thickness increasing and a tapered skive with the thickness decreasing with the width. The direction of the taper could be altered by adjusting the control. This was achieved by changing the 'shift a bit right' statement to a 'shift left' statement.

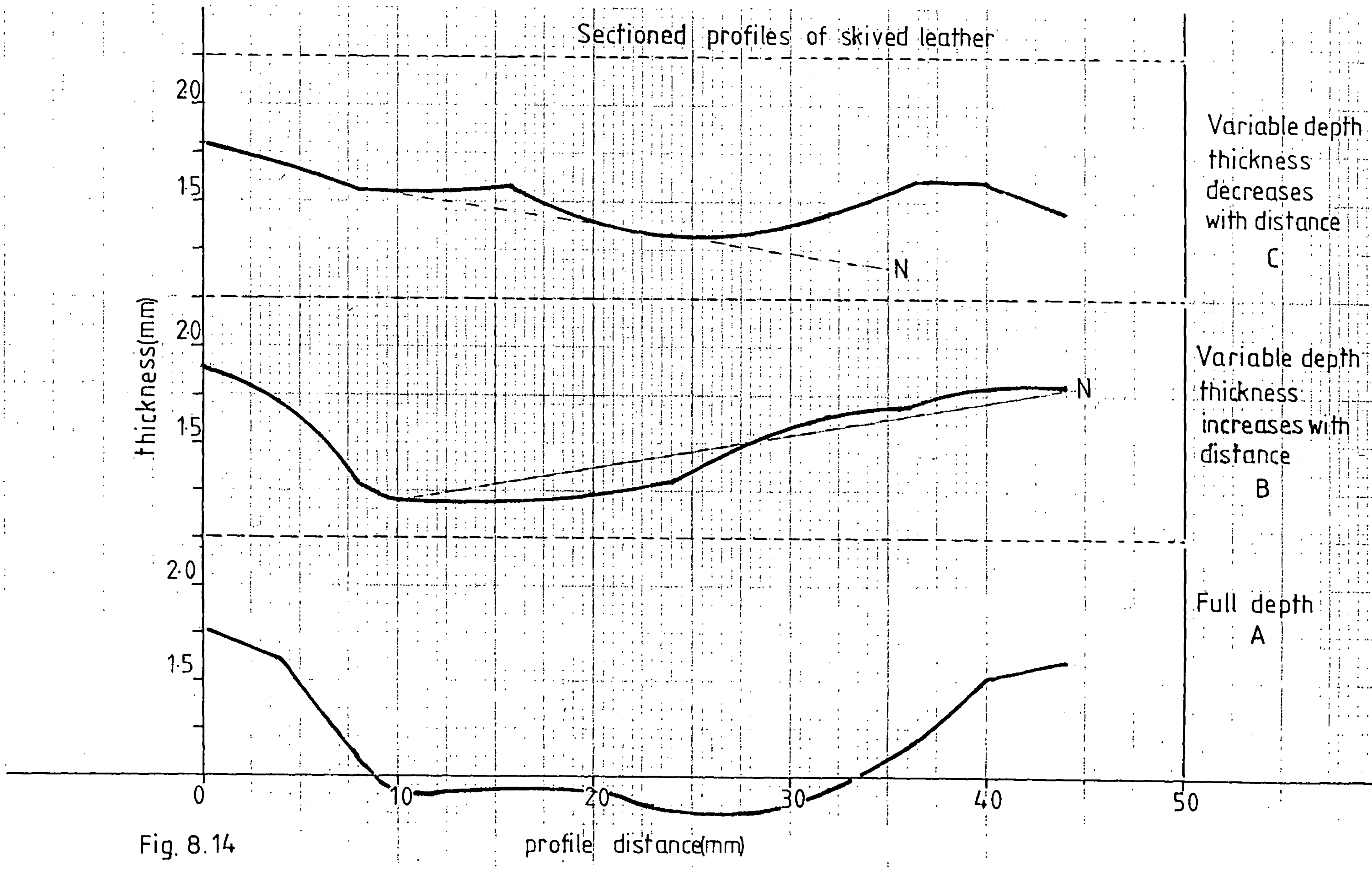

Sectioned profiles of skived leather
thickness(mm)
2·0
1·5
2·0
1·5
2·0
1·5
N
N
Variable depth
thickness
decreases
with distance
C
Variable depth
thickness
increases with
distance
B
Full depth
A
0
10
20
30
40
50
profile distance(mm)

Fig. 8.14

Figure 8.14 shows the three skive profiles and a dotted line, N, which gives the direction of the cut profile. The profile of the skives shows the steep slopes which indicate the start and the finish of the cut. The full depth skive, [A] shows that the cut is not symmetrical or uniform and the base of the profile is not flat. This was due to physical and mechanical variations on the splitting machine. The variable depth profile [B] shows the taper increasing with the width. The skived profile, [C],shows the taper decreasing with the width. The results show a satisfactory tapered profile and prove that the pin depth can be controlled.

Figure 8.15 shows the visible difference between full depth skive and a variable tapered skive. In addition, a cross section of a tapered skive is shown.

8.8 Conclusion

This chapter has shown that the accuracy of the results produced by the new skiving machine was satisfactory. The analysis of the six skived samples shows accurately cut diagonal edges with no indication of any "stepping effect" which was present on the old skiving machine. This proves that the main objective of this project had been successful and that the high pin resolution was satisfactory. The skived shapes were tested at different speeds to determine its limitation on the quality of cut. From the results obtained, the process produced satisfactory skived triangles at speeds up to 160mm/s. This was approximately the specification requested by the customer, BUSM, of 181mm/s. However there was deterioration of the quality, but this could be rectified by slight modification to the tensioning of the conveyor system. Therefore the accuracy of high speed skiving proved that the initial performance requirements for the machine were correct. Similarly, the solenoids provided adequate movement, force and response time. The design of the skiving machine proved that it provided sufficient movement, rate of return, and transmission of force to the pins, to skive at this speed. However, there were difficulties if actuation continued for long periods of

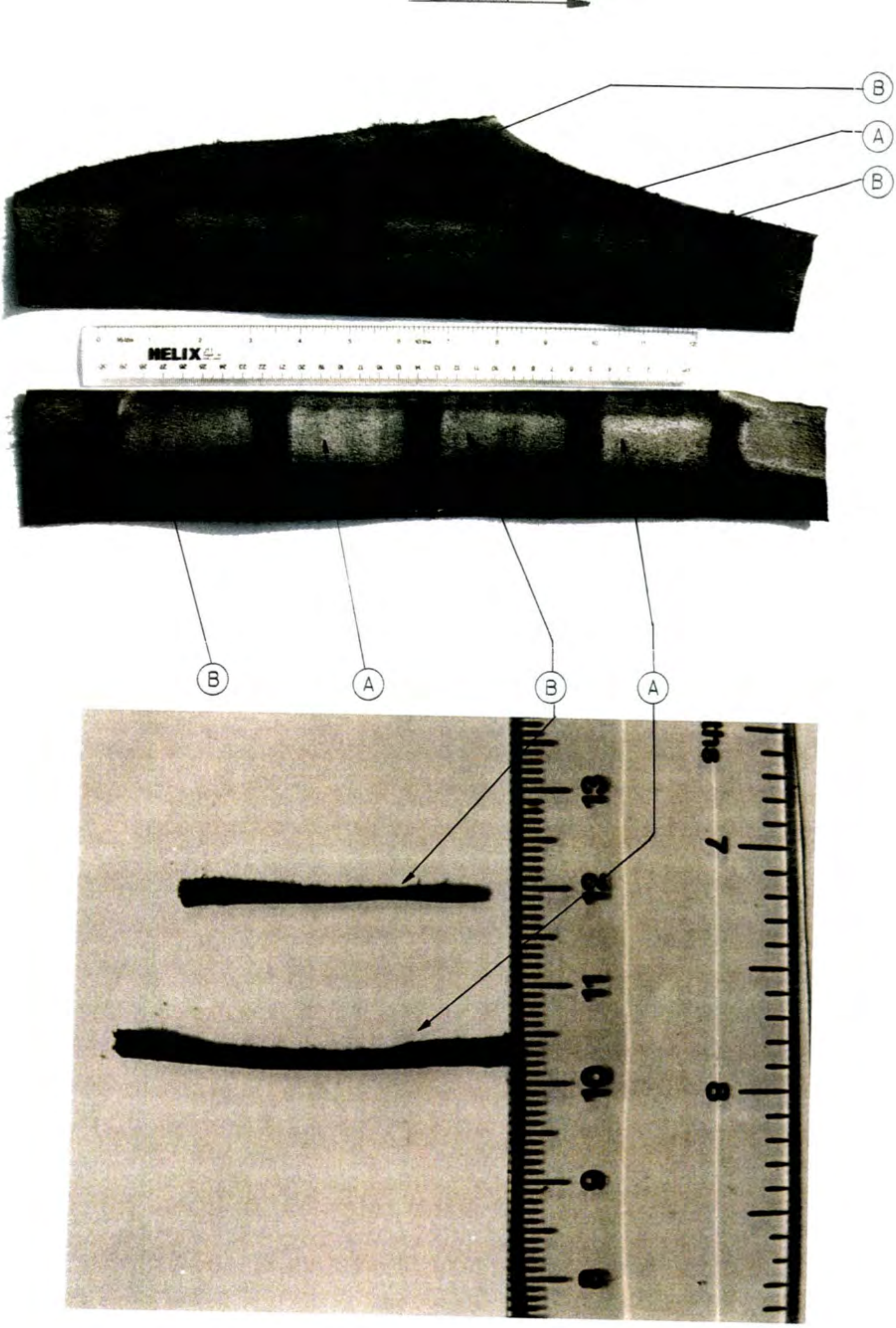


Figure 8.15 Shows the visible difference between a full depth skive (shown as item A) and a variable tapered skive (shown as item B). The bottom photograph show two sectioned views of a full and variable depth skive.

time, due to the solenoid's temperature increasing and reducing the applied force. This feature of the machine needs to be considered during future development.

The second, third and fourth stages of these results were to prove that the skiving process could control the depth of cut. This was not an initial objective of this project, but was requested by the customer, BUSM, for the further development of this machine.

The results showed that the skiving machine produced a repeatable depth of cut. This process depended on the forces exerted by the solenoids being balanced by the return forces. This process proved to be accurate by showing a constant variance between the depths of skived shapes at half and full power supply, see fig 8.8. However, there was difficulty in achieving the control, due to the increase in temperature of the solenoids reducing the applied force and creating a tendency for the depth of cut to reduce. The results showed the control of variable depth could be achieved by the modification of the control program, see fig 8.13. Consequently, a full depth skived triangle was cut beside a variable depth skive on the same strip of leather. These results proved that the variation in depth observed in fig 8.13 was not due to the solenoids heating up. Similarly, the software was altered so that a tapered profile was produced., see fig 8.14. This was done to visually show the variable depth effect by tapering the edges of the skived shape, see fig.8.15 and that each pin could be controlled to cut at different positions. It was discovered that there were disadvantages in controlling the depth of cut because it was dependent on the balance between the variable force provided by the solenoid and the return forces generated by the process. During the experiments it was noted that the depth of cut was affected by fluctuations in the thickness of the leather. It was apparent that an increase in the thickness would alter the balance of forces used to control the process and therefore the depth of cut was increased. This would be a disadvantage if used in shoe manufacture as the thickness of leather used is randomly variable. However, this effect could be controlled by adjusting the height of the machine relative to the variation in leather thickness. Similarly, the balanced forces of the process could be increased to reduce the relative effect of skiving thicker leather.

From the results obtained in this chapter it must be concluded that the skiving machine had satisfied all the initial objectives stated at the beginning of this project. Furthermore, the Skiving Machine had an additional feature in controlling the depth of cut.

CHAPTER 9

Conclusion

9.1 Introduction

This work has successfully demonstrated that the development of the high resolution skiving machine has eliminated the "stepping effect". (The latter was a problem when skiving diagonal lines with the old skiving machine). Therefore, a high standard of quality has been produced from a fully automated skiving process. The flexibility of the design, allows it to be installed into the new splitting machine and the skiving machine can achieve accurate skiving at high conveyor speeds (which satisfied the customer's requirements). In addition to achieving the required objectives of this project, the machine is capable of controlling the depth of cut. Therefore, the machine can skive at variable depths and software has been developed, which enables the automated process to control the movement of each pin. However, the accuracy of the depth is not repeatable and therefore the depth control of the skiving process requires further investigation.

9.2 A summary of the new skiving machine's performance and specification

The performance of the current skiving system is determined by the quality of the component produced, its output speed and its ability to skive different types of leather. The process is capable of skiving a shoe component every two seconds and can achieve a cut which is accurate to within 0.6mm of the required position. The machine has the ability to control the depth of cut and can produce a smooth tapered finish (as shown in figure 8.15). Furthermore, the variable depth of cut can be held for a length of 60mm (to within an accuracy of 0.02mm).

To achieve these performance features, the operating system of the machine is very complex and has six hundred moving components. It must be noted, that these moving parts are contained in a span length of 240mm with each pin exerting a force of up to 165 N (which is dependent on whether the solenoid is in a fully or partially closed position). The movement of so many parts is dependent on the accuracy of the design and manufacture of the components. The skiving machine has over one thousand parts in total and twenty components per pin. There are supporting components which are designed to withstand thrust forces of 13.2 kN. The minimum movement of the pins is 1.5mm and these are spaced to a pitch of 2mm.

Because of the above requirements it has been shown that the skiving machine was very complex and exacting machine to design and assemble.

From the results obtained from chapter 8 it can be seen that the development of the skiving machine is a success. The hardware and software developed to activate the machine have been proved adequate for the current stage of testing the machine, but for future developments they may have to be reviewed.

9.3 **Future Directions**

The immediate development for the new Skiving Machine will be its installation onto the new splitting machine. As previously explained in chapter 5 this will require little modification of components; only 2% of parts will have to be made for the design. This should then be integrated into a more advanced automated skiving process. The latter, comprises of the latest development in vision systems, supplied by BUSM (British United Shoe Machinery Co Ltd.), with a transputer processor system for data communications, linked with the current Motorola microprocessor for the actuation of the solenoids on the skiving machine. A new twin belt conveyor system will be developed and controlled by an additional microprocessor. The introduction of a faster data communication process, such as the transputer and the new vision system, will enable the system to run at higher speeds. Also the larger area of the new splitting machine will enable the largest sized shoe upper to be skived with the new skiving machine. This system will be the prototype for the eventual commercial product.

The overall design of the Skiving Machine has been acceptable as research equipment. However, further developments will have to be introduced if it is going to become a commercial product. The following points give suggested improvements to the design:-

a) To achieve easy maintenance the size of the conveyor belt would have to be increased to allow for the removal of the skiving machine for necessary repairs.

b) Further investigation must be made into the selection of the wire and the method of connection to the plungers and levers. It will be necessary to have a wire whose physical properties prevent deformation and reduce the loss of transmitted movement. If this is not possible, then a return to solid levers may need to be considered.

c) The upper conveyor belt requires further development to increase the strength and rigidity of the material for skiving at high speeds, as discussed in the previous chapter. It is therefore necessary to investigate different conveyor belt materials.

There are further developments required to improve the depth of cut control currently on the machine. As discussed in the previous chapter, due to the fluctuation in the thickness of leather the depth of cut is affected. This is because the depth of cut is dependent on the balance between the return force and the force applied by the solenoids. Therefore, if the thickness of the leather varies, then the resultant force could vary the depth of cut. This could be overcome by adjusting the skiving machine's vertical position, relative to the thickness of the leather. Another method of controlling this effect would be to increase the balanced forces, so that the forces generated by the variation of thickness had little influence in comparison. An ideal method would be to control the position of the pins rather than controlling the force exerted by the solenoids. This method would have an advantage over the above system as it is not affected by variable process forces. During skiving the leather does not have support at the beginning of its edge and therefore less force is required to skive. Therefore, when using the variable force method the leather is cut deeper, but if the pin position was controlled directly this should not affect the depth of cut. The disadvantage of this system is that it requires a closed loop control system for each pin. This process needs further investigation.

The further development of variable depth control will be the next stage in this project with BUSM, British United Shoe Machinery Co. Ltd.

References

R1 American Leather Chemists Assoc. JNL "Split and unsplit chrome tanned leathers Part 47; 1952 p404-425.

R2 Saadat-Sarmadi .M "Investigation of the Machining Processes of Flexible Fibrous materials for Applications in Industrial Automation " P.h.D Thesis University of Durham.

R3 Wilson J.A "Effect of splitting on the tensile strength of leather" Industrial and Engineering Chemistry,Vol 18,1926 p312-313.

R4 Topis S K personal communication University of Durham, December 1993.

R5 Tout N "Investigation of the processes required for the automation of stitch marking in shoe manufacture",P.h.D 1989 University of Durham.

R6 Topis S.K "Investigation of Electrical and Mechanical requirements for the Automation of a Process in Flexible Material Manufacture", P.h.D,University of Durham 1993.

R7 Carvill.J, Deas.K.W, Kennedy.J, Marshall,W.E, Miller.J, Newton.M.J, Smith.J.R, Thornber.E.N, McCutcheon.J.A, "Mechanical Engineering Design Book ", Newcastle upon Tyne Polytechnic,Faculty of Engineering.

R8 Ryder G.H ,"Strength of Materials", S.I. Edition.

R9 Lisk (uk) Ltd "commercial and special purpose solenoids personal communication Rochford.Essex. 1993.

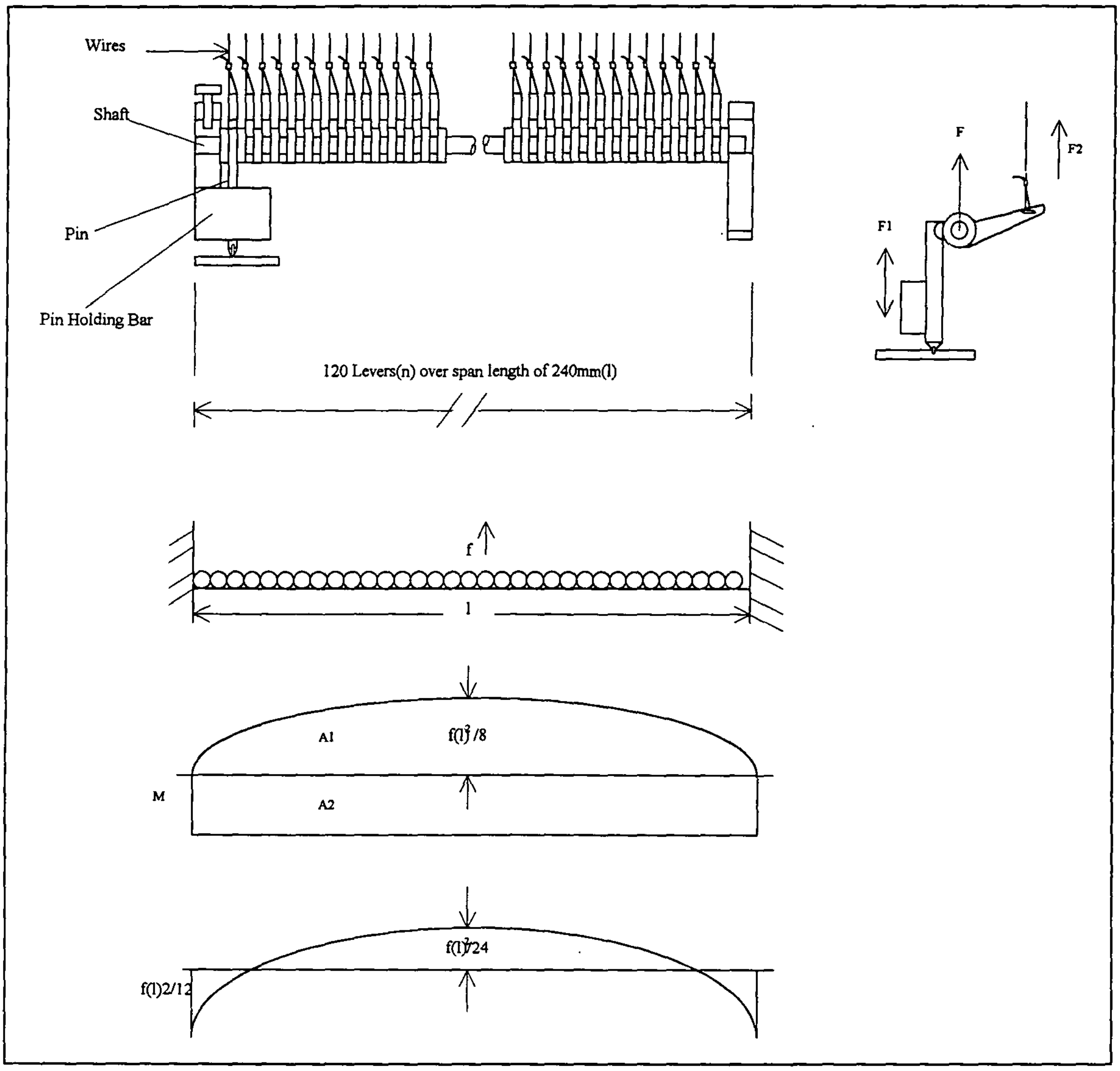
R10 Meriam J.L "Engineering Mechanics vol. 2 Dynamics"Wiley .J

R11 Nasar. S.A, Unnewehr.L.E "Electromechanic and Electric Machines ".

R12 Steven .R .E,"Electric Machines and Power Electronics".

R13 G.W.Lisk Company, Inc. Tubular Solenoids, Catalogue 9A.

APPENDIX A1 SHOWS THE STRESS CALCULATIONS FOR DETERMINING THE REQUIRED NUMBER OF SHAFT SUPPORTS



$$F = F1 - F2 = 165 - 55 = 110 \text{ Newtons}$$

Where F is force on the shaft and F1 is the resultant force from the pin.

If we assume that the lever has a mechanical advantage of 3 to 1,

then F1 = 3 x F2 ,where F2 is the force of the solenoid on the wire.

Therefore the force per mm of span length(f)= F x n /l = 110 x 120/240 = 55 Newtons.

Where n is the number of levers and l is the span length. If we assume that this force is evenly distributed across the length and the shaft is fixed horizontally.

The following equations are taken from G.H Ryder[R 8] from using moment area theory and fixing moment area A2=Ml

ThereforeAl = $2/3(fl^2/8)l = fl^3/12$ and Maximum Bending Moment = M $=fl^2/12$

Maximum Bending stress =(M/I).y = 2689N/mm^2,

Max.deflection = $fl^4/384EI$ = 4.6mm

I is 2nd moment of area for circular shaft $=\pi d4/64$ **E** for steel= 208000N/mm2

diameter (d)=10mm Centroid of shaft (y)=5mm

Note that the stress is too large therefore a number of supports must be introduced for the shaft

If we assume three supports $\therefore$ l=60mm and therefore

deflection = 0.0016mm

Maximum bending stress will be =168 N/mm^2

Therefore it is within the permissible stress limit for the shaft of 200N/mm^2(silver steel).

APPENDIX A2 SHOWS TEST PROGRAM1 AND TEST PROGRAM 2 USED FOR ADJUSTING THE MACHINE FOR MAXIMUM PERFORMANCE.

M.O.Newton,1993, School of Engineering and Computer Science University of Durham

Control Software for High Resolution Skiving Machine
Program activates all the pins from 0-120 in sequence

System : **M 68000**

Programming language : **M 68000 assembler**

ADDR CODE	*LISTING*	
	| * PROGRAM TEST1 * |	
000000 13FC 00FE 0002 3000	movb #0xFE,0x23000	|Binary Line No.0 to be moved to |address 23000.
000008 13FC 00FD 0002 3001	movb #0xFD,0x23001	|Binary Line No.1 to be moved to |address 23001
000010 13FC 00FB 0002 3002	movb #0xFB,0x23002	|Binary Line No.2 to be moved to |address 23002
000018 13FC 00F7 0002 3003	movb #0xF7,0x23003	|Binary Line No.3 to be moved to |address 23003
000020 13FC 00EF 0002 3004	movb #0xEF,0x23004	|Binary Line No.4 to be moved to |address 23004
000028 13FC 00DF 0002 3005	movb #0xDF,0x23005	|Binary Line No.5 to be moved to |address 23005
000030 13FC 00BF 0002 3006	movb #0xBF,0x23006	|Binary Line No.6 to be moved to |address23006
000038 13FC 007F 0002 3007	movb #0x7F,0x23007	|Binary Line No.7 to be moved to | address 23007
0007 4600	TOTAL = 0x74600	|Make Total address=0x74600
000040 183C 0000	movb #0,d4	|Zero contents of Directory d4
000044 163C 0000	movb #0,d3	|Zero contents of directory d3.
000048 41F9 0007 4600	lea TOTAL,a0	|Give a0 the address of |Total =0x74600
00004E 1A3C 0000	movb #0,d5	|Zero contents of directory d5.
000052 243C 0000 0000	movl #0,d2	|Zero contents of directory d2.
000058 103C 001C	movb #0x1C,d0	|Move No.1c or 28 represnting |the number.of Ports of the | M68000 into directory d0 |To be used as counter.

```
00005C 45F9 0002 3000 L1:   lea  0x23000,a2          |Give a2 the address of 0x23000
                                                     |which contains(FE).

000062 183C 00FF             movb  #0xff,d4           |Move(FF) into d4.

000066 1184 2805             movb  d4,a0@(5,d2:l)     |Set Data Directional Register to
                                                     |output  for a0 = 74600 +(  offset of 5
                                                     | +  an incrementof d2).
                                                     |(Data Direction Address)

00006A 47F0 2805             lea  a0@(5,d2:l),a3      |Give a3 the Data Direction Address.

:00006E 1C3C 0008            movb  #8,d6              |Move 8 into d6 .Representing the
                                                     |No.  of Line Outputs in the ports.

000072 1E3C 0000      L3:    movb  #0,d7              |Zero contents of directory d7.

000076 1E1A                  movb  a2@+,d7            |Move FE to d7.

000078 1607                  movb  d7,d3              |Move d7 to d3.

00007A 1183 2801             movb  d3,a0@(1,d2:l)     |Move d3 or(FE)to address
                                                     |a0=74600+(offset of 1 + an
                                                     |increment of d2) output (FE)
                                                     |for firstport address and
                                                     | activate first Thrust Pin.

00007E 49F0 2801             lea  a0@(1,d2:l),a4      |Give a4 the above address.

000082 223C 000D 9018        movl  #0xd9018,d1        |Make a delay of one second so
                                                     | Thrust Pin continues to be
                                                     |activated for one second.

000088 5381           L7:    subql #1,d1              |
00008A 6600 FFFC             bne  L7                  |End Delay.

00008E 163C 00FF             movb  #0xFF,d3           |Move (FF)to d3 ,hence zero ,
                                                     |deactivateThrust Pin at the Port
                                                     | Address.

000092 1183 2801             movb  d3,a0@(1,d2:l)     |Go through other line outputs of
                                                     | port addressand then increment
                                                     |a2 address  by 1.

000096 5306                  subqb #1,d6              |
000098 6600 FFD8             bne  L3                  |Go to next thrust pin of same port
                                                     |address.

00009C 0605 0001             addb #1,d5               |Add 1 to d5.

0000A0 0C05 0001             cmpb #1,d5               |Compare 1 with d5


0000A4 6600 000E             bne  L5                  |If equal make increment d2=2 and
```

```
 0000A8 0682 0000 0002           addl #0x02,d2                    | then decrement 1 from d0
counter
                                                                  | to show that one of the 28 ports
                                                                  |have been run..
                                                                  |Return to start L1.

 0000AE 4EF9 0000 00BE          jmp L4                            |
0000B4 0682 0000 001E  L5:   addl #0x1E,d2                        |If unequal make increment
                                                                  |d2=1e or 28 and decrement 1
                                                                  | from 28 or d0, return to start L1

 0000BA 1A3C 0000               movb #0,d5                        |
 0000BE 5300              L4:   subqb #0x01,d0                    |
 0000C0 6600 FF9A               bne  L1                           |Increment d2 will change
                                                                  |address to next port.

 0000C4 4E4F                    trap  #15                         |
 0000C6 000E                    .word  14                         |Return to monitor.
```

DURHAM SEAS M68000 ASSEMBLER

M.O.Newton, 1993, School of Engineering and Computer Science, University of Durham

Control software for High Resolution Skiving Machine
Program activates all pins eight times from 0-120 in sequence.

System :M 68000

Programming language : M 68000 assembler

```
ADDR   CODE                 LISTING

                            | * PROGRAM TEST2 * |

000000 13FC 00FE 0002       movb  #0xFE,0x23000     |Binary  Line No.0 to be moved to
   3000                                             |address23000.

000008 13FC 00FD 0002       movb  #0xFD,0x23001     |Binary  Line No.1 to be moved to
   3001                                             |address 23001

000010 13FC 00FB 0002       movb  #0xFB,0x23002     |Binary Line No.2 to be moved to
   3002                                             |address 23002

000018 13FC 00F7 0002       movb  #0xF7,0x23003     |Binary Line No.3 to be moved to
   3003                                             |address 23003

000020 13FC 00EF 0002       movb  #0xEF,0x23004     |Binary Line No.4 to be moved to
   3004                                             |address 23004

000028 13FC 00DF 0002       movb  #0xDF,0x23005     |Binary Line No.5 to be moved to
   3005                                             |address 23005

000030 13FC 00BF 0002       movb  #0xBF,0x23006     |Binary Line No.6 to be moved to
   3006                                             |address 23006

000038 13FC 007F 0002       movb  #0x7F,0x23007     |Binary Line No.7 to be moved to
   3007                                             |address 23007

0007 4600                   TOTAL = 0x74600         |Make Total address=0x74600

000040 183C 0000            movb #0,d4              |Zero contents of Directory d4

000044 163C 0000            movb #0,d3              |Zero contents of directory d3.

000048 41F9 0007 4600       lea  TOTAL,a0           |Give a0 the address of Total =0x74600.

00004E 1A3C 0000            movb #0,d5              |Zero contents of directory d5.

000052 243C 0000 0000       movl #0,d2              |Zero contents of directory d2.

000058 103C 001C            movb #0x1C,d0           |Move No.1c or  28 represnting the
                                                    |number of Ports of the M68000
                                                    |into .directory d0.
                                                    |To be used as a counter.
```

```
00005C 45F9 0002 3000  L1:  lea   0x23000,a2          |Give a2 the address of 0x23000 which
                                                      |contains FE.

000062 183C 00FF            movb  #0xff,d4            |Move(FF) into d4.

000066 1184 2805            movb  d4,a0@(5,d2:l)      |Set Data Directional Register to output
                                                      |for a0 = 74600 +( offset of 5
                                                      | + an increment of d2).

00006A 47F0 2805            lea   a0@(5,d2:l),a3      |Give a3 the Data Direction Address.

00006E 1C3C 0008            movb  #8,d6               |Move 8 into d6 .Representing the No.
                                                      |of Line Outputs in the ports.

000072 1E3C 0000       L3:  movb  #0,d7               |Zero contents of directory d7.

000076 1E3C 0008            movb  #8,d7               |Set counter to 8,therefore activating
                                                      |the same thrust pin eight times.

00007A 1A1A                 movb  a2@+,d5             |Move contents of a2 (FE)to d5.

00007C 1605            L8:  movb  d5,d3               |Move d5 to d3.

00007E 1183 2801            movb  d3,a0@(1,d2:l)      |Move d3 or(FE)to address
                                                      |a0=74600+(offset of 1 + an
                                                      |increment of d2) output (FE) for
                                                      |first port address and activate first
                                                      |Thrust Pin.

000082 49F0 2801            lea   a0@(1,d2:l),a4      |Give a4 the above address.

000086 223C 000D 9018       movl  #0xd9018,d1         |Make a delay of one second so
                                                      |Thrust Pin continues to be activated
                                                      | for one second.

00008C 5381            L7:  subql #1,d1               |
00008E 6600 FFFC            bne   L7                  |End delay.

000092 163C 00FF            movb  #0xFF,d3            |Move (FF)to d3 ,hence zero
                                                      |,deactivate Thrust Pin at the
                                                      |Port Address.

000096 1183 2801            movb  d3,a0@(1,d2:l)      |Go through other line outputs of port
                                                      |address and then increment a2
                                                      |address by 1.

00009A 223C 000D 9018       movl  #0xd9018,d1         |Make delay of one second so
                                                      |Thrust Pin continues to be
                                                      |deactivated second for one .

0000A0 5381            L9:  subql #1,d1               |
0000A2 6600 FFFC            bne   L9                  |End delay.
0000A6 5307                 subqb #1,d7               |
0000A8 6600 FFD2            bne   L8                  |After activating pin 8 times go to
                                                      | next pin.

0000AC 5306                 subqb #1,d6               |
0000AE 6600 FFC2            bne   L3                  |Go to next thrust pin of same
```

```
                                                          |port address.

0000B2 DAFC 0001               addw #1,a5                |Add 1 to d5.

0000B6 BAFC 0001               cmpw #1,a5                |Compare 1 with d5.

0000BA 6600 000E               bne  L5                   |If equal make increment d2=2 and
0000BE 0682 0000 0002          addl #0x02,d2             |then decrement 1 from d0 counter
                                                         | to show that one of the 28 ports have
                                                         |been run .

0000C4 4EF9 0000 00D4          jmp  L4                   |Return to start L1.

0000CA 0682 0000 001E  L5:     addl #0x1E,d2             |If unequal make increment d2=1e or
                                                         |28 and decrement 1 from 28 or d0
                                                         |return to start L1.

0000D0 3A7C 0000               movw #0,a5                |
0000D4 5300            L4:     subqb #0x01,d0            |
0000D6 6600 FF84               bne  L1                   |Increment d2 will change address to
                                                         |nextport.

0000DA 4E4F                    trap  #15                 |
0000DC 000E                    .word  14                 |Return to monitor.
```

DURHAM SEAS M68000 ASSEMBLER

Appendix A3

The New Skiving Machine

A.1 General Assembly Drawing

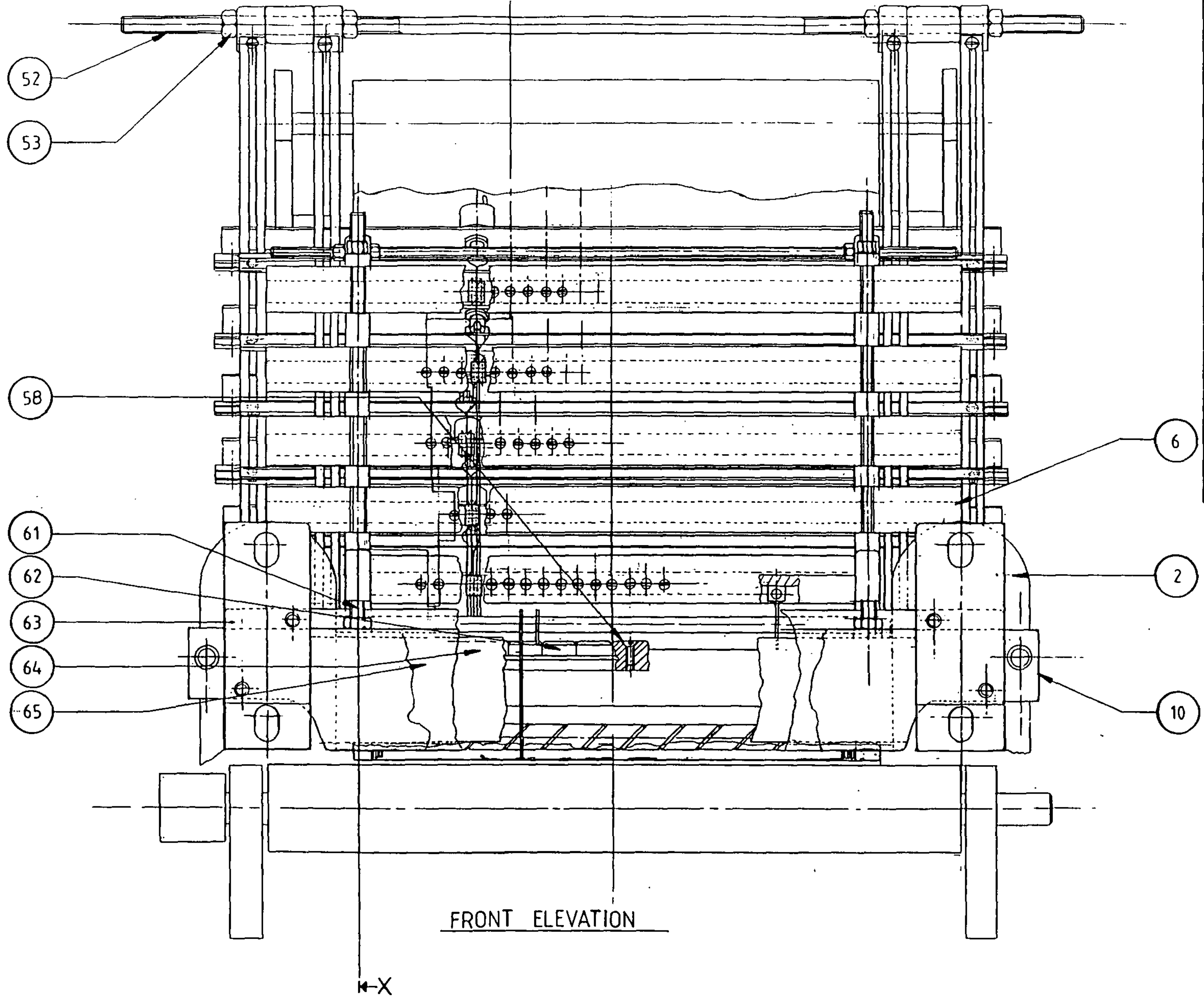
The G.A. drawing gives a representation of the machine that was subsequently built. A copy of the G.A. drawing entitled `Solenoid Mounting Assembly' is enclosed in Appendix A6. Figures A.0/A.1 show the side and front elevations of the original General Assembly drawing. This drawing will be referred to as the new Skiving Machine for the purpose of this thesis. The following describes the drawing procedure.

Starting from the space available under the conveyor (i10,fA.1), the positions of the back stop (i2,fA.0), knife guide (i10,fA.1), knife (i13,fA.1) and feed roller (i11,fA.1) were determined. From knowing these positions the front plate (i10,fA.0) and its connection to the pin mechanism (i3,fA.1) was drawn.. Height adjustment was added to the front plate to achieve the ideal skiving position. The positions and angles of the wires, connected to the solenoids (i22,fA.1), were drawn so they didn't interfere with each others movement and this determined the position of the pulleys (i6,fA.1). The height of the pulleys above the splitting machine had to be suitably spaced in relation to the conveyor, levers (i1,fA.1) and solenoids. From knowing the position and the mechanical advantage of the lever the relative dimensions of the shaft (i2,fA.1) to the pins could be found. Secondary systems of operation and other structural peripherals were then included in the drawing.

A.2 Machine Movement

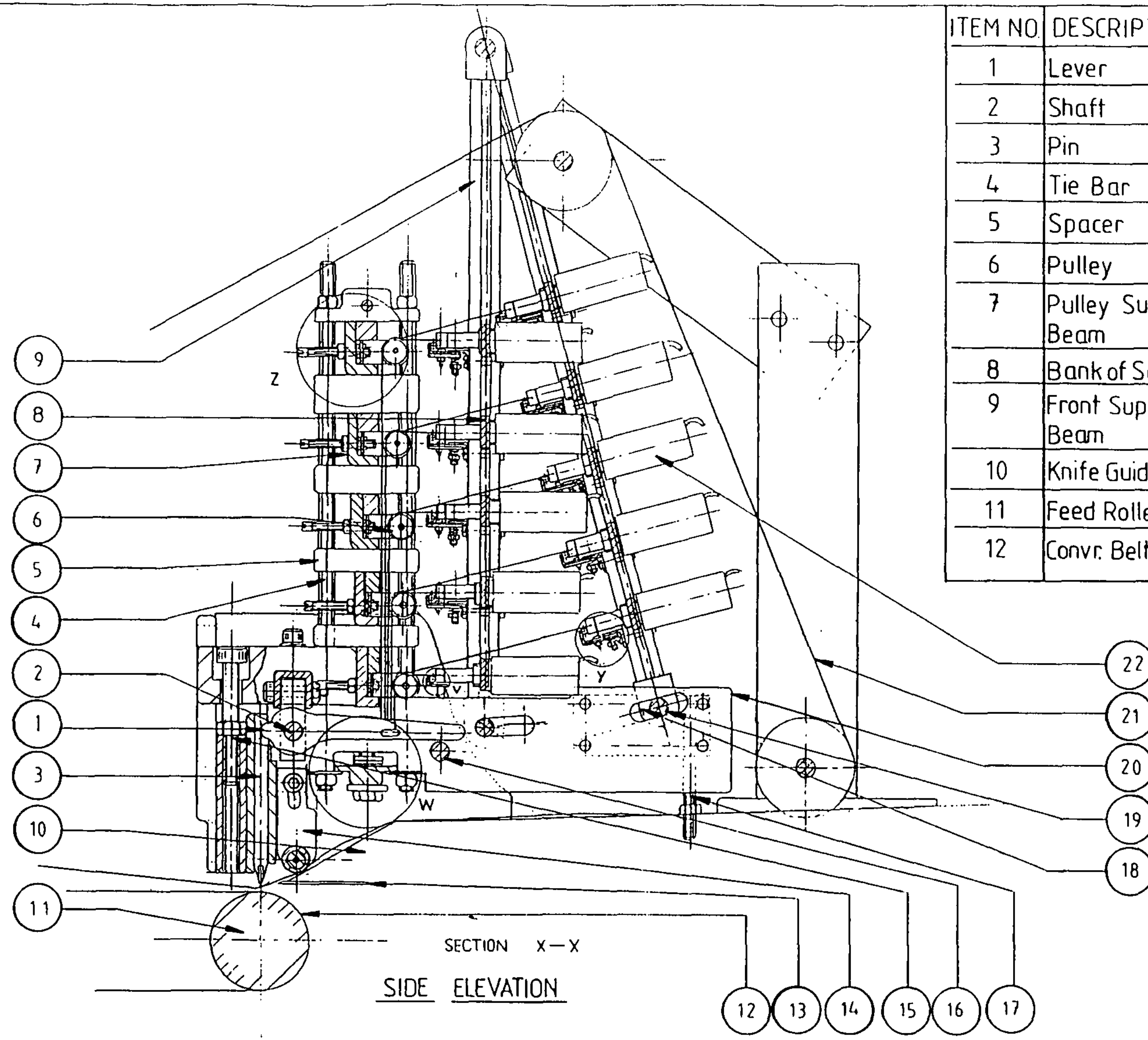
A primary operating system was designed for the new Skiving Machine, see figures 5.0/5.1. The following is a description of the machine's operation.

The leather was fed between the feed roller (i11,fA.1) and the front plate (i10,fA.0). As the leather passed above the knife, the pins situated in the pin holder (i65,fA.0), which was connected to the front plate, pushed the leather onto the knife



ITEM NO	DESCRIPTION
2	Back Stop
6	Pulley Support Beam
10	Front Plate
52	Tie Bar
53	Nut
58	Adjustable Magnet Holder
61	Crossbar Adjust Screw
62	Magnet
63	Front Bracket
64	Back Plate
65	Pin Holding Bar

FIG A·0 Shows front view of GA drawing



ITEM NO.	DESCRIPTION		
1	Lever	13	Knife
2	Shaft	14	Roller Assy
3	Pin	15	Crossbar Adjust Screw
4	Tie Bar	16	Stop Bar
5	Spacer	17	Foot Adjust
6	Pulley	18	Rear Support Beam
7	Pulley Support Beam	19	Tie Bar
8	Bank of Solenoids	20	Crossbar
9	Front Support Beam	21	Convr. Belt Upper
10	Knife Guide	22	Solenoid
11	Feed Roller		
12	Convr. Belt Lower		

FIG A.1 Shows side view from GA drawing

(i13,fA.1) and cut around the surface area of the pin. The levers were connected to the pins via a joint and the pins (i3,fA.1) were pushed down by the levers which pivot on a supporting shaft (i2,fA.1). The shaft was located onto the crossbar (i20,fA.1) which supported banks of solenoids (i8,fA.1). The clevis of the solenoids (i22,fA.1) were connected to wires which were directed around pulleys and connected to the ends of the levers. The pins returned due to the force of the leather, the upper conveyor belt (i21,fA.1) (superstrate), the lower conveyor belt (i12,fA.1) (substrate) and an adjustable bar which housed a number of magnets (i58,fA.0). These magnets attract the levers down to their original stop position and also allow the wires to be pre-tensioned before actuation of the pins. The leather was pushed through, underneath the mechanism by a conveyor belt and a roller (i14,fA.1) positioned behind the pins. The machine was positioned under the upper conveyor belt (superstrate). The conveyor belt allowed the leather to be positioned accurately during the transportation to the skiving area.

A.3 **Mechanisms**

It has been discussed, in previous chapters, the requirements necessary to adjust the machine so it provides optimum performance whilst in operation. The following describes the mechanisms, or secondary systems of operation, used to adjust the skiving machine.

a) Reference to Figure A.2. This was a mechanism to adjust the stroke of the plunger in the solenoid. The solenoids were connected in a series of banks, which meant that each solenoid was secured in a pre-drilled hole which was located in a bar. These bars were supported by beams at either end.

The stroke adjust mechanism comprised an adjustment support bar (i28,fA.2), plunger adjustment bar (i31,fA.2), a spring (i33,fA.2) countersunk screw (i29,fA.2), rubber cushion (i30,fA.2) and block (i34,fA.2).

The adjustment support bar was secured through the support beams and into the solenoid support bar (i27,fA.2) with two screws. The plunger adjustment bar was positioned under the adjustment support bar. The block was placed under both and secured with a screw, spring and nut. The countersunk screw was placed into the slot of the plunger adjustment bar and the block and was secured with a nut. The rubber cushion was placed onto the plunger adjustment bar and infront of the plunger to absorb any vibration.

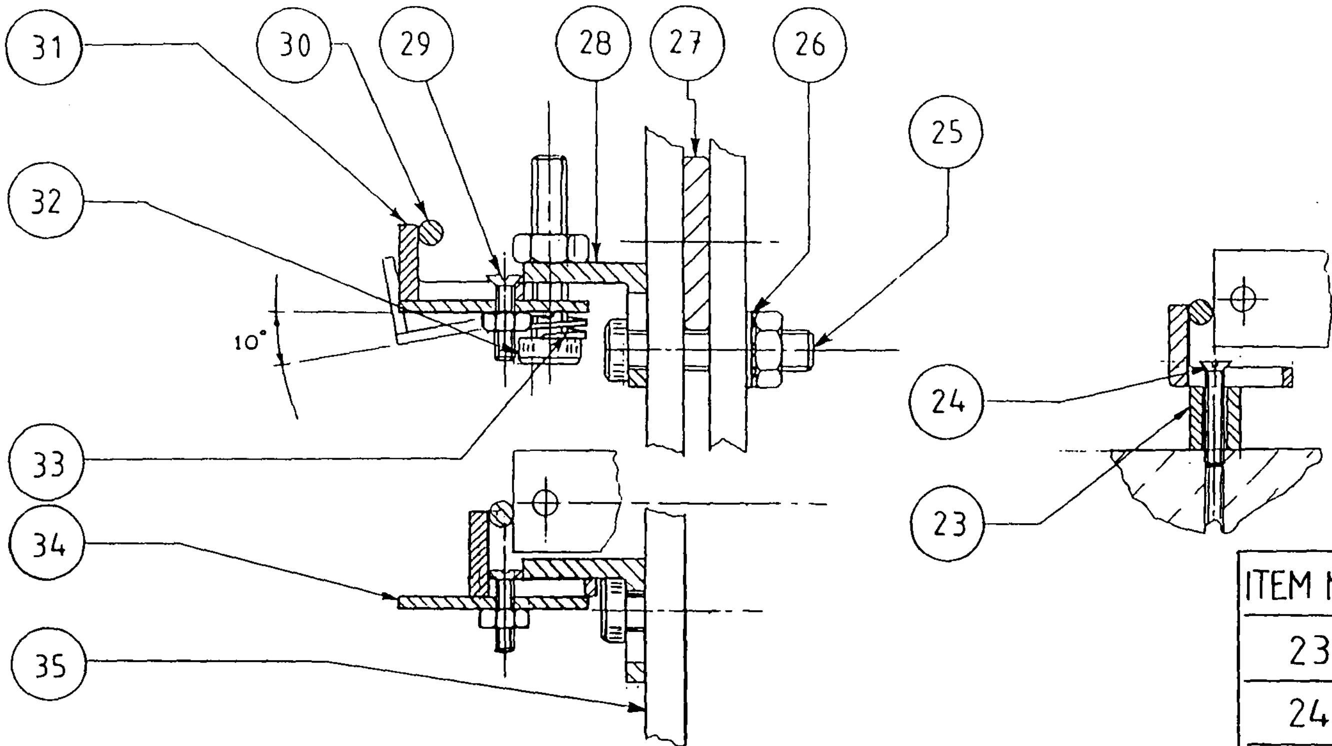
The plunger adjustment bar could slide along its slot and therefore adjust the length of stroke of the plunger. It was secured in position by tightening a nut on the countersunk screw. The spring allowed a 10° angular movement of the plunger adjustment bar to allow for any shock absorption. There was a slot in the adjustment support bar which allowed the mechanism to move up or down.

b) Fig A.3 shows the pulley adjustment mechanism which allowed the pulley to move in and out. It was required because the wire needed to be kept in tension otherwise the required transmitted movement was not achieved at the pins.

For instance if there was 6 mm of stroke movement of the plunger and 1 mm of slack wire then the movement of the pin would be 1 2/3 mm rather than 2 mm.

The mechanism comprised of a pulley adjustment bar (i42,fA.3), adjustment pins (i40,fA.3), two circlips (i41,fA.3), pulley bracket (i45,fA.3), pulley (i38,fA.3), spindle (i37,fA.3), top adjustment bar (i39,fA.3) and shim (i44,fA.3).

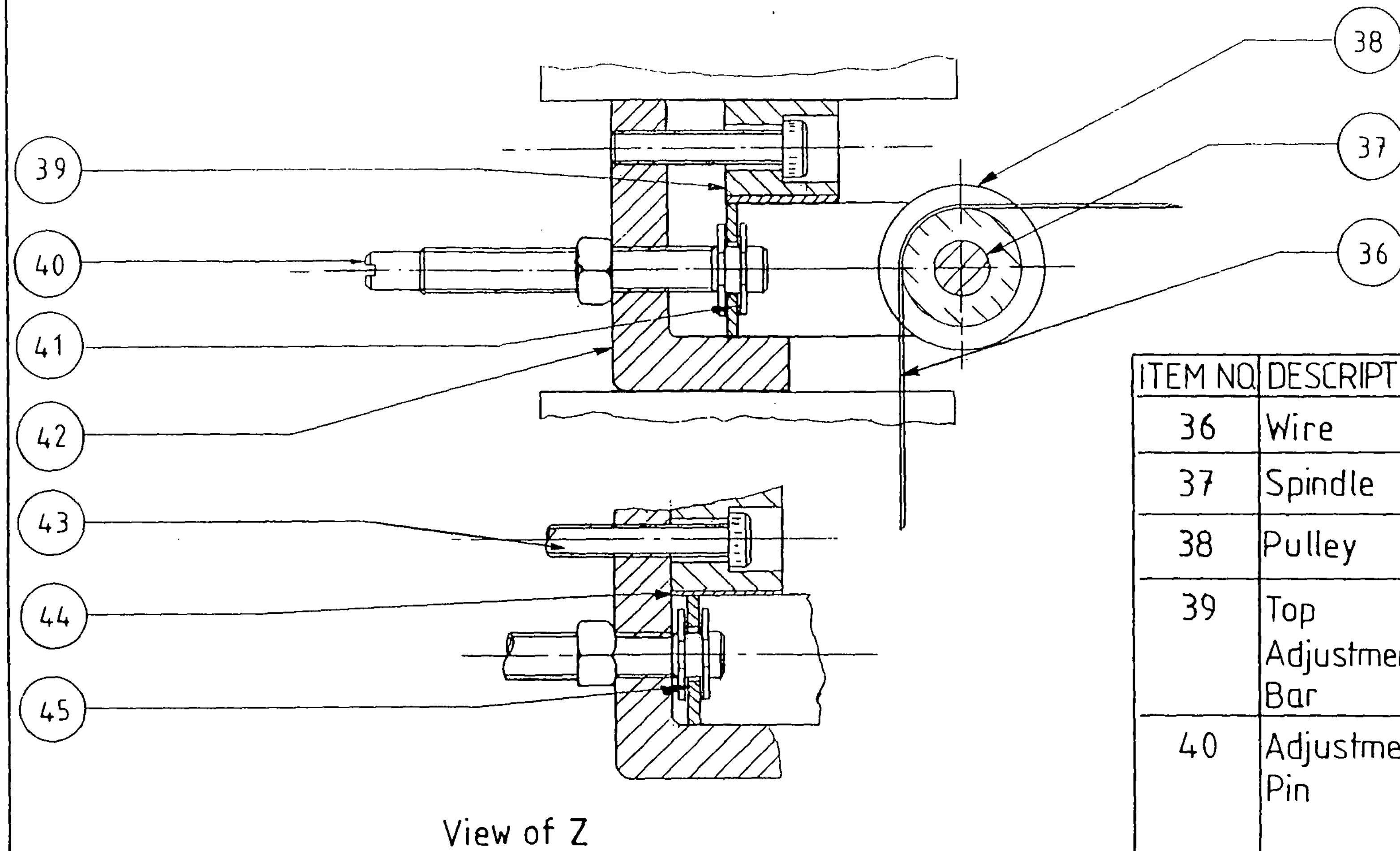
The spindle was cut to a length of 10 mm ensuring that the ends of the spindle was rough with fraze. The spindle was made from 4 mm diameter Silver Steel which allowed for good tolerancing between the spindle and the pulley. This also allowed for free movement of the pulley. The spindle was positioned through the hole of the bracket and the hole of the pulley, with the pulley inside the bracket. The assembly was secured by crimping the ends of the spindle so expanding over the holes of the bracket. Care was taken in not to exert excess force on the crimp otherwise the spindle would bend and cause fouling with the movement of the pulley. The bracket was required to have the adjustment pin connected to it before the pulley was located. The adjustment pin was a steel bar with an M4 thread machined onto the centre



View of Y

ITEM NO	DESCRIPTION
23	Spacer
24	C/Sunk Screw
25	Screw
26	Lock Washer
27	Solenoid Support Bar
28	Adjustment Support Bar
29	C/Sunk Screw
30	Rubber Cushion
31	Plunger Adjustment Bar
32	Screw
33	Spring
34	Block
35	Support Beam

FIG A.2 Shows the Plunger Adjust Mechanism



ITEM NO.	DESCRIPTION
36	Wire
37	Spindle
38	Pulley
39	Top Adjustment Bar
40	Adjustment Pin
41	Circlip
42	Pulley Adjustment Bar
43	Screw
44	Shim
45	Pulley Bracket

FIG A.3 Shows Pulley Adjustment Mechanism.

position and two `U' cuts at one end. There was a slot at the other end to allow for adjustment by a screwdriver. The adjustment pin was pushed through the end hole of the bracket and positioned so that the width of the bracket was between the two `U' cuts of the adjustment pin. Two circlips were then located into the `U' cuts, by using an applicator, and so securing the bracket onto the adjustment pin. The pulley assembly was screwed into the pulley adjustment bar which allowed the pulley to move horizontally. A shim and a top adjustment bar assisted in making the mechanism move rigidly.

The purpose of using circlips was to allow the thread to rotate and the pulley assembly not to rotate, therefore moving in a horizontal plane with the orientation of the pulley constantly in a vertical position. This meant that when the screwdriver turned the adjust pin the pulley moved out without turning.

c) Fig A.4 shows a mechanism to adjust the return of the levers to their stop position and to pre-tension the wires.

It comprised of a magnet holder which had tapped holes drilled into it at a pitch of 20 mm and magnets were screwed into the holes. The magnets were positioned directly under the levers of the machine and were secured by two bolts located under the crossbar. The bolts had two narrow nuts which allowed the bar to be lifted and lowered. When the bolts were turned the magnets were lifted and brought closer to the levers so increasing the magnetic attraction. This force holds the lever in the stop position and enables the wire to be pre-tensioned by adjusting the pulley mechanism.

d) Fig A.5 shows the shaft mounting and support mechanism which had a number of purposes.

It was discussed earlier that the shaft (i68,fA.5) might require additional supports (i76,fA.5) due to the bending forces that may occur if a lot of levers were activated at the same instant.

This was one of the reasons for the shaft mounting mechanism being used. It comprised a shaft support beam (i74,fA.5), shaft supports and nuts/screws (i75,fA.5). The shaft supports were located when the levers were pushed onto the shaft (i68,fA.5). The thickness of shaft support is 1 mm and was located between two levers on the shaft. The support beam was secured with the shaft using the same bolt as shown. The shaft supports were connected to the beam by three screws and nuts which locate through the slots of the beam. The slots allowed the supports movement of 10 mm along the shaft.

The shaft supported 120 levers and between each lever there was a washer. The Supports allowed the adjustment of the washers and assisted in the alignment.

e) Fig A.1 shows the side elevation of the G.A. drawing. The banks of solenoids (i8,fA.1) were connected to support beams (i9,i18,fA.1) by screws. The beams supported five banks of solenoids with twelve solenoids per bank. There are front support beams (i9,fA.1) and rear support beams (i18,fA.1) each with 60 solenoids connected with five banks. As shown in fig 5.1 the front and rear support beams were connected to each other at the top with tie bars (i4,fA.1). The ends of the support beams were connected to the cross bars (i20,fA.1) with tie bars. These were located into slots and meant that both support beams could be adjusted and pivoted with respect to each other. This allowed for additional tensioning of the wires and adjustment of the solenoid positions. The beams were secured at the top and bottom by tightening nuts on the tie bars.

The banks of solenoids were secured to the beams by two screws either side. These screws could be loosened and the banks raised or lowered to suit their positions in relation to the pulley. This allowed the solenoids three directions of movement.

f) Fig A.1 shows the structure of the pulley support beams (i7,fA.1) which held the pulleys (i6,fA.1) in position relative to the solenoids. It was required that the pulleys should also be offset. There were five pulley support beams each holding twenty four

ITEM NO	DESCRIPTION
46	Washers
48	Magnet Holder
50	Bolt

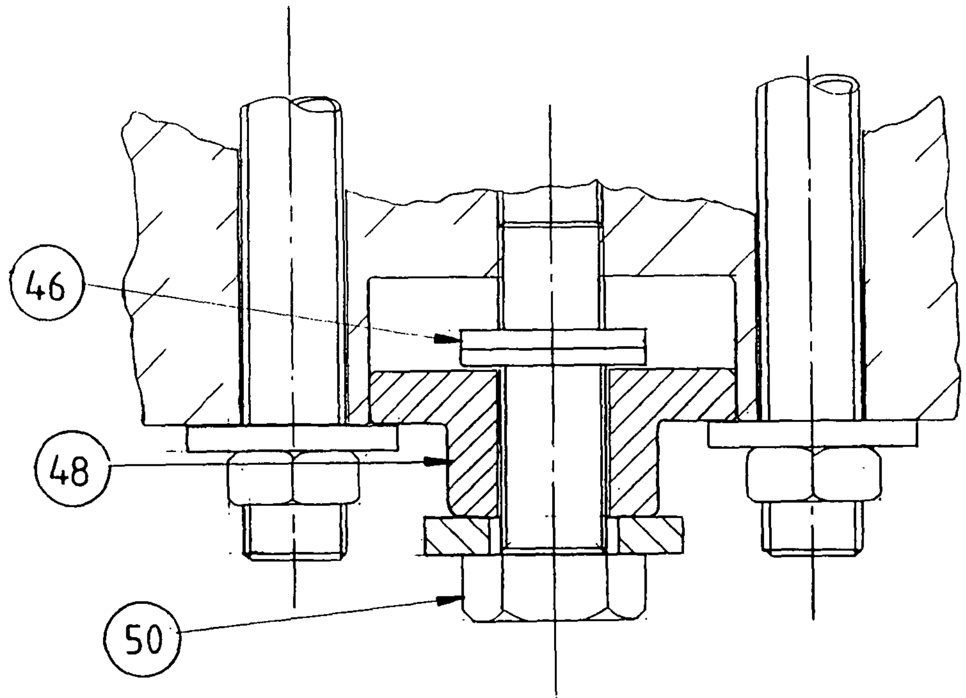


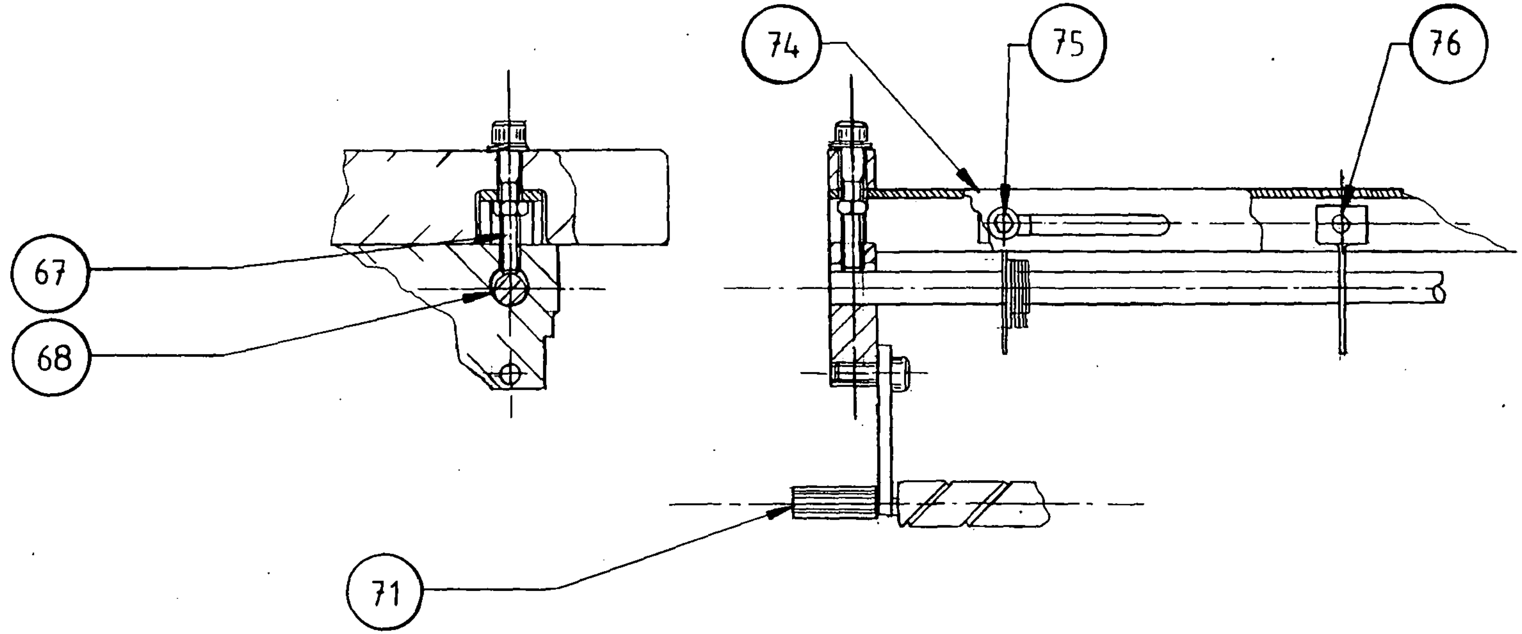
FIG A-4 Shows the mechanism for adjusting rate of return pulley assemblies, due to the lack of space available the pulleys must be offset in the vertical plane so the pulley support beams did not interfere with the wires of the upper pulleys. It was therefore necessary to have an adjustment mechanism that allowed the position of the pulleys be altered and then secured. This was achieved by using the structure shown in fig A.1. The pulley support beams were stacked on top of each other and separated by spacers. These spacers (i5,fA.1) were connected via tie bars (i19,fA.1) to the crossbar (i20,fA.1). To set the pulley support beams in the correct position all that needed to be done was to loosen the tie bar nuts and alter the beam. Then the tie bars tightened to secure the position. It could be necessary to mark or scribe the positions of the pulley support beams onto the spacers to give an adequate reference point and indicate if the beams slip out of position. This mechanism also assisted any adjustment to the wires as it reduced excess length and increased tensioning. It was an advantage to measure the positions on both sides of the beam.

g) Fig A.1 shows that the crossbar is connected to the front plate by a screw and nut.

This allowed the height of the crossbar to be adjusted relative to the height of the front plate. Therefore if the screw was lowered then the shaft was lowered and the pins were consequently lowered. This mechanism therefore set the height of the pins relative to the front plate and pin holder. This would also adjust the roller (i14,fA.1) mechanism connected to the crossbar behind the pins.

h) Fig A.0 also shows the front plate (i10,fA.0) and front brackets (i63,fA.0). The front brackets connected the front plate and the pin holder with two screws and nuts on both sides. The front bracket was profiled to allow for two operations.

1) The bracket had slots which connected onto the back stops (i2,fA.0) of the old splitting machine and this allowed the Skiving Machine to move up and down to the required height above the knife to produce the ideal skive. This also allowed the machine to be lifted if any leather gets trapped.



ITEM NO	DESCRIPTION
67	Shaft Screw
68	Shaft
71	Roller Assy
74	Shaft Support Beam
75	Screw
76	Shaft Supports

FIG A.5 Shows Shaft Mounting and Support Mechanism

2) The front bracket was profiled to allow for a distance of 5 mm to be available in front of the machine before it touched the roller of the conveyor belt. This was useful because it meant that the machine could be moved forward to the ideal skiving position.

To adjust the height, feet were fitted to the rear of the machine to ensure that it remained level at all times.

i) There was a roller (i14,fA.1) positioned behind the pins and secured onto the crossbar (i20,fA.1). This roller applied pressure onto the conveyor and assisted in pushing the leather, at a constant speed, underneath the machine. The roller was pivoted on a housing bracket which was attached to the crossbar. The height could be lowered or raised.

A.4 **Changes to the Design**

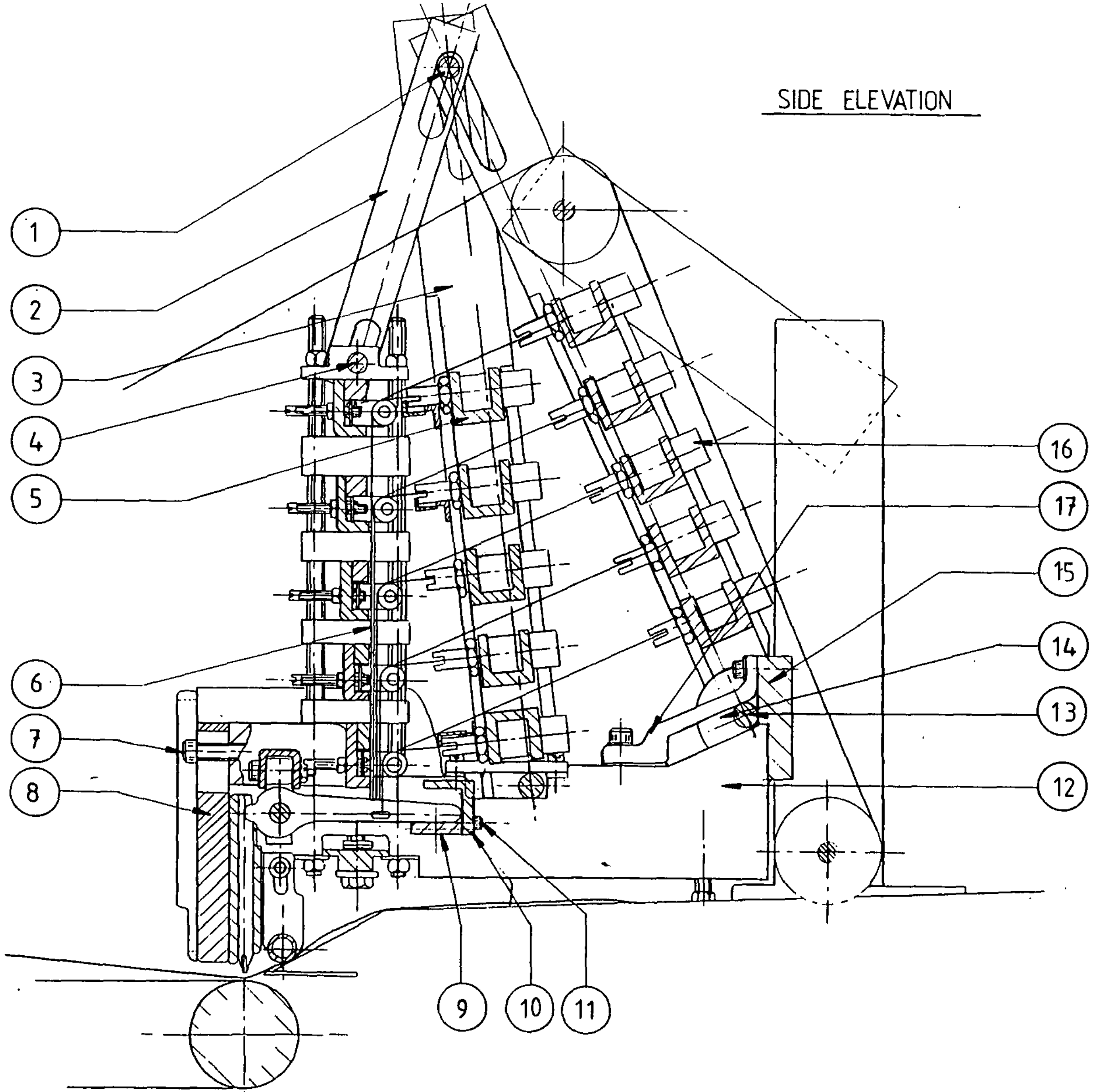
It was necessary to redefine all the factors which influenced the design of the machine at this stage of development.

Fig A.6 shows the side elevation of the changed G.A. drawing. The reasons for changing components was as follows:-

a) It was discovered that the bank of solenoids (i8,fA.1) had limitations in dimension and strength.

As mentioned previously the solenoids had to be positioned accurately or the wires or solenoids might foul each other. Fig A.1 shows the solenoids mounted into the holes of the bar and secured with lock nuts. The bar will be referred to as the solenoid support bar (i27,fA.2) .

The width of the solenoid support bar was a dimension which was important to the positions of the solenoids. If the width was increased it would interfere with the solenoids or wires. The thickness of the solenoid support bar was also a restriction because the plunger stroke adjustment mechanism, when mounted to the support beams (i9,i18,fA.1), would have interfered with the lock nut of the solenoid. It was



ITEM NO	DESCRIPTION
1	Tie Bar
2	Support Bar
3	Front Major Support Beam Assembly
4	Tie Bar
5	Solenoid Support Bar
6	Wire
7	Screw Adjust
8	Front Plate
9	Stop Bar
10	Top Lever Adjust Bar
11	Screw
12	CrossBar
13	Tie Bar
14	Spacer
15	Rear Plate
16	Rear Major Support Beam Assembly
17	Pivot Block

FIGA.6 Shows the later changes to the design

determined that the thickness of the lock nut and the bar should be less than the outer thickness of the support beams.

The investigation suggested that the solenoid support bar would require 16 mm diameter holes drilled into the bar at a pitch of 20 mm. It was calculated that the stress induced by the machining process would bend the support bar and the weight and forces exerted by the solenoids would certainly deflect and permanently deform the bar. It was therefore necessary to secure the solenoids in a support which allowed the required dimensional tolerances and also the required strength and rigidity. This was achieved by using a channel section with concentric holes drilled through both faces, see fig A.7.

The machining of the holes at a pitch of 20 mm needed to be at a high tolerance because the outer diameter of the solenoid was 19 mm diameter. This alteration to the solenoid support bar meant that the support beams also required revision. The support beam shown in fig A.1 shows an assembly built from six separate components. It was decided that this method was not practical for a number of reasons:-

1) The time and cost would be greater to machine or manufacture the individual components.

2) The time taken to assemble would be greater because of its complexities.

3) There was no confidence in its reliability because of its flimsy structure. Each support beam held a work load of sixty solenoids and therefore required more rigidity.

It was decided that it was cheaper to use standard channel sections and modify them to suit the needs of the design.

Fig 5.6 shows how the new solenoid support bars (i5,fA.6) fitted into the new front and rear major support beams (i3,i16,fA.6). The support beams had a slot which served two purposes.

1) It allowed the screws to be located through the beam/bar and allowed vertical adjustment of the solenoid support bar.

2) The slot had a counter slot which allowed the nut of the securing screws to be housed and locked in position. The clearance of the slot allowed the nut to be located

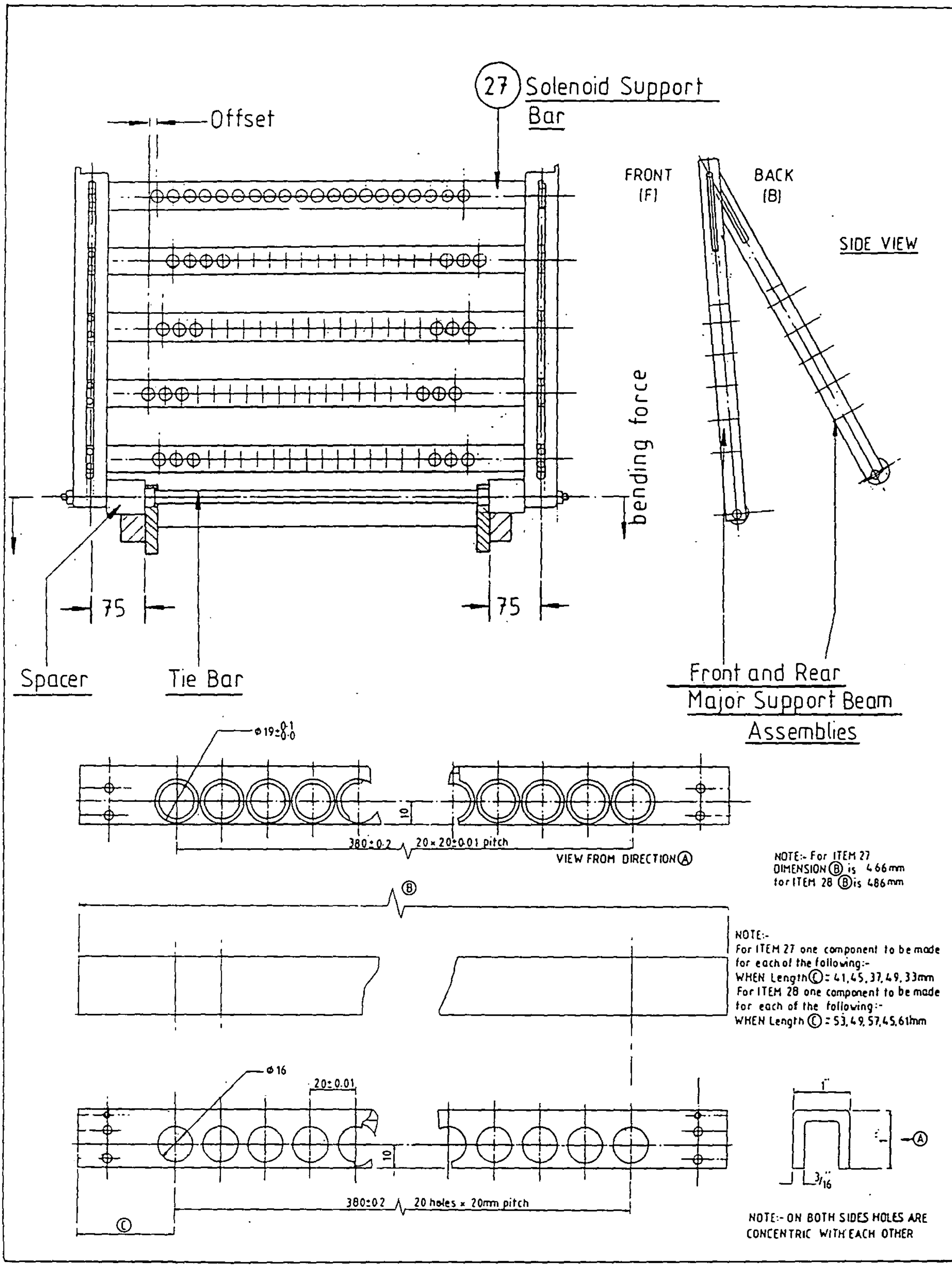


FIG A·7 Shows the bending force in the Tie Bar and the dimensional accuracy for the Solenoid Support Bar across the width of its flats but prevented it from turning because of the corners. Therefore the nut was locked in position.

The front and rear major support beams were connected in slots at the top of the structure by a tie bar (i1,fA.6). The slots allowed additional movement which the previous design would not allow.

Further design was then required to the crossbar (i12,fA.6) connection for the support beams. This was due to the adjustments required at the ends of the beam and the requirement of having wide solenoid support bars to allow for an increase in solenoids for the new splitting machine. The beams were connected to the crossbar slots by tie bars (i13,fA.6). Each solenoid weighed 71 gms [R13] and therefore the total weight of the rear major support beam assembly (i16,fA.6) was approximately 5 kg.

The front and rear major beam assemblies comprise of major support beams, solenoid support bars, spacers, tie bars, solenoids, screws and nuts.

The rear major support beam assembly was approximately 150 mm wider than the crossbar assembly. As the beam assembly was supported by tie bars this would cause an additional problem due to the bending force being applied to the ends of the tie bar. This would therefore bend the tie bar or damage the threads and as a result the mechanism could not be disassembled. A solution to this problem was to design spacers that supported the structure, see fig A.7.

b) It was also decided that all the solenoids must be tilted at an angle to assist the plunger to fall out under its own weight. This meant that the front and rear major support beam assemblies would exert a force due to their own weight. This force could cause the structure to become unstable during operation. It was therefore necessary to add an additional support (i2,fA.6) to connect the top of the beams to the pulley supports. It can be seen from fig A.6 that a support bar connects the tie bars (i1,fA.6) from the solenoid beams to the pulley supports (i4,fA.6).

c) The connection of the crossbar (i12,fA.6) to the front plate (i8,fA.6) required to be altered because the previous design did not give the stability and accuracy needed for the structure during its operation. There was too much movement between front plate and crossbar. To solve this problem and still have the same adjustment available, it was decided to attach the crossbar with a screw located into a vertical slot in the front plate. This meant that the screw could be loosened and moved up or down in the slot to alter the position of the pins and roller. This amount of movement was also decided by the plate position behind the pin holder. This plate also had slots which allowed it to be raised and lowered to the required heights. Once this height had been set then the machine did not have to be altered.

d) In addition to the above changes it was also necessary to redesign the stop bar (i9,fA.6) and to add an additional top lever adjust bar (i10,fA.6). This acted as an extra mechanism which allowed all the levers the same amount of movement. The stop bar was able to pivot by being supported by two screws at either side of the crossbars. This adjustment meant that the start position of the levers could be altered and therefore it could serve a number of purposes:-

1) The stop bar could be tilted so that the magnets attracted a greater force. This improved the pre-tensioning of the wires and the force to return the levers.

2) It sets all the levers to the same start position. This was because the levers rest on the bar.

3) The stop bar could be tilted and therefore set the height of the pins. It must be noted that this was before the levers were wired.

4) The stop bar could compensate for wires extending. This could be achieved by lowering the tilt of the stop bar and therefore reducing the amount of slack wire.

It can be seen from the physical properties of the wire in chapter 4, that the characteristics would vary for each lever. This was because the wires on different banks of solenoids would have different lengths. The position of the pulleys relative to their lever and solenoid connections would have a greater variation in pin movement.

It was assumed that the wires would vary in length as the machine operated. It was therefore necessary to have this mechanism to limit the movement of the levers to the same amount. The top lever adjust bar (i10,fA.6) was connected to the stop bar (i9,fA.6) by two screws (i11,fA.6) at each side.

The screws were located in slots in the adjust bar which meant the amount of lever movement could be adjusted. The adjust bar also served a lot of important purposes:-

1) It could prevent the plunger from not reaching energisation position. This was necessary to reduce the effect of residual magnetism which was present after the solenoids energisation or closure position.

2) It could allow the plunger to energise but also induce sufficient tension in the wire to overcome the residual force left after energisation therefore increasing the rate of return.

3) A higher rate of return could be achieved by adding a spring type substrate material underneath the top lever adjust bar.

4) It could assist to overcome any kinks or deformation in the wire by inducing added force to compensate for this problem.

These adjustments could be used to assist in the performance testing in chapter7.

e) A rear plate (i15,fA.6) was attached to the back of the machine, see fig A.6.

The plate connected the two crossbars (i12,fA.6) with four screws. The screws set the distance between the crossbars and kept the alignment accurate with respect to the height and length. The two lower screws were counter bored and the upper two screws connected the pivot blocks (i17,fA.6) to the plate. The pivot block had been added to increase the angle of the rear major support beams assembly (i16,fA.6) to allow for the plunger of the solenoid to return. The tie bar (i13,fA.6) and spacer (i14,fA.6) were connected on either side of this block inducing a compression force which was used to secure the beams in position. This plate provided the rigidity to the structure.

A.5 **Dimensional Considerations**

To discuss the critical dimensions of the machine it is necessary to consider the moving components of the primary operating system.

a) The thrust pins are located into the thrust pin holding bar (i65,fA.0). The thrust bar is made from polyacetal plastic and has a hundred and forty 1 mm wide slots at a 2 mm pitch. The slots are 8 mm deep and 72 mm long. The thrust pins are located into the slots and allowed a clearance fit so ensuring a free movement. The pins are made from brass which gives a good free moving contact with the plastic. A thrust plate holds the pins in the pin holding bar. The clearance allowed between the slot and the pin must not exceed 0.1 mm as this would affect the quality of the skive, as was shown by Topis [R6] on determining the best skiving position. This showed that a gradual increase to 1mm from the ideal skiving position would reduce the depth of skive to zero.

In the new machine the tip of each pin is soldered onto cut strips of brass sheet and had an outer diameter of 2 mm. The sides of the tips are ground to a width of 1.8 mm. This allows for any angular orientations in the pin structure or any accumulative tolerances in the slots of the pin holder.

b) The lever engages into the semi-circular joint of the pin and is housed in the slot of the pin holding bar. The width of the lever (i1,fA.1) is 1 mm and has to have a clearance fit with the pin and slot width.

Another important dimensional constraint was for the design of the pin holding bar. The width of the bar between the back stops (i2,fA.0) of the old splitting machine and the vertical centres of the pins defined the position for the pins to skive in relation to the knife. From Topis [R6], the average calculated dimension for the ideal skiving position which was taken from the back stops to the outer diameter of the pin of the old skiving machine was shown to be approx. 2.0 $\pm$ 0.1 mm. The diameter of the pins meant that the required distance between back stop and pin centre would be 3.5+-0.1mm. It must be noted that if it was designed to be positioned at 3.5mm then it would be necessary to introduce a tolerance of +-0.5 as an allowance for the

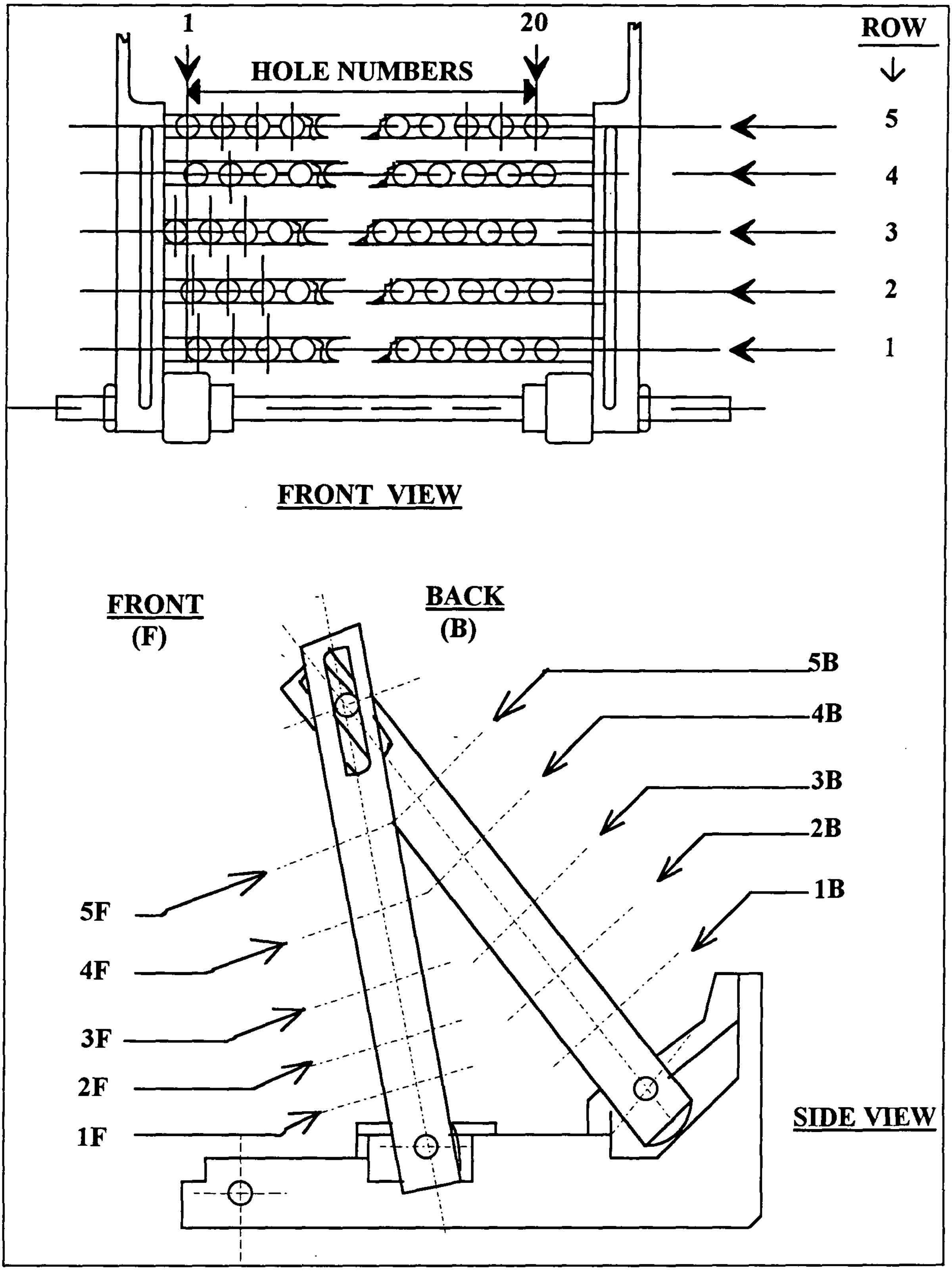


FIG A.8 *Shows the identification of the backs of solenoids.*

dimensional variations. Therefore the width of the holding bar between back stop and the centre of the pin row was 4mm.

It can be seen from the above that it was very important to achieve accuracy in the components produced, and the manufacturing processes were chosen accordingly. The levers were laser cut, ensuring good tolerances between each lever. The crossbars were cut on the same fixture bed and the shaft was manufactured to a high tolerance.

The design of the lever was based on an analysis of the stresses found from the experiment described in Chapter 4. It should be noted that the levers were strengthened around the shaft, and cut to allow for adequate movement between the stop bar and the adjust bar. The nose of the lever allows a maximum pin movement of 2mm and the pivot hole gives a clearance fit with the shaft. The levers are mounted onto the shaft and spaced by washers 0.9 mm thick to allow for the alignment between lever and pin.

c) The wires are connected to the ends of the levers (i1,fA.1) as shown. They were bent through the hole of the lever and pushed through an annealed stainless steel collar which was then crimped twice. The collar has a diameter of 1 mm and therefore during the crimping process was not to be allowed to bend or interfere with neighbouring wires to avoid friction during the operation of the Skiving Machine.

d) The wires are passed around the pulleys on the pulley adjustment bar (i42,fA.3). The adjustment bar ensures that the lever and the wires are in line. The solenoid support bars were restricted to a channel section with a height and width of 25 mm. This was because of the lack of space available and also to prevent the wires from the solenoids interfering with each other. There needed to be twenty holes drilled through both sides of the bar at a pitch of 20 mm. The front holes had a diameter of 16 mm to suit the neck of the solenoid and the rear holes were of diameter 19 mm for the body of the solenoid. Due to the thickness of the section the holes were drilled 10 mm from the bottom, see fig A.7. This meant that the rear holes had a 0.5 mm gap between

						PIN NUMBERS															
ROW NO.	**FRONT or BACK**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**< HOLE NO.**
1	B (33 mm)	E	E	E	X	1	11	21	31	41	51	61	71	81	91	101	111	X	E	E	E	
1	F (43 mm)	E	E	E	X	6	16	26	36	46	56	66	76	86	96	106	116	X	E	E	E	
2	B (41 mm)	E	E	E	X	5	15	25	35	45	55	65	75	85	95	105	115	X	E	E	E	
2	F (51 mm)	E	E	E	X	10	20	30	40	50	60	70	80	90	100	110	120	X	E	E	E	
3	B (37 mm)	E	E	E	X	3	13	23	33	43	53	63	73	83	93	103	113	X	E	E	E	
3	F (47 mm)	E	E	E	X	8	18	28	38	48	58	68	78	88	98	108	118	X	E	E	E	
4	B (49 mm)	E	E	E	X	9	19	29	39	49	59	69	79	89	99	109	119	X	E	E	E	
4	F (39 mm)	E	E	E	X	4	14	24	34	44	54	64	74	84	94	104	114	X	E	E	E	
5	B (45 mm)	E	E	E	X	7	17	27	37	47	57	67	77	87	97	107	117	X	E	E	E	
5	F (35 mm)	E	E	E	X	2	12	22	32	42	52	62	72	82	92	102	112	X	E	E	E	

KEY **E - Empty hole , no solenoid.** **X - Solenoid not used, no pin.**

TABLE A.9 ***Shows which solenoids activate the thrust pins.***

each hole and the bottom of the bar. So it was necessary to have the pitch drilled accurately because any variation or accumulation in tolerances would break the bar. The rear holes required to be concentric with the front holes to allow tilting of the solenoids. Each solenoid support bar had to have the holes offset at a distance of 2 mm so the wire from each solenoid was aligned with a wire from a lever.

Figures A.8 and A.9 give the pin numbers which are operated or activated by the solenoids on each support bar of the front and back support beams.

APPENDIX A4 SHOWS TEST PROGRAM3 USED FOR CREATING SKIVED SHAPES DURING THE ANALYSIS OF RESULTS

M.O.Newton 1993 School of Engineering and Computer Science, University of Durham

Control Software for dynamic pin matrix skiving (32 pins at 2mm resolution)

System : **M 68000**

Programming Language **:M 68000 assembler**

```
        ADDR  CODE                     LISTING

                                   *|PROGRAM TEST3|*

                 |
                 | VIAs 1 to 3 are used as the outputs on the A and B sides
                 | VIA 4  is used as an input for the switches  (implemented later)
                 |
   0007 4683                  oraa2 = 0x74683           |address of I/O reg A2
                                                         |side
   0007 4681                  orab2 = 0x74681
   0007 4663                  oraa1 = 0x74663           | etc
   0007 4661                  orab1 = 0x74661
   0007 4643                  oraa3 = 0x74643
   0007 4641                  orab3 = 0x74641
   0007 4663                  iraa4 = 0x74663

   0007 4667                  ddra1 = 0x74667           |address of DDR reg
                                                         |A1
   0007 4665                  ddrb1 = 0x74665
   0007 4687                  ddra2 = 0x74687
   0007 4685                  ddrb2 = 0x74685
   0007 4647                  ddra3 = 0x74647           |etc
   0007 4645                  ddrb3 = 0x74645

000000 47F9 0000 00B6   loop:  lea    string,a3
000006 43F9 0000 00B8          lea    dat,a1            |sets data address in a1

00000C 13FC 00FF 0007   start: movb   #0xff,ddra2       |sets ports a and b for
                                                         |output
   4687
000014 13FC 00FF 0007          movb   #0xff,ddra1
   4667
00001C 13FC 00FF 0007          movb   #0xff,ddrb1
   4665
000024 13FC 00FF 0007          movb   #0xff,ddrb2
   4685
```

```
00002C 1A3C 00FF                 movb  #0xff,d5          |sets lamp pattern in d5

000030 2A3C 0000 0020    l3:     movl  #32,d5            |d5 is the counter for
                                                         | the 32 bits
000036 263C 0000 0000            movl  #0,d3             |d3 is where the data
                                                         | bit pattern is

00003C 2E3C 0000 0000    l5:     movl  #0,d7
000042 1E19                      movb  a1@+,d7           |gets ascii char from
                                                         |DAT

000044 0C07 0020                 cmpb  #0x20,d7
000048 6700 0006                 beq   l44
00004C 0003 0001                 orb   #1,d3             |ORs  bit
000050 4E71              l44:    nop
000052 0485 0000 0001            subl  #1,d5             |decr count for line of
                                                         |bits

000058 6700 000A                 beq   outl
00005C E38B                      lsll  #1,d3
00005E 4EF9 0000 003C            jmp   l5
000064 4E71              outl:   nop
000066 0C83 AAAA AAAA            cmpl  #0xaaaaaaaa,d3    |check for end of data
00006C 6792                      jeq   loop

00006E 2C3C 0000 5555            movl  #0x005555,d6      | delay between
                                                         |complete patterns

000074 5386              l4:     subql #1,d6
000076 6600 FFFC                 bne   l4

00007A 4683                      notl  d3
00007C 13C3 0007 4661            movb  d3,orab1          |output low byte to
port A1

000082 E09B                      rorl  #8,d3
000084 13C3 0007 4663            movb  d3,oraa1          |output byte 2 to B1

00008A E09B                      rorl  #8,d3
00008C 13C3 0007 4681            movb  d3,orab2          |output byte 3 to A2
000092 E09B                      rorl  #8,d3
000094 13C3 0007 4683            movb  d3,oraa2          |output byte 4 to B2


00009A E09B                      rorl  #8,d3

00009C 23C3 0000 00B2            movl  d3,mmm
0000A2 47F9 0000 00B6            lea   string,a3
0000A8 4EF9 0000 0030            jmp   l3
0000AE 4E4F              out:    trap  #15

0000B0 000E                      .word 14
                                 .even
```

```
0000B2 0000 0000        mmm:   .long  0
0000B6 7C 00                   string: .asciz  "|"
                                .even
         |ruler       "12345678901234567890123456789012"
0000B8 6F 20 20 20 20  dat:   .ascii   "o                               "
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20
0000D8 6F 6F 20 20 20         .ascii   "oo                              "
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20
0000F8 6F 6F 6F 20 20         .ascii   "ooo                             "
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20
000118 6F 6F 6F 6F 20         .ascii   "oooo                            "
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20
000138 6F 6F 6F 6F 6F         .ascii   "ooooo                           "
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20
000158 6F 6F 6F 6F 6F         .ascii   "oooooo                          "
     6F 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20 20 20 20
     20 20
000178 6F 6F 6F 6F 6F         .ascii   "ooooooo                         "
     6F 6F 20 20 20
     20 20 20 20 20
```

```
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20
000198 6F 6F 6F 6F 6F       .ascii   "oooooooo                  "
    6F 6F 6F 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20
0001B8 6F 6F 6F 6F 6F       .ascii   "ooooooooo                 "
    6F 6F 6F 6F 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20
0001D8 6F 6F 6F 6F 6F       .ascii   "oooooooooo                "
    6F 6F 6F 6F 6F
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20
0001F8 6F 6F 6F 6F 6F       .ascii   "ooooooooooo               "
    6F 6F 6F 6F 6F
    6F 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20
000218 6F 6F 6F 6F 6F       .ascii   "oooooooooooo              "
    6F 6F 6F 6F 6F
    6F 6F 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20
000238 6F 6F 6F 6F 6F       .ascii   "ooooooooooooo             "
    6F 6F 6F 6F 6F
    6F 6F 6F 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20
000258 6F 6F 6F 6F 6F       .ascii   "oooooooooooooo            "
    6F 6F 6F 6F 6F
    6F 6F 6F 6F 20
```

```
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20
000278 6F 6F 6F 6F 6F     .ascii   "ooooooooooooooo                "
       6F 6F 6F 6F 6F
       6F 6F 6F 6F 6F
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20
000298 6F 6F 6F 6F 6F     .ascii   "oooooooooooooooo              o"
       6F 6F 6F 6F 6F
       6F 6F 6F 6F 6F
       6F 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 6F
0002B8 6F 6F 6F 6F 6F     .ascii   "ooooooooooooooo               oo"
       6F 6F 6F 6F 6F
       6F 6F 6F 6F 6F
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       6F 6F
0002D8 6F 6F 6F 6F 6F     .ascii   "oooooooooooooo              ooo"
       6F 6F 6F 6F 6F
       6F 6F 6F 6F 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 6F
       6F 6F
0002F8 6F 6F 6F 6F 6F     .ascii   "ooooooooooooo             oooo"
       6F 6F 6F 6F 6F
       6F 6F 6F 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 6F 6F
       6F 6F
000318 6F 6F 6F 6F 6F     .ascii   "oooooooooooo            ooooo"
       6F 6F 6F 6F 6F
       6F 6F 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 6F 6F 6F
       6F 6F
000338 6F 6F 6F 6F 6F     .ascii   "ooooooooooo           oooooo"
       6F 6F 6F 6F 6F
       6F 20 20 20 20
```

```
      20 20 20 20 20
      20 20 20 20 20
      20 6F 6F 6F 6F
      6F 6F
000358 6F 6F 6F 6F 6F      .ascii   "oooooooooo               ooooooo"
      6F 6F 6F 6F 6F
      20 20 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      6F 6F 6F 6F 6F
      6F 6F
000378 6F 6F 6F 6F 6F      .ascii   "ooooooooo               oooooooo"
      6F 6F 6F 6F 20
      20 20 20 20 20
      20 20 20 20 20
      20 20 20 20 6F
      6F 6F 6F 6F 6F
      6F 6F
000398 6F 6F 6F 6F 6F      .ascii   "oooooooo               ooooooooo"
      6F 6F 6F 20 20
      20 20 20 20 20
      20 20 20 20 20
      20 20 20 6F 6F
      6F 6F 6F 6F 6F
      6F 6F
0003B8 6F 6F 6F 6F 6F      .ascii   "ooooooo               oooooooooo"
      6F 6F 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      20 20 6F 6F 6F
      6F 6F 6F 6F 6F
      6F 6F
0003D8 6F 6F 6F 6F 6F      .ascii   "oooooo               ooooooooooo"
      6F 20 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      20 6F 6F 6F 6F
      6F 6F 6F 6F 6F
      6F 6F
0003F8 6F 6F 6F 6F 6F      .ascii   "ooooo               oooooooooooo"
      20 20 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      6F 6F 6F 6F 6F
      6F 6F 6F 6F 6F
      6F 6F
000418 6F 6F 6F 6F 20      .ascii   "oooo               ooooooooooooo"
      20 20 20 20 20
      20 20 20 20 20
```

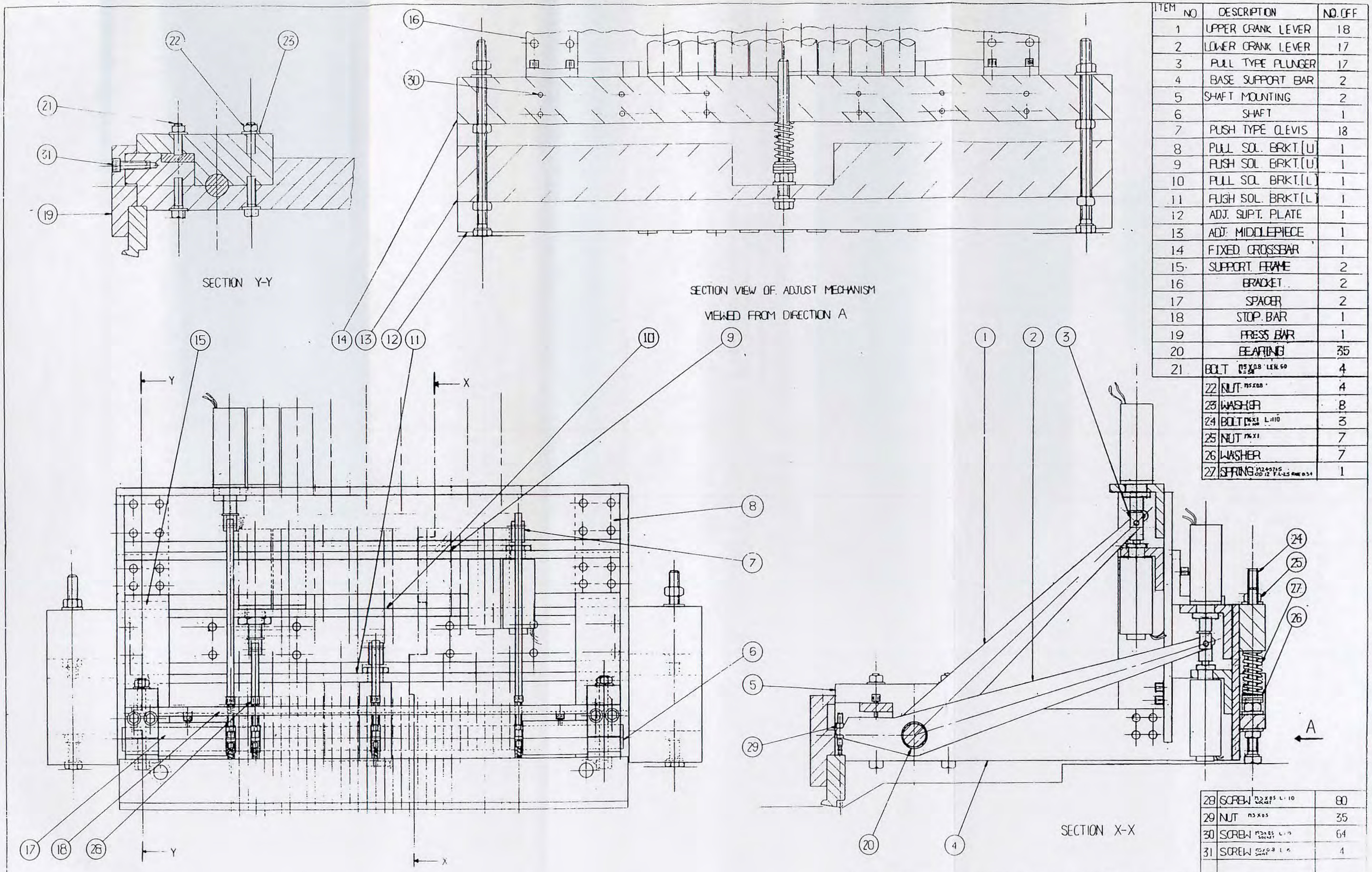
```
        20 20 20 20 6F
        6F 6F 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F
000438 6F 6F 6F 20 20      .ascii   "ooo               oooooooooooooo"
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 6F 6F
        6F 6F 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F
000458 6F 6F 20 20 20      .ascii   "oo               ooooooooooooooo"
        20 20 20 20 20
        20 20 20 20 20
        20 20 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F
000478 6F 20 20 20 20      .ascii   "o               oooooooooooooooo"
        20 20 20 20 20
        20 20 20 20 20
        20 6F 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F
000498 20 20 20 20 20      .ascii   "                 ooooooooooooooo"
        20 20 20 20 20
        20 20 20 20 20
        20 20 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F
0004B8 20 20 20 20 20      .ascii   "                  oooooooooooooo"
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 6F 6F
        6F 6F 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F
0004D8 20 20 20 20 20      .ascii   "                   ooooooooooooo"
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 20 6F
        6F 6F 6F 6F 6F
        6F 6F 6F 6F 6F
        6F 6F
0004F8 20 20 20 20 20      .ascii   "                     ooooooooooo"
        20 20 20 20 20
        20 20 20 20 20
```

```
    20 20 20 20 20
    6F 6F 6F 6F 6F
    6F 6F 6F 6F 6F
    6F 6F
000518 20 20 20 20 20      .ascii   "            oooooooooooo"
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 6F 6F 6F 6F
    6F 6F 6F 6F 6F
    6F 6F
000538 20 20 20 20 20      .ascii   "             ooooooooooo"
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 6F 6F 6F
    6F 6F 6F 6F 6F
    6F 6F
000558 20 20 20 20 20      .ascii   "              oooooooooo"
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 6F 6F
    6F 6F 6F 6F 6F
    6F 6F
000578 20 20 20 20 20      .ascii   "               ooooooooo"
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 6F
    6F 6F 6F 6F 6F
    6F 6F
000598 20 20 20 20 20      .ascii   "                oooooooo"
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    6F 6F 6F 6F 6F
    6F 6F
0005B8 20 20 20 20 20      .ascii   "                 ooooooo"
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 20 20 20 20
    20 6F 6F 6F 6F
    6F 6F
0005D8 20 20 20 20 20      .ascii   "                  oooooo"
    20 20 20 20 20
    20 20 20 20 20
```

```
       20 20 20 20 20
       20 20 20 20 20
       20 20 6F 6F 6F
       6F 6F
0005F8 20 20 20 20 20     .ascii  "                          oooo"
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 6F 6F
       6F 6F
000618 20 20 20 20 20     .ascii  "                           ooo"
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 6F
       6F 6F
000638 20 20 20 20 20     .ascii  "                            oo"
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       6F 6F
000658 20 20 20 20 20     .ascii  "                             o"
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 20 20 20 20
       20 6F
000678 2A 20 2A 20 2A     .ascii  "* * * * * * * * * * * * * * * * " |end pattern
       20 2A 20 2A 20
       2A 20 2A 20 2A
       20 2A 20 2A 20
       2A 20 2A 20 2A
       20 2A 20 2A 20
       2A 20
DURHAM SEAS M68000 ASSEMBLER
```

APPENDIX A5 SHOWS THE GENERAL ARRANGEMENT DRAWING FOR THE OLD SKIVING MACHINE

[REDUCED FROM A1 TO A3 SIZE]



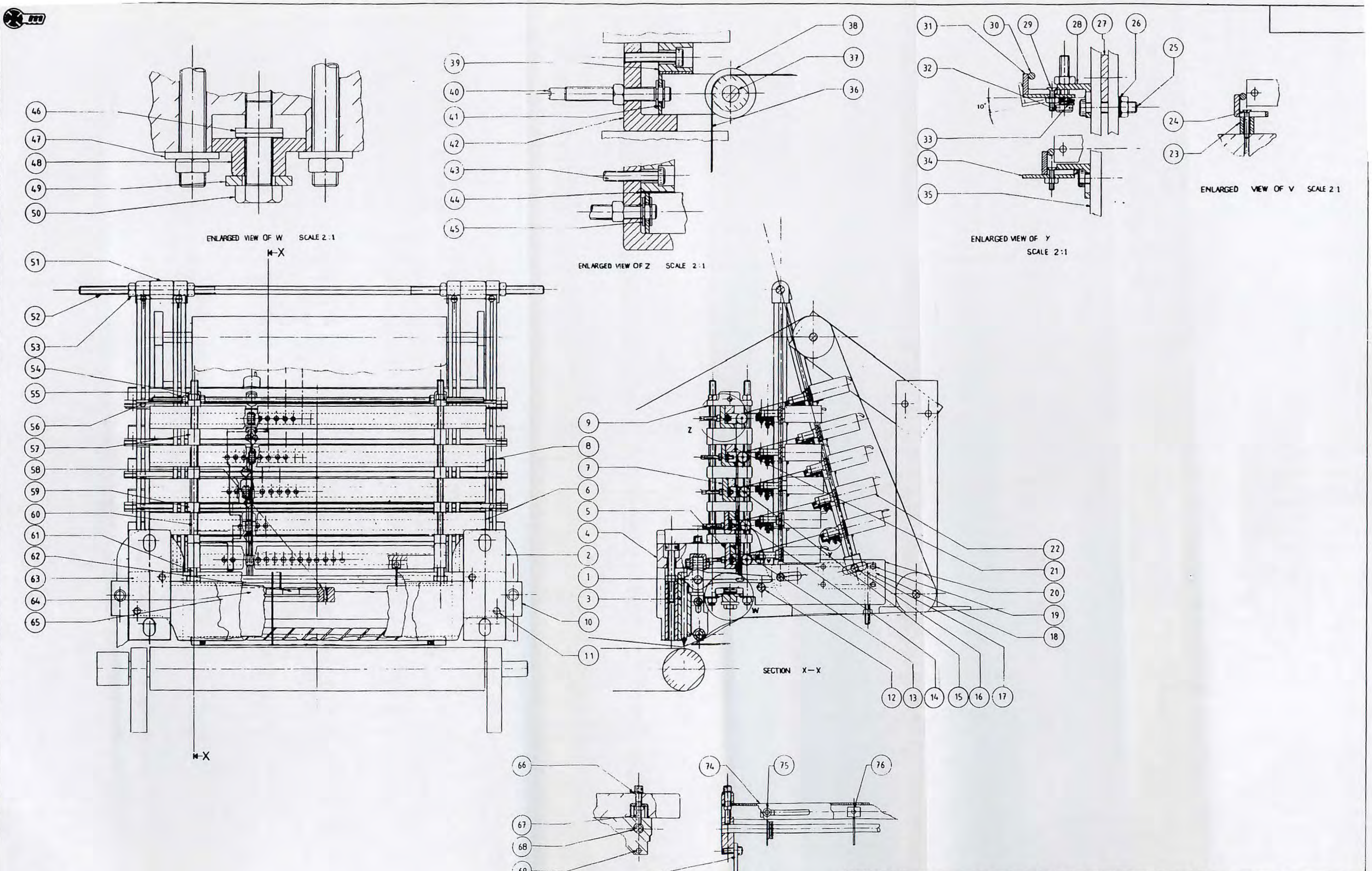
ITEM NO	DESCRIPTION	NO. OFF
1	UPPER CRANK LEVER	18
2	LOWER CRANK LEVER	17
3	PULL TYPE PLUNGER	17
4	BASE SUPPORT BAR	2
5	SHAFT MOUNTING	2
6	SHAFT	1
7	PUSH TYPE CLEVIS	18
8	PULL SOL. BRKT.(U)	1
9	PUSH SOL. BRKT.(U)	1
10	PULL SOL. BRKT.(L)	1
11	PUSH SOL. BRKT.(L)	1
12	ADJ. SUPT. PLATE	1
13	ADJ. MIDDLEPIECE	1
14	FIXED CROSSBAR	1
15	SUPPORT FRAME	2
16	BRACKET	2
17	SPACER	2
18	STOP BAR	1
19	PRESS BAR	1
20	BEARING	35
21	BOLT M5X0.8 LEN 60	4
22	NUT M5X0.8	4
23	WASHER	8
24	BOLT M6X1 L=110	3
25	NUT M6X1	7
26	WASHER	7
27	SPRING	1
28	SCREW M3X0.5 SOCKET L=10	80
29	NUT M3X0.5	35
30	SCREW M3X0.5 SOCKET L=15	64
31	SCREW M5X0.8 SOCKET	4

DRG NO	DATE	PROJ	SCALE	TITLE	DRAWN BY
—	291189	3RD ∠	1:1	SOLENOID MOUNTING ASSY	M.O.NEWTON

APPENDIX A6 SHOWS THE GENERAL ARRANGEMENT DRAWING

FOR THE NEW SKIVING MACHINE

[REDUCED FROM A1 TO A3 SIZE]



THE FOLLOWING APPLY UNLESS OTHERWISE STATED			Part No. M/c Title SOLENOID MOUNTING ASSEMBLY	Material
TOLERANCES	Machine Finish	Projection 3rd ANGLE		
Metric Whole mm	Paint Finish	Scale 1:2		
1 dec. place .	Chem. Finish	Dimensions m.m	Description	
Imp. Fraction	Plating Finish	Imp. equivalents are ringed	Quan. per M/c	Make
Decimal	Heat Treat.	Dr. M.O.NEWTON	The British United Shoe Machinery Company Limited LEICESTER	This drawing is the property of this company. It is confidential and must not be lent or copied except by written consent.
Angles		Tr.		
Similar Parts:		Ch.		