THE DEVELOPMENT OF A HIGH - SPEED PATTERNING SYSTEM FOR A NARROW - FABRIC WEAVING MACHINE

by

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CHAPTER 1: INTRODUCTION

1.1 PROJECT INITIATION

The project described in this thesis was initiated by Professor G R Wray and Doctor R Vitols, both of whom are members of the Academic staff of the Department of Mechanical Engineering at Loughborough University of Technology. Between them they have many years of experience of engineering for the Textile Industry. Working with other members of the University staff they have undertaken several projects involving innovative machines and processes,[1] some of which have been made available to the U K textile industry, either by means of patent licencing via the National Research Development Corporation, or by direct University/company contractual agreements.

1.2 PREVIOUS EXPERIENCE OF TEXTILE PATTERNING

One of the projects undertaken by the Textile Group of the Department of Mechanical Engineering led to the development of a textile manufacturing technique and the design of an associated production machine. This has been commercially exploited by a subsidiary of the Pickering Group, Blackburn Limited, Lancashire and has been named the "Locstitch" machine. This machine produces a pile fabric by a sewing process on a base material. The loops of the Locstitch fabric are locked together to prevent unravelling. The original machine produced a plain, i.e. unpatterned fabric at speeds of the order of 2 metres/minute. The second phase of the development work was aimed at sculpture patterning and resulted in a system of introducing a variation of the height of the pile loops, independently of the others across the width of the machine, whilst the machine was running at the same high production speeds as for the plain fabric.

This sculptured pattern thus comprised high and low pile loops. Due to the high speed at which this machine operated the pattern control system was based on modern electronic principles rather than on the traditional mechanical techniques more commonly associated with textile machinery. The inventors found that the speed capabilities of the system were far in excess of any comparable mechanical system and were also greater than those required for the manufacturing technique in question.[2]

This fact,coupled with the realisation that a great number of fabric manufacturing processes are retarded by their use of traditional patterning systems, led to a consideration of the feasibility of developing a modern patterning system which would not reduce the rate of production when compared with plain fabric manufacture.

1.3 PROCESS IDENTIFICATION

The basic concept for the proposed project was initially to 'up-rate' an existing textile process, preferably some high-speed process which is known to suffer a large reduction of performance when incorporating a traditional patterning system.

It was anticipated that the technique developed could later be adapted for use with processes other than that originally chosen, both within textile manufacture and elsewhere. Therefore, to embrace the widest possible number of 'other' processes, a very high speed production process was selected namely the weaving of narrow fabrics by means of needle weft insertion. It was well suited for a variety of reasons:

a) at the time of the conception of the project the maximum speed of plain, narrow, woven fabric production was in the region of 3000 machine cycles per minute (picks per minute) and, as such, was probably one of the fastest known fabric producing machines;

b) the reduction in the operating speed these machines when a traditional patterning system is incorporated is drastic; the speed of patterned fabric production being between one fifth and one tenth that of the plain fabric production speed;

c) the system developed would be of real benefit to British Industry. There is presently only one U.K. manufacturer of narrow fabric needle looms, the Bonas Machine Company Limited, and informal discussions with them indicated a genuine interest in the results of any work in this area;

d) the U.K. narrow fabric industry is well represented in the East Midlands, especially around Derby and thus contact with this industry from a base in Loughborough would be convenient and;

e) compared with many other fabric producing machines a narrow fabric needle loom is well suited to experimental work in that it is relatively inexpensive to buy, compact, economical in raw materials consumption, and is of relatively straightforward uncomplicated construction; moreover whilst it has a large number of elements requiring independent control for patterning, there are not as many as are usually found in other textile machines, e.g. warp knitting machines and broadlooms, and therefore the envisaged development time and costs to a prototype stage should be lower.

1.4 PROJECT FUNDING

Professor Wray and Doctor Vitols made an application for support funding to the Science Research Council based on the above-mentioned factors and were awarded a grant to undertake a three year study of this problem. A proportion of the grant provided for the engagement of a full-time Research Assistant, namely the author of this thesis, and also a full-time support technician.

The study was commenced in February 1977 and the work was carried out within the Department of Mechanical Engineering at Loughborough University of Technology under the supervision of Professor Wray and Doctor Vitols.

CHAPTER 2: THE INCORPORATION OF PATTERNS IN WOVEN FABRICS

2.1 WEAVING

The basic principles of weaving yarns together to produce a fabric have been known for over 25 centuries and they still form the basis of the manufacture of a large proportion of the cloth produced today. These principles are briefly described in Appendix 1.

The simplest form of weave, the plain weave, can be produced on a very simple loom. All that is required is a means of separating the warp yarns such that alternate yarns counted across the fabric are raised and lowered to allow the weft yarn to be inserted by some method. The warp yarns must then exchange positions before a reed presses the weft yarn tightly into the fabric. The next weft yarn can then be inserted. The only other requirements are a means of supplying the warp yarns at the rate they are required and a means of taking up the fabric as it is made.

The plain weave requires the warp yarns to be controlled as two separate groups; if provision is made on the loom to control more than these two groups, then the construction of the weave produced can be more complex, e.g. with 3 groups a twill can be produced. The degree of complexity of construction increases rapidly as the number of groups of warp yarns is increased.

2.2 PATTERNS IN WOVEN FABRICS

It is not easy to define at what point a fabric of fairly complex structure becomes a patterned fabric. However, it is usually evident that in patterned fabric the arrangement of yarns is only repeated, both warp and weft-wise, at a pitch of very many yarns; this is known as a "pattern-repeat" and, in order to construct a fabric which is patterned, it is therefore necessary to have a much larger number of independently moved warp yarns. It is more normal to consider each warp yarn being controlled separately by some mechanism and only when the pattern is repeated are corresponding yarns from each pattern controlled by a common output of the mechanism.

A pattern in a woven fabric can take two basic forms, namely a pattern due to texture variations or a pattern due to colour variations. These may, of course, be combined into a single fabric.

A textured pattern is achieved by interlacing the yarns to produce surface effects at specific areas on the fabric. These areas can be considered as localized changes of fabric structure but, when viewed overall, a patterned appearance can be observed. An example of this type of patterning is Brocade.

A coloured pattern is achieved by using yarns of the required colours and where a particular colour is required for the pattern the appropriate yarn is brought to the upper (face) surface of the fabric where it will be visible. Where the colour is not required the yarn is held either within or beneath the body of the fabric. With this form of patterning it is normal that intermediate warp and weft yarns are used to form a stable ground fabric which acts as a background for the design and as a support structure for the "figuring yarns".

A colour patterned woven fabric will belong to one of two groups, warp-figured or weft-figured. This implies that the figuring yarns i.e. the coloured yarns run in either the warp or the weft direction. Both forms are used, but one important difference is that for warp-figuring only the warp yarns must be controlled, the same

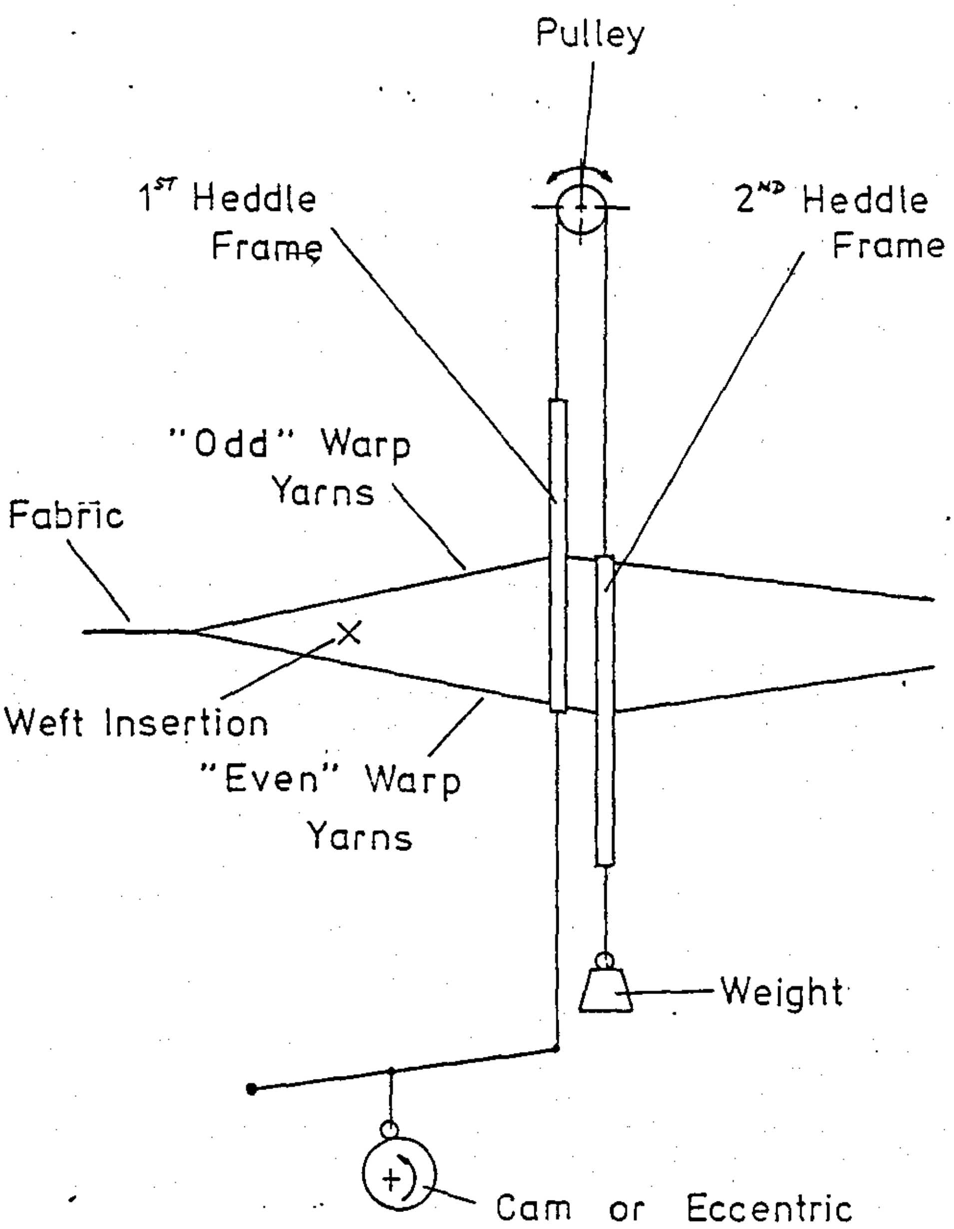


Fig. 2.1. Cam Shedding for 1×1 Weave

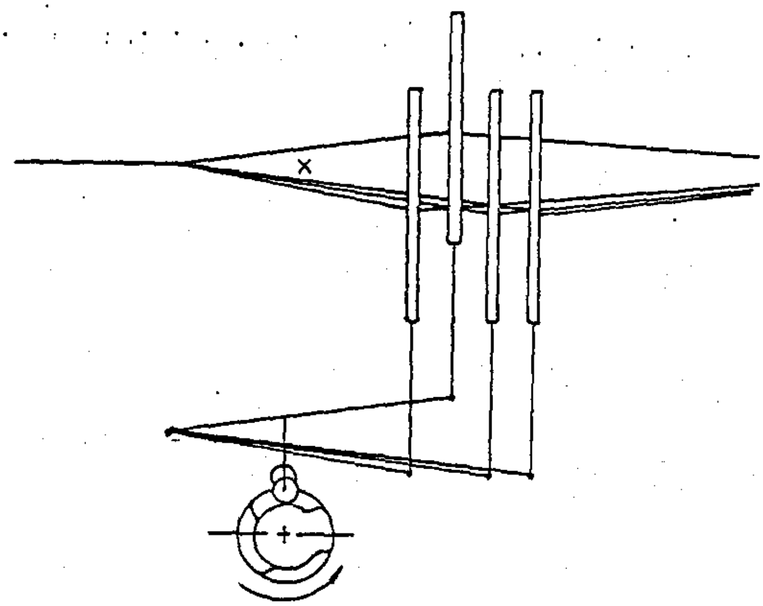


Fig 2.2a. Cam Shedding on 4 Shafts

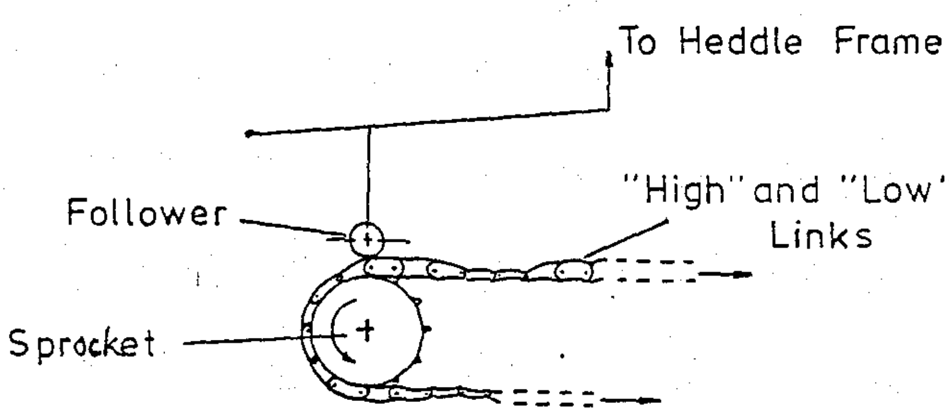


Fig 2.2b. Cam Shedding with Extended Chain

weft yarn being inserted for every pick. Weft-figuring, on the other hand, supplies the colours by selecting one of several differently coloured weft yarns, but a precise selective control of the warp yarns is also demanded (just as in the case of warp-figuring methods) in order to present the weft to the surface of the fabric wherever it is needed.

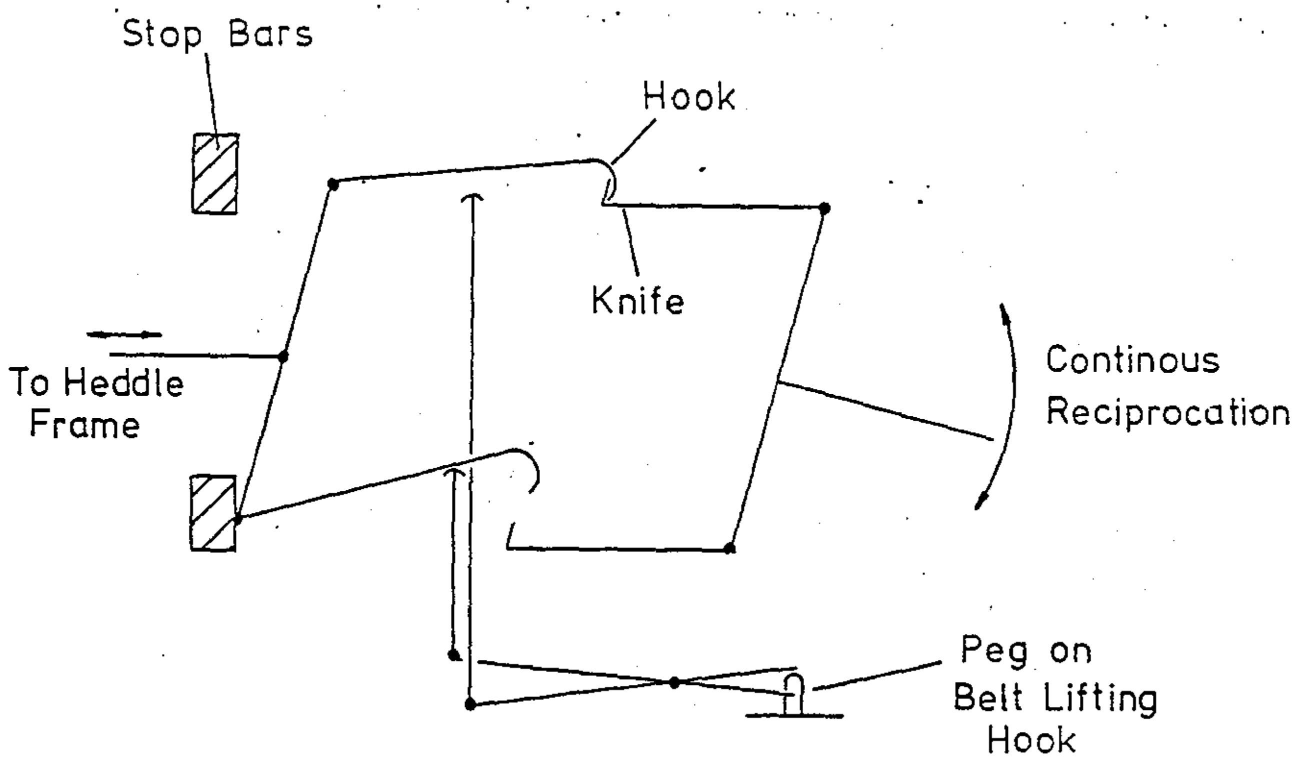
2.3 WARP SHEDDING MECHANISM[4,5]

The action of separating the warp threads, so that the weft can be inserted, is known as shedding and the gap formed is termed the shed.[6]

2.3.1 Cam (or Tappet) Mechanisms

The simple plain weave requirement of raising and lowering alternate threads and interchanging them after each pick insertion is easily achieved, for example by the mechanism shown in figure 2.1. Alternate warp yarns are passed through headles mounted on a common frame which is caused to reciprocate vertically. This frame is connected to a second frame, to which the other warp threads are attached, by a flexible link passing over a pulley; thus as one frame is raised the other is lowered.

When it is required to control 3 or more frames it is possible to use a cam (tappet) operation as in fig 2.2.a. In practical terms the space available limits the number of frames thus controlled to about 12. Looms fitted with such a system are often referred to as tappet looms. The number of picks inserted before the pattern sequence is repeated is limited to approximately 10 with normal cams, but this can be extended almost indefinitely by using chains with cam links as in fig 2.2.b.



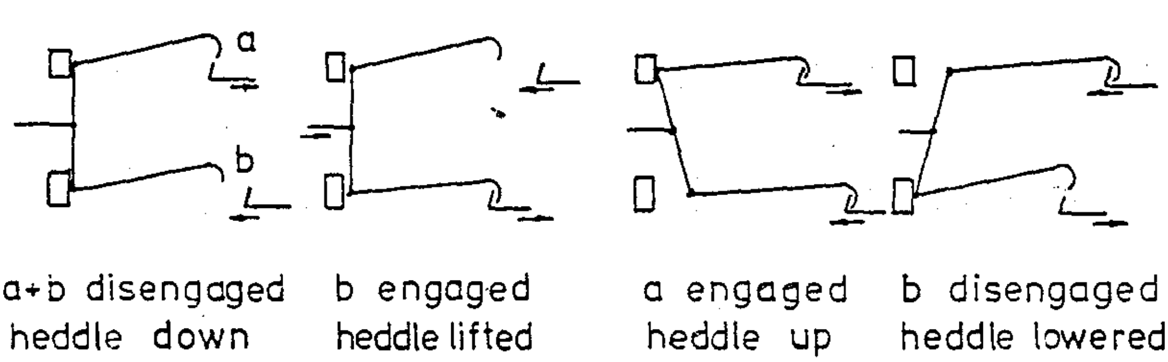


Fig 2.3. The Keighley Dobby

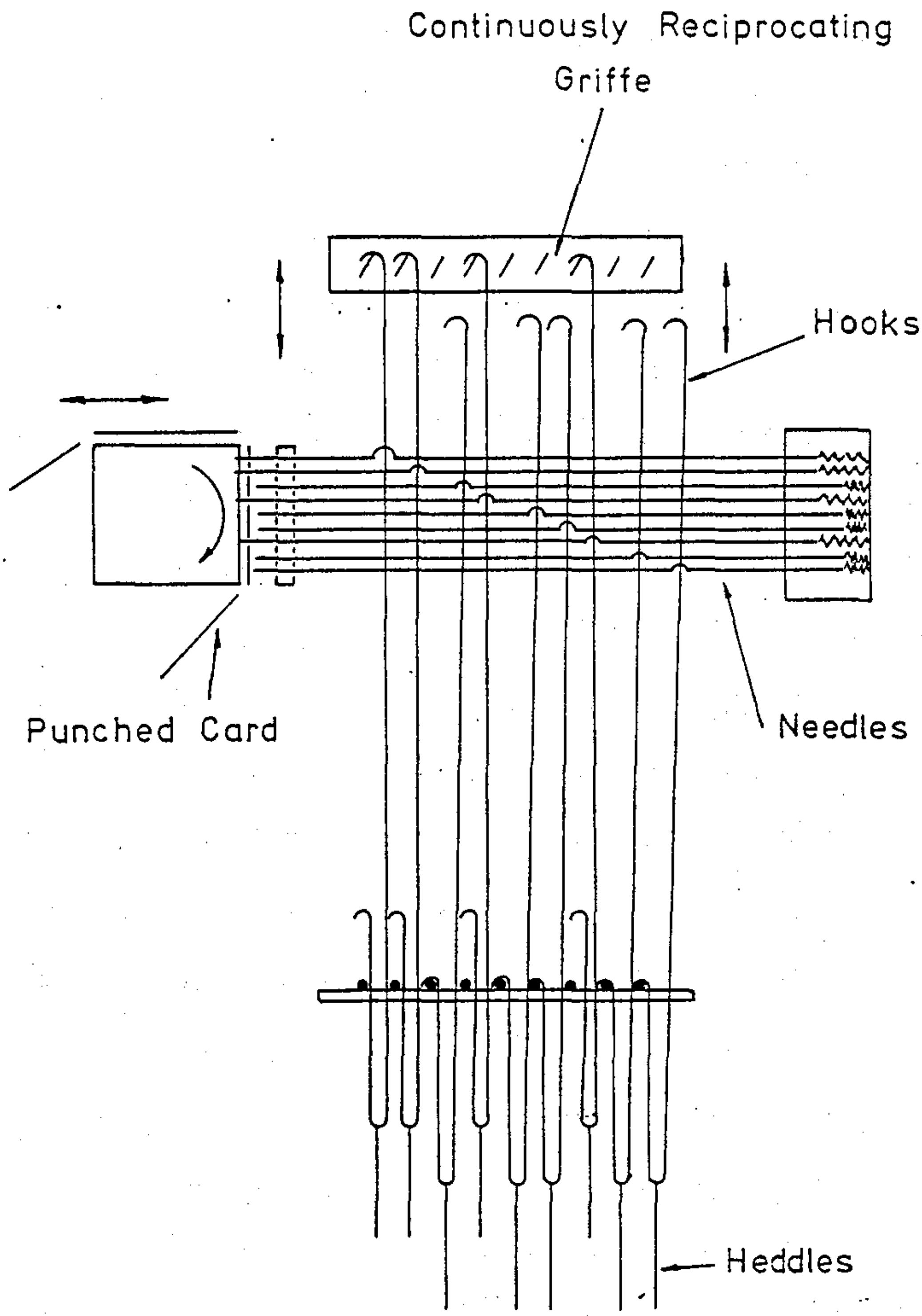


Fig. 2.4 The Principle Of The Jacquard.

2.3.2 Dobby Mechanisms

Greater control can be achieved with a family of mechanisms known as "dobbies". The number of frames is again limited, to about 36, but the pick repeat length is large since the engagement of the frames with their drive means is controlled by pegs inserted into a belt or some other form of pattern chain (See fig 2.3.).

2.3.3 Jacquard Mechanisms

None of the above mechanisms provide sufficient control to produce intricately patterned fabrics. This problem was solved in 1801 by Joseph Jacquard's invention of an ingenious mechanism, the principle of which is illustrated in fig. 2.4.. The warp yarn arrangement is previously encoded as a series of holes in a set of 'cards'. For each shedding action a set of needles is advanced towards the next card in the sequence and the presence of the holes is sensed by the lack of reaction to the movement of the needles. This signal is then used to engage the drive to hooks, which in turn are connected to the warp threads. Jacquard mechanisms are capable of independently positioning over 2000 warp yarns.

The Jacquard principle has been in continuous use since its conception 180 years ago. Improvements have been made to the mechanism but the basic operating principle remains the same. Its continued use is due to two factors; firstly, it will perform the function for which it is required in the majority of instances, and secondly, there is no reasonable alternative.

The following characteristics of the traditional Jacquard system show that there is considerable scope for its improvement.

a) The system is very mechanical in principle with several intermittant reciprocating motions. This tends to limit the speed at which the system will perform satisfactorily.

b) The control cards are expensive to punch because they must be durable in use, they are susceptable to wear and damage and are bulky to handle and store.

c) The mechanism is large and is usually situated high above a loom making access difficult.

d) It is a complex mechanism with a large number of moving parts. It is therefore expensive to manufacture and requires regular maintenance.

In the very recent past more radical changes have been made to the system by various manufacturers. The cards have been replaced by continuous plastic film,the motions have been smoothed, and the whole mechanism has been made more compact and more reliable. The main result has been higher operational speeds, e.g. the Verdol Company manufactures a Jacquard claimed to be capable of operating at 1000 picks/min, as opposed to the more conventional speeds of 200 to 300 picks/min.[7] This is partially a response to the increased weaving speeds of modern looms, e.g. modern gripper shuttle looms of the Sulzer type can achieve efficient weaving at over 400 picks/min., whilst the air-jet and water-jet looms typically achieve speeds in the region of 700 picks/min. However, such modern weaving machines tend to be used to produce plain fabrics, due mainly to the cost and unreliability of running a Jacquard type mechanism at these higher speeds.

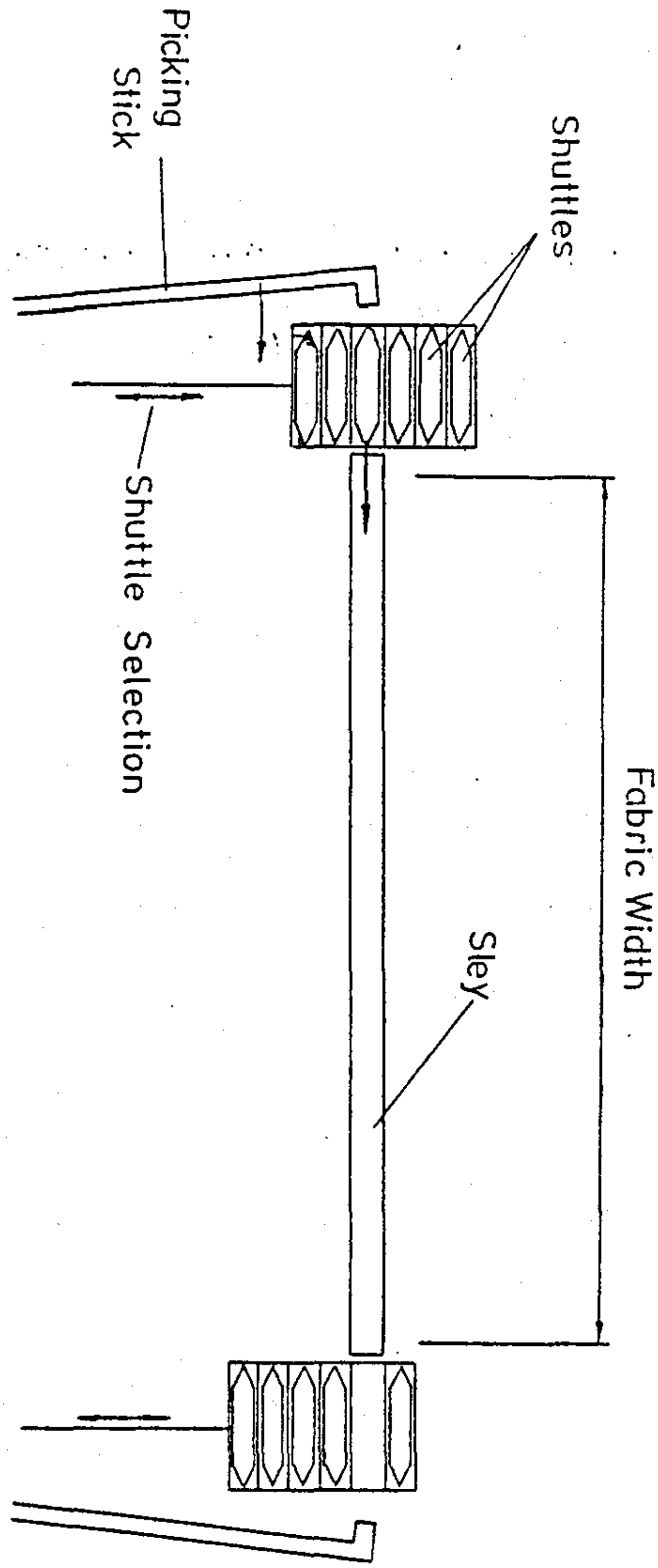


Fig . 2.5. Shuttle-Box Weft Selection

2.4 WEFT SELECTION [4,8]

Weft selection is an important requirement for any woven fabric producer who wishes to weave cloths incorporating colour designs. For use with conventional shuttle looms, a system known as the shuttle-box was developed many years ago which allows the interchange of two or more shuttles filled with different yarns without stopping the loom. As can be seen from Fig 2.5, the shuttle in flight comes to rest in an empty compartment of the box which is then moved so that a different shuttle is presented to the impact action of the picking stick. There is normally a box on each side of the loom to facilitate the inclusion of single picks of a yarn. The movement of the box is normally controlled by a Dobby type mechanism, the coding of which is not a simple task in the instance where two boxes are used since a particular shuttle does not always return to the same compartment after each pick.

Weft selection has also been devised for the newer types of weaving machines. In most cases this consists of a means of presenting one of several yarns to the weft insertion system be it a gripper shuttle, a rapier or a fluid-jet.

2.5 PATTERN PREPARATION

At present, whatever means of selective warp shedding and weft insertion are employed, the process of preparing the controlling belts, chains or cards is largely manual and often extremely tedious. The design, as received by the weavers is a drawing on a sheet of paper; it is then transferred to a sheet of squared paper where each square represents an intersection of a warp and a weft yarn. The required configuration of yarns in the fabric is derived from this; the necessary drawing-in charts for the yarn arrangement in the loom and the coded information on the cards or belts is also produced by reference to it. Therefore, even for a simple design, this process can take many man-hours and, for a large design, a period of weeks is not exceptional.

The knitting industry is faced with similar processes but in recent years electronics have been employed to undertake many of the laborious routine tasks; several very powerful computer systems are available to the knitted fabric designer and producer which are capable of reducing the pattern preparation time to a matter of minutes.

The weaving industry appears to be much slower in utilising this new technology . Some aids however, are available, notably digitizing tables, which assist the transformation of a design into a series of binary digits. Some work is also being undertaken on systems to fully automate the production of Jacquard cards but these are not yet in general use.

Nevertheless, as long as the conventional Jacquard type mechanism is used, the cost of the cards themselves and their storage will continue to be large and this cost cannot be meaningfully reduced.

2.6 NARROW FABRIC WEAVING

There is one particular area of woven fabric production where the traditional methods of warp and weft yarn selection and control are insufficiently fast to produce patterned fabric at speeds remotely approaching the current production rates of plain fabric.

Narrow fabric looms were intially derived from the broadloom types and they employed similar principles of operation.

However, the single shuttle traversing the whole width of the loom, was replaced by several shuttles each passing only through that portion of the shed of warp yarns corresponding to the width of fabric being produced. Thus multiple fabrics are produced side-by-side across the width of the loom.

The main limitation to speed, as with broadlooms, was imposed by the acceleration and deceleration of the heavy wooden shuttles. Modern narrow fabric weaving machines now appear very different. They may still produce a number of tapes simultaneously, but for each fabric a separate weaving head is used. This consists of an eyed needle, (fig 2.6), replacing the shuttle as a weft-insertion means, which is mounted on a pivot such that it can advance through the shed of the warp and protrude beyond the far selvedge. If a weft yarn is threaded through the eye of the needle, the effect is to take a loop of yarn across the shed. At the far slevedge a small latch-needle advances and catches this loop of weft yarn so that as the eyed-needle retracts the weft loop is retained in the shed. The warp shed is then changed and a reed beats up the fell of the fabric prior to the needle advancing again to lay-in another pick of weft yarn. The action of the latch needle on the far slevedge is to knit together the ends of the weft loops in order to produce a neat selvedge but the exact means used has no significant effect on the current investigation.

The combination of this means of needle weft-insertion with a well-designed chain-tappet type shedding action results in very high weaving speeds being achieved. For example the Bonas Varitex 2/65, as used in the current studies, can achieve speeds of 3000 picks/min and this is not exceptional for such modern types of loom.

However, whilst this type of loom can produce complex structures of fabric using the 16 headle frames provided, it cannot produce patterned narrow fabrics, i.e. articles such as labels, badges and fancy trims. The makers of this loom do offer an uprated Jacquard mechanism called the Mini Jacq, which has only 54 hooks and a claimed operational speed of 1500 picks/min and without weft selection. Very recently this firm has announced a new range of similar looms which can be fitted with full Jacquard and weft selection to operate at speeds in the region of 700 - 800 picks/min. This is still well below the plain fabric operating speed of 3000 picks/min: therefore, even with modern machines productivity rates are still lowered when patterned fabrics are manufactured.

2.7 THE NEED FOR A HIGH SPEED PATTERNING SYSTEM

Given the present state of weaving technology, the narrow fabric producer wishing to sell to the market of badges, labels, name tapes and fancy trims is faced with three main options:-

a) He can invest in the older style weaving machinery, consisting of a multihead shuttle loom fitted with a full Jacquard and a six or eight box weft selection system. He will then have a system capable of 200 - 300 picks/minute producing several identical tapes simultaneously;

b) He can invest in the needle-type narrow fabric loom fitted with a very much limited Jacquard and with little or no weft selection. This will produce either one or two tapes at perhaps 1500 picks/min, i.e. well below the speed at which the basic machine could produce plain fabrics; or

c) He could produce a plain tape, at high speed on a needle loom, and later print the design onto the fabric. He will produce substantially more fabric, not only because of the higher weaving speed, but also because he has no need to change the way the machine is set up to change the design on the finished article.

As a result of these options a growing proportion of the short-run patterned narrow fabric e.g. labels and badges, have been produced via option (c) . The product is of inferior quality to a woven pattern, but is very much cheaper; although for example, a garment manufacturer would prefer to label his goods in a way that is durable and commensurate in quality with the garment, he cannot afford to commission very expensive labels.

Therefore it would appear that there is a current need for a high speed, versatile, narrow fabric loom with high patterning capability. If the patterning system were to be compatible with existing high-speed needle looms, so that its use with existing machines would be possible, the potential application would be much greater. Further improvements in the efficiency of the production of short-run patterned narrow fabrics could be achieved if the system permitted a degree of automation of the processing of the pattern data required for the control of the system.

CHAPTER 3: THE DEFINITION OF THE PROBLEM : AND A SPECIFICATION FOR ITS SOLUTION

3.1 CONSIDERATIONS OF SPECIFICATION PREPARATION

Having recognised the technological gap in the production of patterned woven narrow fabric, and having ensured that there is a commercial demand for these products, the next step is to produce a specification for a system to fill the gap.

In preparing the specification regard was given to the following considerations:

a) any system produced will be eventually intended for commercial operations so due regard must be given to areas such as reliability, capital cost, running cost, acceptance by a traditional industry, ease of use and quality of output;

b) any proposed system must be feasible, utilising the latest proved technology.

c) any proposed system must be reasonably versatile, so that it is viable from the machine builders view point.

d) the system should embrace as much of the production of the patterned fabric in an integrated manner as possible, and be able to link successfully with existing techniques both prior to and after its own contribution.

These constraints tend to act upon the quality and validity of engineering design and manufacture, eg if a component is to work reliably for a specified period it must be designed and manufactured such that it can perform its function for that period. But they will also affect the choice of principle of operation,e.g.a system using a novel means of yarn propulsion may require a great deal of textile research before users are confident enough to employ it.

The research is aimed to benefit the UK Textile Machinery Industry and therefore it was decided at an early stage to base the work on a narrow fabric weaving machine of the type built in the UK. A machine was purchased for use with this project, a Bonas Varitex 2/65. After familiarisation with this machine, the existing technology, and the desired product a specification was drawn up.

Amplification of specific points will be found within the relevant chapters.

3.2 SPECIFICATION FOR A HIGH SPEED PATTERNING SYSTEM

The specification is for a system capable of introducing patterns into fabric, as it is produced by a Bonas Varitex 2/65 narrow fabric needle loom, by individual warp yarn control during shedding combined with weft yarn selection. The following detailed requirements are required:

3.2.1 Each yarn is to be individually and independantly controlled during the shedding part of the weaving cycle. On every cycle it must be possible for each yarn to be moved to the upper or lower plane of the shed or held in the position selected in the previous cycle.

3.2.2 The maximum warp density to be achieved is 60 warp yarns per centimeter. When handling lower density warps the unused selector systems should be protected from damage and preferably immobilised to reduce wear, noise, power consumption etc.

3.2.3 The maximum fabric width to be produced is 65 mm.

3.2.4 The system must be capable of operating at speeds up to 3000 picks per minute. Satisfactory performance is to be achieved over the whole range of speeds available from the basic machine.

3.2.5 Ideally the stress generated in the warp yarns by the selector system will not exceed that generated in the present system; however, it is essential that it is sufficiently low not to damage any of the range of warp yarns that can be handled by the unmodified machine.

3.2.6 The shed angle formed by the selector system is to be great enough to allow weaving within the fault rate specification (see below).

3.2.7 The threading of warp yarns through the selector system must be reasonably easy to accomplish. It must be possible to replace a broken warp end with all the other warp yarns in place.

3.2.8 It must be possible to select one of at least 4 weft yarns in a random sequence as required by the pattern input.

3.2.9 The fault rate due to the weft passing on the wrong side of a warp yarn must be less than one error per 10^5 selections (this corresponds to one fault per 8" length of fabric with 150 warp ends per inch 2½" wide and 30 picks/in).

3.2.10 The components of the system are to be located in the existing machine using the space originally used for the headle frames, headle levers, pattern chains and the weft insertion needles. Ideally the width of the warp actuators should be no greater than that of the fabric being produced. (This will allow easier utilisation of this principle on other machines.) If necessary a separate control box or panel may be added to the machine to house some of the components.

3.2.11 The introduction of patterning instructions to the system should be such that:-

a) It is easy to change from one pattern to another.

b) The compilation of instructions, either "on line" or "off line" should be reasonably straightforward and use only resources normally available to an industrial user.

c) Patterns must be easily re-introduced into the system with a minimum of recompilation.

d) Patterns, or instructions stored "off line" must not be subject to deterioration in normal conditions.

e) The basic construction of the fabric must be introduced into the system as easily as possible.

f) If possible, some form of alarm should be incorporated to warn of errors in pattern reading and miss-selection of warp.

3.2.12 The system must have a commercially acceptable life, commensurate with that of the basic loom. Any servicing required should be as simple as possible; any part requiring frequent attention or replacement should be readily accessible and easily removed.

3.2.13 The basic operational requirements of the system must be provided from normally available mains services.

3.2.14 The complete system must be safe and comply with current British Legislation.

CHAPTER 4: THE WARP SELECTION SYSTEM

4.1 OUTLINE OF THE SYSTEM

It is intended to control the vertical position of the warp yarns in the region immediately behind the beat-up reed of the loom. Thus the warp selection mechanism will replace the conventional heald frame arrangement in terms of both function and position (fig. 4.1).Fig 4.2 is a photograph of the bench mounted rig used to test and develop the principle of the system. Each warp yarn position is controlled by passing the yarn through an eye in the heddle element. This is moved perpendicular to the warp plane by one of the two driving cross members, which would lie across the machine, below the warp plane. The drive between the heddle element and the cross member is achieved by means of latches attached to the heddle element engaging in drive lugs on the cross member. The latches are controlled by a control element which lies alongside the heddle element. The controlling action of this element, a small axial change of position, is derived from the motion of the control cross member, the selectable drive here being achieved by the shape of the components together with an electromagnetic device.

4.2 THE COMPONENTS OF THE SYSTEM

4.2.1 The Heddle Element

The heddle element is a long slender component; for use on the rig its length was 300 mm and its cross-sectional dimensions were 2 mm x 1 mm (see Fig 4.3). Due to the loading to be applied to this component it needs to be made in a light and stiff material. Steel was used for the development work but other materials such as carbon fibre could be considered for future work.

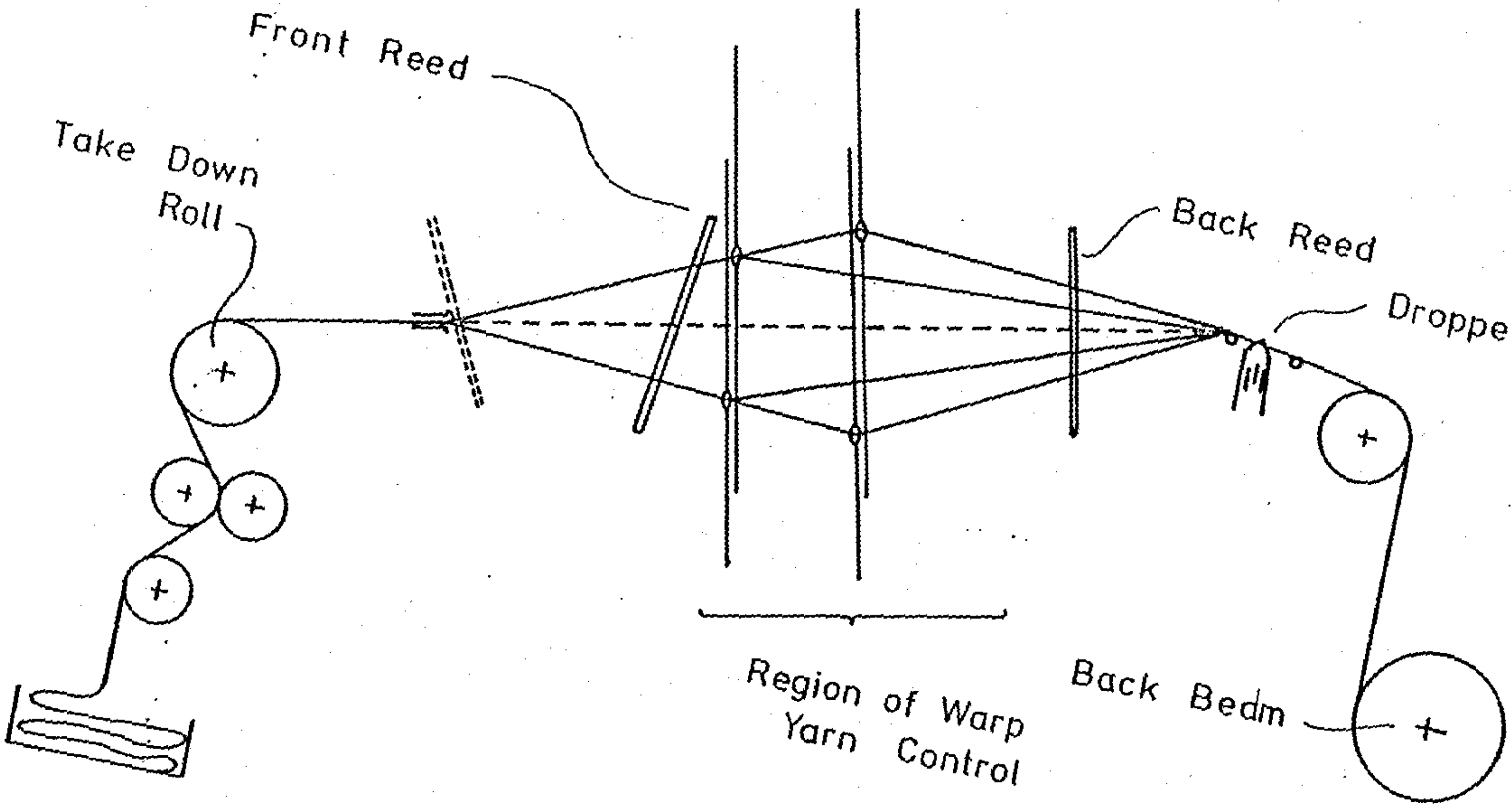


Fig 4.1. The Region of Warp Yarn Control.

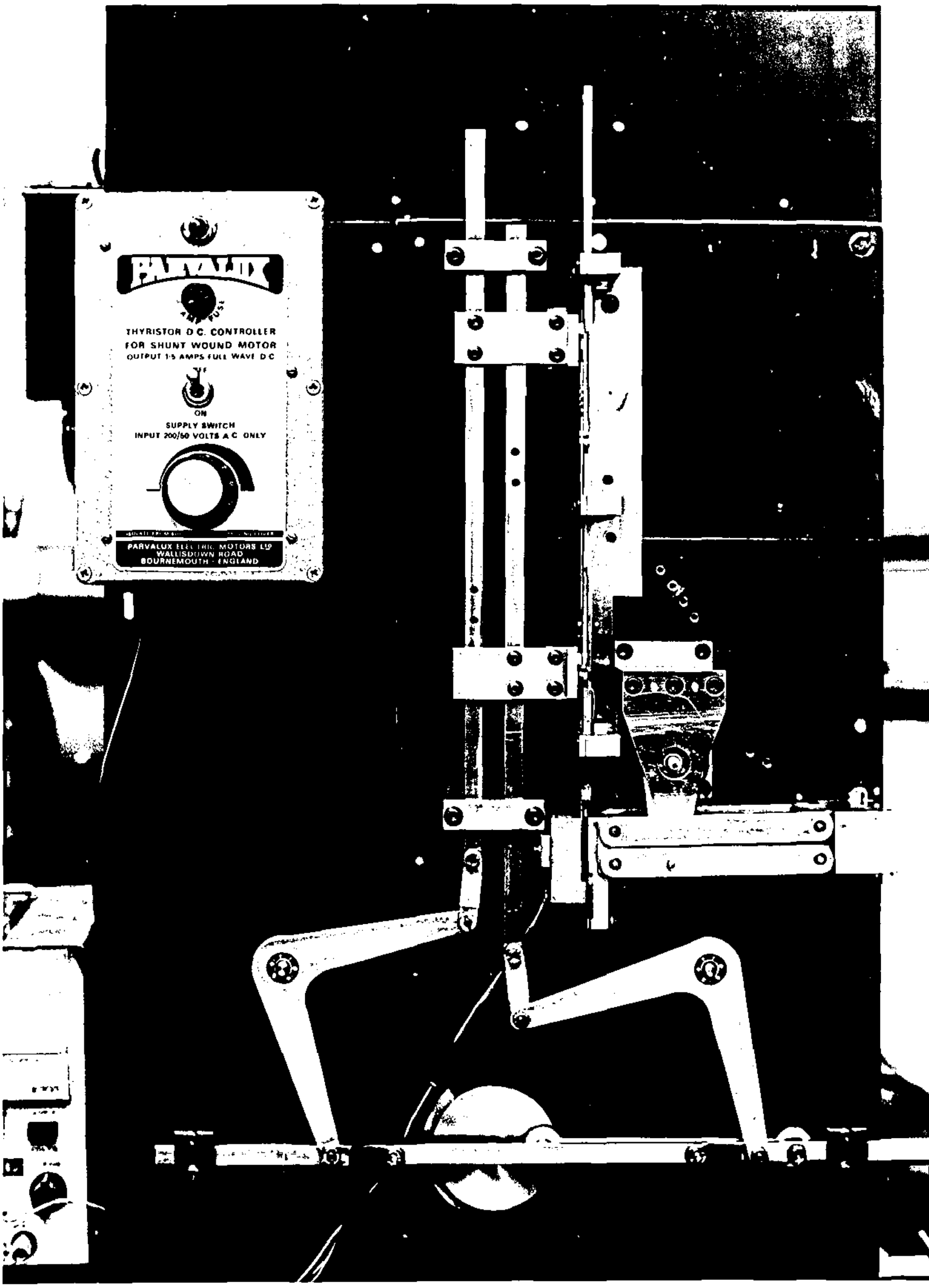


Fig. 4·2 The Bench Rig.

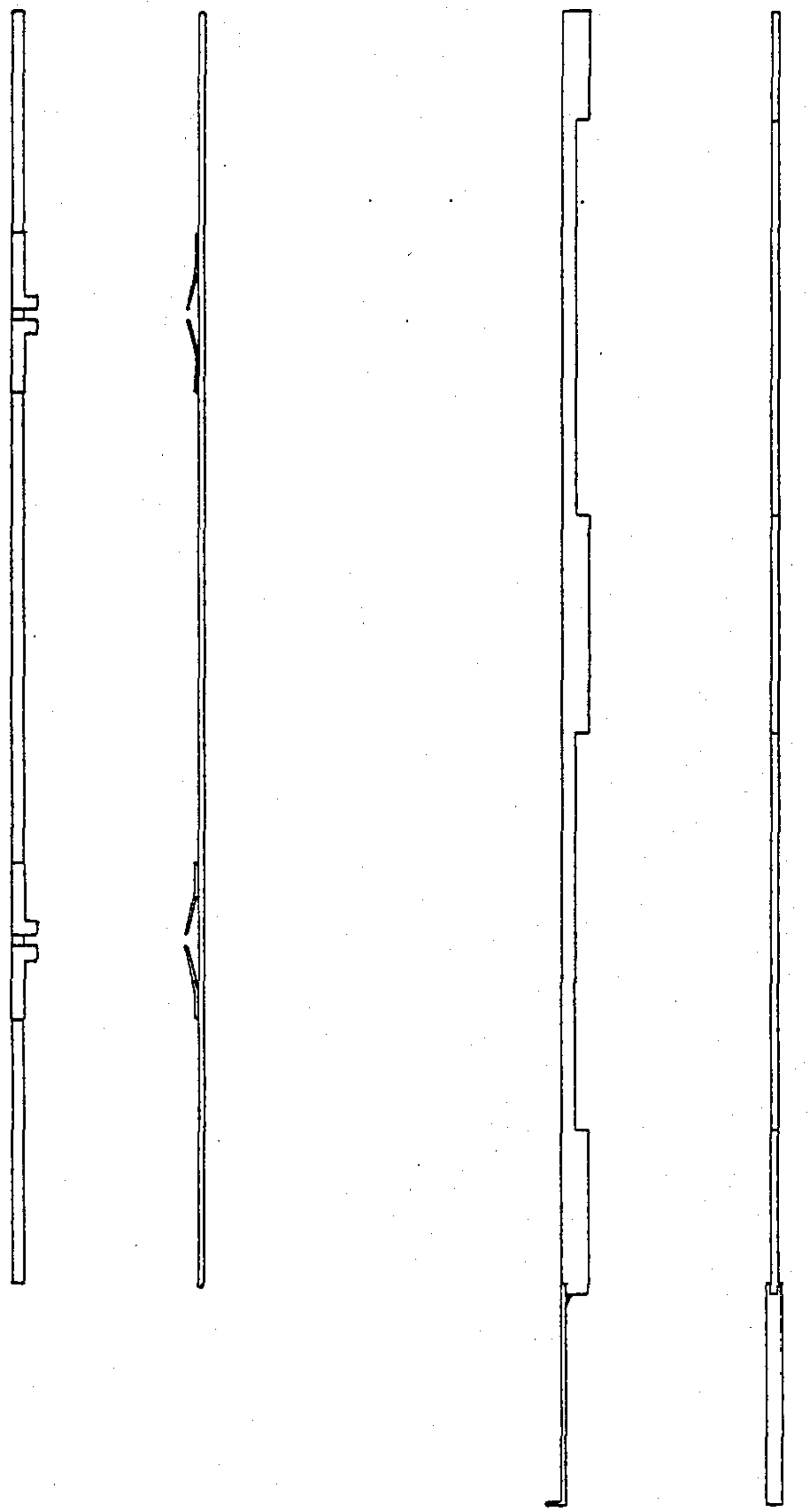


Fig. 4.3. The Heddle and Control Elements

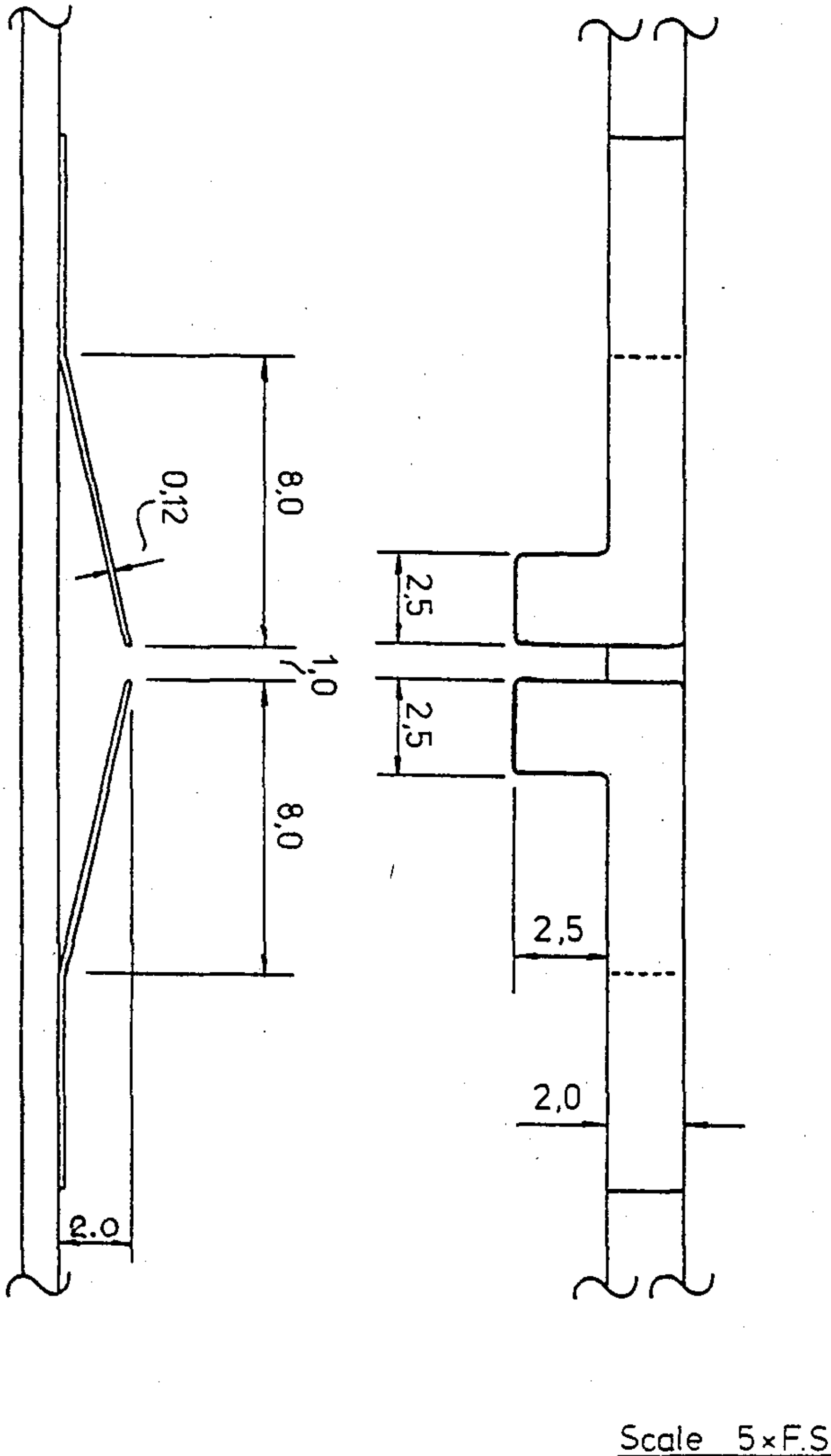


Fig. 4.4. The Heddle Latch

The element runs in guide slots formed in cast iron supports at the top, centre and bottom of the element, such that the motion allowed is perpendicular to the warp plane. The upper end of the element would be connected to the warp yarn to be controlled either directly, by virtue of an eye through which the yarn passes, or indirectly via a wire or cord, but this would need a return spring of some form attached above the warp plane to keep it in tension. This could present problems in terms of space and speed.

4.2.2 Heddle Latches

These latches are the means by which the heddle element is connected to the driving force which is required to move the element, and with it the associated warp yarn. They are cut from spring steel 0.25mm (0.012") thick and are permanently attached to the heddle element by means of a soldered joint. Other fixing techniques such as brazing, spot welding and electron beam welding may be employed in the future.

The shape of the latch (see Fig 4.4) is such that from the point of fixture the latch departs from the side of the heddle element at an angle of approximately 20^{o}. If pressed sideways it will flex and lie flat against the element. The free end of the latch protrudes beyond the front edge of the element and it is this protrusion which is deflected into the path of the lug on the driving cross member when the latch is flattened by the control element.

There are four latches attached to each heddle element, one pair between the upper and middle guide slots and one pair between the middle and lower guide slots. The lower of each pair is to drive the element upwards, and the upper latch to drive it downwards.

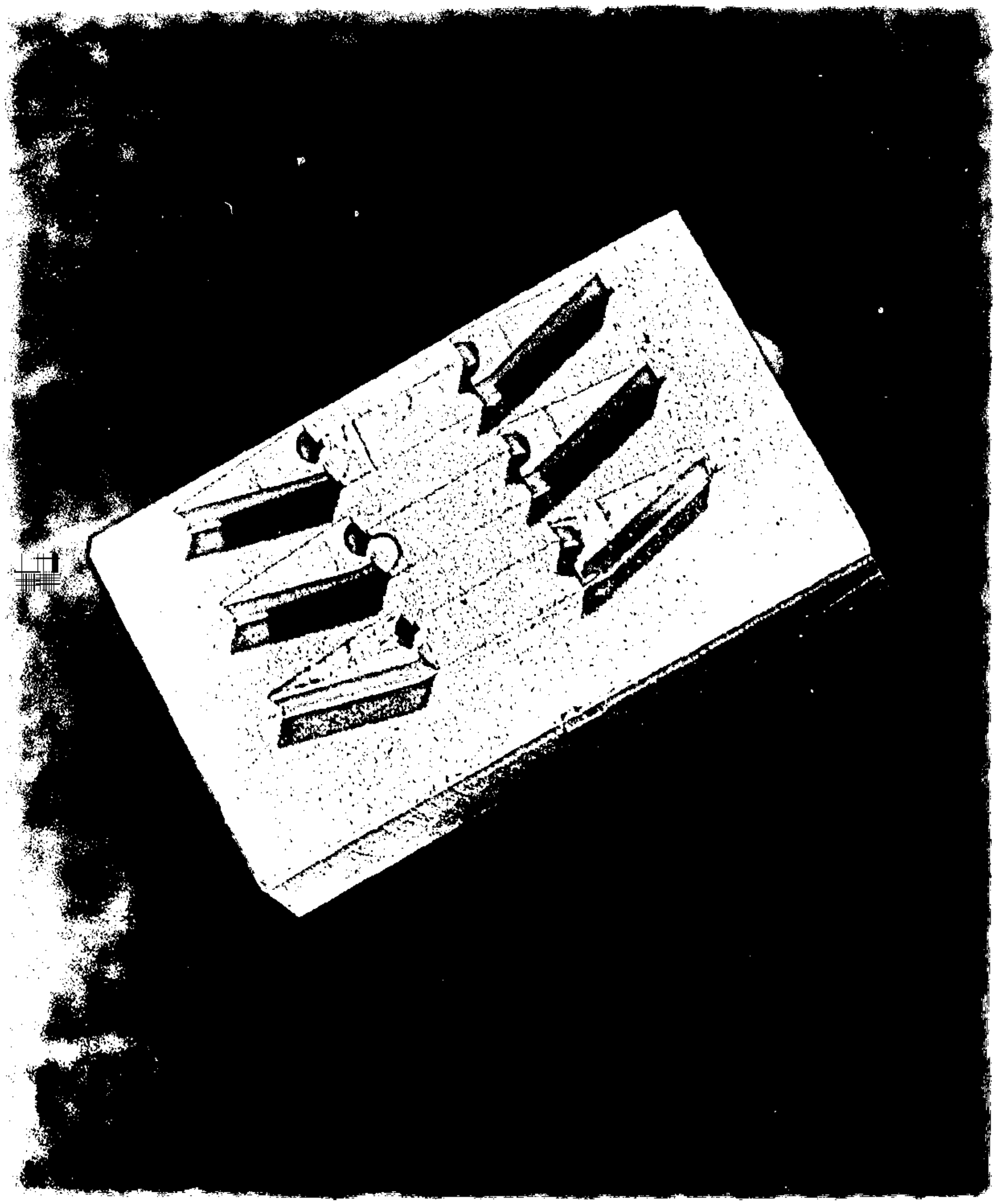
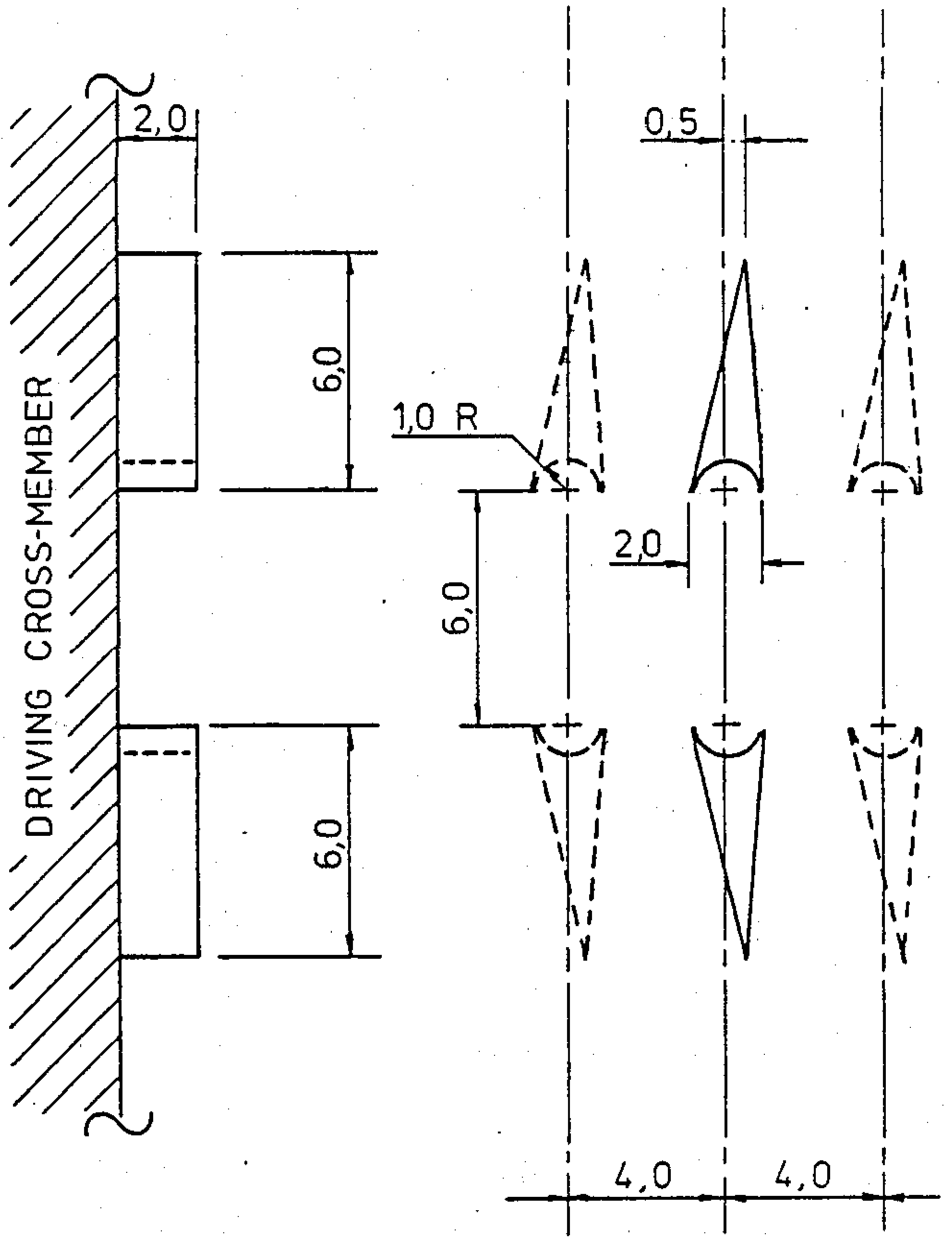


Fig. 4·5 The Driving Lugs.



Scale 5×F.S.

Fig. 4.6. The Drive Lugs

4.2.3 Driving Cross-Members

Each heddle element derives its motion from two driving cross-members. These lie across the weaving machine, immediately in front of the heddle element, one adjacent to each pair of latches. The cross-members reciprocate continuously in the direction of heddle movement with a stroke fractionally in excess of the stroke required of the heddle element, and at a cycle rate half that of the weaving machine. The two members have a half-cycle phase difference between them so that during each cycle of the weaving machine one of the members will rise from its lower to its upper position, and the other will move from the upper to its lower position. The motion of the cross members is sinusoidal as this avoids excessive accelerations, limits the impact velocity between latches and driving lugs, and is relatively easy to derive reliably in a machine situation. On the face of each of the cross-members, next to the heddle element, are the driving lugs. These are shaped (fig. 4.5) so as to engage and hold the latches when these are operated by the control element. The reversal of motion of the cross-member automatically releases the latch from the lug.

4.2.4 Control Element

The selection of the latches is achieved by the control element, which is similar to the heddle element but of a larger cross section (4mm x 1 mm) (see Fig 4.3). The control element runs in guide slots alongside the heddle element, adjacent to the latches, with a clearance of 0.5mm between them. The control element has a length of reduced cross section opposite each pair of latches to allow them to adopt their natural shape. The length of this reduced section is sufficient to allow very nearly the full stroke of the heddle element without the control element interfering with the latches.

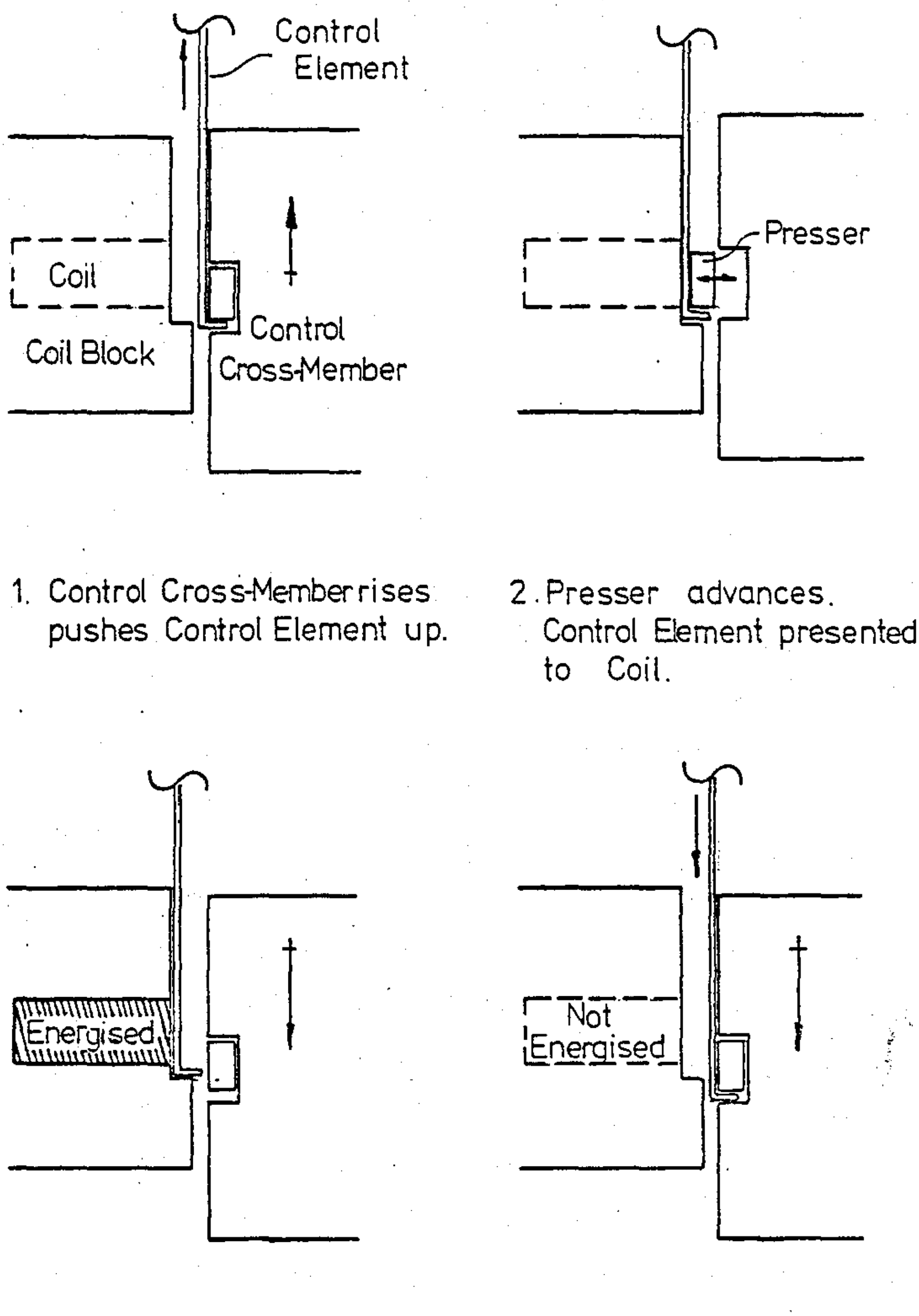
However, if the control element is displaced axially, a small distance, as the heddle element reaches the end of its stroke, the control element presses on the side of the latch and 'closes' it, i.e. it is deformed such that it lies flat against the heddle element and consequently will engage with the driving lug. A small upward movement of the control element will close the lower latches as the heddle element reaches the bottom of its stroke; conversely a small downward movement will close the upper latches at the top of the heddle element stroke. The total movement of the control element to achieve this 'switching' is only 2mm.

The axial position of the control element is determined by a mechanism acting on its lower end, which is made of spring steel and shaped so that its hook -end is normally engaged with a slot on the control cross-member.

4.2.5 Control Cross-Member

This is a third member which lies across the machine below the two driving cross members. Like them it is also reciprocating vertically but with a 3 mm stroke and at a cycle rate equal to that of the weaving machine i.e. double that of the driving cross members. The motion is phased to reach the bottom of its stroke as the driving cross members reach the upper and lower limits of their strokes.

Normally the hook-end of the control element is sprung into mesh with a slot on the control cross-member, thus the control element moves with the cross-member and reaches its "down" position as the drive cross-members are in the correct position to engage any closed latches. As described in section 4.2.4, if the heddle element is in its upper position, the control element in the down position will close the upper latches, and the drive lug



1. Control Cross-Memberrises pushes Control Element up.

2. Presser advances. Control Element presented to Coil.

3a. Control Element retained in upper position.

3b. Control Element descends with Control Cross-Member.

Fig. 4.7a The Coil Cycle

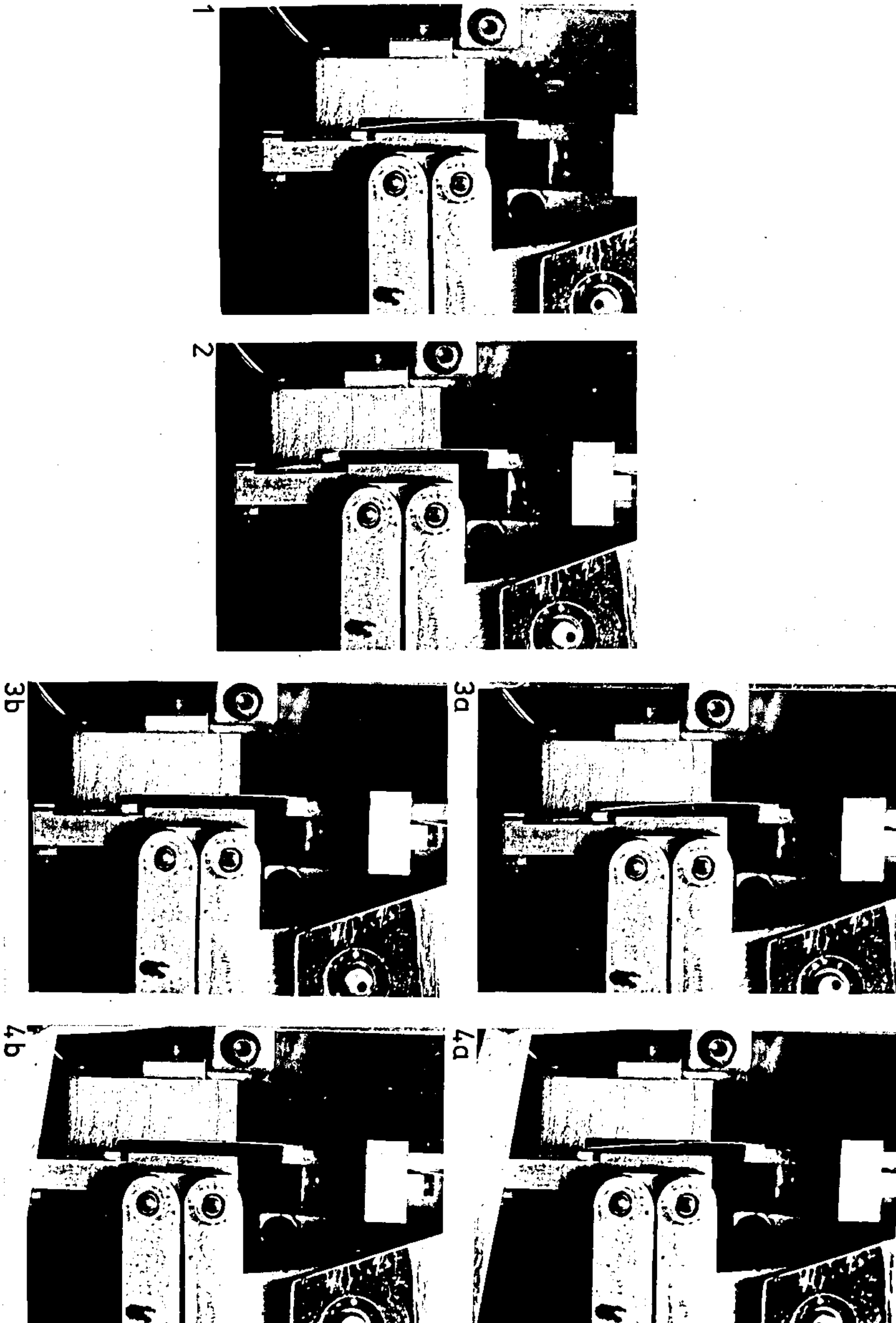


Fig. 4·7b The Control Element-Presser-Coil Block Cycle.

on the cross-member about to descend will be engaged, the result being the downward movement of the heddle element. If the heddle element is already in its lowest position then no latches are closed and the element stays where it is.

4.2.6 Presser and Coil Block

To engage the lower latches, and so drive the heddle element upwards, the control element must be in its upper position as the driving cross-members reach the ends of their strokes. To achieve this a device called a presser advances from the control cross member each time the control cross-member reaches the top of its stroke and pushes the hook end of the control element out of mesh with the slot in the control cross-member (see Fig 4.7) and back on to the face of the coil block, which is located opposite the control cross-member.

The coil block is made of a magnetically "soft" material such as cast iron and contains an electrical coil for each control element. The coil is positioned in the block so that as the end of the control element comes into contact with the block it covers the end of the coil and so completes a circuit of material of high magnetic permeability through and around the coil. Consequently, if an electrical current is passed through the coil a magnetic flux of high density is built up in the completed magnetic circuit. This causes the end of the control element to adhere to the coil block and, as the presser retracts and the control cross-member descends, the control element is retained in its upper position resulting in the closure of lower latches, if the heddle element is in its lower position. As a result the heddle element is driven upwards.

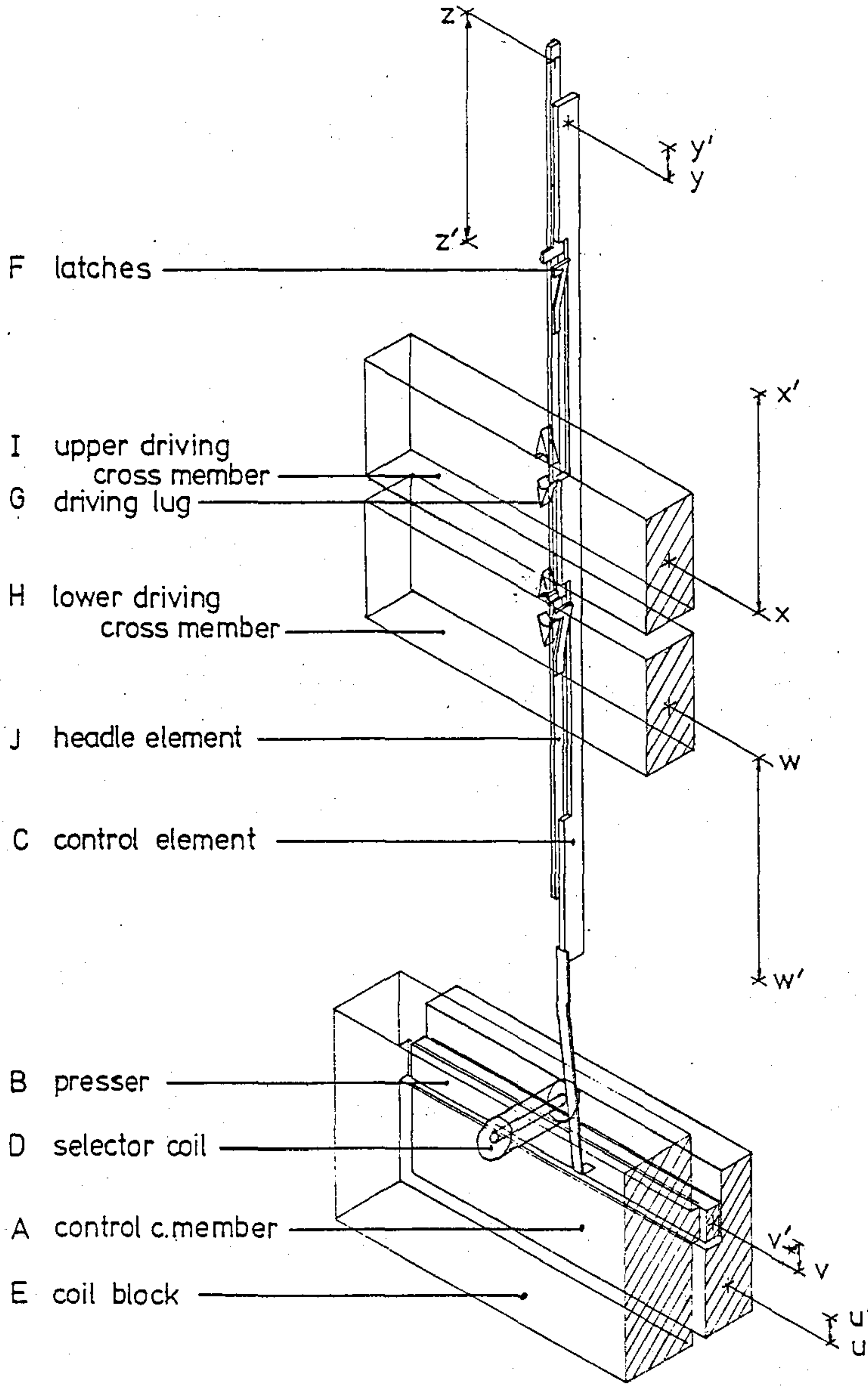


Fig. 4.8. The Components of the System

If the coil is not energised then the hook leaves the block due to its spring pressure against the presser and re-engages the slot in the control cross-member to be taken to its low position. It should be noted that the shape of the cross-member, the coil block and the control element end are such that soon after the cross-member starts to descend the hook is positively held either in mesh with the slot or out of mesh against the coil block. The result of this is that the proportion of the cycle over which the coil must hold and select the control element is relatively small (approx. 20%); thus the greater part of the cycle is available for switching the coil currents and the consequent decay and build-up of electrical currents and magnetic fields.

4.3 SEQUENCE OF OPERATION OF SYSTEM

The sequence of operations for one selection of one warp thread is given below:-

1. Control cross member (A) rises U - U')

2. Presser (B) advances(V - V') as control cross member reaches top of stroke.

3. Lower end of control element (C) is pressed against coil block (E).

EITHER:-

4a If coil (D) is energised, control element remains against coil block as presser retracts(V'- V).

5a If heddle element (J) is in lower position (Z'), the lower latches of each pair (F) are closed.

6a. Closed latch engages driving lug (G) of rising cross member (H or I).

7a. Heddle element is driven to upper position (Z' - Z).

N.B. If the heddle element is already in upper position (Z), no latches are closed by control element and heddle element remains stationary.

OR:-

4b. Coil (D) is not energised, so lower end of control element remains sprung against presser (B) and re-engages slot in control cross member (A) as presser retracts.

5b. Control cross member descends (U' - U) taking control element to lower position (Y).

6b If heddle element (J) is at upper position (Z) the upper latches of each pair (F) are closed.

7b. Closed latch engages driving lug (G) on descending cross member (H or I).

8b. Heddle element is driven to lower position (Z').

N.B. If heddle element is already in lower position no latches are closed by control element and heddle element remains stationary.

Fig 4.9 shows the movement of various components through several cycles of the machine. The electrical Pulse A, lasting 0° - 50° of main shaft revolution, results in the control element staying at the top of its stroke for one complete shaft revolution, B.C.

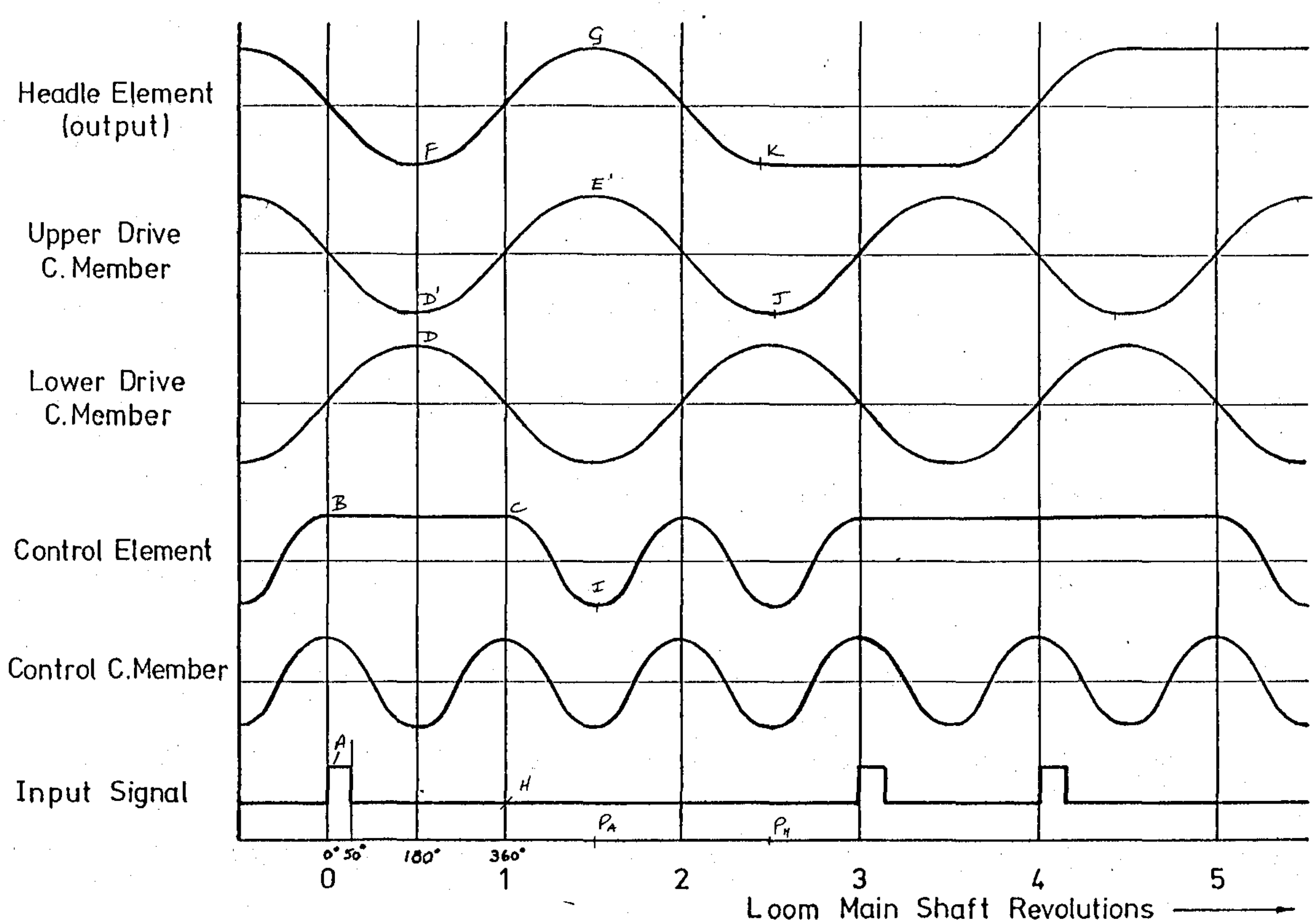


Fig. 4.9. The Timing of the Cycle

Thus when the driving cross members reach the end of their strokes, at 180^0 of shaft revolution, at D and D',the lower latches are closed. The upper cross-member is about to ascend, D' to E' and engage the latch and so the heddle element is driven upwards,F to G. The cross-member uses a full shaft revolution to rise, and the warp thread reaches the top of its stroke, E' at 540^0 of shaft revolution. Thus between the start of the control pulse and the time of insertion of the corresponding pick, P_A, there are 1½ revolutions of the main shaft. This presents no problems since once the control cross-member has started to descend the information has been mechanically locked into the system and will not be lost even if the electrical control power is switched off.

The absence of a control pulse may be similarly followed through the system. The end of the control element is not retained by the coil block and so re-engages the slot in the control cross-member; consequently at the critical moment for latch selection, it is in its low position, I. This closes the upper latches and as the falling cross-member descends, E' to J, the heddle element is taken with it, G to K. Thus at the time of pick insertion P_H the warp thread is at the bottom of the shed.

4.4 APPLICATION OF THE SYSTEM TO A NARROW FABRIC LOOM

As stated in Section 4.1, as yet the system has only run as part of a bench mounted rig. However, during its design and development consideration has always been given to the way in which it would be applied to an actual loom, and in particular the Bonas Varitex 2/65 narrow fabric weaving machine.

It is envisaged that the mechanisms described in this chapter would be positioned below the warp plane, in the space conventionally occupied by the heddle frames and pattern chains. This allows good access to the warp and maintains a low centre of gravity for the machine.

The heddle elements would be arranged on a staggered matrix of 25 rows of 16 elements. This allows a 4mm pitch along the rows and a 12mm pitch between rows if the limitations of keeping within the fabric width and space available are considered. This tight packing of the elements can be achieved if alternate rows are turned to face the rear of the machine; then the cross-members can be used by the two rows of elements which face them thus reducing the number of cross-members by half, as well as using the space more effectively.

The driving cross-members will be attached at their ends to an arm pivoted below the fell of the fabric. Thus the stroke of each cross-member will be proportional to the distance of the cross-member from the line of the fell. This is to reduce the movement of all the heddle elements to the minimum required to produce a specified shed angle.

The control cross-members will also be linked at their ends but the same motion is required for all of these members since the movements required by all the control elements to provide reliable 'switching' of the latches is a function of latch shape and these are all the same irrespective of position.

The motions for both sets of cross-members may easily be derived from eccentrics or cranks since the exact form of the motion is not critical.

4.5 ADVANTAGES AND DISADVANTAGES OF THE SYSTEM

The desirable features and advantages of this system when compared to others are numerous:-

4.5.1 The warp threads are only moved when necessary, e.g. if it is required that a warp thread be held in the top of the shed for two successive picks then the yarn is raised prior to the first pick, held stationary in the up position until the second pick is inserted and only then moved if the low position is required for the third pick. Many existing systems return all the threads to a common position, usually the centre or bottom of the shed, on each cycle, the selection for the next pick then taking place from this position.

4.5.2 Since the stroke of the driving cross members can be arranged to be proportional to their distance back from the fell, a common shed angle is formed by all of the warp threads. This can be fixed at the minimum required for weaving and as a result each warp thread is only displaced the absolute minimum necessary. Many other systems lift all of the warp threads the same amount, this stroke being determined by the shed angle subtended by the threads controlled at the furthest distance from the fell. Thus any threads controlled nearer to the fell, which require a smaller stroke to subtend the same angle, are moved a distance greater than the minimum.

4.5.3 Since the mechanism requires an input signal which is directly related to the position required of the warp yarn, the occurence of a selection error will not affect subsequent selection. Some systems operate in such a way that the signal dictates a <u>change</u> of position of the yarn, in such systems the occurence of an error is perpetuated in subsequent selections.

4.5.4 Since the system can be positioned below the weaving area, access to, and visibility of, the heddle area is good from the normal operator position making threading operations easier. It also allows the addition above the weaving area of the multi-yarn feed arrangement that is needed with a weft selection system.

4.5.5 Because the electrical coils do no mechanical work, and operate with a flux circuit composed almost entirely of materials with a high magnetic permeability, the coils themselves can be very small and require only a low signal power input. Thus the driving signal can be derived far more easily, and cheaply from the output of a microprocessor.

4.5.6 In addition to the low power of the signals to drive the coils, due to the operating cycle of the selectors, the signal is only required over a small proportion (approx. 20%) of the machine cycle. Thus the total average power requirement is small as is the resistive power loss and consequent heat generation in the coils.

4.5.7 Due to the design arrangement of the system all the electrical and magnetic components are stationary. This helps to provide the reliability required since conductors are not being stressed, the design is cheaper since no moving electrical contacts are needed, and the relatively heavy magnetic materials do not require to be moved.

4.5.8 The total number of moving parts is low. The cross-members are "shared" by many elements and, since they are moving continuously, they can be designed to give high reliability and low power consumption. The only individual moving parts for each yarn are the heddle elements and control elements which would be suitable for mass production keeping replacement costs low.

In addition to the features listed above there are unfortunately two which are less desirable:-

4.5.9 At present the system provides no means other than friction for holding in position the heddle elements which are not to be moved. At the moment of maximum warp tension, at beat-up, those yarns which are being moved will be close to the middle of the stroke and thus the force due to the tension is taken by the let-off device on the warp beam. However, the tension in those threads held, either at the top of the bottom of the shed, will act so as to bring the elements to the centre. Thus some form of retaining device, acting on the stationary elements, between selections, could assist the reliable operation of the system.

4.5.10 If a heddle element is not required for the manufacture of a particular fabric, then it should be made to remain stationary to reduce wear, noise and power consumption. To do this with the present system the relevant control element must provide a constant signal due to its position. If this signal to the coil is removed, the control element stays permanently meshed with the control cross-member and reciprocates continuously. To achieve no motion of either control element or heddle element, a signal must be applied to the coil for each pick; the control element will be stationary with its lower end held against the coil block and the heddle will be stationary in the upper position.

It would be more desirable for the element to be "parked" with no signal applied it. This could be achieved by a means of mechanically locking the end of the control element against the coil block thus providing a truely inert system for unused ends.

CHAPTER 5: THE DEVELOPMENT OF THE WARP SELECTION SYSTEM

5.1 INTRODUCTION

The warp selection system developed in response to the needs identified in Chapter 2 and which takes the form described in Chapter 4, is the result of a long process of design and experimentation. This development programme is summarized in this Chapter.

The Jacquard mechanism as it is used today has its origins back in the 18th Century and has been evolving slowly to its present form. The changes that have been made are in respect of detail only and the basic operating principle has remained essentially unaltered, a testament to its inventor. Today, manufacturers of modern narrow fabric looms claim to be able to run their looms, fitted with Jacquard mechanisms, at speeds in excess of 700 picks/min. e.g. the Bonas Mini Jac. To achieve this speed a great deal of tuning of the mechanism has been required. Early in this investigation it was considered that if the target speed of 3000 picks/min for a warp selection system was to be attained then a new principle of operation would be required, the Jacquard having been pushed very nearly to its limits to reach a quarter of the target speed.

In the search to find a suitable principle on which the system could work a very large number of possible ideas were considered. The only limitation quickly realised was that the input to the system, conveying the pattern information, should be electrical in nature. The reasons for this were:-

i) Speed - it is extremely unlikely that any mechanical system of data handling would be able to cope with the target speed;

TABLE 1: ELECTRICAL → MECHANICAL TRANSFORMATIONS

TRANSFORMATION	EFFECT	CHARACTERISTICS AND SUITABILITY TO THIS STUDY
ELECTRO-MAGNETISM	A FORCE IS EXERTED ON A 'FERROUS' OBJECT BY THE MAGNETIC FIELD CREATED BY AN ELECTRIC CURRENT	A COMMONLY USED EFFECT EG SOLENOIDS. THE MAGNETIC FIELD CAN BE CONTROLLED AND GUIDED AROUND A 'FERROUS' PATH. LARGE FORCES CAN BE EXERTED. FORCES DECREASE RAPIDLY ACROSS 'NON FERROUS' GAPS
ELECTRO-MAGNETIC	A FORCE IS EXERTED ON A CONDUCTOR CARRYING AN ELECTRIC CURRENT IN THE PRESCENCE OF A MAGNETIC FIELD	A COMMONLY USED EFFECT EG MOTORS AND MOVING COIL LOUDSPEAKERS. HIGH STRENGTH MAGNETIC FIELD REQUIRED TO PROVIDE USEFUL FORCES.
ELECTRO-STATIC	A FORCE IS EXERTED ON AN OBJECT CARRYING AN ELECTRIC CHARGE IN THE PRESCENCE OF THE FIELD OF A SECOND ELECTRIC CHARGE	RARELY USED IN 'DYNAMIC' SITUATIONS. HIGH VOLTAGES REQUIRED. FORCES DECREASE RAPIDLY WITH DISTANCE BETWEEN CHARGES.
MAGNETO-STRICTIVE	A DIMENSIONAL CHANGE OCCURS TO AN OBJECT IN THE PRESCENCE OF A MAGNETIC FIELD	PHYSICAL EFFECTS ARE SMALL. MORE COMMONLY CONSIDERED A NUISANCE EG "HUMMING" OF TRANSFORMERS
ELECTRO-STRICTIVE	A DIMENSIONAL CHANGE OCCURS TO AN OBJECT IN THE PRESCENCE OF AN ELECTRIC FIELD.	HIGH FIELD STRENGTHS REQUIRED. PHYSICAL DISPLACEMENTS SMALL. HAS FOUND SOME APPLICATION IN ULTRA SONIC TRANSDUCERS.

ii) Convenience - many operations are easily accomplished by electrical signals using well-established technology and the micro-electronics revolution permits even more.

iii) Cost - electrical components are usually readily available to match most needs at a moderate cost.

An alternative to an electrical input was considered; fluidics have some of the advantages of electronics, although a system able to cope with 400 channels would be expensive both in terms of investment and running costs. Fluidic elements were larger and more costly than their electronic equivalents, even before the advent of micro-electronics. The fluidic industry appears to be contracting and so components are likely to become less economic if the supply is reduced. The running cost of fluidics also has to be considered; a system capable of controlling 400 or more outputs would consume a large quantity of compressed air, the cost of which is rising as fuel costs increase.

Once the limitation of an electrical control input was accepted then the search for operating principles could start with a consideration of the ways in which electrical power may be translated into a mechanical effect. These are listed in Table 1 with comments on their suitability to the purpose in question.

Some of the more promising schemes which arose from consideration of the possible input transformations are outlined in Appendix 2 . Many more ideas were rejected after simple consideration of the system capabilities compared with the requirements detailed in the Specification (see Chapter 3).

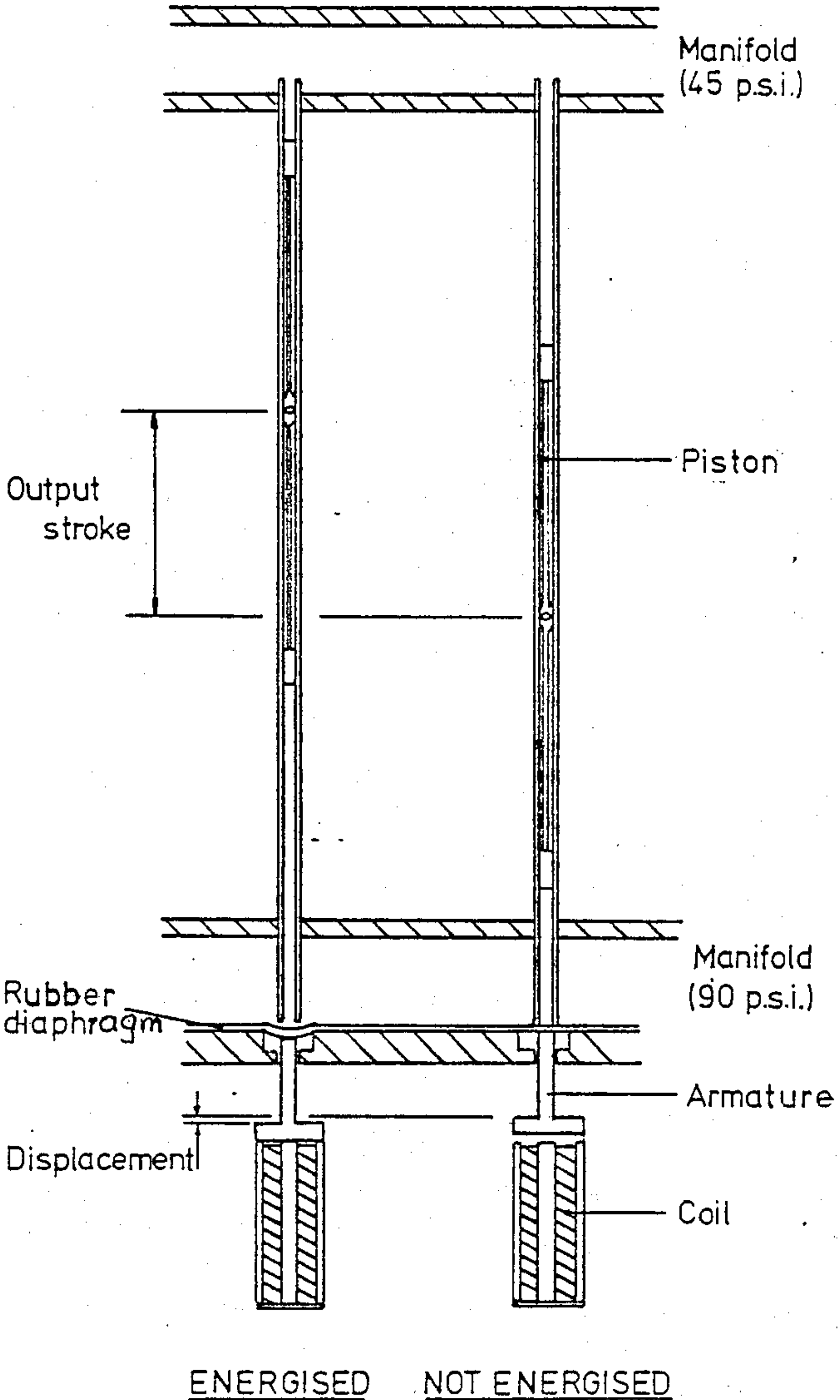


Fig. 5.1. The Pneumatic System

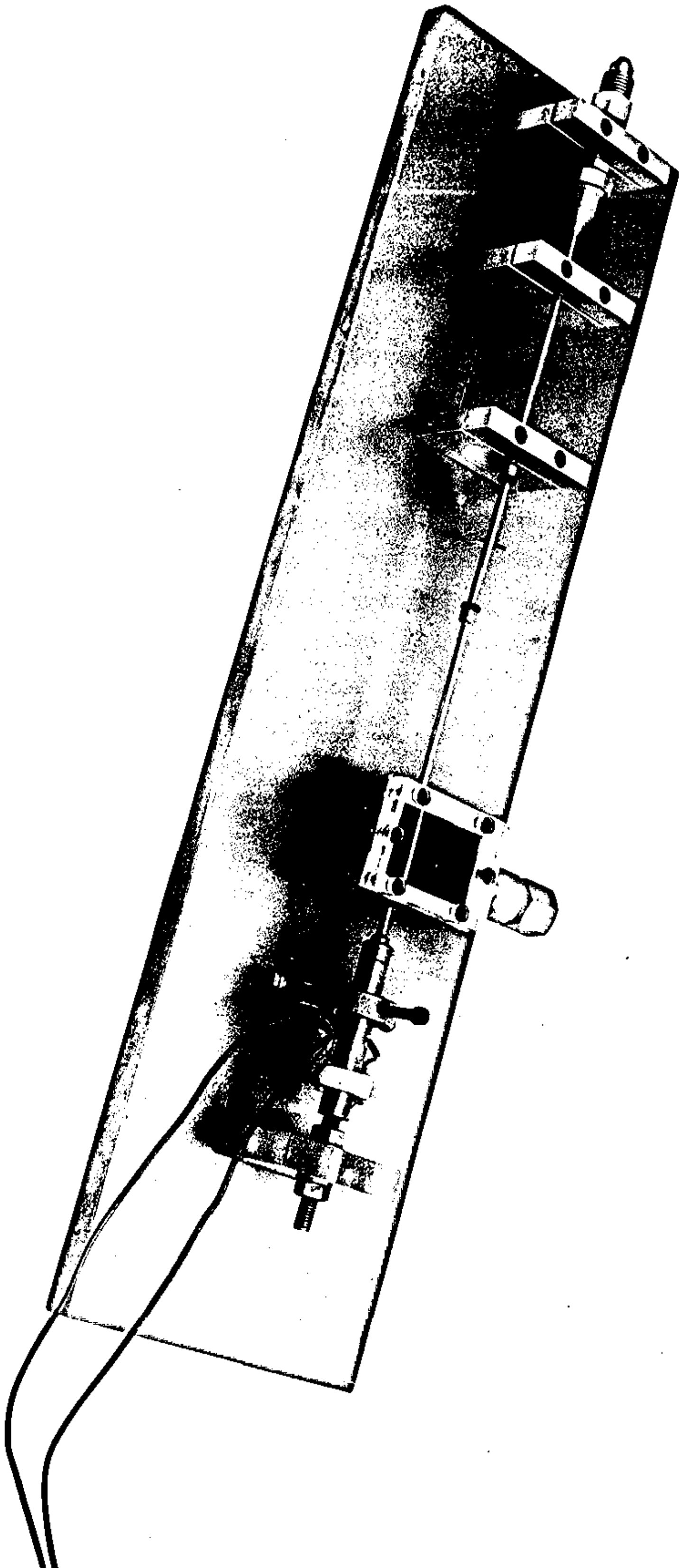


Fig. 5·2 The Pneumatic Rig.

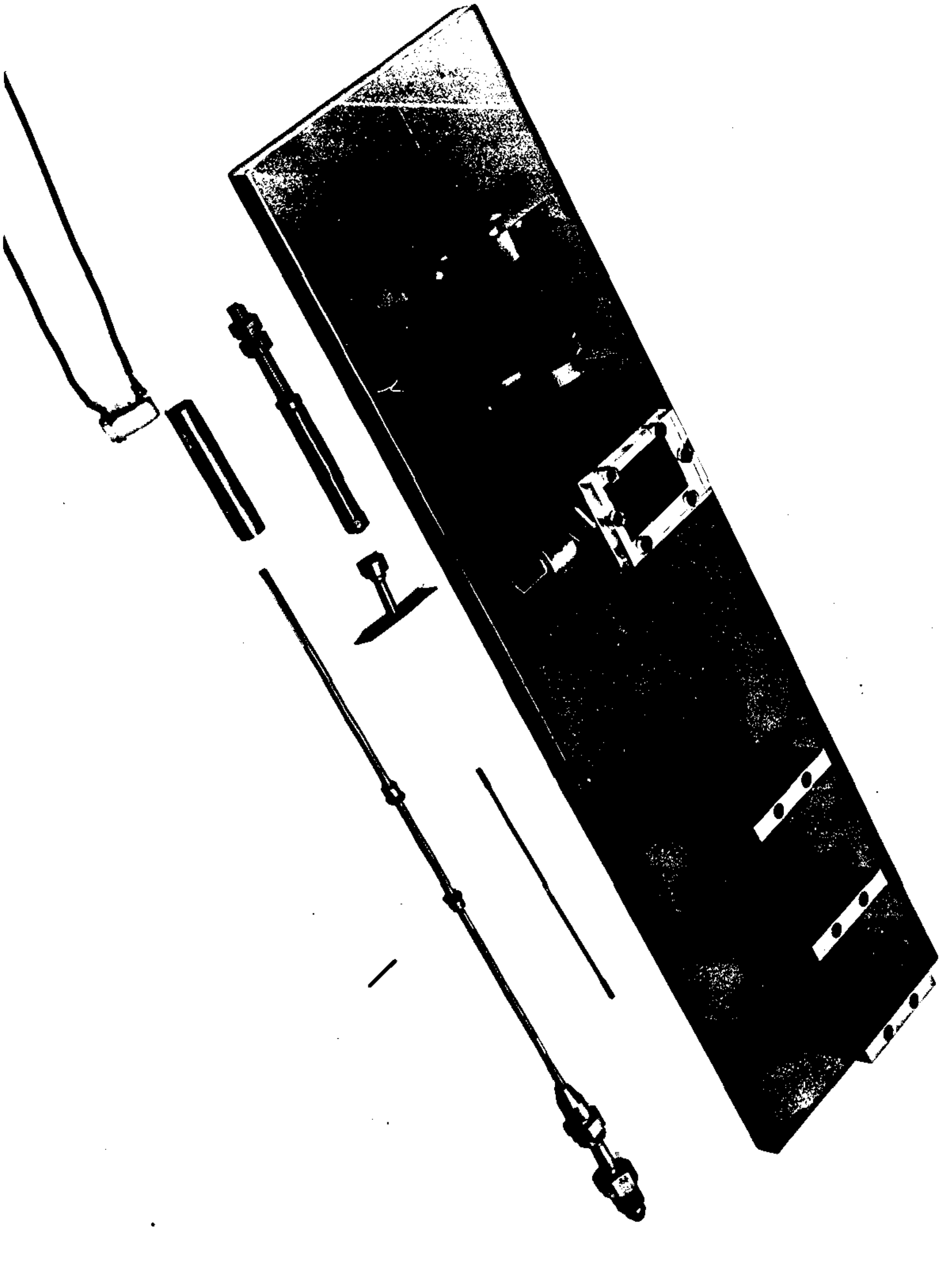


Fig. 5·3 The Components Of The Pneumatic Rig.

A pneumatic system was investigated initially (see Section 5.2.1) but after some experimental work the idea was abandoned. Work then continued on a mechanical system.

5.2.1 Development of a Pneumatic System

The system, as initially envisaged, (see Fig 5.1) consisted of very small bore (1mm diameter), purpose made, pneumatic cylinders and pistons. The cylinders were to be made from stainless steel capillary tubing, the pistons from silver-steel rod with PTFE ends and the pneumatic control was to be from a purpose made solenoid which pulled a rubber diaphragm away from the end of the capillary tube to allow air at high pressure to act on the end of the piston. The return motion was to be achieved by a lower air pressure acting continuously on the other end of the cylinder.

Figs. 5.2 and 5.3 show the rig which was built to test the system. It was intended that the warp yarn to be controlled would pass through a hole made in the centre of the rod of the piston, thus avoiding additional connecting components and keeping the moving mass and frictional forces to a minimum. To allow the yarn to pass through the walls of the cylinder, two slots were cut opposite each other in the tube. The only satisfactory way of doing this was found to be by electrodischarge machining, which left a smooth, burr-free edge. After trying, unsuccessfully, to make a piston with PTFE ends, brass was used. This required a greater clearance in the cylinder than the PTFE to obtain similar frictional drag, the result being a greater leakage past the piston end. This was further increased by the tendency of the capillary tube, out of which the cylinder was made, to be imperfectly round, it having been manufactured by extrusion.

Another problem encountered with the tube was its tendency to bend, especially after the slots had been made in it. If the tube was not carefully supported, in a straight position, the piston jammed.

The solenoid which served to pull the rubber diaphragm from the end of cylinder tube was made with 900 turns of 36 SWG copper wire. This resulted in an impedance of 6.7 ohm and, being fed from a 14V source, the power consumption was 1.7 watt. The stroke required of the solenoid was 0.76mm , the force available with this stroke was 40gm rising to a 100 gm pull-off force. To obtain fast operation of the solenoid it was powered by a capacitor-discharge circuit, this provided an initial 1 amp pulse falling to a 0.5 amp holding current.

5.2.2 Results of Tests

The rig was set up with an air supply pressure of 620 KN/m^2, (90 lb f/in^2) on the solenoid controlled end, and 310 KN/m^2 (45 lb f/in^2) as the constant return pressure. This caused a 24gm force to act in either direction on the piston which had a weight of 0.95 gm.

The position of the solenoid with respect to the diaphragm was found to be very critical, so much so that, after a period of operation during which the solenoid would warm up, the thermal expansion of the solenoid was sufficient to require a resetting of its position.

To test the speed of response of the system the solenoid was switched from a signal generator, the frequency of which was increased until the piston had just sufficient time to complete its stroke before the air pressure was switched.

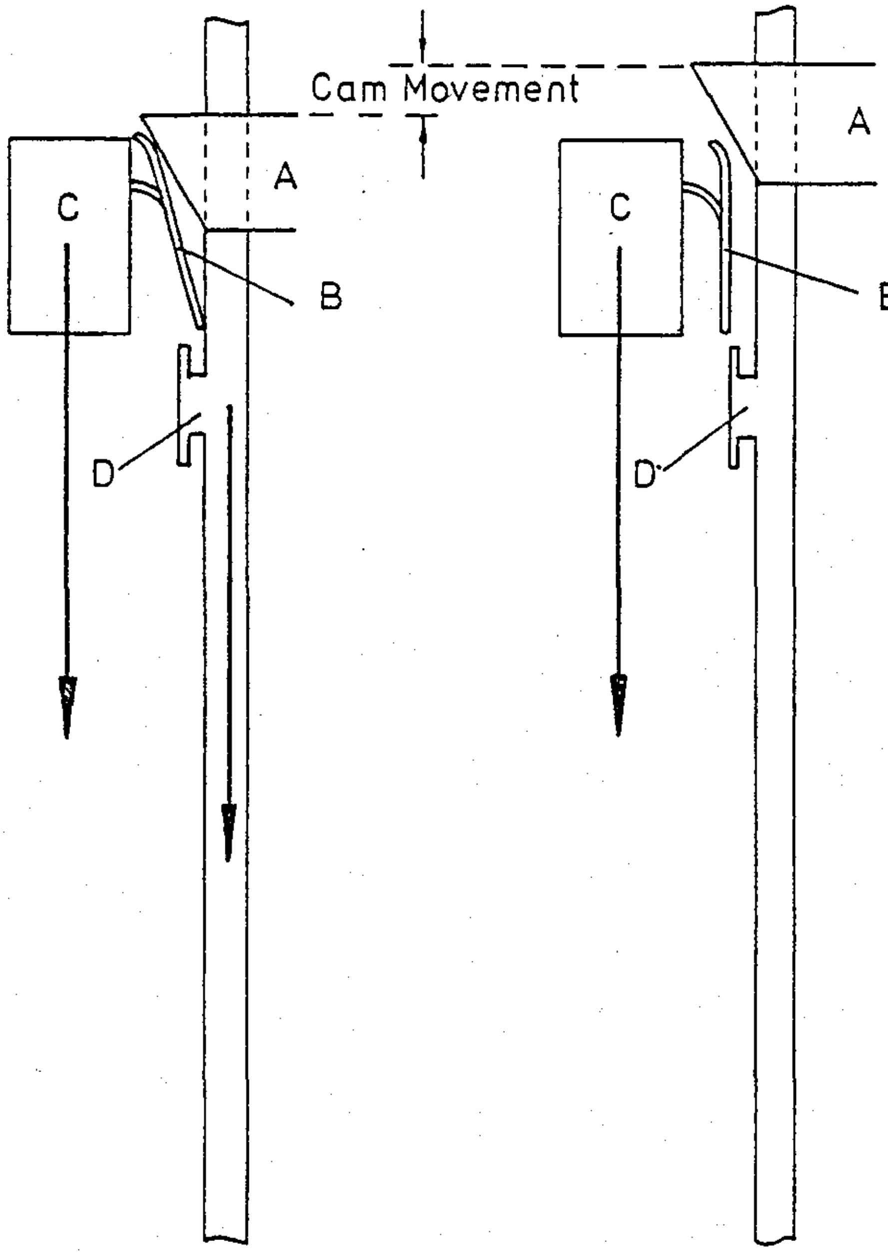


Fig. 5.4. The Spring/Latch System

For a 25mm stroke the maximum frequency achieved was 5 Hz, i.e. 100mS to travel from one end of the stroke to the other. This compared with 20 mS allowable for a 50 mm stroke if the 3000 ppm is to be achieved.

Bearing in mind the inadequate results of the test, and the careful attention required for setting up the system if it was to work at all, it was concluded that the chance of the system being improved sufficiently to meet the specification was very low and so work was discontinued on this pneumatically based approach.

5.3 MECHANICAL SPRING LATCH

5.3.1 Basic Concept

Following the failure of the pneumatic system the next idea to be tested was the spring latch system. It was obvious after a short while that electromagnetic forces could not provide motions large enough and fast enough to drive the heddle directly. The aim of this system is to act as a 'mechanical amplifier' of a small movement, which can be electromechanically derived, into the large output stroke required for shedding.

The basic concept, (See Fig 5.4) is to use a linear cam, A, to open a spring latch, B, attached to member, C, which is continuously reciprocating over the required output stroke. The cam is held in one of 2 positions; if it is positioned such that it is nearer the centre of the motion of member C, the spring latch will be opened when the member reaches the end of its stroke. In this open state the spring latch on the return stroke, will engage with a lug on the heddle D. The heddle is then driven by the latch through the stroke of the member C. As the member returns the latch will automatically disengage.

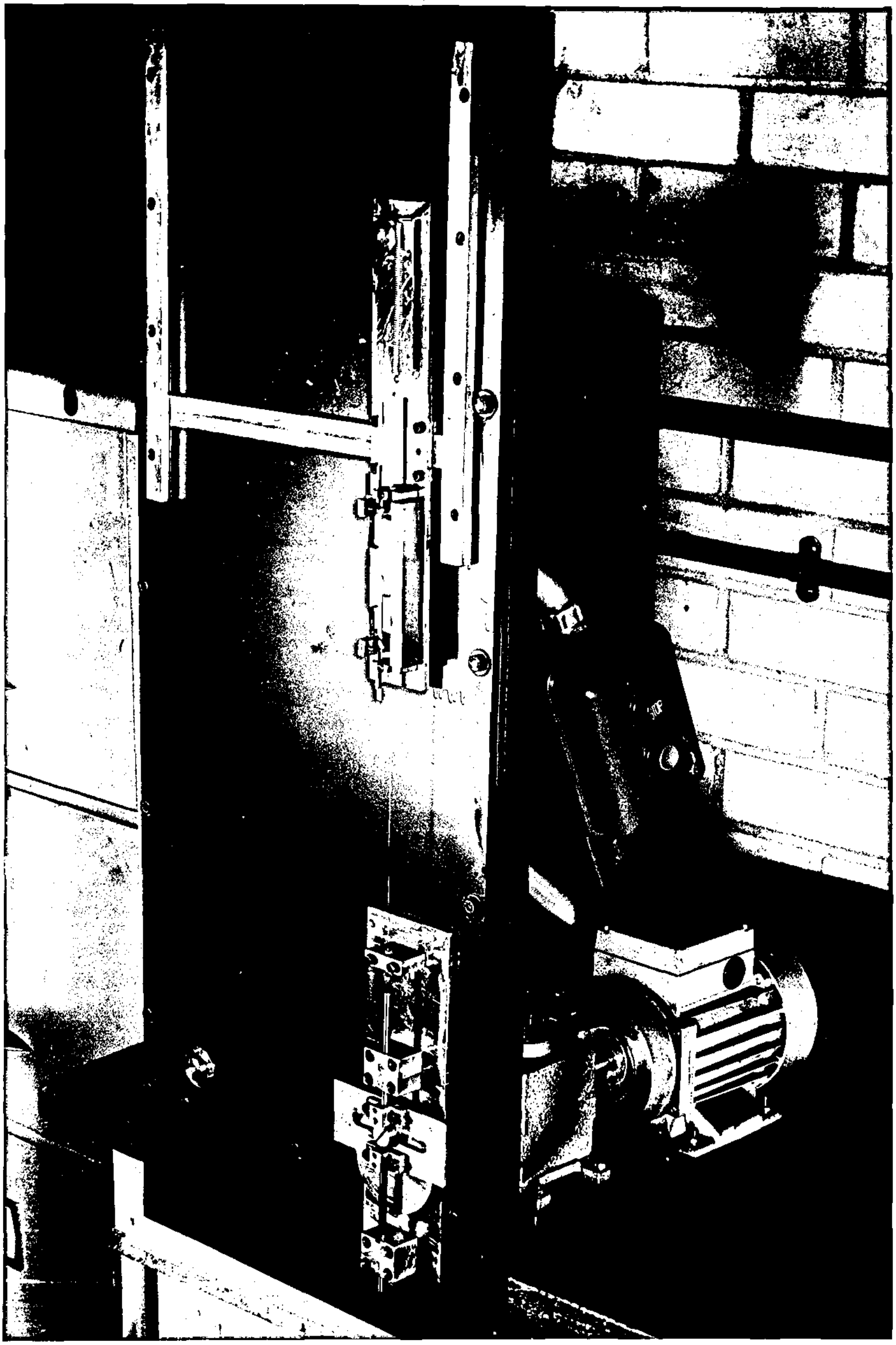


Fig. 5·5 The First Rig.

If however, the cam is in its position furthest from the centre of the motion, the spring latch remains closed and consequently misses the lug on the heddle as the member C makes its return stroke, consequently the heddle remains where it is. The mechanism is duplicated to drive the heddle on the return stroke of member C.

The position of the linear cams therefore determine the position of the heddle, the input signal being a 2mm movement.

5.3.2 Development of the First Rig

5.3.2.1 The Rig

A powered rig was built for the purpose of investigating the behaviour of mechanical spring latch systems as described in the previous section (see Fig 5.5). It consisted of a means of producing a sinusoidal reciprocal motion. This motion could be then used to move a member corresponding to member C, to which could be attached the spring latches. The linear cams for this work were fixed so that the latches were opened at both ends of the stroke on every cycle. Thus the heddle was driven continuously up and down but was reselected at each end of its stroke. This allowed work to be carried out on the latch performance without having to deal with problems of the electromechanical interface at this stage.

The rig was so constructed as to allow testing of various cords and wires whilst held under tension and guided through various eyes. This was in case it was found necessary to expand the spacing of the heddle actuators to make connections to the heddles via some form of flexible ties.

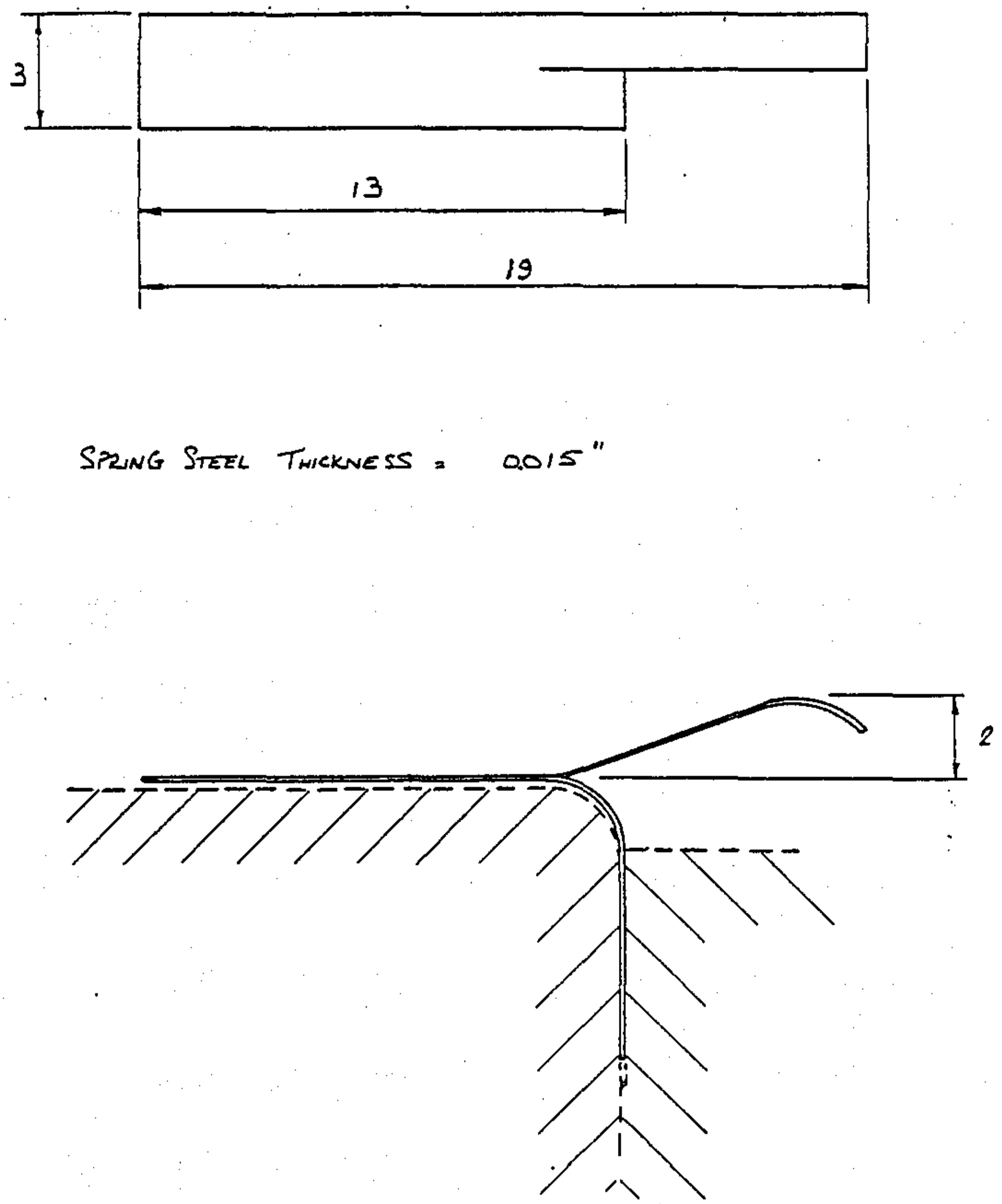


Fig 5.6. Spring Latch Dimensions

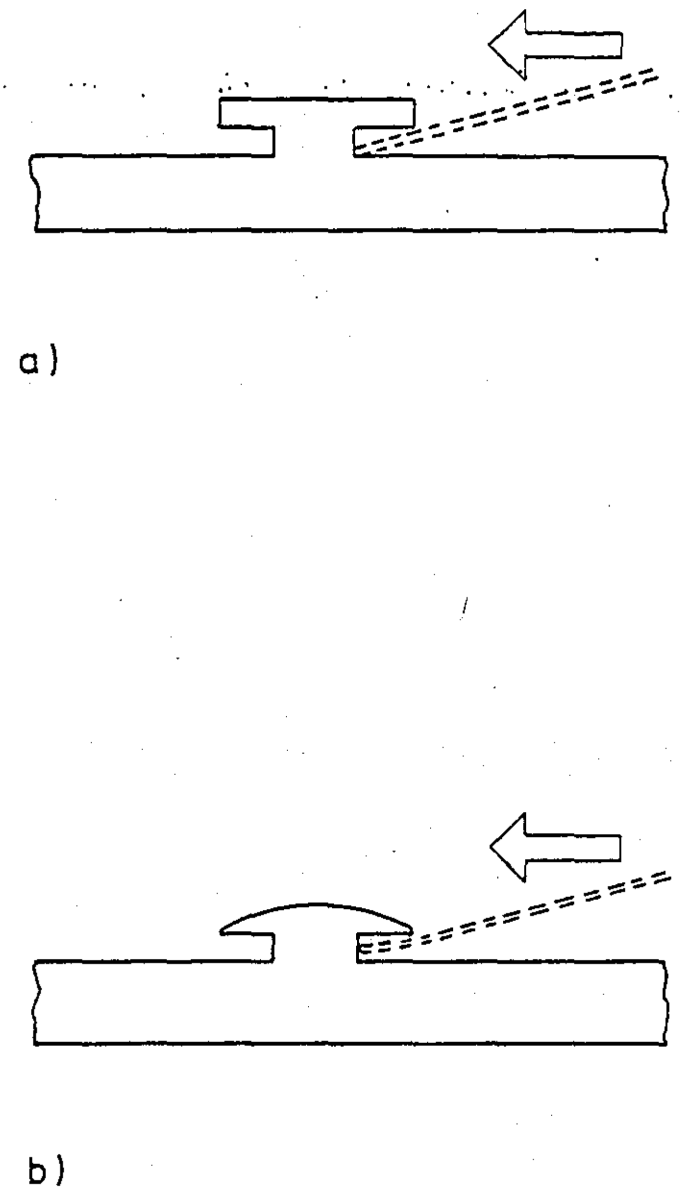


Fig 5.7 a) Original Drive Lug.
b) Modified Drive Lug.

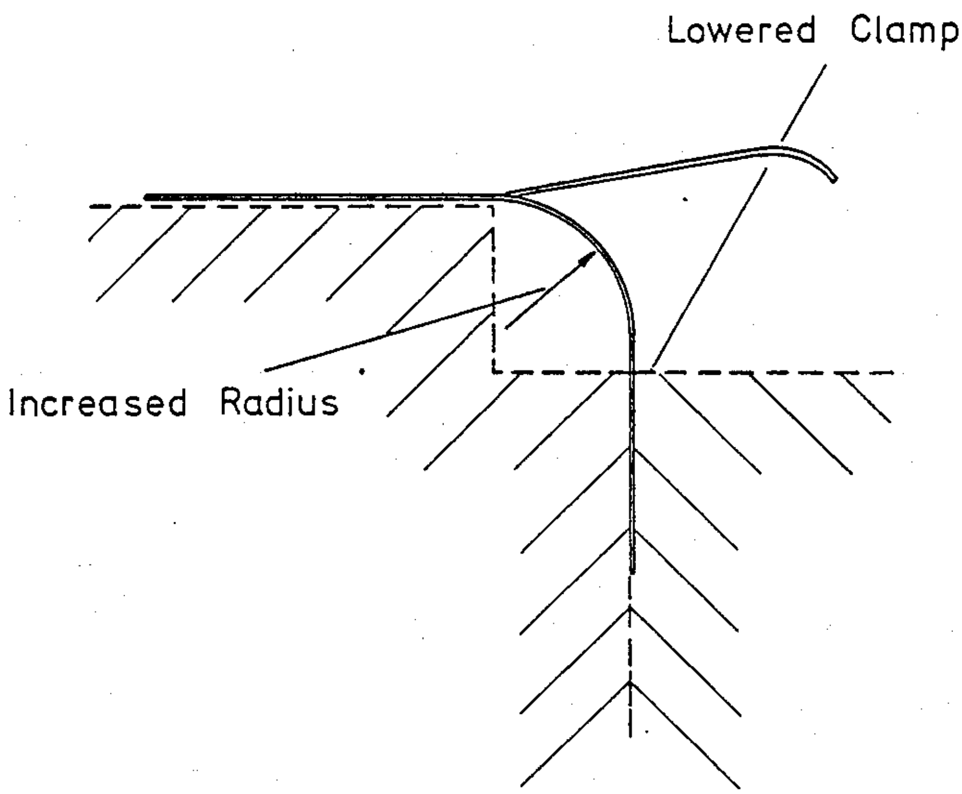


Fig 5.8. A Modified Latch

5.3.2.2 Fig 5.6 shows the shape and dimensions of the spring latch/driving lug combination that was tried initially. Theoretical calculation of the forces required to bend the spring latch proved to be complex and inaccurate due to the small size and difficulty in dealing with complex shapes and variable reaction points. A practical approach produced results far more quickly and the thickness of the spring steel used was reduced from the initial 0.035" to 0.015". The shape of the drive lug on the heddle was also soon modified to that shown in Fig 5.7. It was found that the original shape retained the latch well enough if there was sufficient resistance to the motion of the heddle; this was undesirable as excess forces would be required to move the heddle and so the modified shape was used. This retained the latch more effectively.

A detent system was fitted to the heddle to prevent overrun and with this combination of latch and lug, the rig was run at speeds up to 1000 picks per min.

However, it was soon found that the latches were not satisfactory in that after a short period of use fracture occured at the point of maximum bending. Variations in the hardening and tempering procedure failed to improve their performance.

In an attempt to improve the strength of the latches the radius of the bend of the support leg was increased and the effective length of the leg increased by clamping further from the bending zone, see Fig 5.8. These modifications made little difference however.

As an alternative, the thickness of the spring steel was reduced to 0.005", the aim being to reduce the maximum value of strain in the material of the latch, due to the bending of this leg. Naturally this resulted in 'weaker' spring action, but it still appeared to be sufficient.

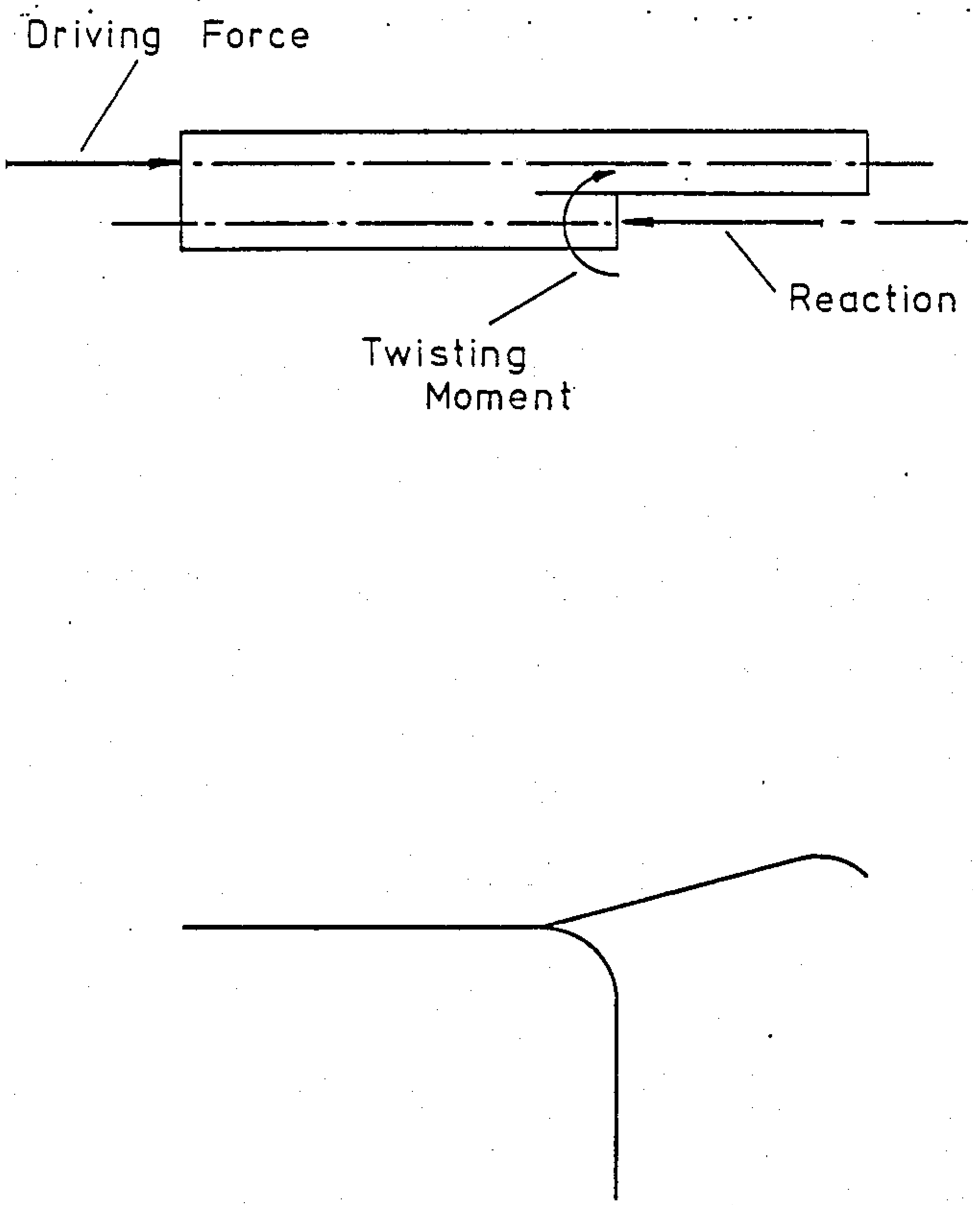


Fig 5.9. The Effect of Offset Loading

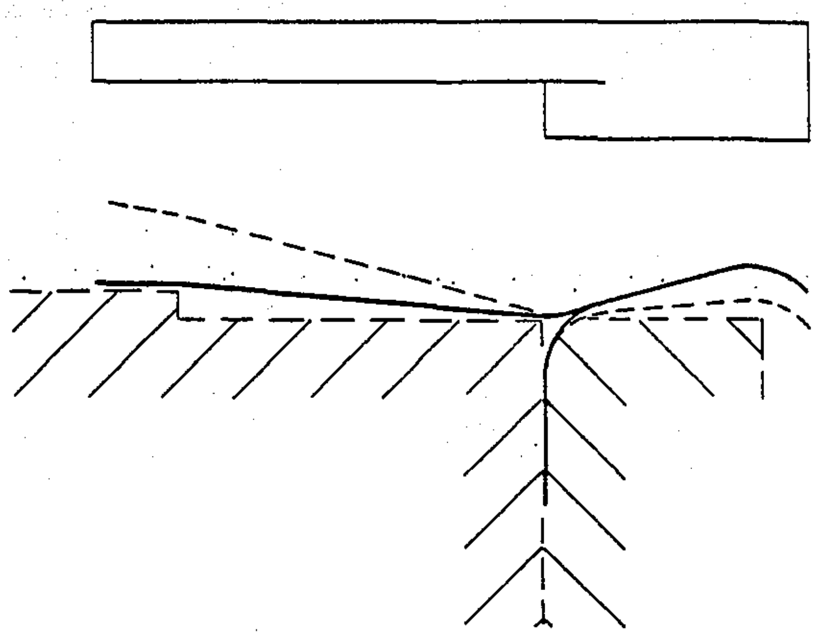


Fig 5.10 The Reverse Leg Latch

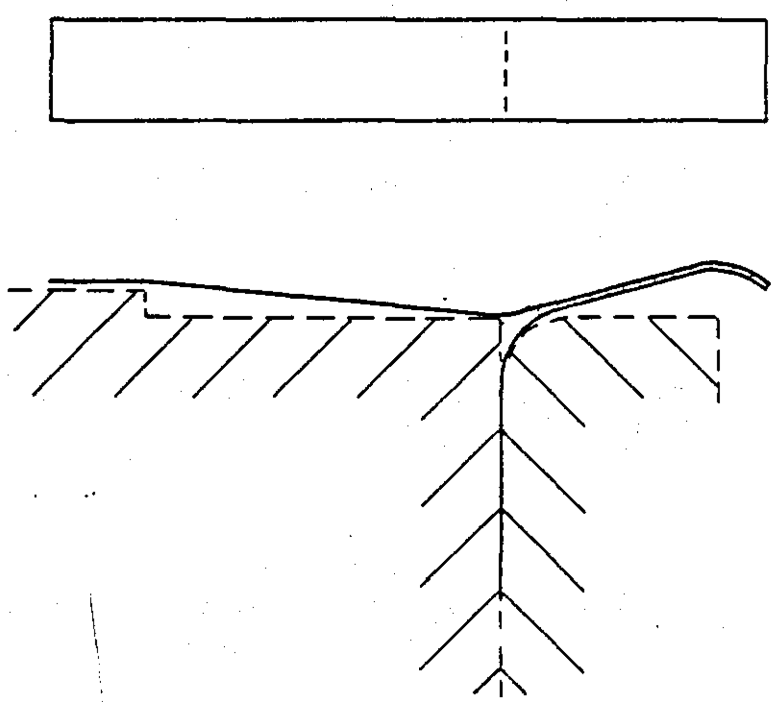


Fig 5.11 The Soldered Combination Latch

These springs ran satisfactorily with few failures due to fracture occurring. However two faults were noted. Firstly it was found that after a period of running the latches suffered a permanent set, i.e. they failed to fully recover their original shape; secondly, offset axial loading of the latches (see Fig 5.9) produced a twisting moment which, combined with the permanent set, resulted in occasional 'misses' i.e. failure of the latch to engage the heddle.

It was at this stage that a further variation of latch shape was tried. The new form had a bend of the support leg in the opposite direction to that used previously (see Fig 5.10). This meant that the portion of the latch on which the cam acted was double the original width, and consequently stiffer. The advantage of this was that less motion of the latch was lost because of deflection in this part of the latch. Additionally the clamp which held the leg of the latch could be contoured to fit the shape of the open latch, so as to give much greater axial support to the latch. Trials of this latch were performed with the rig and, whilst improvements were observed in the aspects expected, actual performance deteriorated due to an increased susceptibility to the twisting moment caused by the offset load of the heddle.

To overcome the twisting problem a step was taken which had been avoided previously. That was to make a latch from two pieces of spring steel soldered together (see Fig 5.11). The joint itself would be an area of possible failure and the additional eventual manufacturing costs incurred by this more complex design would probably be several times the cost of a latch if it were a one-piece design. It does however, have many benefits, including: having a greater resistance to the twisting moment; the ability to choose two different thicknesss of spring steel for the leg and the lever; a very much stiffer cam follower; and due to the spring being wider, the spring could be thinner for a

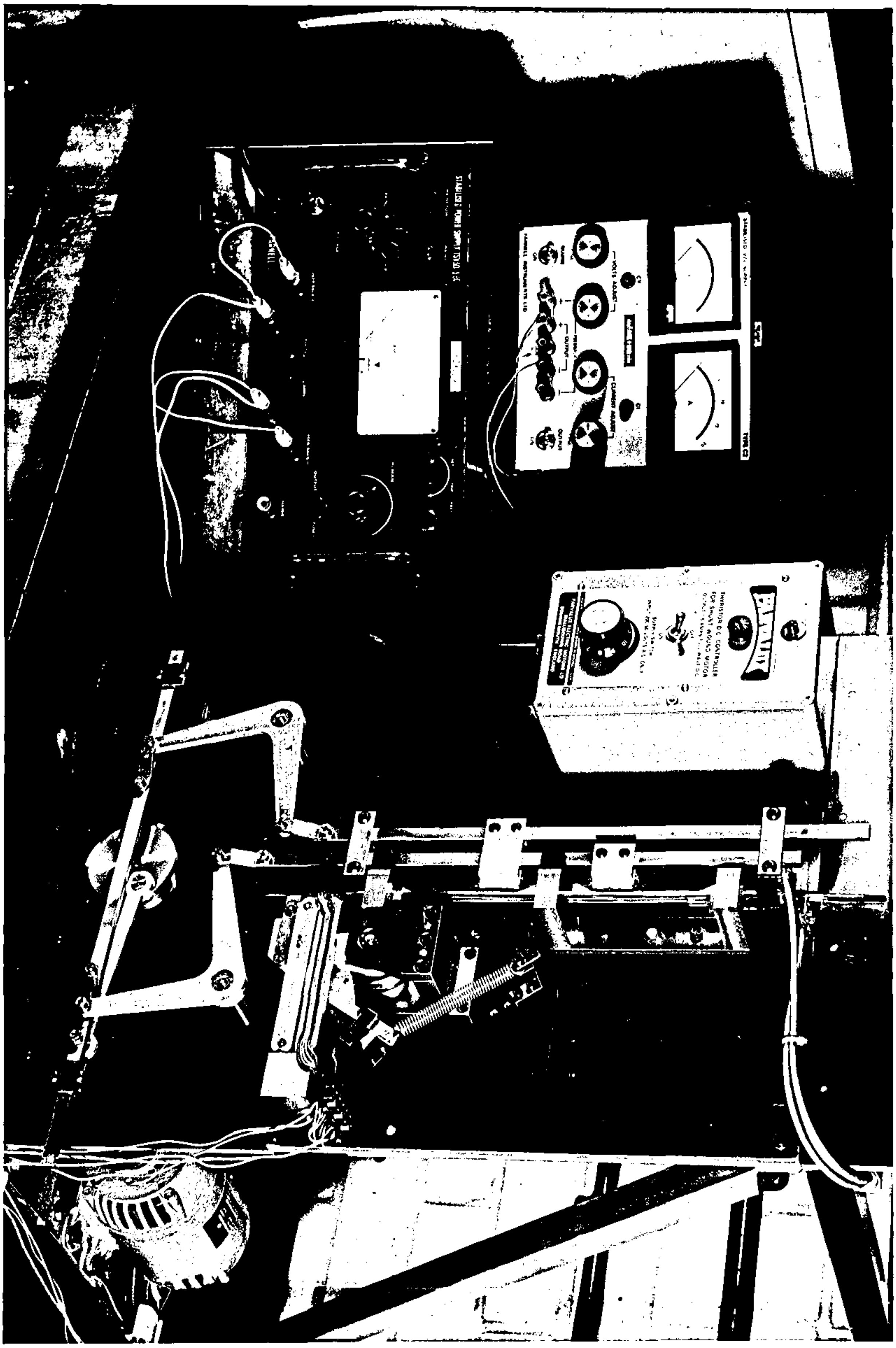


Fig. 5·12 The Second Rig.

particular closing force, resulting in lower strain levels and consequent increased life.

The composite spring latches generally worked well, such failures as did occur tended to be caused by the failure of the soldered joint used to hold the parts together.

One very important aspect of the system which had not yet been tested was the ability of the spring latches to act selectively. There was no provision for a moveable selection cam on the first rig and it was decided that, rather than modify this rig, it was better to build a new rig, capable of selective actuation and incorporating several other features which would be required for a more complete testing of the principle.

5.3.3 Development of the Second Rig

5.3.3.1 The Rig

Figure 5.12 shows the second rig built for development of the mechanical latch system. It features two vertically reciprocating members, phased so that as one rises through its stroke the second is descending. In this way motion is always available in both directions. The motion of these is derived from a rotating crank mechanism via two bell cranks. The resultant motion is very close to sinusoidal and the phase relationship of the two members is guaranteed.

The rig was designed to accommodate three sets of elements. This was so that the effect of adjacent systems could be observed, which could be important if some of the components, such as the latches, were made in a bank.

The drive for the rig was from a variable speed DC motor with an available range of speeds from 100 rev/min to 1500 rev/min (equivalent to 200 to 3000 picks/min). The motor also drove a cam shaft which operated a set of four microswitches, the output of these could be used as a pattern input to the selector systems. The pattern repeat of the camshaft was the equivalent of 12 picks and a sequence was used which tested each of the latches to engage, and to miss, the lug on the heddle element.

5.3.3.2 Control Element Motion Development.

One of the major reasons for building the second rig was to provide a movement to the latching cams to cause heddle selection. By virtue of the principle of the system, in order to move the heddle element in the desired direction, the movement of all four of the cams is the same, e.g. to move the element downwards, the upper cam must be brought towards the latch at the top of the stroke, i.e. downwards, whilst the lower cam must be taken back from the latch at the bottom of the stroke i.e. downwards also. This is repeated for the second pair of latches and so all the cams are moved in unison. This is important since it allows all of the cams to be attached to a single member known as the control element, and it is a small vertical movement of this which controls all of the latches cooperating with one heddle element.

To obtain the motion of this control element, direct acting solenoids were initially considered. However, due to the space constraint imposed by the necessity of eventually fitting the system to the loom the permissible size of solenoid was very limited. Calculations suggested that an adequate pull would not be available from a solenoid small enough to be accommodated, especially considering the high speeds desired. A trial was made using Diamond H, LSX 1 type solenoids which confirmed these pessimistic predictions

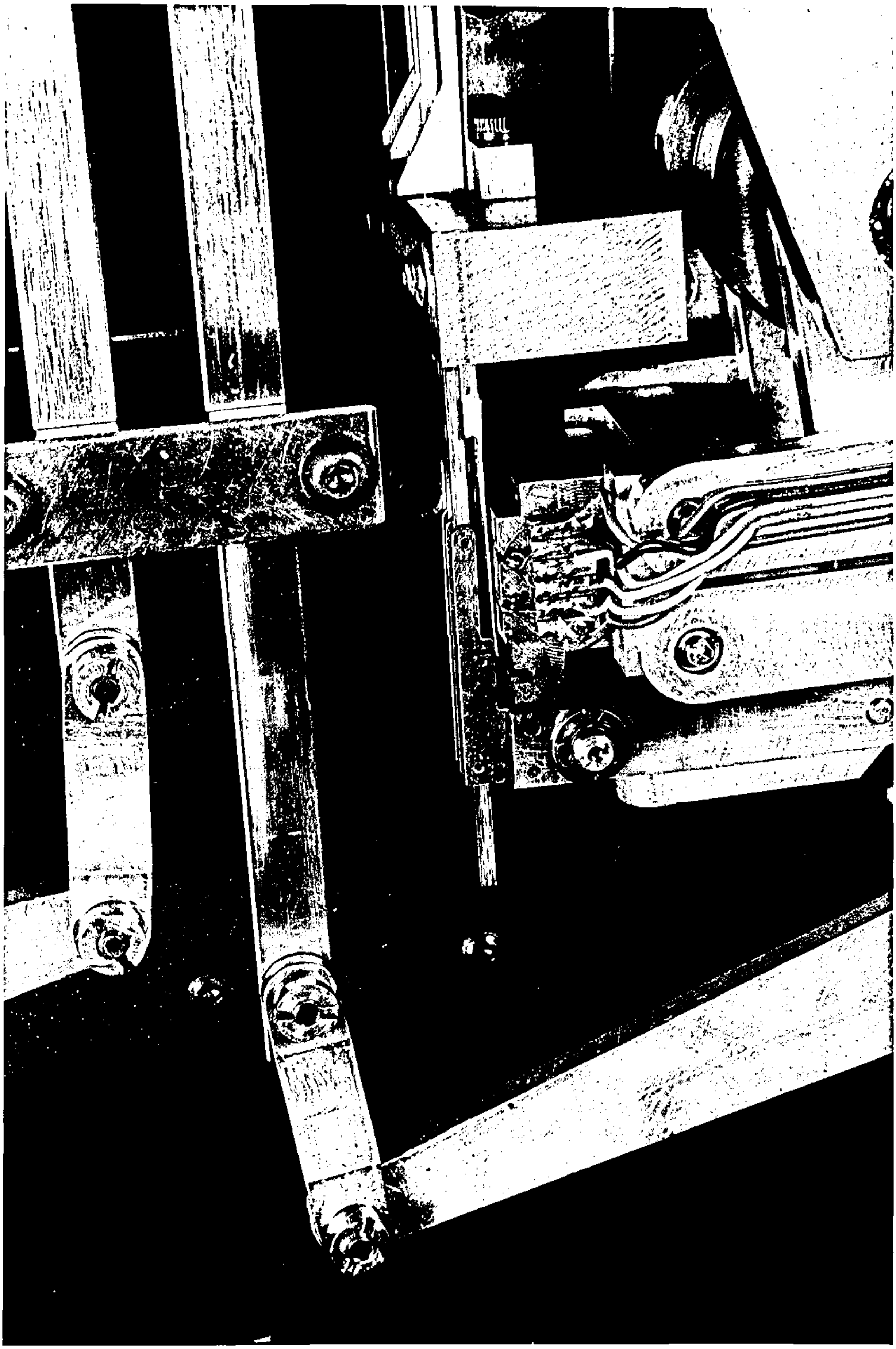
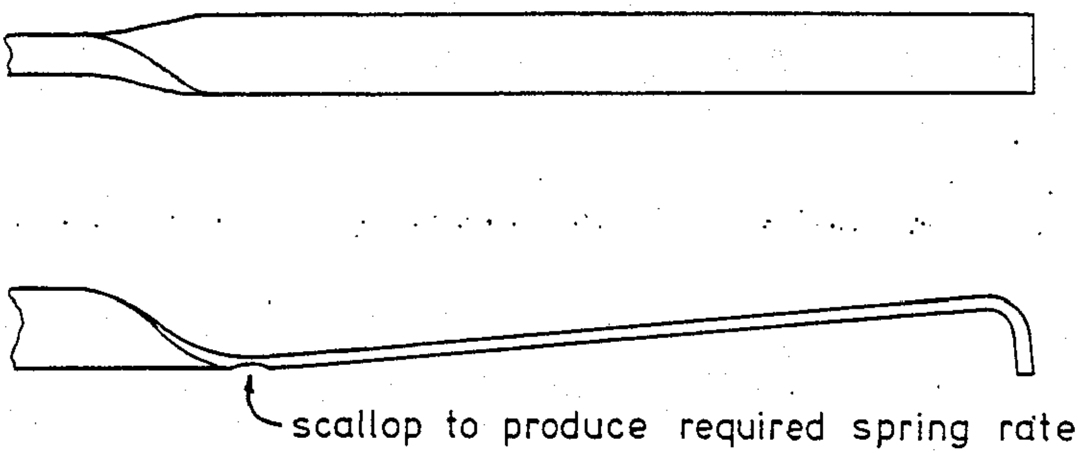


Fig. 5·13 The Magnetic Catch Mechanism.

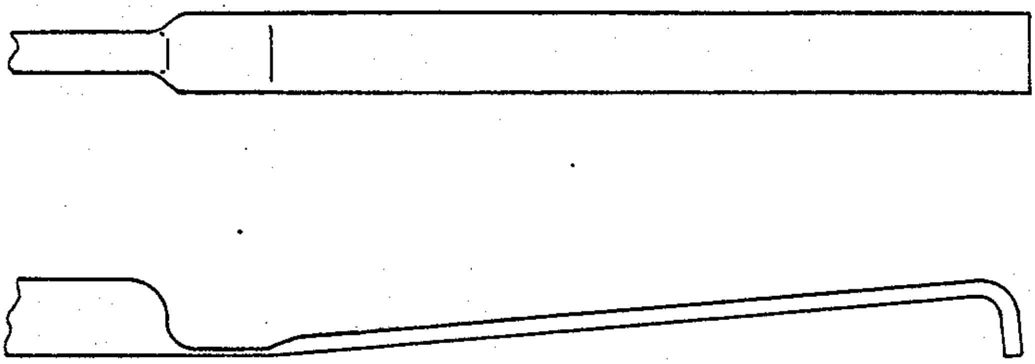
Therefore, a different mechanism was conceived to drive the control element (see Fig 5.13). This utilises an electro-magnetic catch; a coil being made and fitted into a hole in a cast iron block so that the face of the coil and its core are flush with the surface of the block. When the coil is energised any ferro-magnetic object which is placed against the surface of the block to cover the end of the coil, thereby completing a magnetic circuit, is held there by the magnetic field. In the case of the control element mechanism, the necessary ferro-magnetic object is the lower end of the control element which has been twisted and bent so that, in its relaxed shape, the end is held away from the block. A 'finger', acting on the back of the control element, then presses the lower end of the element against the force of the block where, if the coil is energised it is retained, as the finger retracts. Up to this point in the cycle the control element has not moved in the vertical direction. This is achieved by moving the coil block down and back up whilst it holds the end of the control element. To assist the transmission of the drive forces there is a hook on the end of the element which engages a slot in the block. The movement of the block is timed so that, at the bottom of its motion, the latches are reaching the ends of their strokes and the control element is either up, if the coil is not energised and the control element has sprung free of the block, or down, if the hook on the element is engaged by an energised coil.

In this form the control element drive worked at speeds approaching 600 picks/min. Two modifications were introduced after a short while to improve the performance. These were:-

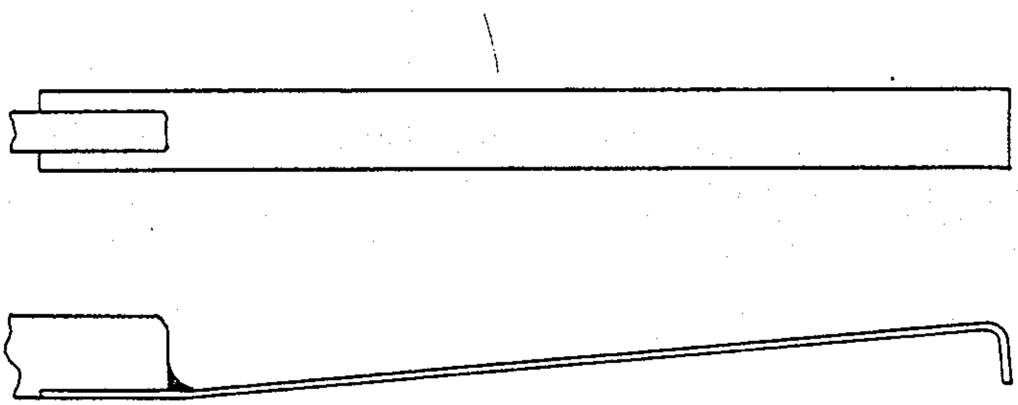
a) The lower end of the control element, which had been formed by twisting through 90^{o} (to achieve greater area of contact with the block) and thinning of the section of bending (to achieve the desired spring 'rate'), was now



a) Twisted Form



b) Pressed Form



c) Soldered Form

Fig. 5.14 Control Element Lower Ends

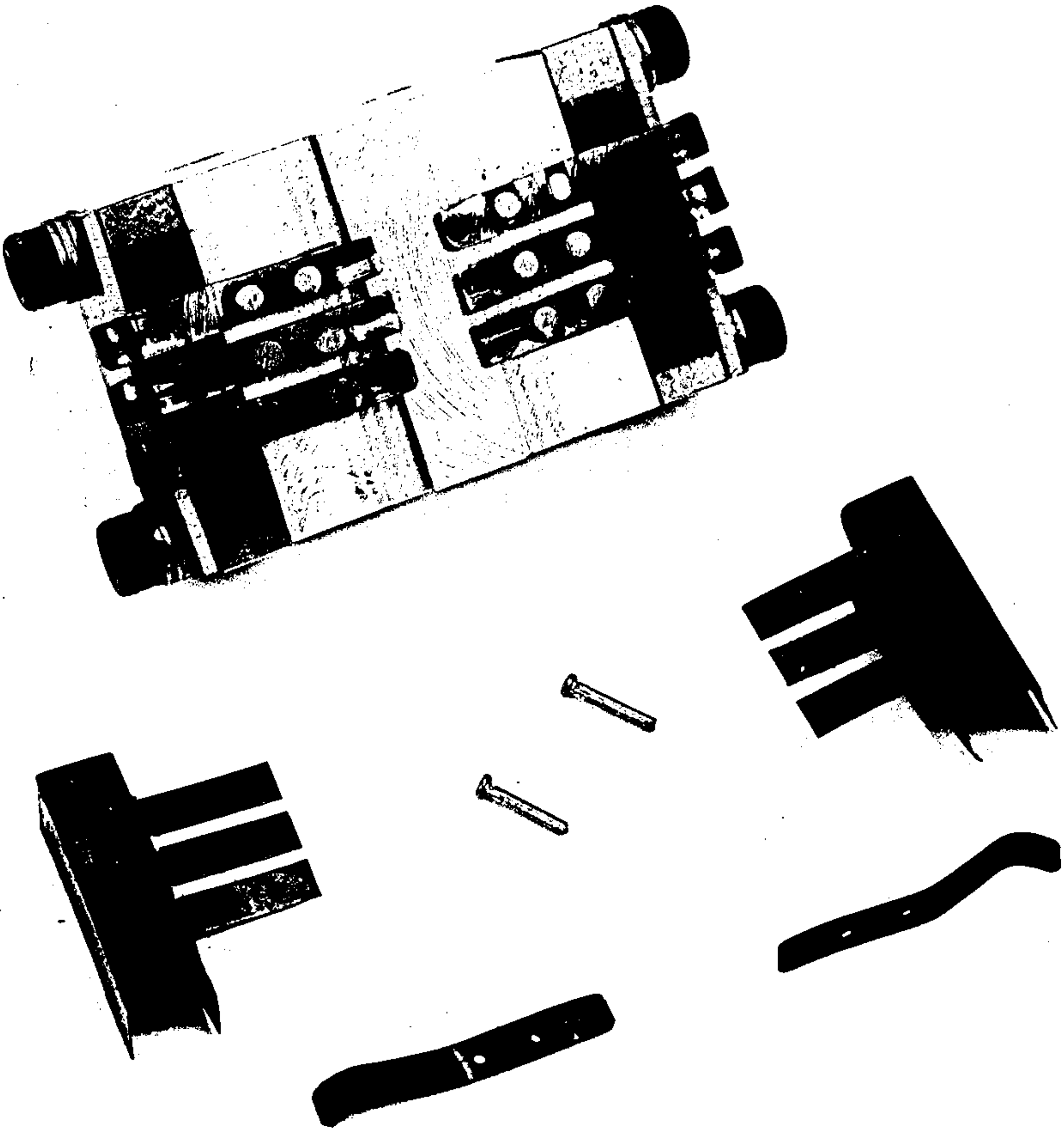


Fig. 5·15 The Combination Spring Steel Latches.

manufactured by means of a press tool made for the purpose. This produced the required shape in one operation and resulted in a more resilient component (see Fig 5.14).

b) The design of the coil was altered to increase the retaining force produced; this in turn allowed a higher spring rate to be used in the control element, thus facilitating an increased speed at which it would clear the block when not selected (for dimensions and performance of the coils see appendix 3).

In this form the control element drive worked at higher speeds, in excess of 1000 picks/min.

After considerable use it was found that the design of the control element end was not satisfactory, in that, despite careful heat treatment of the component, failures at the hook end and also in the region of bending occured on occasion. To overcome this problem the pressed form of end was discontinued and replaced by a spring steel end which was silver-soldered into position. The material composition of this part of the component was then far more suitable for the duties it needed to perform. Also it was easy to select the correct thickness of spring steel to match the performance of the coil and so obtain maximum operating speeds. It is this form of element end that is in use at the moment, the only difference being a higher melting point braze is used for the joint as this allows subsequent hardening and tempering of the spring to reduce the risk of brittle fracture close to the joint.

5.3.2.3 Latch Development

The design of latch tested on the second rig were of the type shown in Fig. 5.15. They were similar to the type used on the first rig, the major differences being:-

a) The supporting parts, or legs, of a row of latches were combined in a single piece of spring steel, appropriately cut to allow all of the levers (in the case of the rig, 3) to be mounted upon it and still be allowed independent movement. This principle would allow a simple method of mounting the latches and easy replacement of a whole row of latches without the requirement of precise location of individual latches.

b) The lever part of the latch was attached to the common supports by means of copper rivets rather than solder. This was an attempt to improve the reliability of the joint.

This form of latch was used with the same form of driving lug on the heddle element as was developed in the first rig. The system ran well with full control of heddle movement from the cam operated microswitches at speeds up to 700 - 800 picks/min. This upper working limit to speed appeared to be due to the latching of the spring on the heddle element. As designed, the latching action relied on the latch always pushing the heddle element. If the heddle moved forward relative to the latch drive, then the latch is released from the lug and the driving force to the heddle element was removed. It appeared that as the speed of the rig increased so did the 'uneveness' of the heddle motion until it was sufficient to disengage the drive.

In an attempt to overcome this problem, the latch system was modified so as to provide a more positive retention of the latch. The spring latch was replaced by a rigid lever secured in the drive block by a hinge pin, the drive lug on the heddle element being replaced by a fixed pin on the side of the element. When opened the latch lever located over the pin on the heddle element providing both a positive drive in the forward direction and a degree of restraint to prevent the heddle element from "running

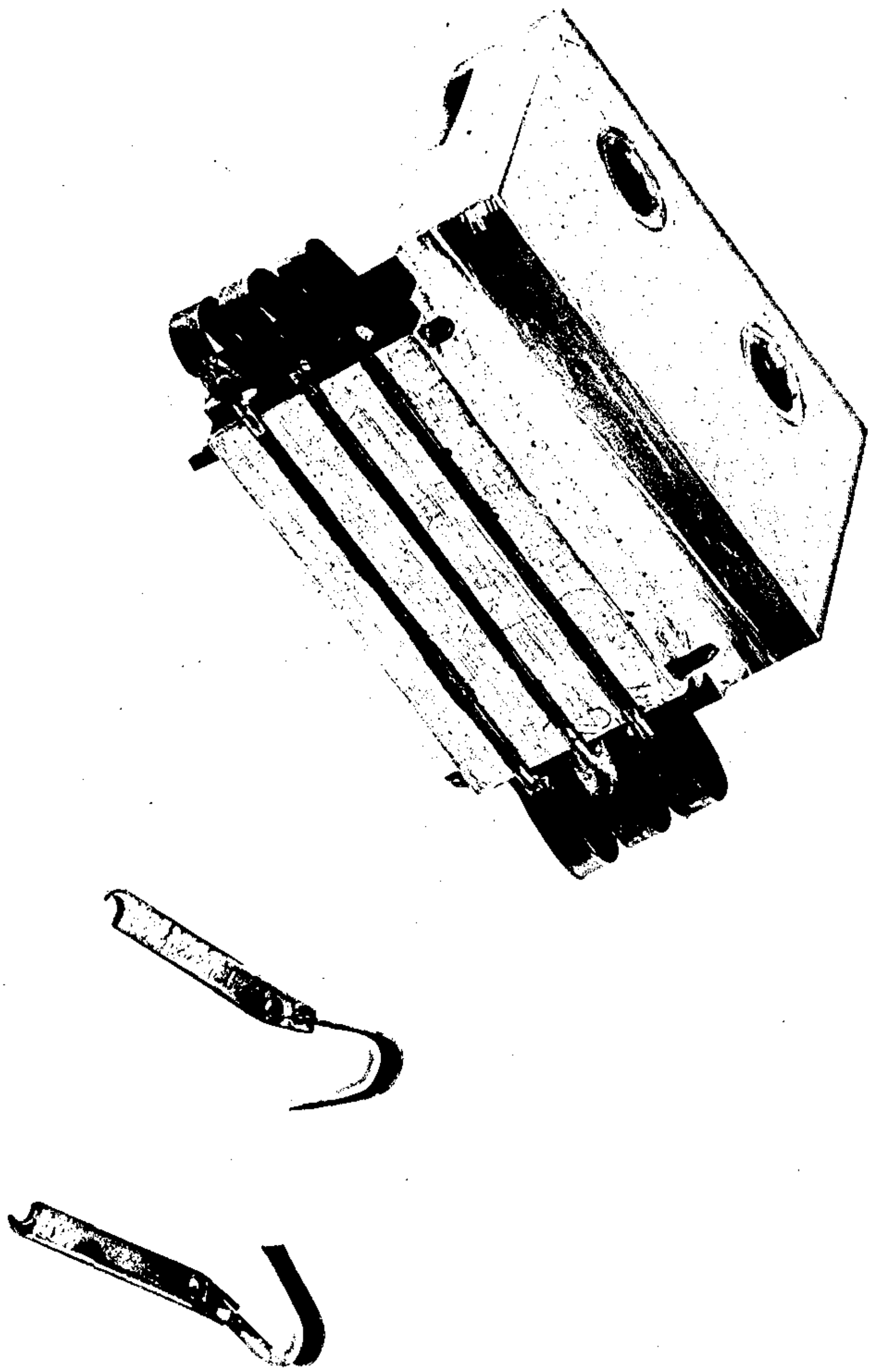


Fig. 5·16 The Pivoted Fabricated Latches.

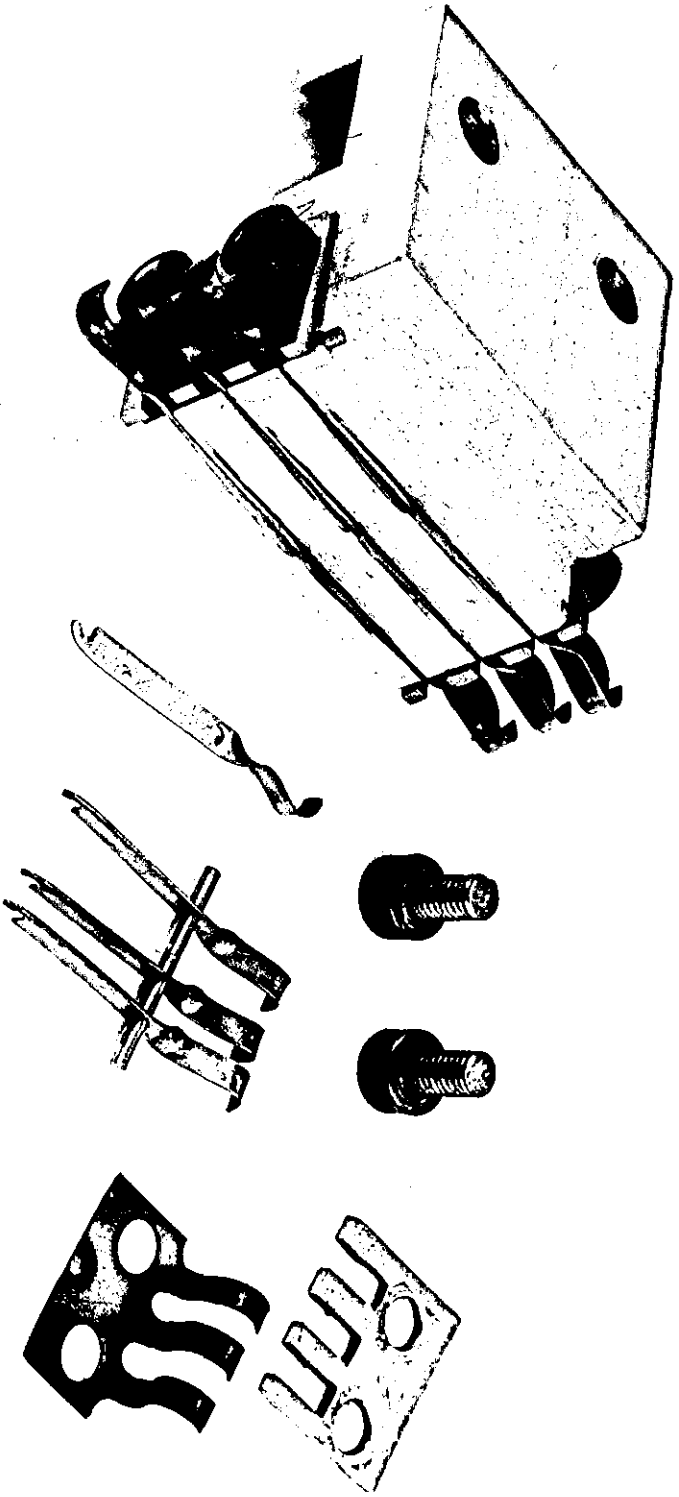


Fig. 5·17 The Pivoted Twisted Latches.

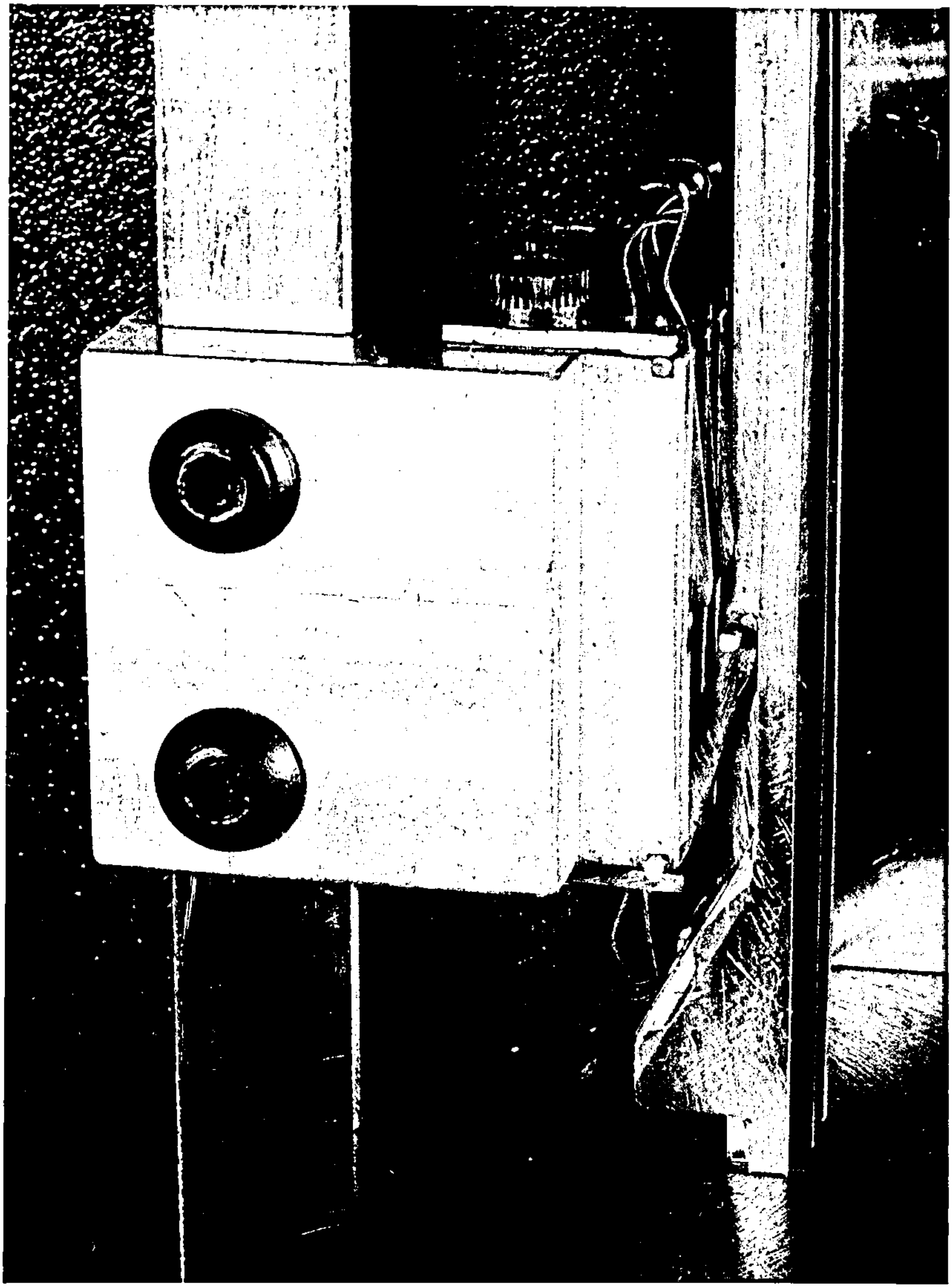


Fig. 5·18 The Twisted Latch Engaging The Drive Peg.

away" from the latch block (see Fig 5.16). To prevent the heddle element from being drawn backwards by the latch, once it has reversed its motion at the end of the stroke, a detent was fitted to the heddle element to hold it in its end position. This took the form of a length of spring steel, secured at one end and bent at the other so that its edge located in a nick in the appropriate position on the back of the element.

An additional benefit of the design with the latch then working along the centre line of the control element rather than that of the heddle element was that the twisting movement due to the offset loading of the latch by the linear cam, was removed.

It was at this stage that a photo-electric system which registered the heddle positions was fitted to the rig. This was necessary to check that the motion of the heddle elements was correct, as at the speeds involved it was impossible to follow the elements by eye. The output of these sensors was fed to an ultraviolet recorder to provide a permanent record of heddle movement.

This design of latch ran reasonably well; such faults as did occur were due to overstressing of the return spring portion of the latch resulting in deformation and fractures, and to inaccuracies of manufacture of the very small latch components, resulting in difficulties in obtaining a consistent performance.

With a view to the eventual manufacture of the latches a further modification was made; the lever was made from spring steel strip, twisted and bent into the required shape (see Fig 5.17 and 5.18) thus obviating the need to join two components as in the previous design. A separate return spring was used as this allowed a greater freedom of choice for the thickness of the spring material and hence the force produced.

In this form the system ran satisfactorily at 1200 picks/min. Faults started to occur at speeds in excess of this and they were due to a variety of reasons:-

a) The control element drive was close to its upper speed limit, miss-selection and hook end fracture occuring occasionally;

b) The latches missed the drive peg; and

c) The latches remained open resulting in selection by two latches moving in opposite directions - with disastrous consequences.

5.4.1 System Review

At this stage in the development of the system it was felt that although improvements in performance had been obtained by modifications, the price paid was a greater complexity of the system and an increase in the number of components required. These trends were not desirable in that they would most likely be accompanied by an increase in cost of manufacture and a decrease of reliability in service. Consequently the system was reviewed with these points in mind. The outcome was the system as it stands now (see Chapter 4)

5.4.2 Control Element Motion

The major change made here was to invert the operation of the mechanism. The lower end of the control element still engages a slot to derive its motion, but now the spring bias of the hook is such as to maintain this engagement rather than to disengage from the slot. The coil block, when energised now serves to hold the hook out of mesh. Three advantages have been gained:-

i) The electrical connections to the block are not subjected to any flexing or movement;

ii) The relatively heavy coil block is held stationary whilst a light 'slot' is moved; and

iii) The finger has been replaced by a presser which is more precise in its positioning and also constructed with a flexure rather than a hinge pin or bearing.

In rebuilding this part of the rig the opportunity was taken to experiment with other coil forms in an attempt to obtain the best compromise between the space occupied and the performance of the coil (details in Appendix 3).

5.4.3 Latch System

When reviewing the system, and the way it had developed, it was thought that some of the advantages of the original concept had been lost. The main drawbacks were:-

i) the way the latch itself, originally made from a simple pressing of spring steel and all its motion being due to its flexure, had become a precisely shaped piece of spring steel, involving drilling and twisting;

ii) a hinge pin, subject to wear;

iii) a separate closing spring;

iv) a mounting block requiring delicate milling and drilling; and

v) the precise assembly of all these parts.

After much though,.involving again the principle of inversion of function, the present system (described in the previous chapter) was conceived. The hinged latch on the cross member has been replaced by a latch, pressed from spring steel, attached rigidly to the heddle element. The driving peg on the heddle element becomes a driving lug on the cross member. The ramp-like linear cams on the control elements become the "cutouts" on the new control elements. The advantages gained are numerous and include:-

a) There are no moving parts on the cross-members and the banks of driving lugs which are simply machined are easily replaced should it become necessary.

b) Should damage occur to a latch, the heddle element is easily replaced with another. The setting of the latches is easily achieved with a jig.

c) The amount of rubbing and the forces involved in the opening and closing of latches by the control element is reduced.

Despite the primary objects of these system changes being a reduction of cost and increase in life and reliability, an almost immediate increase in operating speed was achieved. The main reasons for this were the greater ease with which the components were made, the greater tolerance allowable in the system, and the very much easier "setting-up" of the system. In this form speeds in excess of 1600 picks/min were consistently achieved.

CHAPTER 6: THE WEFT SELECTION SYSTEM

6.1 INTRODUCTION

The object of the study, as described in this thesis, is to develop a method of introducing patterns into woven fabric at very high speeds. The achievement of the novel high - speed warp selection, as described in Chapter 4, satisfies this basic criterion ; with it's use, woven fabrics could be produced incorporating a wide variety of warp figured patterns and fabric constructions (see Section 2.2). However in commercial terms a pattern employing weft figuring is preferred to one employing warp figuring. The reasons are:

(i) warp figuring requires coloured yarns to be present in the warp over the width of appearance of that colour in the pattern, in addition to the base fabric warp yarns. Being supplied in the warp direction, these yarns must be present along the full length of the fabric. Thus more yarn is normally consumed to produce a given area of colour than when employing weft figuring;

(ii) warp figuring requires a large number of coloured ends of yarn, which normally have to be wound onto a beam; weft figuring is usually achieved with a single end of each colour, taken directly from the yarn package;

(iii) since, with weft figuring, the warp contains only yarns required for the base weave, the same warp can be used on a wide variety of patterns, whereas the warp required for warp figuring is usually wound to incorporate the figuring yarns for one specific design ; and

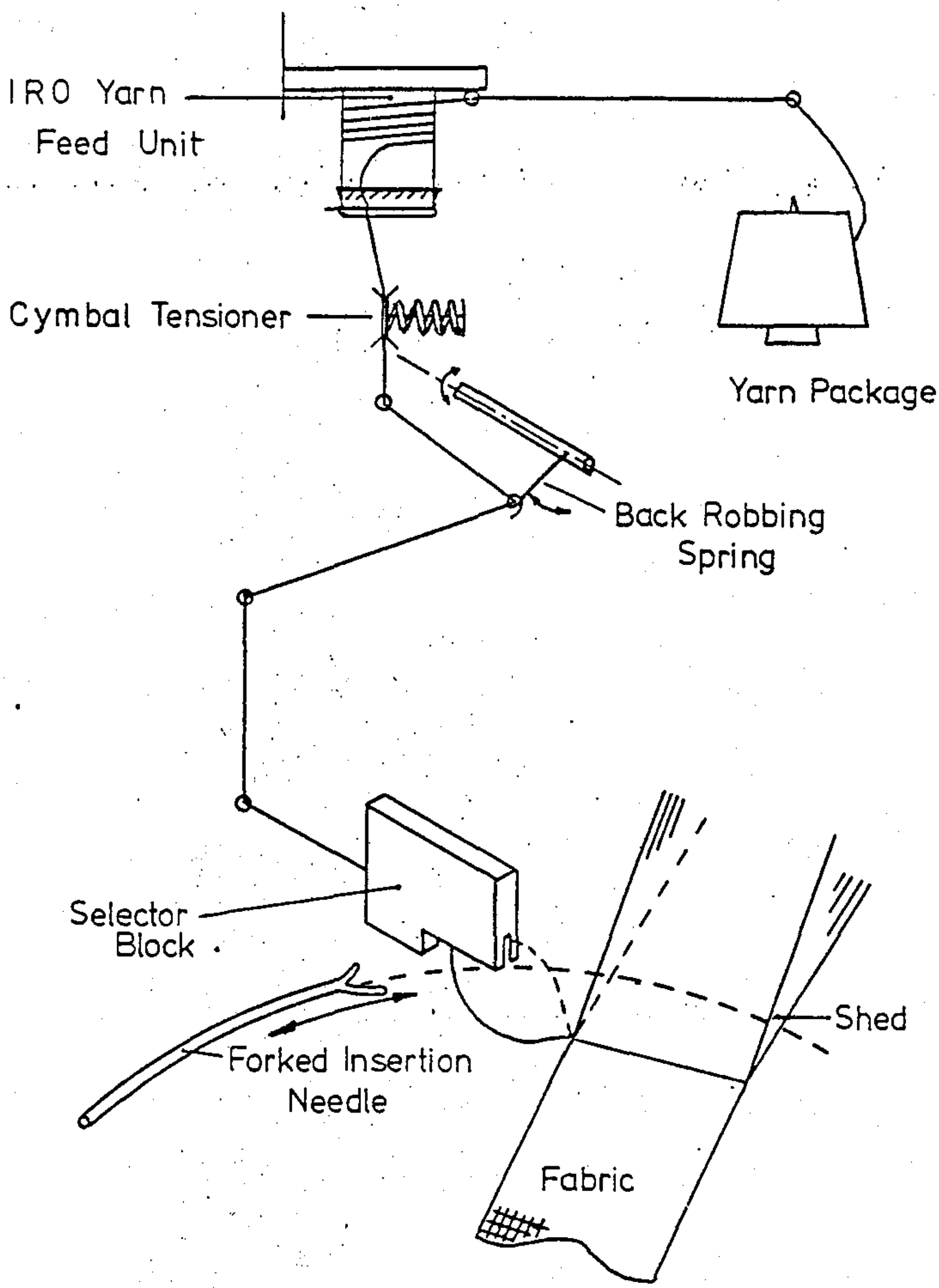


Fig. 6.1. The Weft Selection System

(iv) to change from one warp figured design to another, usually entails the complicated, and tedious, drawing in of the new warp, whereas a change of weft figured design often requires only a change of the weft yarns and the pattern input data.

Consequently, if a system of weft selection is available for use with the warp selection as described in Chapter 4, the scope of the combined system is very large and it is more likely to gain commercial acceptance than a warp selection system alone. It is also possible that a weft selection system would find application in producing striped, check and tartan type fabrics in conjunction with conventional cam chain shedding.

This chapter describes the system in the developed form. The subsequent chapter summarises the preliminary research and the development work which resulted in the system described here.

6.2 OUTLINE OF SYSTEM

The system is shown schematically in Figure 6.1. Each weft yarn is drawn from its supply package by a commercially available yarn storage and feed device positioned close to the weaving zone. It is drawn off at a constant low tension. Additional tension is applied as required by means of a conventional cymbal tensioner. The yarn passes to the weft selector via a simple device which alternately feeds the yarn forward and draws it back on a cycle synchronised to the weaving machine.

The weft selector consists of a series of air jets, one for each yarn. Each yarn is drawn through its corresponding jet by the air flow in it. In the normal state the yarn leaves the jet block from its front face; if however a secondary jet, angled down across the main jet, is fed with air the yarn will leave the jet block through the bottom face.

Any yarn leaving the jet block via the front face is well clear of the forked weft insertion needle as it advances on a path which takes it just below the jet block before entering the shed of the warp. Any yarn corresponding to a pressurised secondary jet which leaves via the lower face is caught by the weft needle and carried through the shed to form a pick. The retention of the loop in the shed is by conventional means, either a weft knitted edge or a catch thread knitted edge.

6.3 SYSTEM COMPONENTS

6.3.1 Yarn Feed Arangement

The weft yarn feed system as fitted on the standard Bonas Varitex 2/65 loom is similar to that found on most narrow fabric needle looms. The single weft yarn is drawn from the supply package at a constant rate, i.e. a preset fixed length of yarn, is supplied for every cycle of the machine. As a result the fabric produced is even and consistent, more or less irrespective of the tension in the yarn.

This system works well in a situation where the same yarn is used for every pick. Unfortunately, it will not work when several weft yarns are used in some form of sequence and as a consequence each yarn is used intermittently. It was necessary therefore to change the yarn feed system for one in which yarn is fed to the insertion needle only as required. Any form of positive feed would require an intermittent drive of very fast response and the very high weaving speeds quoted in the specification would involve extremely high accelerations and decelerations of the yarn and more particularly of the feed mechanism. Such a system would therefore be expensive and liable to inaccuracies in yarn feed resulting in poor quality fabric.

Consequently, the system employed with the weft selection system uses the yarn tension to control the yarn feed; basically if the yarn is pulled so that the tension rises to a preset limit, yarn is drawn from the system until sufficient has been supplied to lower the tension.

The yarn is actually drawn from the supply package brought to the weaving area by an IRO yarn storage and feed device, type SFS 1706. This unit stores a length of yarn around the rotating body of the device, the yarn being dispersed over the end of the body at an even, low tension. Thus variations in tension due to the package winding and minor snags along the yarn path from package to weaving area are overcome.

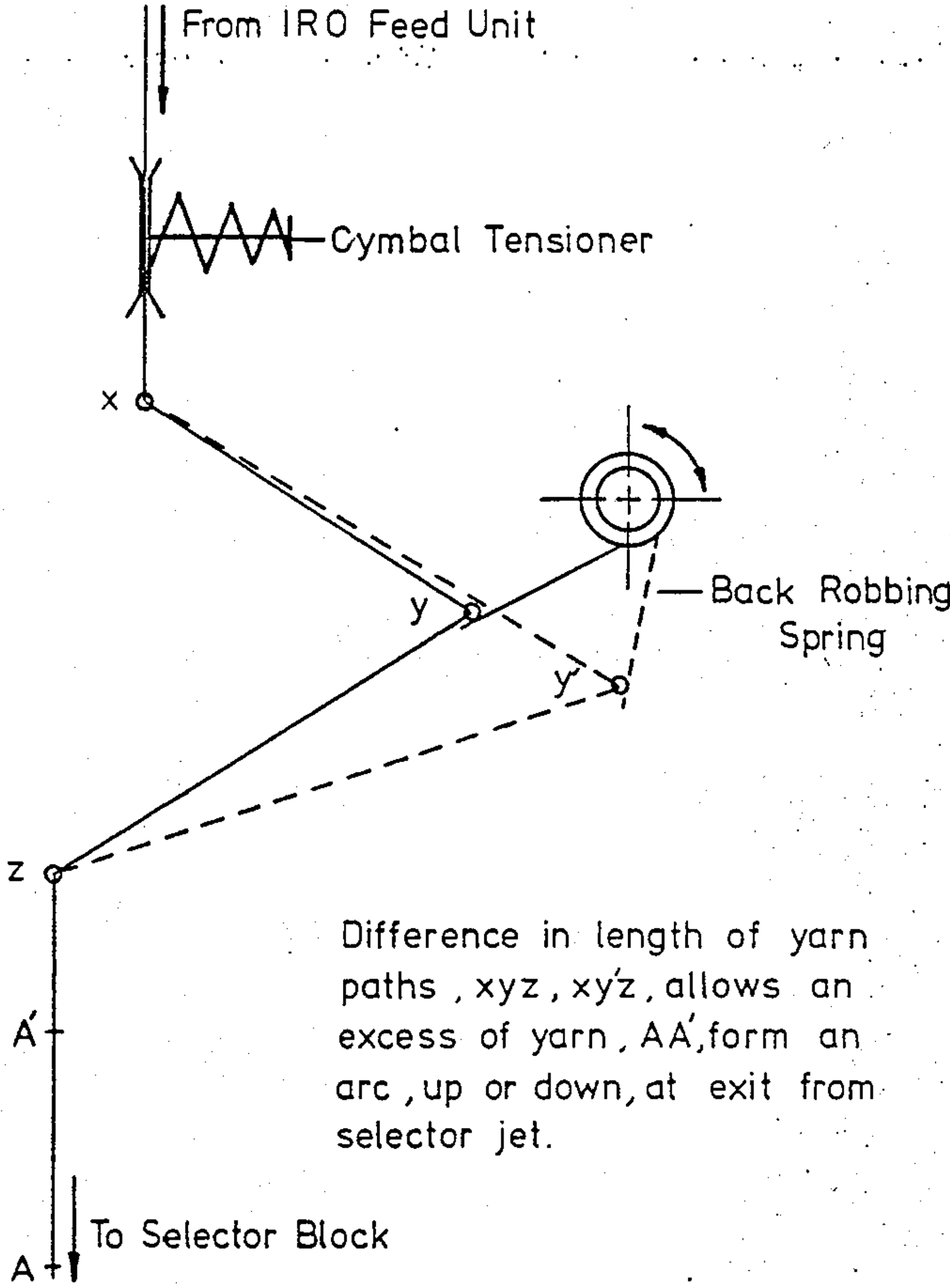


Fig. 6.2. The Means of Back Robbing

The low even tension is then increased to the desired level for weaving by means of a cymbal tensioner. Here the yarn is passed between the faces of two discs which are pressed together by spring pressure. The tension in the yarn is increased by the friction of the yarn on the plates. This device, unlike the storage unit, can only increase yarn tension and since the tension increase is addititive, variations of input tension are apparent at the output, hence the need for the storage unit to provide an even input tension.

To enable the selection jets to function, a small amount of extra yarn, at very low tension, is required immediately prior to the yarn pick up by the weft insertion needle; this allows the yarn on leaving the jet to arch either upwards, away from the weft insertion needle, or downwards, into the path of the needle. Later in the cycle, as the weft insertion needle starts to retract, the excess yarn needed to allow the latch needle to enter the weft loop is released and must be drawn back to produce a tight knitted selvedge. This forward and backward feed of the yarn is accomplished by a simple device, a straight wire spring attached, radially, to a reciprocating shaft. (See Figure 6.2) The yarn passes through an eye in the end of the spring and the device is positioned so that the yarn path length between the cymbal tensioner and the weft selector is altered as the shaft reciprocates; the shortening path allows the excess yarn to feed forward through the jet to form the desired arch, the lengthening path draws the surplus yarn from the knitted selvedge.

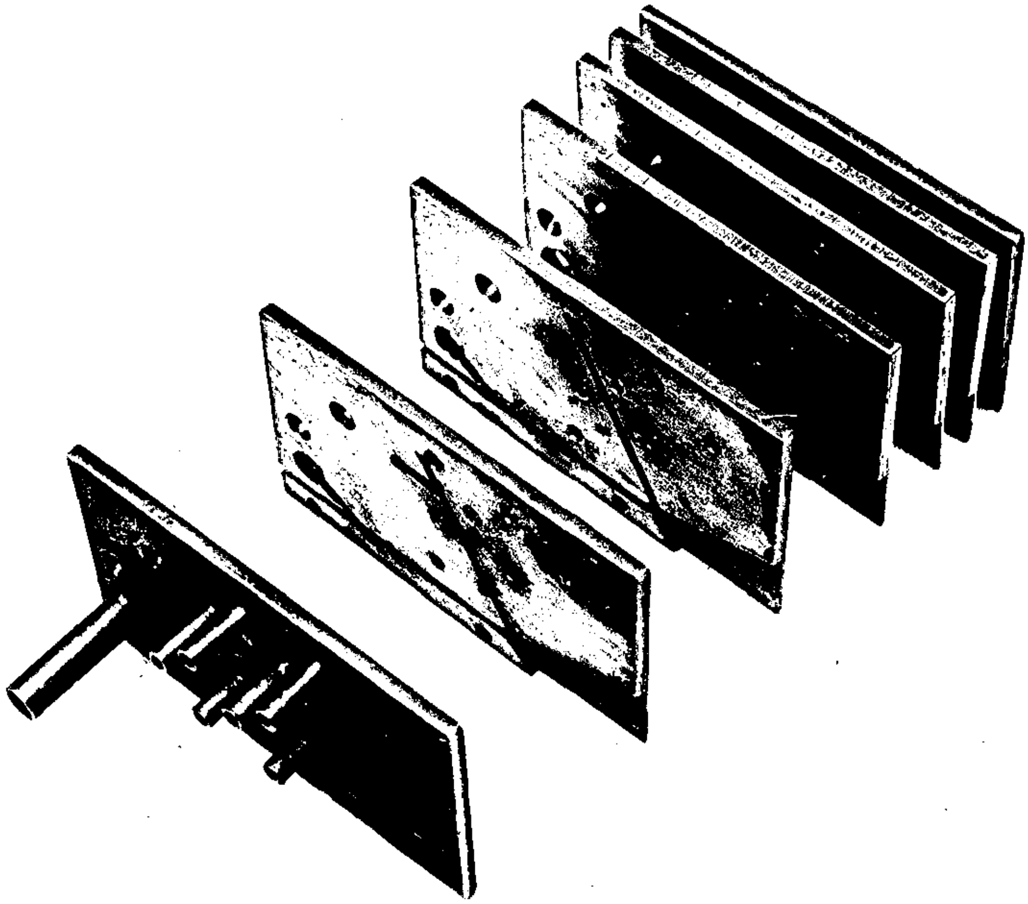


Fig. 6·3a Wafer Construction Of The Jet Block.

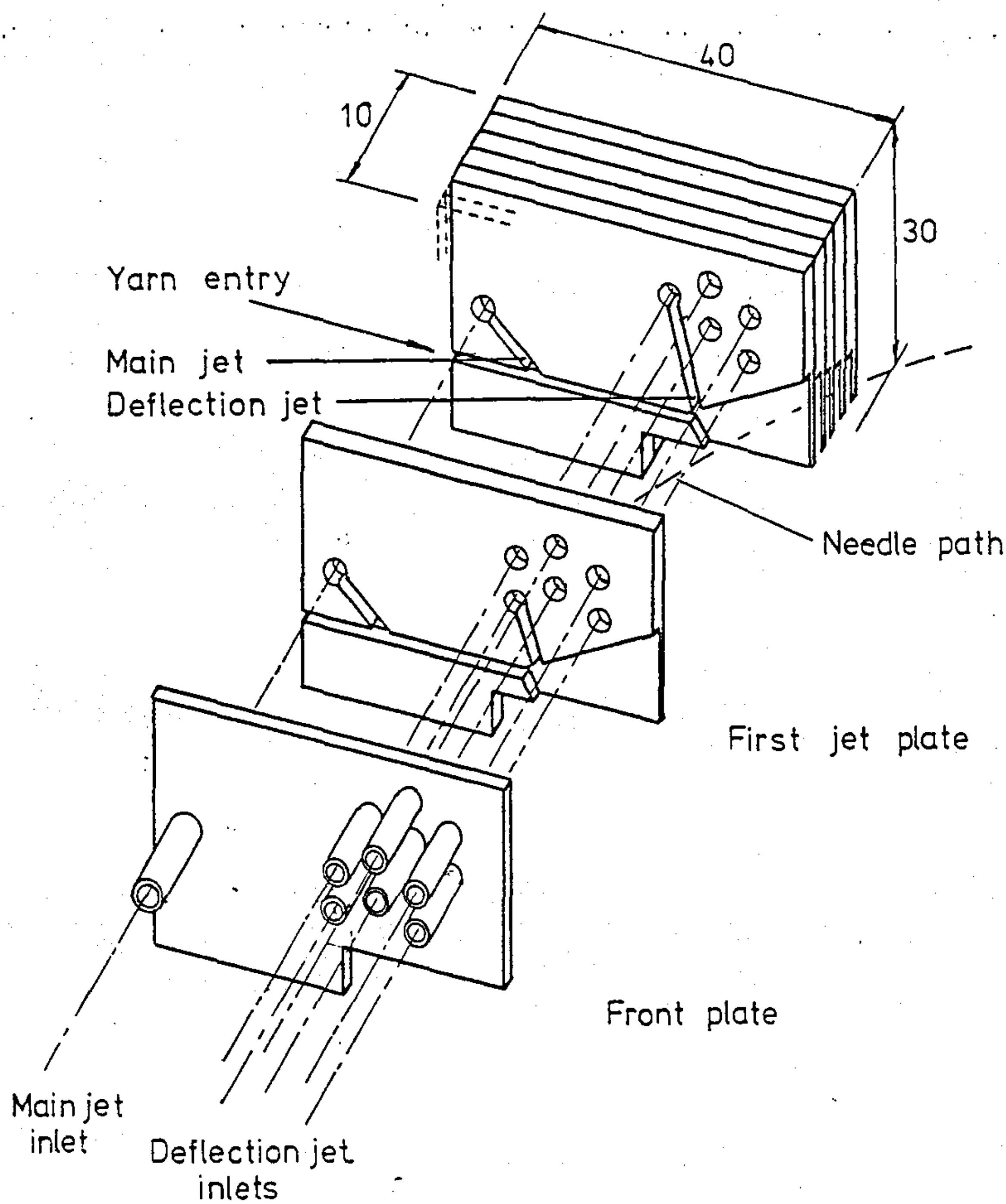
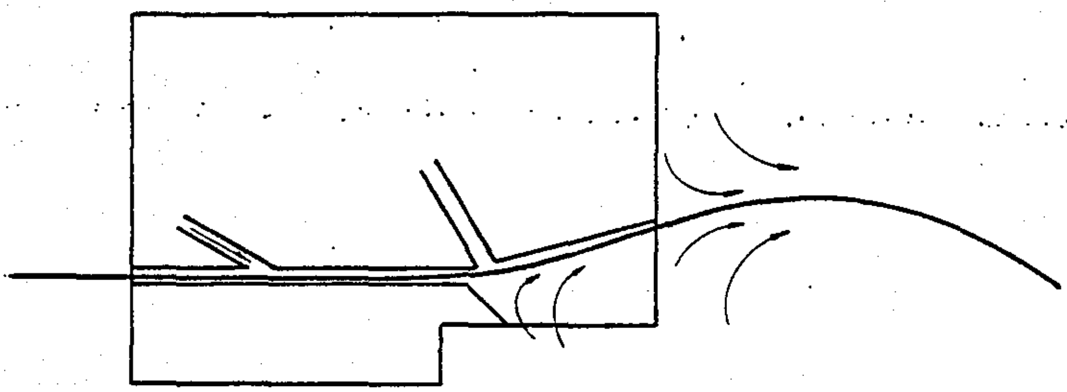
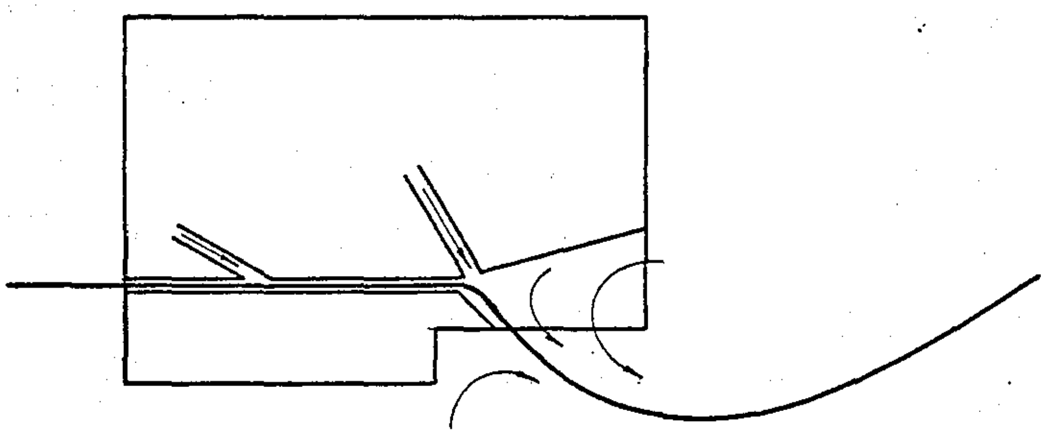


Fig. 6.3b The Jet Block Wafer



(a) Jet in non-select state : deflection jet not pressurised , air flow and yarn adhere to upper wall of jet exit .



(b) Jet in select state : deflection jet pressurised , air flow and yarn deflected downwards.

——— yarn

———→ air flow (induced outside jet)

Fig. 6.4. Air Flows in Selecter Jet

6.3.2 Weft Yarn Selector

The selector jet block is an assembly of several jets which are formed in thin plates, 1.5 mm thick. These are combined in a wafer - type construction to form the block, one plate for each weft yarn. The input ports to the jets are brought out sideways through the block to provide a very compact assembly. (See Figure 6.3)

Each plate has a main jet of section 1 mm x 1 mm passing from back to front. Air is introduced into the jet via a duct angled so as to induce air flow from back to front of the block. (See Figure 6.4) After 20 mm of straight jet the upper and lower walls diverge; the upper at an angle of 15^{o} to the axis of the jet, the lower more acutely at 45^{o} to the axis. Since the axis of the jet is close to the base of the block the lower wall soon interrupts the lower face of the block and the jet is open to the atmosphere. Normally the air passing along the jet forms a streamline flow and in the divergent region adheres to the upper wall by the phenomenon known as the Coanda[9] effect as shown in Figure 6.4a. (The lower wall diverges too rapidly for this effect especially as the area of low pressure at the corner of the divergence is readily able to induce air from the atmosphere).

The weft yarn to be controlled by the jet passes along the axis of the jet. By virtue of the drag of the air the yarn tends to be pulled forward and any slack along its length becomes apparent at the exit of the jet. The yarn follows very closely the streamlines of the jet and consequently normally leaves the jet close to the upper wall, i.e. high on the front face of the block. Additionally due to the momentum in the air as it leaves the jet, any slack yarn forms an arch upwards thus ensuring that it is well clear of the path of the advancing weft insertion needle.

When it is required to select a yarn, a secondary jet within the block is pressurized; this is positioned such that the air flow in this jet detaches the flow of the main jet from the upper wall and deflects it towards the rapidly divergent lower wall as shown in Figure 6.4b. The air from the main jet, and the yarn with it, now leaves the jet block through the lower face where it is intercepted by the fork of the advancing weft insertion needle.

6.3.3 Control Signals for Selector

Air is passed continuously along each of the main jets from a manifold within the jet block. The air supply is direct from a filter regulator combination unit. The weft selection control is by means of a pulse of air to the corresponding secondary jet. This pulse lasts the whole duration of the weaving cycle and is timed to start at 90° of main shaft revolution (weft needle fully retracted is at 0°). Because of the very low flow rate of air required in this pulse it is possible to use a small electrically controlled valve (Clippard Minimatic EVO3M) to derive the signal. The small size of the valve is beneficial, not only because of the high response speed obtainable, but also in that a very low power signal (0.65 watt) is required to drive it. Thus the signal is easily obtained from the output micro-processor.

Using this combination of selector jet and control valve, in test conditions, a selection rate of 100 selections per second has been achieved.

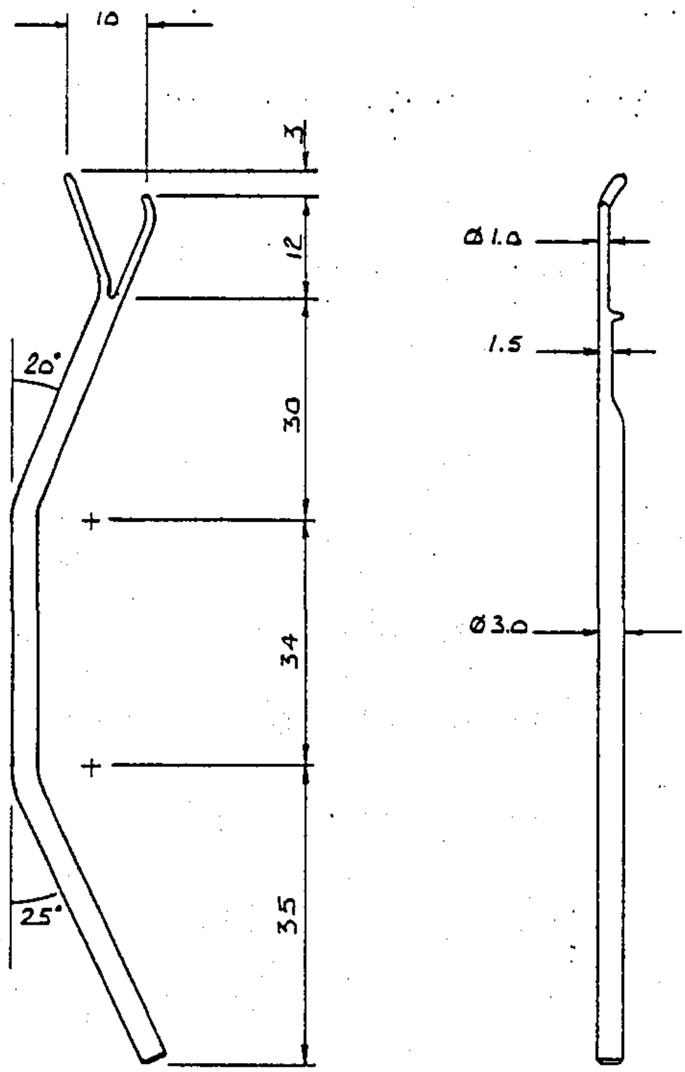


Fig 6.5. The Weft Insertion Needle

6.3.4 The Weft Insertion Needle

A weft insertion needle with a forked end replaces the standard needle with an eye for weft control. Apart from this difference it is very similar to the standard needle and can be mounted in the standard holder (See Figure 6.5). The front arm of the fork lies roughly on the arc of motion of the needle and the end, which is angled back slightly, is designed to separate any warp threads which are crossed in the shed, i.e. due to "hairyness" of the yarn or some other reason that two adjacent yarns adhere to each other as they pass to form a shed with the result that they remain in the centre of the shed. It is also designed to clear the latch needle on the knitted selvedge side.

The trailing arm of the fork is shorter and angled out from the back of the needle. Its function is to sweep across the exit points of the bottom face of the selector block and guide any yarns there into the root of the fork.

The root of the fork is designed so that as the yarn runs in the fork it will always leave the needle from exactly the same point; this is essential for successful interaction with the latch needle so as to form a knitted selvedge.

6.4 OPERATION OF SYSTEM

The operation of the weft selection system is reasonably straightforward; other than the positioning of the weft needle (which is the same as with the standard system) there are only three variables. The first is the tension setting on the cymbal tensioner. This must be sufficiently high to form a neat knitted selvedge but not so high as to damage the weft yarns. The setting will vary depending on the fabric being produced and the yarns being used.

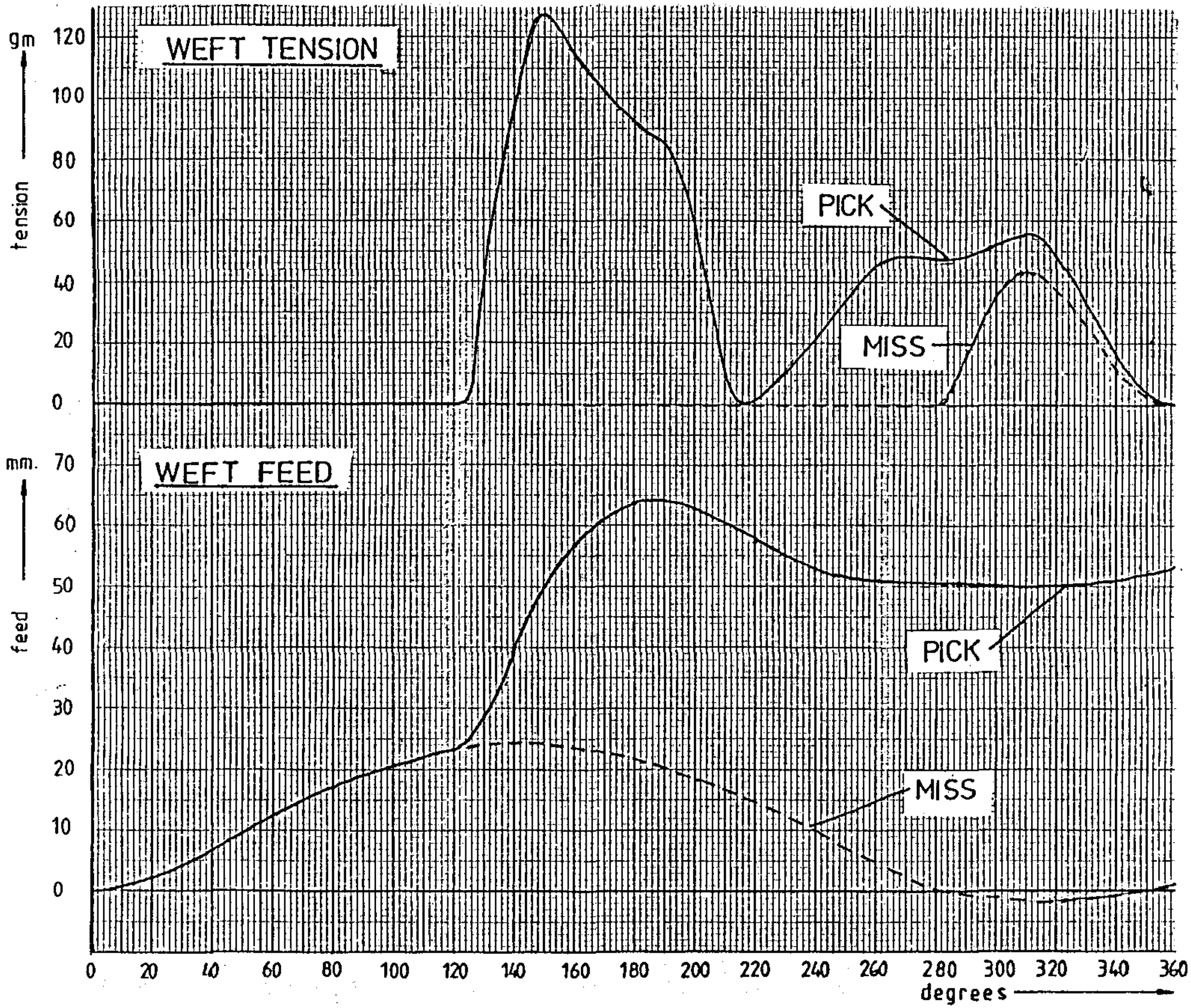


Fig. 6.6. Weft Yarn Tension.

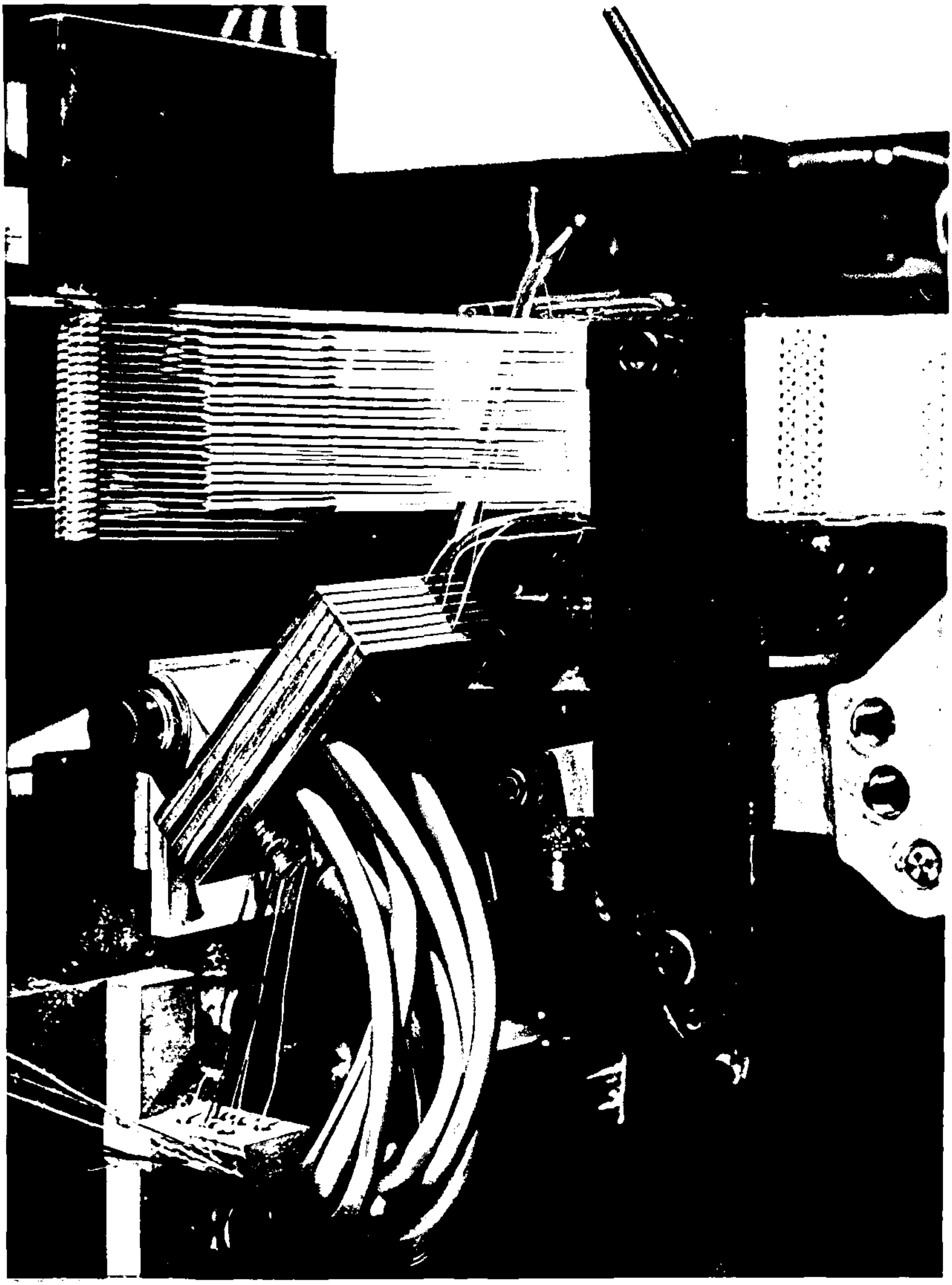


Fig. 6·7 The System Applied To The Bonas Loom.
(Needle and Jet Block)

The second variable is the timing of the air pulse to the selector. If the pulse has a duration of one cycle of the machine, then the pulse may be applied as soon as after the previously selected yarn has been received by the the weft needle as is practicable. In experimental work the timing used for the start of the pulse was 90^{o} - 100^{o}, taking the weft needle fully retracted as the datum measure 0^{o}.

The third variable is the setting of the back-robbing spring. This depends on the yarn being used and the type of selvedge formed. The timing used in experimental work was the spring fully retracted at 325^{o} and fully advanced at 145^{o} (taking 0^{o} as above). The stroke of the spring is adjusted to give the correct amount of slack for yarn pick up by the insertion needle; this usually produces a satisfactory selvedge. The effect of the interaction of the components of the system on yarn feed and tension in a typical example can be seen in Figure 6.6.

In trials conducted on a variety of yarn types typical rates of air consumption were found as follows:

- Each main jet - 4 litres/min at S.T.P.
- Each secondary jet (when 'on') - 3 litres/min at S.T.P.

6.5 APPLICATION OF THE SYSTEM TO A NARROW FABRIC WEAVING LOOM

The application of the system to a narrow fabric weaving loom is straightforward the new weft insertion needle replaces the standard needle and is positioned to the same settings as the standard. The jet block is positioned approximately 2mm above the path of the fork of the weft needle at a point prior to the entry of the needle into the shed (see Figure 6.7). In order to obtain full benefit from the system, the means of mounting should be adjustable so that the optimum position for every fabric width can be achieved.

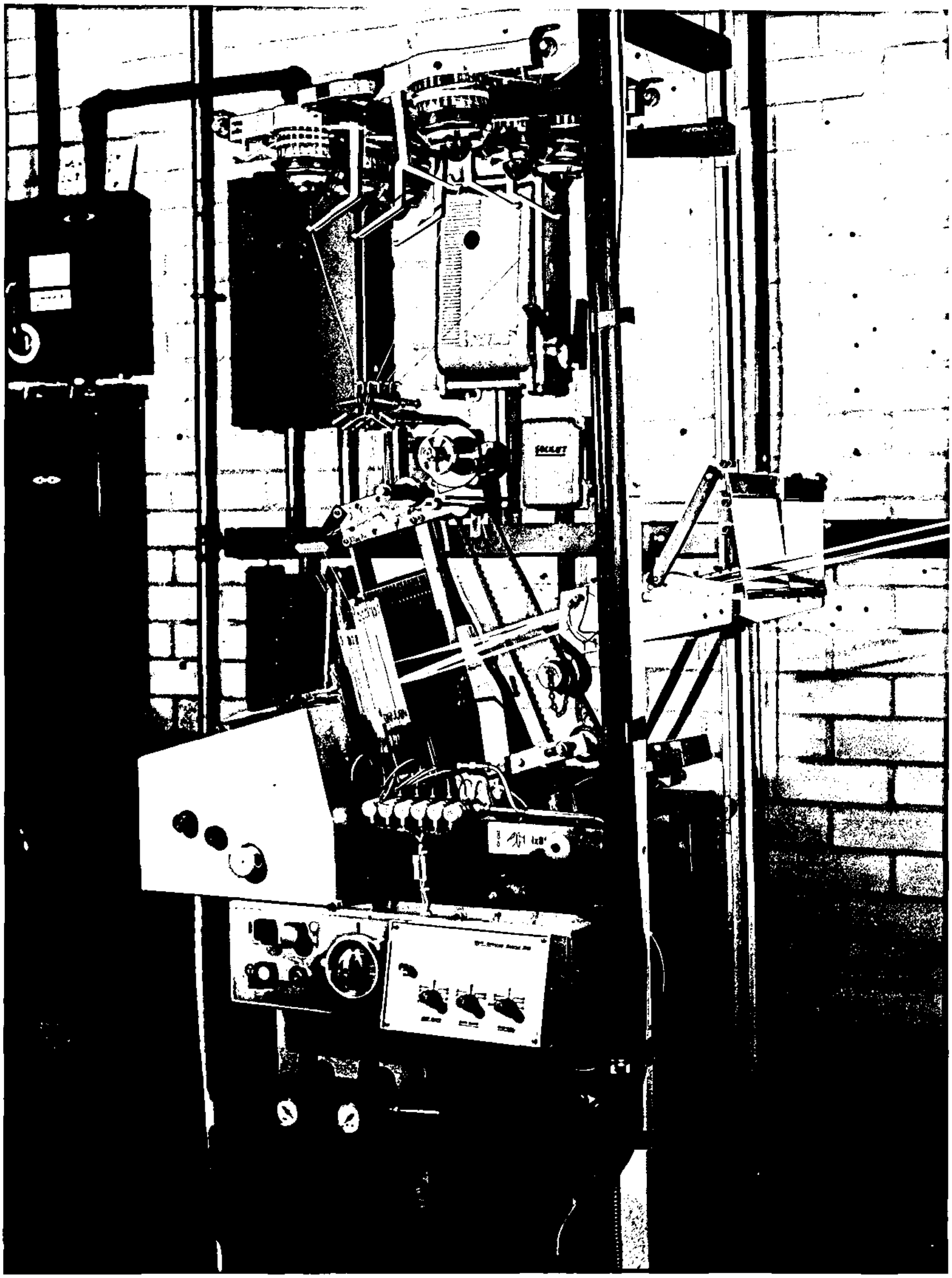


Fig. 6·8 The System Applied To The Bonas Loom.
(Side View Of The Machine)

The control signals to the solenoid valves need to be synchronised to the weaving machine and this can be achieved accurately by use of a photo-emitter-receiver and timing disc attached either to the main shaft or to another shaft with a fixed relationship to the main shaft.

The positive yarn feed used with non-selectable systems is removed from the machine and its drive used to operate the back-robbing spring. The correct relationship of one oscillation for each loom cycle for this,can easily be obtained by use of appropriate pulleys. Timing adjustment when required can be achieved by slackening the most convenient pulley in the drive, adjusting, and then re-tightening.

The IRO units and cymbal tensioners may be positioned wherever practicable (see Figure 6.8), but the closer to the weaving zone the better since friction will be introduced at each eye through which the yarn passes and the extension of the weft yarn whilst under tension will increase with the length of tensioned yarn.

6.6 ADVANTAGES AND DISADVANTAGES OF THE SYSTEM

6.6.1 The addition of the weft selector system to a weaving machine of the narrow fabric needle type is straightforward. All that is required is the replacement of the standard needle, the replacement of the weft feed, and the mounting of the selector block and the associated valves. Thus it is feasible that the system be fitted to existing machines as a conversion as well as being fitted to new machines as they are built.

6.6.2 The selector block requires no mechanical connections to the weaving machine other than the mounting bracket. If this is adjustable then the optimum position for yarn pick-up for any fabric width is obtainable. This is particularly important on machines where the stroke of the weft insertion needle is adjustable.

6.6.3 The small physical size of the selector block allows a relatively large number of weft yarns to be controlled in an area where space is limited. The number of yarns controlled is more likely to be limited by the cost and size of the yarn feed required by each yarn before passing through the selector block.

6.6.4 The weft selector itself has no moving parts thus wear and reliability will be significantly better than in a system employing mechanisms and bearings. The commercially available yarn feed device has a high life expectancy as do the pneumatic valves. The back robbing device is simple and should easily be designed to have a life expectancy comparable to the rest of the system.

6.6.5 The small power requirement of the electronically controlled valves, especially as in most cases only one valve will be energised at any one time, simplifies the provision of controlling signal. A microprocessor output would require only a small amount of modification before being able to control the valves.

6.6.6 Since the weft yarns are drawn from their supply packages by a self-powered feed device the packages may be mounted some distance from the weaving area. This could be very important in complex weaves when a large number of weft yarns is required.

6.6.7 The back robbing device, fitted to control yarn tension and feed to facilitate the pick up by the weft needle, has the added benefit that yarn is fed forward at the time of beat-up thus eliminating the peak in the weft tension that usually occurs on standard systems.

6.6.8 This system feeds into the fabric only as much yarn as is actually needed. Thus it may be that, in fabrics which require a weft thread to appear on the face side only towards the knitted selvedge, less yarn would be used than if a full pick had to be inserted.

6.6.9 The major disadvantage of this system is in fact the open forked needle passing through the shed. Whilst precautions have been taken to minimise the risk, there is still the possibility of warp yarns being caught by the fork as it passes. Several means of overcoming this are being looked at, including modification of the shape of the fork to reduce the risk, and the possibility of using a fork which closes once the weft yarn has been located in it.

6.6.10 On the fabrics tried to date it appears that the weft tension setting required is higher than on a normal, non-selecting system. This is required to produce satisfactory selvedges and, to date, it has had no adverse effect on the weft yarns. It is an undesirable feature however, and a modification of the back robber and yarn tensioner might be needed to reduce the peak tension.

CHAPTER 7: THE DEVELOPMENT OF THE WEFT SELECTION SYSTEM

7.1 INTRODUCTION

In Chapter 6, the finally derived weft selection system was described, but this was of course, the culmination of a considerable amount of innovative and development work. This Chapter summarises that work.

7.2 COMMERCIALLY AVAILABLE WEFT SELECTION SYSTEMS

There already exist a variety of systems capable of weft selection. The choice as to which to use on a particular weaving machine is obviously dependent on the means of weft insertion normally employed by the machine. For example a shuttle-box system is commonly used on conventional shuttle looms, and a variety of systems can be used to present one of several weft yarns to the rapier end on a rapier loom.

In the area of narrow fabric needle looms, two systems worthy of note are currently available. These systems are manufactured by Bonas Machines Co Limited, who fit them to their Supertex range of weaving machines, and by Jakob Müller on the Texnova Multicolour range of weaving machines.

7.2.1 The Bonas System

The Bonas Machine Co Limited have recently offered a weft selection system for use on their Supertex range of looms. The principle on which it operates is straightforward, see Figure 7.1. The weft insertion needle possessing an eye at its tip, as normally used for single weft fabrics, is replaced by a needle with its tip formed into an open fork. The various weft yarns pass, via a yarn tensioning arrangement, through headles controlled by a mechanical Jaquard whose main function is to control the warp yarns.

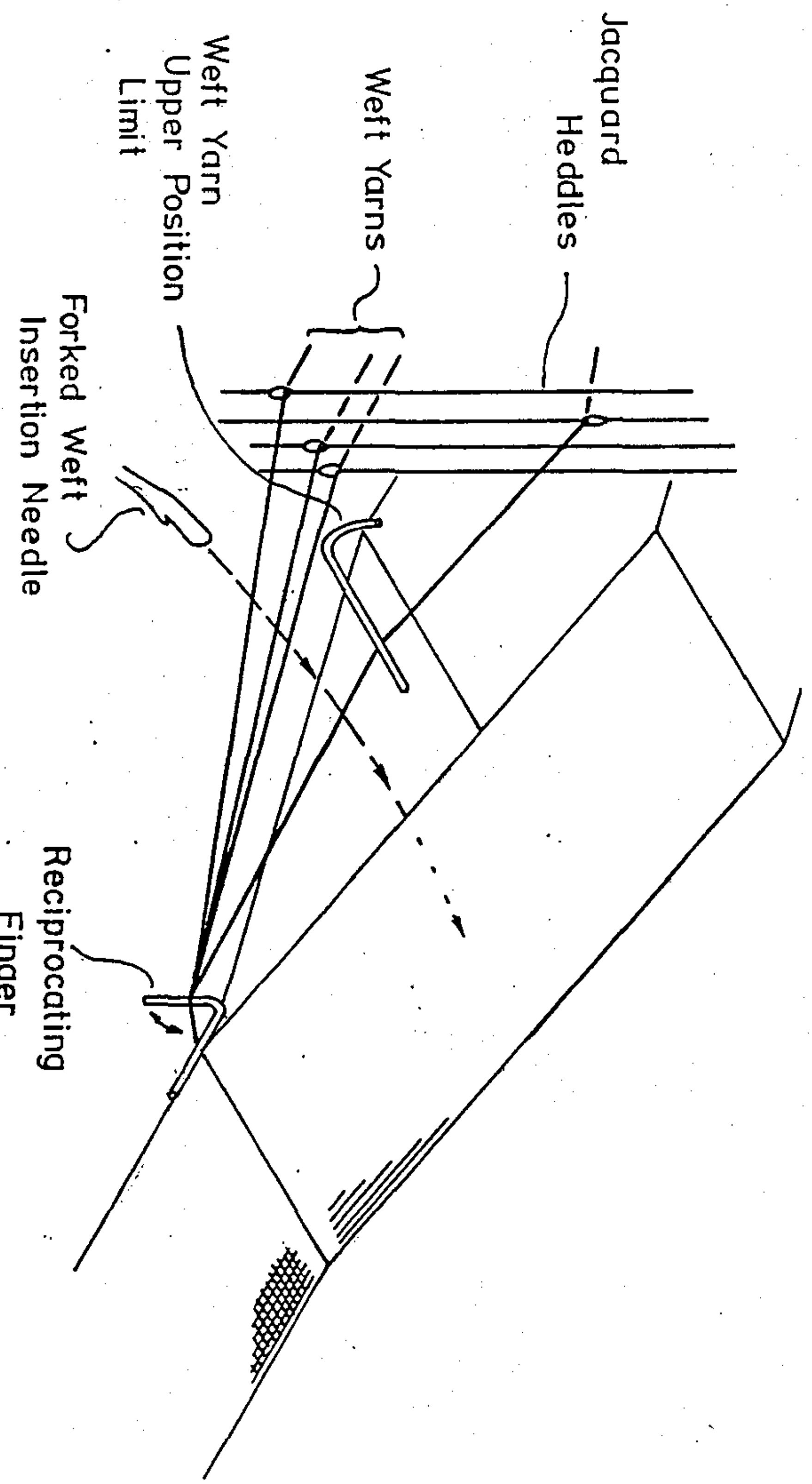


Fig. 7.1 The Bonas System

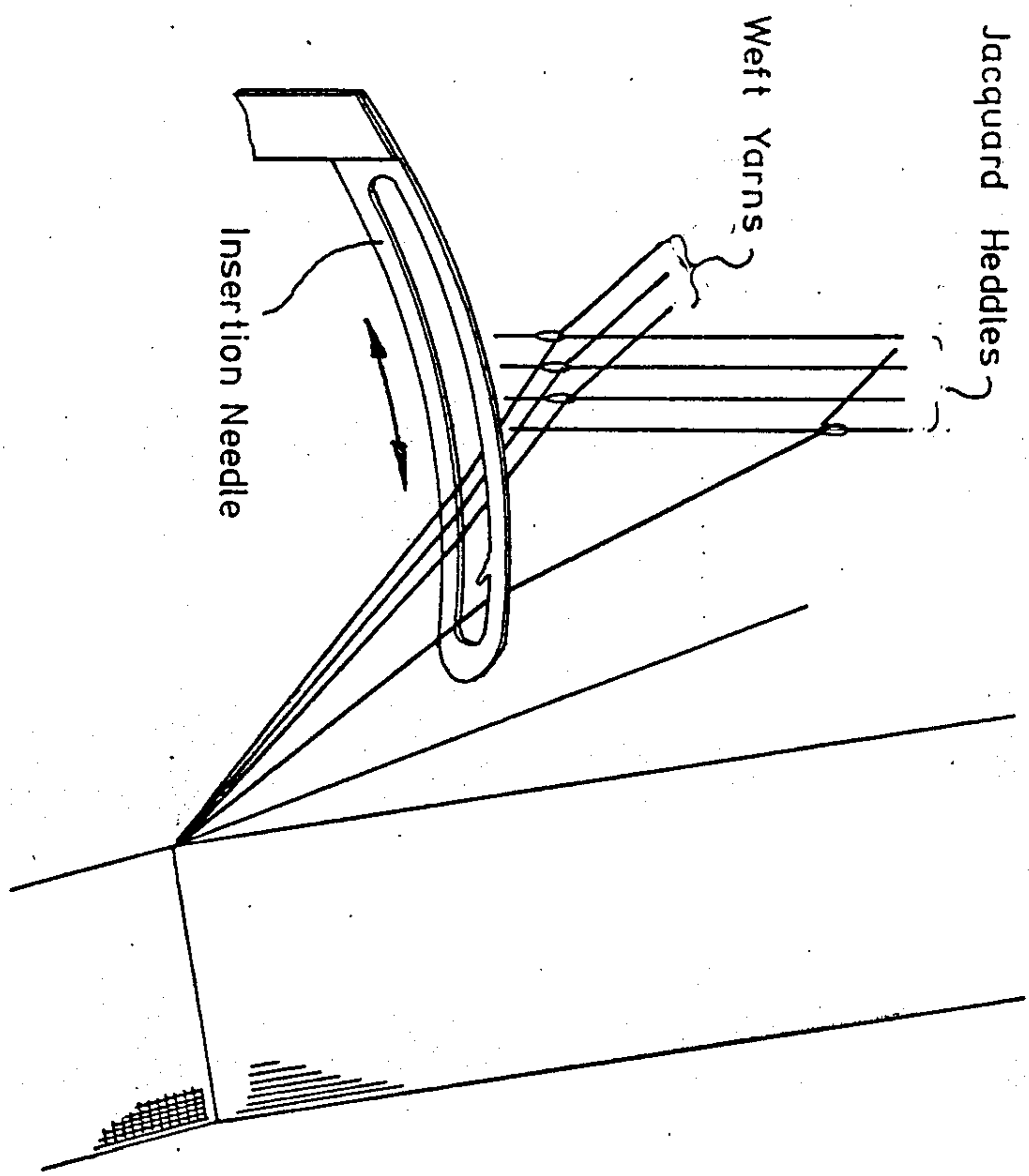


Fig. 7.2 The Müller System

The required weft yarn for any pick is raised by the associated headle, from its normal lower position, so that it lies in the path of the advancing forked weft insertion needle. To gain more precise control of the position of the yarn, for more reliable collection by the weft insertion needle, a small element is reciprocated in synchronism with the machine, such that it makes contact with the yarn and holds it in a fixed position immediately prior to the passage of the insertion needle.

Because the system relies for its control motion on a mechanical Jacquard, its speed is limited to that of the Jacquard. This is of no serious consequence in this application, since the weaving speed is also limited by the Jacquard, via the warp shedding requirement. However should the mechanical Jacquard be replaced by a very much higher speed warp shedding mechanism, then the speed limitation of the weft selection could be significant.

7.2.2 The Müller System* [10]

This system employs a flat weft insertion needle, having a slot which runs the whole length of the needle and through which all of the weft yarns pass (see Figure 7.2). Prior to its arrival at the needle an individual weft yarn is passed through the eye of a corresponding headle of the Jacquard system, as with the Bonas system; thus any one of the yarns may be raised by its headle and so run against the upper edge of the slot. Close to the 'point' of the needle, and attached to the upper edge of the slot, there is a hook; thus, as the needle advances from its fully retracted position, any yarn held up against the top edge of the slot is caught by the hook and carried into the shed by the needle.

The remaining yarns, which are held down against the lower edge of the slot are missed by the hook and so remain outside the shed as the needle advances.

The great advantage of this system over the Bonas system is the external shape of the needle; as it is presented to the warp threads, its smooth surface has no projecting hook to accidentally catch any stray warp threads which may not have been formed into a perfect shed.

The speed limitation considerations are the same as those with the Bonas system, because the Müller system is also controlled by a standard mechanical Jacquard mechanism.

*Footnote

The patent[10] referring to this system was granted to a company named BREVITEX and the machines on which the system is fitted are known as TEXNOVA machines. The company selling the machines is FINATEX S.P.A. who are subsidiary of JAKOB MÜLLER LTD.

7.3 THE REASON FOR DEVELOPING AN ALTERNATIVE SYSTEM

Both of the systems described in the previous sections are designed for use with a mechanical Jacquard, the speed of which is limited. If a high - speed warp selection is available then there are two features, common to both systems, which could impair their performance at the higher speed, vis:-

(a) To control the selection of the weft threads, both existing systems rely on Jacquard controlled headles. These headles can be placed in the required position for weft, selection, and the drive to them provided via flexible ties.

These ties perform satisfactorily at present operating speeds but would be prone to much higher failure rates at higher speeds, especially since, at higher speeds, higher returning forces are needed thus resulting in much higher tensions in the ties." Consequently it may not be practicable to obtain the desired output from the Jacquard in the best position for weft selection.

(b) The very high speeds attainable by narrow fabric needle looms are in part attributable to the optimisation of the needle stroke for particular width of fabric being produced, ie it is normal to adjust some of the linkages on the machine to produce a short needle stroke on very narrow fabrics and a longer stroke for wider fabrics; the accelerations of the needle and associated parts are thus minimised. When weft selection of the type described is employed, the point at which the weft yarn is caught by the insertion needle is fixed by the construction of the machine; adjustment would be very difficult to achieve due to the required mechanical connections to the Jacquard mechanism. Consequently if the loom is to remain versatile, and be capable of producing fabrics of varying widths, the weft selection must be arranged for the widest fabric, ie for a long insertion needle stroke. When producing a narrower fabric the long needle stroke must still be used, since the weft pick up point is fixed; thus the machine cannot run at the higher speed normally associated with a narrower fabric.

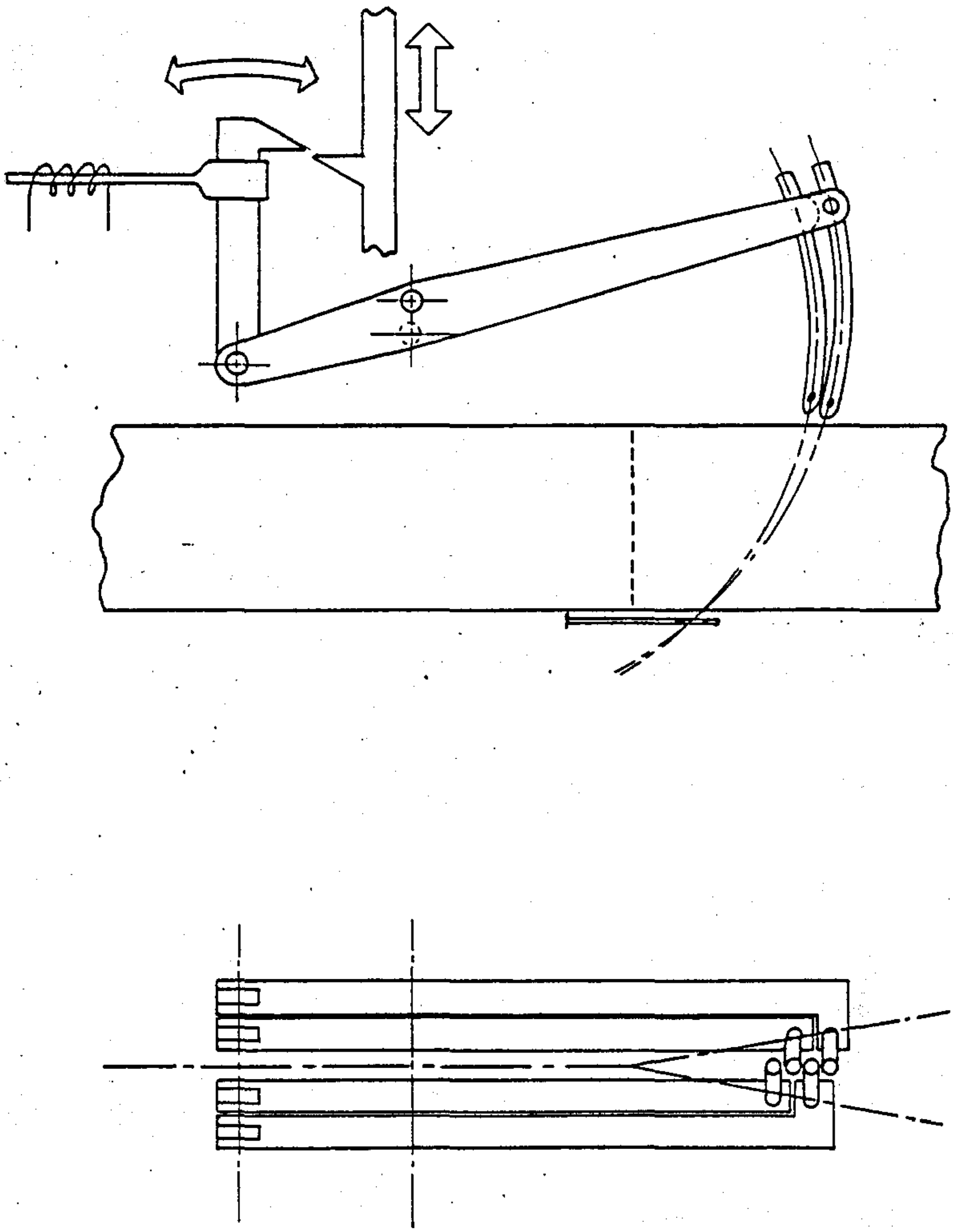


Fig 7.3 A Selectable Needle System

There would appear to be a need for a weft selection system, for use with narrow fabric needle looms, which is:-

(a) independent of the warp selection system; and

(b) adjustable to cope with various needle strokes

7.4 POSSIBLE OPERATIONAL PRINCIPLES

There are three basic forms of system which could select and insert weft yarns utilising the motions available on standard narrow fabric needle looms and these are discussed below.

7.4.1 Selectable Needles

In this form of the system each weft yarn has associated with it, a needle similar to that used with a single weft on the standard machine. Each of the needles is connected to the drive from the machine via some form of link which can be disconnected (see Figure 7.3). When a weft yarn is required in the fabric the drive to its associated needle is connected and the needle advances as on a single weft machine; the other, unrequired, needles are not connected and remain stationary.

The disadvantages of this type of system are:-

(a) the motions of the needles must be so arranged that all pass through a common point, on the side of the fabric opposite the needle entry into the shed, so that the selvedge - forming latch needle may interact in the same manner with all of the insertion needles; and

(b) the mass which must be selectively moved during each cycle of the machine is relatively high; consequently, high forces would be required to accelerate these masses at the high weaving speeds envisaged. Since these high accelerating forces must be generated in some manner, the transducers used would tend to be large and consume high levels of power, alternatively some mechanism could be used to "amplify" a smaller signal. Either technique would involve a higher cost and reduce the reliability due to an increased tendency to wear.

7.4.2. Open Fork-End Needle

To reduce the mass which has to be moved selectively, one could use a continuously reciprocating single needle which can insert any one of several yarns into the shed. This is basically the system employed on the Bonas loom. The constant motion of the weft insertion needle is much easier to obtain at the required high speeds than an intermittent motion. Some means of presenting the yarn to the open fork of the needle is required. At the lower speeds at which the Bonas loom runs, with a mechanical Jacquard, driving the weft yarn from the Jacquard is quite acceptable. For higher speed applications, some other weft presentation system may be required for the reasons given in Section 7.3.

7.4.3 The Müller Type Needle

This type of needle has been described in Section 7.2.2. The major advantage is greater safety whilst passing into the warp shed. The limitation of weft presentation as described for the open fork applies to this type of needle as well. However, no attempt has been made by the author to increase the speed of operation by the development of a faster yarn presentation system, because this could merely constitute an improvement of the Müller system and, as such, would perhaps be covered by the existing patent.

7.5 YARN PRESENTATION MEANS

7.5.1 Pneumatic

It was decided to employ an open fork needle for weft insertion. For this a weft yarn presentation device is required. Pneumatic means of accomplishing this was considered for the following reasons:

(a) the moving mass of this type of presentation system is very low, comprising the yarn itself and a small quantity of air;

(b) the moving parts of the system are reduced to practically zero ; the only moving component, other than air, being a diaphram within an electrically - operated pneumatic valve ; and

(c) the interface between the electrical signal and mechanical effect may be remote from the selection area and connected to it via flexible tubes, thus allowing easy positioning of the selection device for optimum needle stroke.

There are however two possible problems with such a system, namely:

(a) a very high speed and long life electronically operated pneumatic control valve is required; and

(b) the quantity of compressed air required may prove costly, particularly when the machine is running continuously.

7.5.2 Solenoid

An alternative means of presenting the weft yarns to the insertion needle was the use of solenoids to control the position of headle - like components through which the weft yarns would pass. This would be similar in form to the use of a Jacquard system to control the weft position as in the Bonas and Müller systems.

Direct action of solenoids on the headle element would not be preferred due to the length of stroke that would be required. If an intermediate link were used to provide an increase in output stroke, the inertia of the components to be moved at high speed, plus the returning spring forces, which would have to be overcome, would require a large solenoid. It would prove difficult to mount several large solenoids conveniently, and the power consumed by the solenoids would necessitate more expensive circuitry to operate at the desired high speeds.

7.6 INITIAL TESTS AND FEASIBILITY STUDY

In order to assess the feasibility of employing a pneumatic yarn presentation system together with an open fork weft insertion needle, three basic tests were performed as detailed below.

7.6.1 Solenoid Valve and Air Jet Response Speed

The target speed of the system is 3000 picks per minute, ie a total cycle time of 20 msec. In order for a pneumatic system to work at this speed, the time taken for the valve operation, and consequent air jet response, must be less than this machine cycle time. A review of commercially available valves showed that most manufacturers claimed a response speed of over 20 msec for their valves; only one claimed a response time as low as 5 msecs, namely, Clippard Minimatic for their EV3 type valves.* This type of valve is very small and can cope with pressures up to 100 psi but only small flow rates, of the order of 17 litres/minute.

* Footnote

Since the review was made, a small valve has been brought onto the market by FESTO Ltd. This has a claimed response time of 10 msec and is approximately half the cost of the Clippard valve.

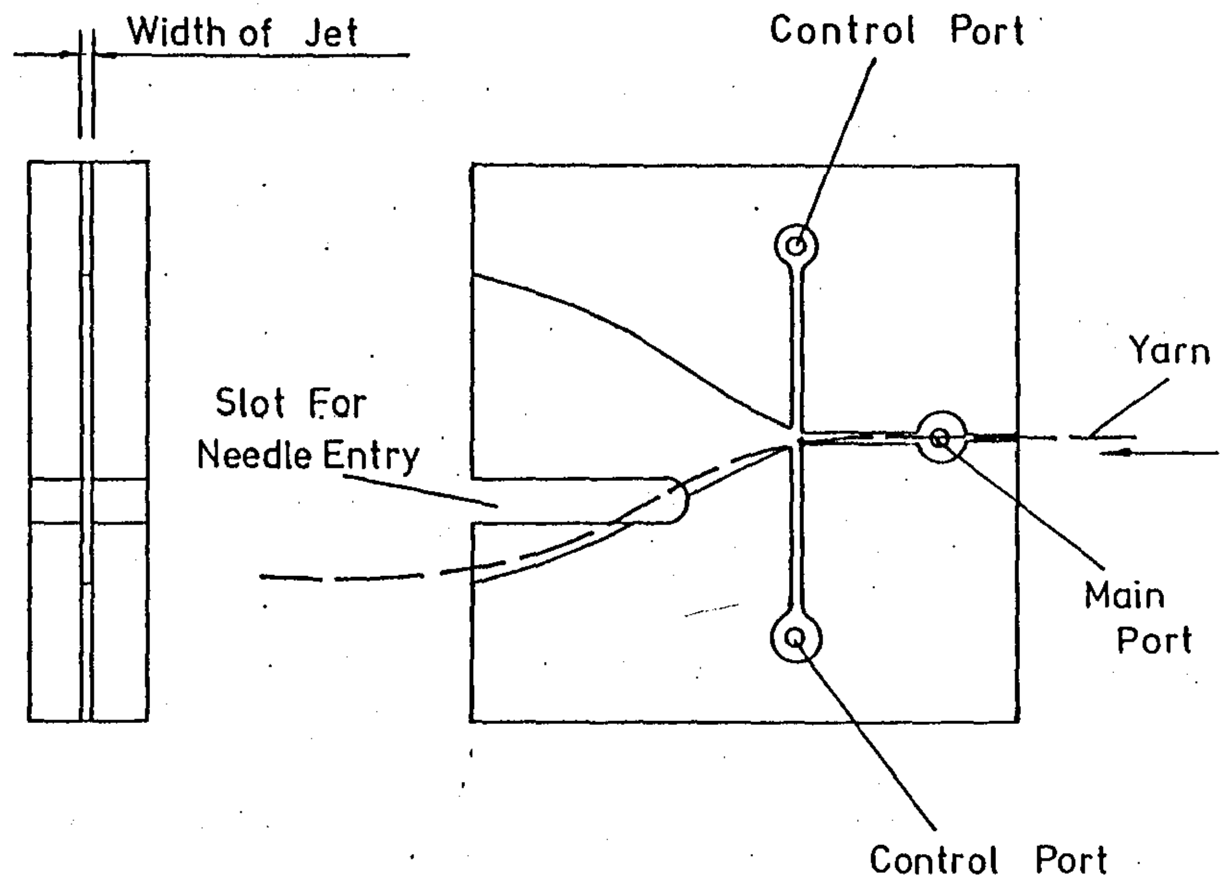


Fig 7.4. The Bistable Jet

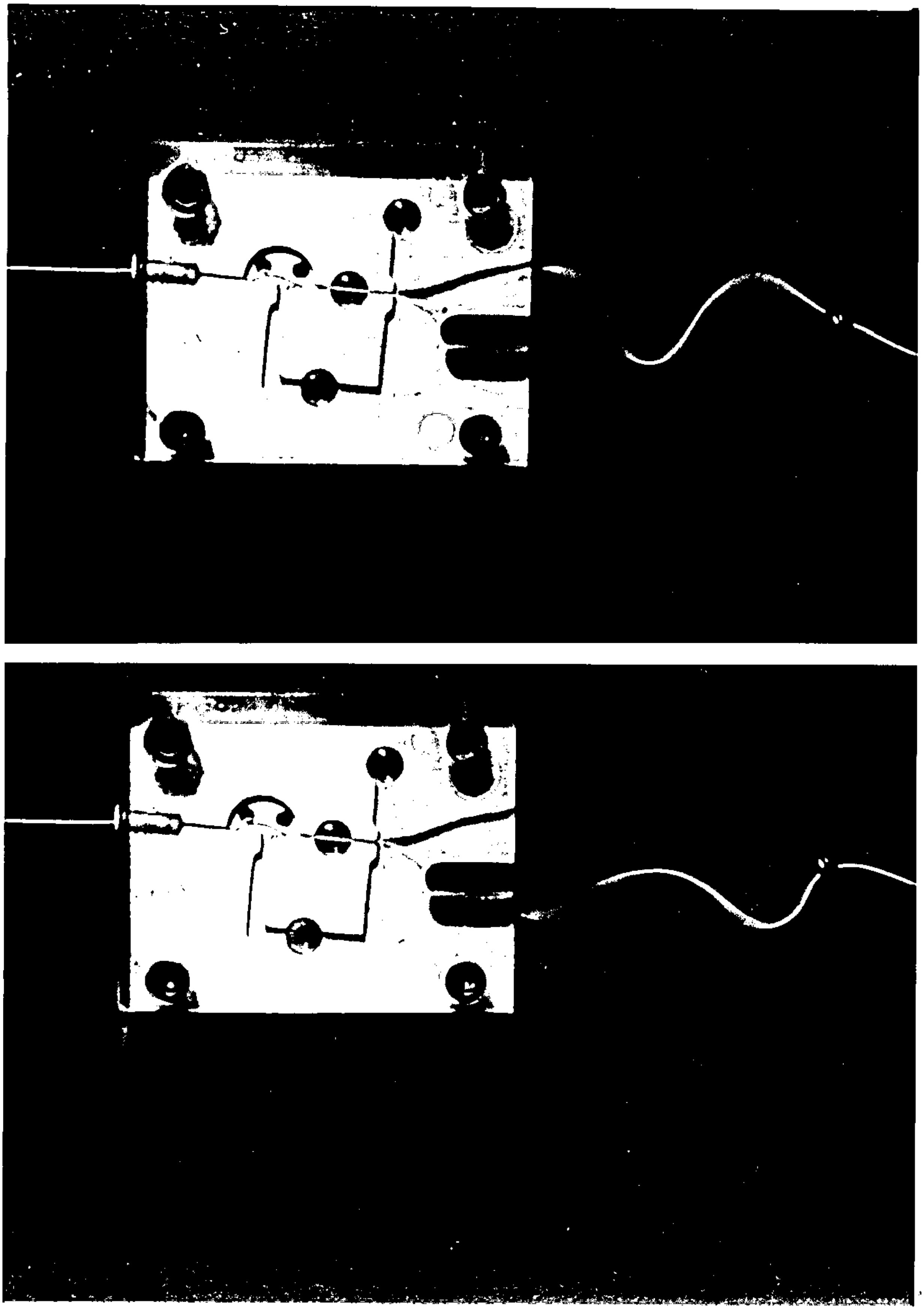


Fig. 7·5 1st Jet Trial (Upper) Yarn " Miss "
(Lower) Yarn "Select "

Means of minimising the selectable flow of air required by the jet were considered. The most obvious was to use a constant flow of air to entrain the yarn, together with two smaller, selectable, flows to deflect the main flow, and the yarn with it, into one of two paths. The configuration is basically that of a fluidic bistable wall attachment device without the flow splitter normally used to direct to flow into one of the two output ports (see Figure 7.4).

A simple perspex model was made, and air was fed from a constant pressure source to the main jet of the device and also to the input of a Clippard Valve, type EVO.3, the output ports of which were connected, via flow resistors so that the flows could be balanced, to the two deflecting jets of the model. A control signal for the valve was derived from the output of a variable frequency signal generator via a circuit which modified the signal to one with a high voltage (twice the nominal coil rating) pulse of 1 msec duration, subsequently falling to the nominal voltage.

In order to observe the air flow in the device, a yarn was streamed in the main jet, i.e. to simulate the weft yarn in the actual application. The frequency of the control signal was increased to the point where the yarn, as observed by stroboscope, would no longer complete the full stroke of the movement from one wall to the other of the output jet (see Figure 7.5).

The maximum frequency thus achieved was 100 Hz, i.e. a cycle time of 10 msec. The failure above this frequency was not due to the response of the jet, but due to the response of the valve, (this agrees with the manufacturer's quoted switching response time of 5 msec as, during the cycle used, the valve switched both on and off).

Following the success of this test the following two modifications were made to the jet:-

(a) a slot was cut across the output port of the jet. This would be required in practise as the weft insertion needle must enter the jet to catch the weft yarn; and

(b) A small yarn reservoir was built into the jet. The yarn whilst being deflected into the non-catch output position is also deflected into a reservoir within the jet. When the deflection jets are switched, to cause the yarn to adopt the select output position, a small length of excess yarn is released. This allows the yarn on the output side of the jet to form the correct arched path necessary to carry it through the catch position.

These modifications made no difference to the speed of operation of the jet since the slot appeared to have no observable effect on the flows within the jet. The yarn reservoir was totally ineffective and was therefore dropped from subsequent jet designs.

7.6.2 Fork End Needle

To ascertain whether or not an open forked weft insertion needle would produce a satisfactory fabric*, a needle was made which was similar to the standard, eyed, weft insertion needle, but which possessed an open fork end.

* Footnote

At the time of these tests the Bonas system was yet to be released by the manufacturer and no other system using such a needle was known.

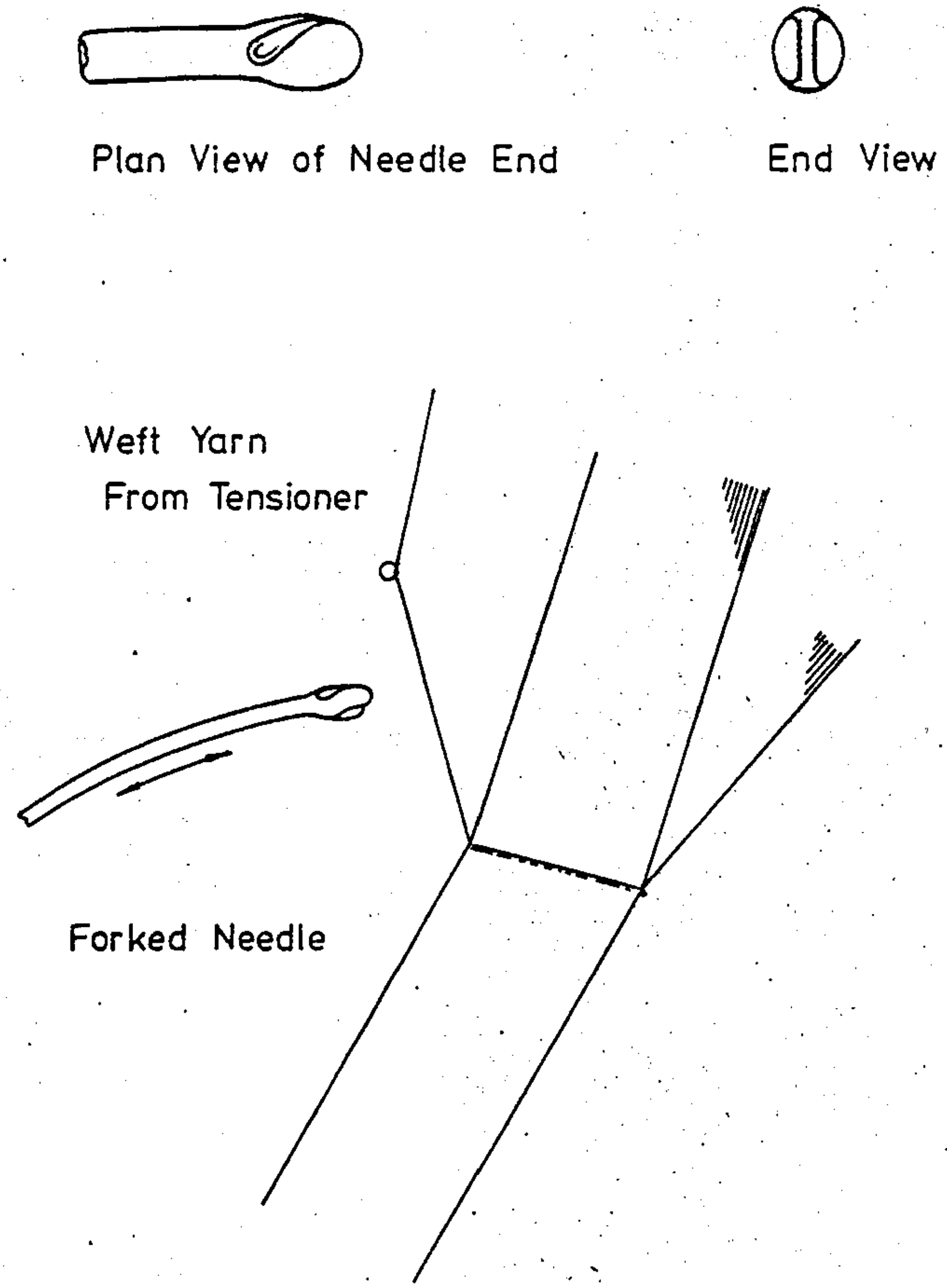


Fig . 7.6. Forked Weft Needle Trial

This was fitted to a standard Bonas weaving machine (see Figure 7.6). The only other modification was the provision of a yarn guide through which a single weft yarn ran. This was close to the yarn collection point and maintained a constant position for the yarn at the moment of collection. In this form the loom was run and, after minor adjustments of needle position, it performed satisfactorily. It was found however that extra care had to be taken in applying the warp sheet tension; if too low the tendency was for warp yarns to snag on each other at the point of crossing in the shed, this resulting in yarns being present in the shed space and in the path of the advancing weft insertion needle. With a smooth insertion needle this may have led to weaving faults, but, with the forked, needle, the result was more serious, an almost certain source of warp yarn breakages. However, this problem seldom occurred when the correct warp tension was applied.

7.6.3 Negative Weft Yarn Let Off

Since, when weft yarns are selectively inserted, the feed required of any one yarn is intermittent and follows an irregular sequence, some means other than the positive yarn feed fitted to the standard machine would be required. It was decided that a positive feed, intermittently driven, would not prove satisfactory at the high target speed. Consequently tests were made to ascertain the quality of weaving that could be achieved using a negative let off system, ie a system which allows yarn to be drawn from a supply according to the tension in the yarn.

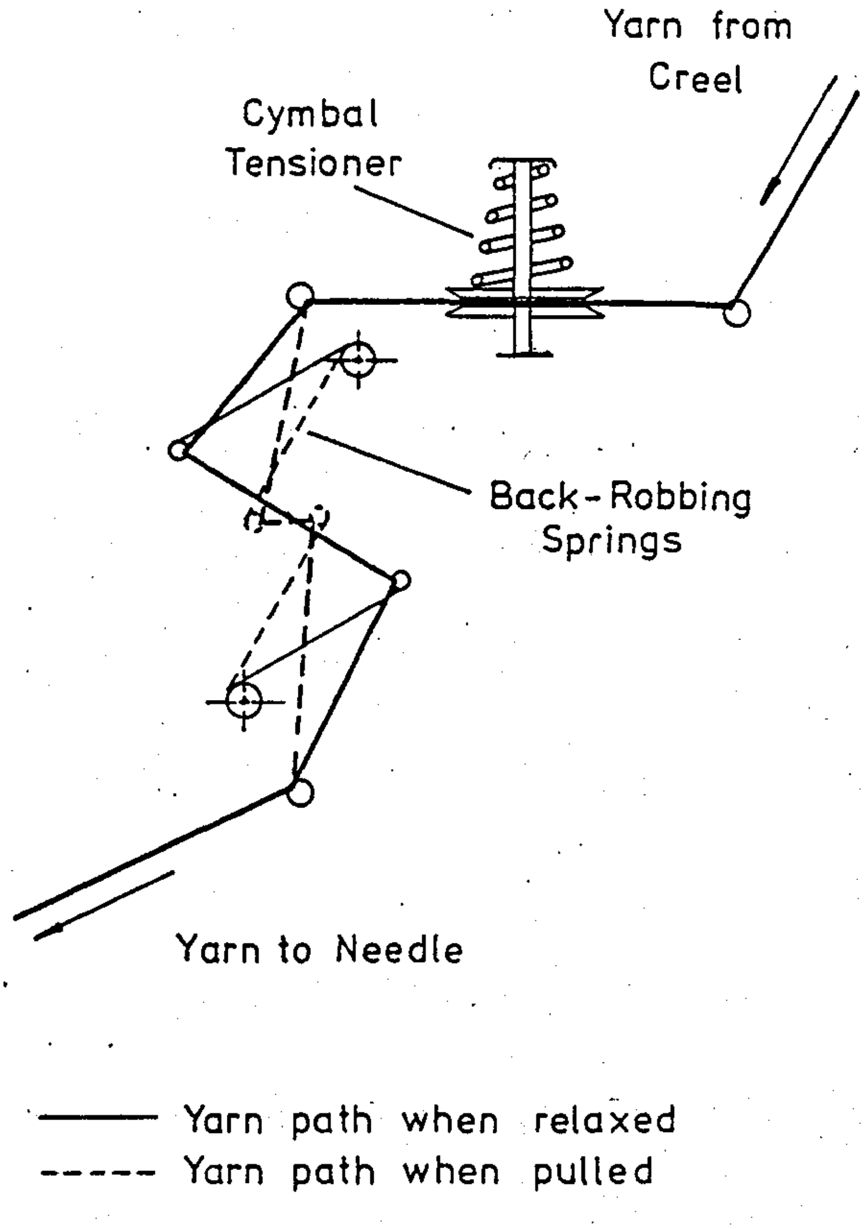


Fig. 7.7. Weft Yarn "Let-Off"

A simple system consisting of a 'cymbal' tensioner together with 2 back-robbing springs was tried with both the standard weft insertion needle and the forked needle as used in the previous tests (see Figure 7.7). The cymbal tensioner holds the yarn until sufficient tension is applied to the yarn to overcome the frictional forces generated in the tensioner, any additional pull applied to the yarn then draws yarn through the tensioner from the supply package. The back-robbing springs are required to take up an excess of yarn drawn by the weft insertion needle as it travels past the far selvedge, which it must do to form the knitted selvedge in conjunction with the latch needle. The excess yarn is released as the needle starts its return stroke and, if this excess is not withdrawn, a poor selvedge results.

The machine would weave with this system, although the effect of varying conditions prior to the cymbal tensioner was apparent in the weaving zone. It is to be noted that the cymbal type tensioner, whilst reasonably accurate and consistent in performance, has only an additative effect on the tension of a yarn running through it. The effect of a variation in weft tension is to slightly alter the width of the fabric produced, and this is generally unacceptable.

Nevertheless, the simplicity of this system is attractive, and, rather than investigate other more complex means of weft yarn supply, a means was sought of supplying a constant, low tension, input to the cymbal tensioner. After experimentation with various ideas, a commercially available yarn feed unit, the IRO SFS 1706, was purchased and tested. This performed satisfactorily and has been used as the basis of the weft supply in all subsequent work.

7.6.4 Conclusion of Initial Trials

The three main areas of doubt in a pneumatic weft selection system have been investigated and, in all cases, it has been proved that any problems encountered are capable of solution. It was therefore decided to continue work on this approach as it appeared to offer advantages over any other envisaged system.

7.7 DEVELOPMENT OF WEFT SELECTION SYSTEM

7.7.1 The First Machine - Mounted System

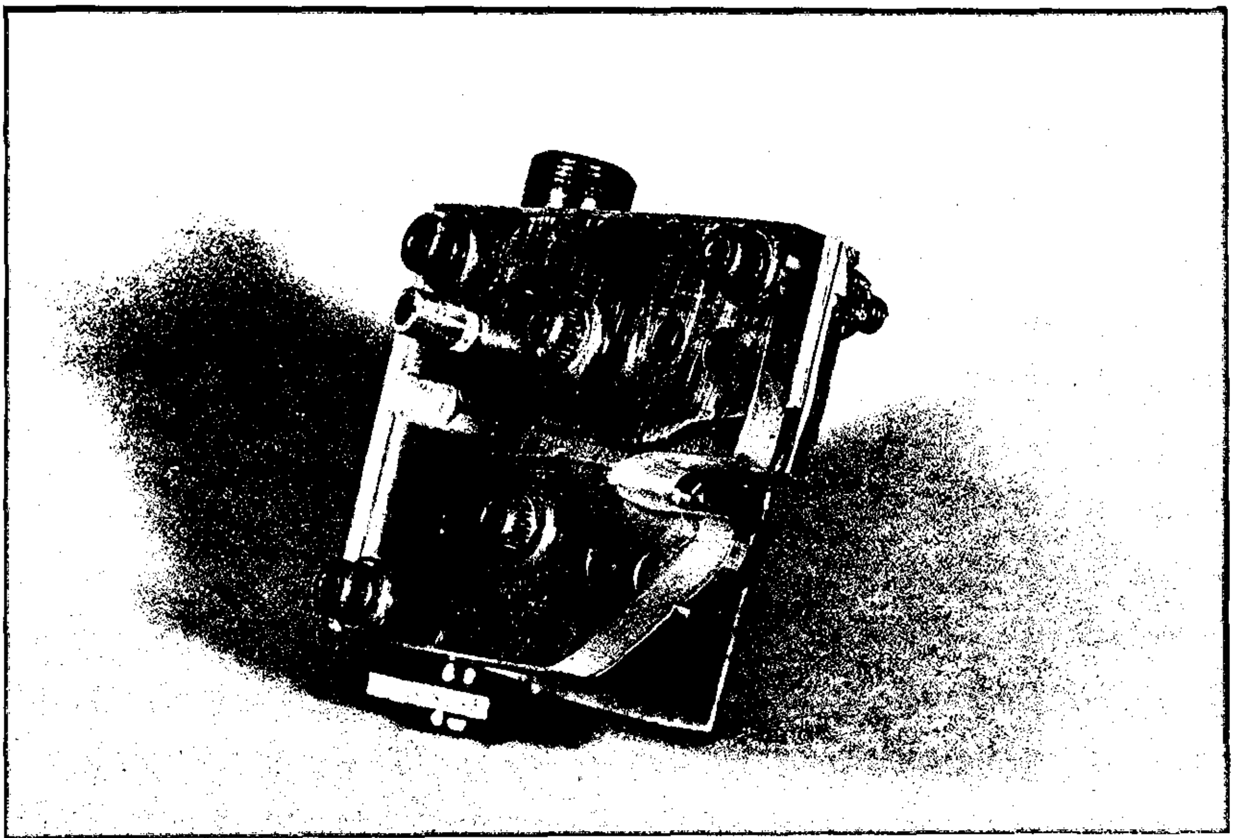
7.7.1.1 The Jet

The first model jet made for the feasibility tests was intended for bench use only and, whilst the dimensionswere approximately correct for adaption to a machine, it was not practical to test it in actual weaving operation. Consequently a single jet was manufactured such that it could be fitted to the machine .

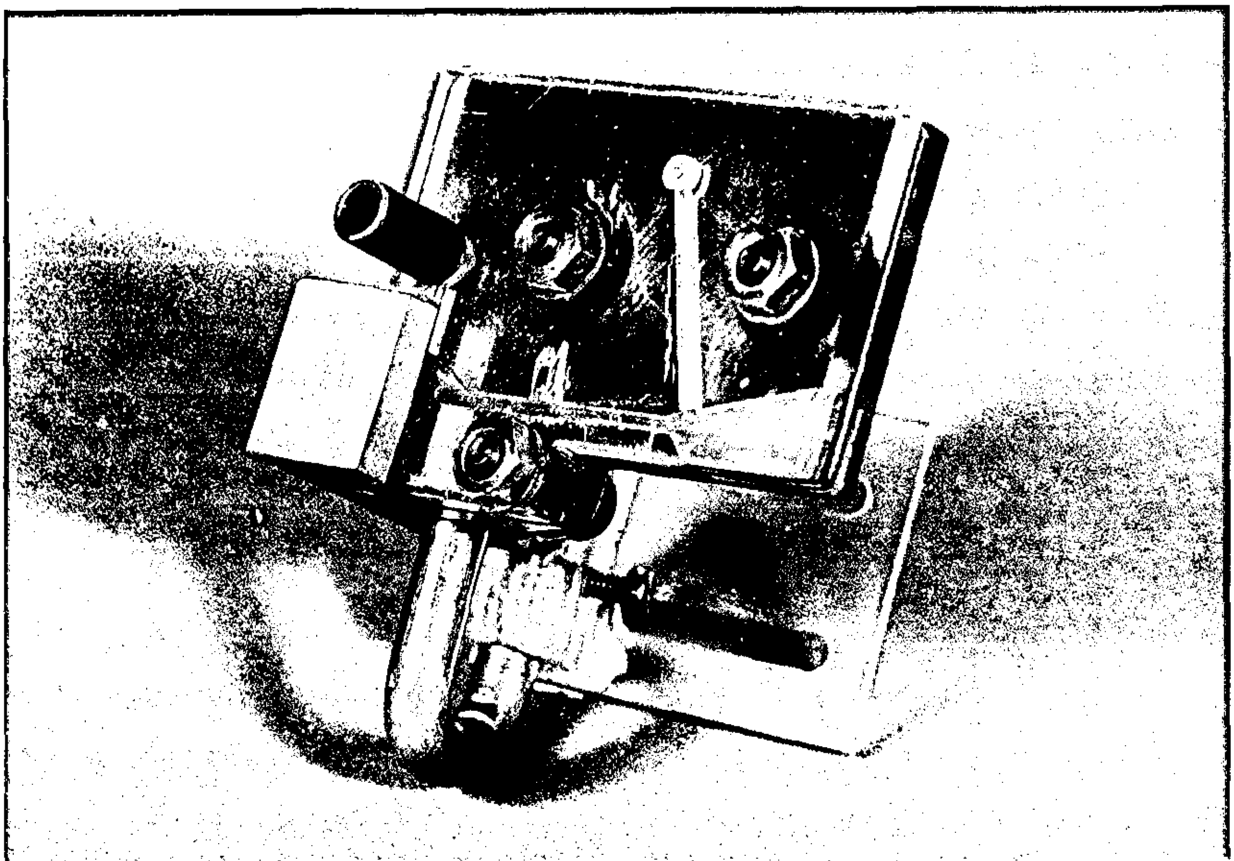
The design of the jet was based on the initial model. The differences were:-

(i) the overall dimensions were smaller to allow use in the restricted space on the machine;

(ii) the pneumatic yarn reservoir provided in the model was omitted due to poor performance and insufficient capacity; and



(a)



(b)

Fig. 7·8 a) The First Single Jet.
b) A Later 2 Jet Block.

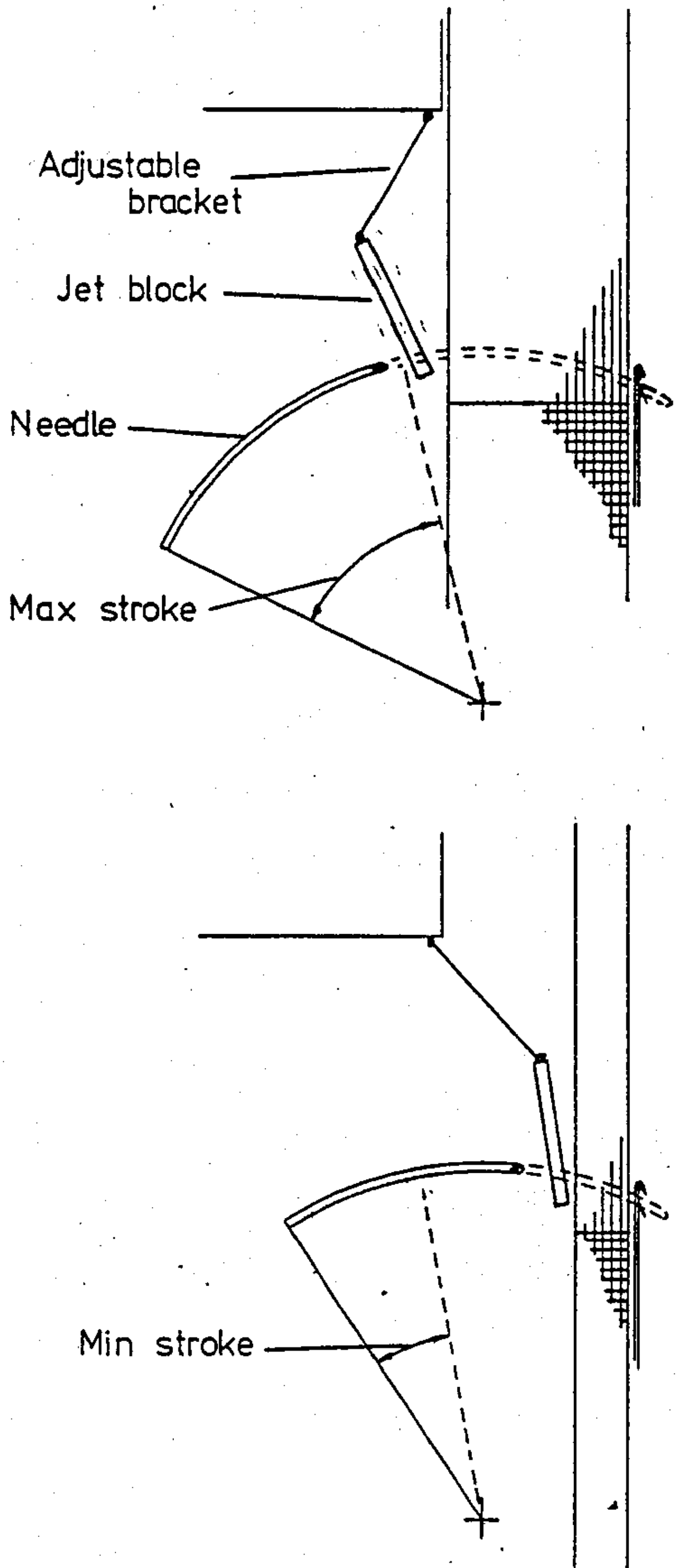


Fig. 7.9. Jet Block Positioned For "Narrow" And "Wide" Fabrics

(iii) A modification was made to the jet soon after initial testing. This involved a change from a central main air feed to a side jet which induced air flow along the jet. This was because the central air feed caused the yarn to pull back from the yarn collection zone and insufficient yarn was thus available for the yarn path to pass through the collection point.

The air jet, shown in Figure 7.8a, was mounted on the machine by means of an adjustable bracket so that the optimum position for yarn collection could be used (see Figure 7.9).

The control signal for the pneumatic value was derived from a disc mounted on a shaft of the machine, cut-outs in the disc being sensed by an optical pick up, and the signal thus obtained being amplified before being fed to the valve. The form of the signals was such that the single yarn in the jet re-selected into the lower (selection) position on each cycle of the machine prior to the passage of the weft insertion needle. In between these selection periods, the yarn was returned to the upper (non-select) position. This was done in order that a simulation of selection was obtained, even though a single weft yarn was employed.

7.7.1.2 Yarn Feed Arrangement

The yarn feed arrangement, used in conjunction with the above described jet, is shown schematically in Figure 7.10.

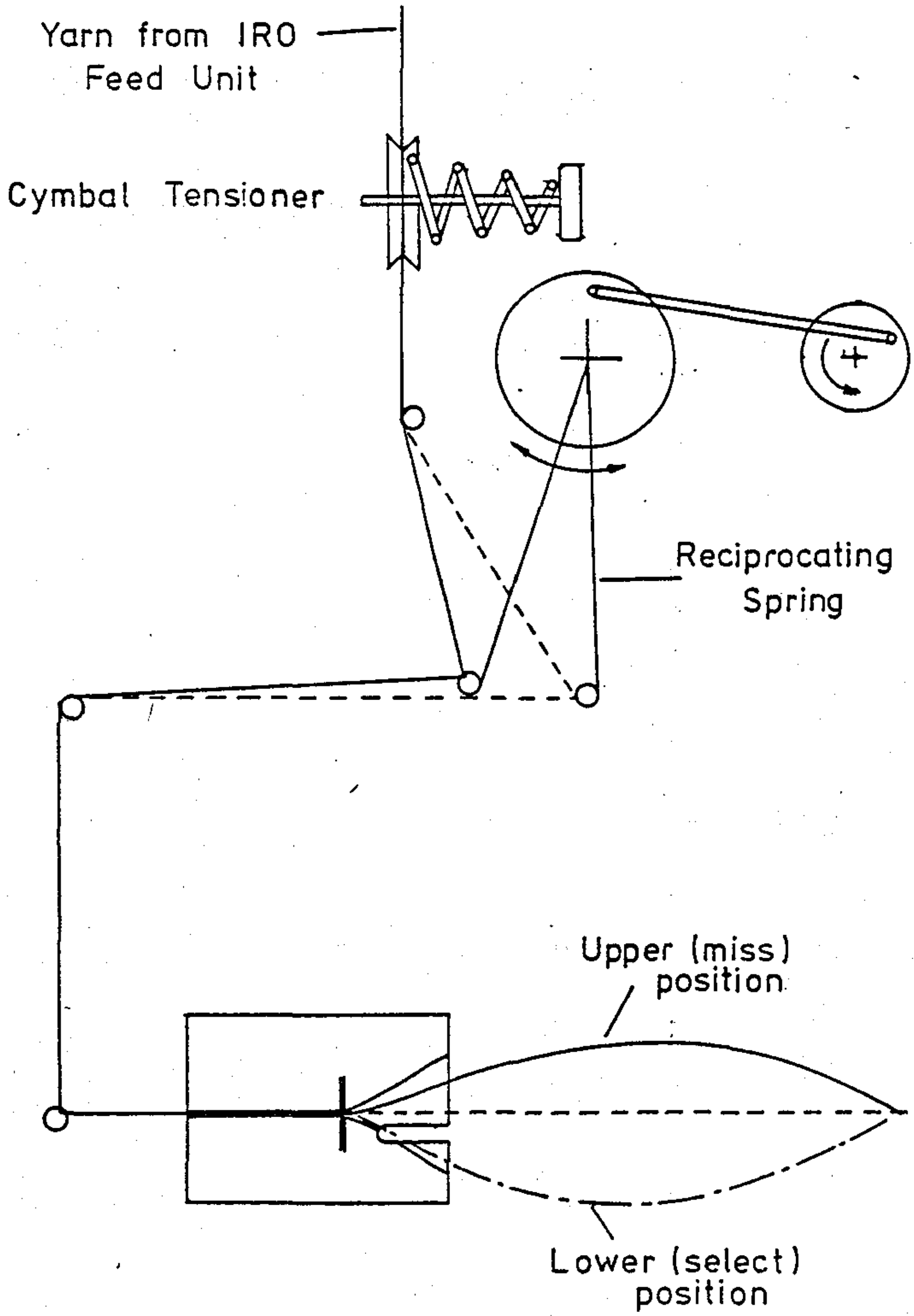


Fig. 7.10. The Weft Feed System

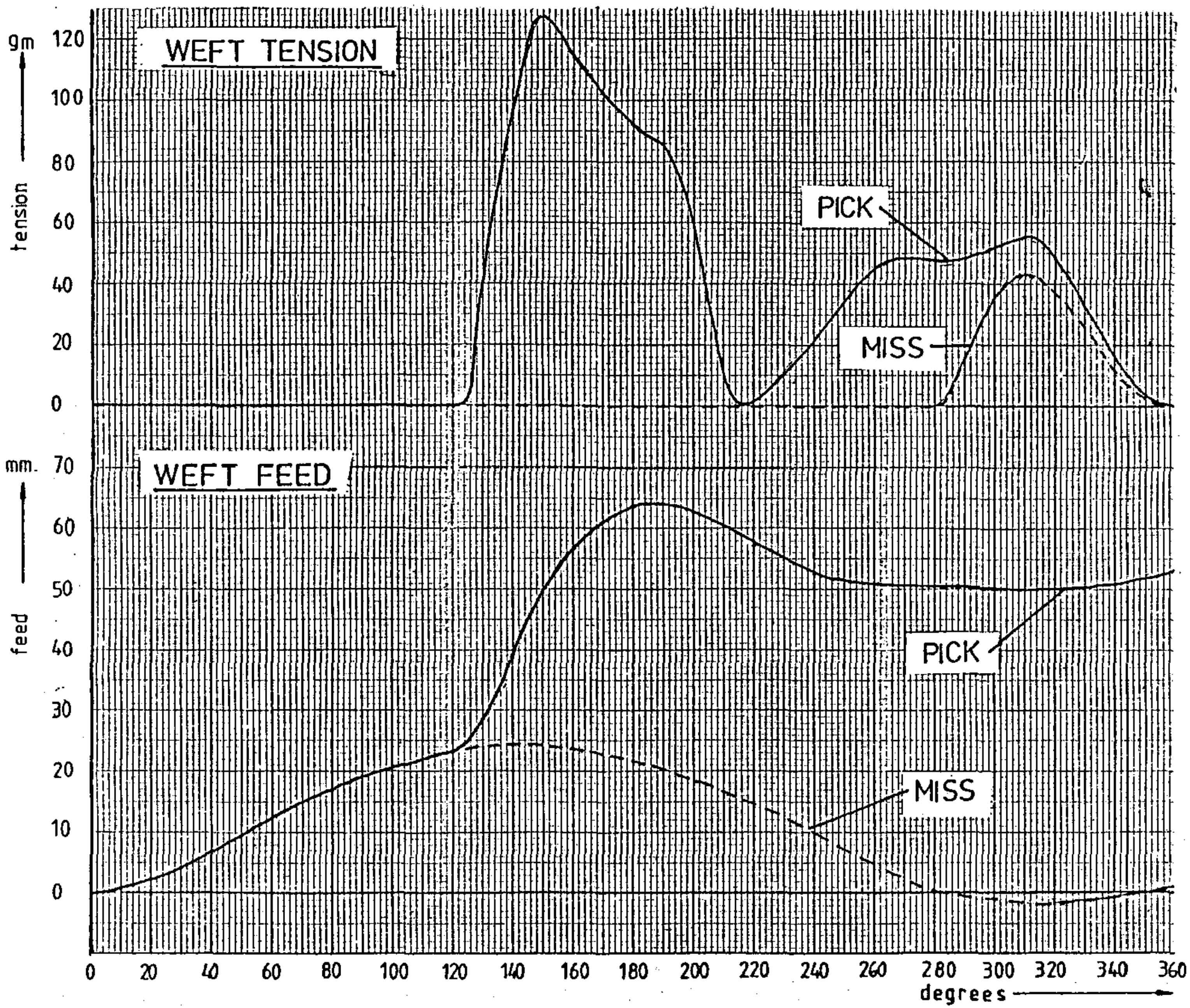


Fig 7·11 Weft Tension and Feed

The yarn was drawn from the supply package by the yarn feed unit, namely the IRO type SFS 1706 mentioned in section 7.6.3. The yarn, after being drawn from the unit, was passed through a cymbal type tensioner employing ceramic discs and a low rate spring. The reason for using a separate tensioner after the yarn feed unit, the let-off tension of which is adjustable only by replacement of a component of the unit, is to provide the possibility of adjustment of the tension whilst the machine is running. (Replacement of the component in the feed unit involves stopping the machine and breaking the yarn for access).

In order for the air jet to deflect the yarn either up, for miss, or down, for select, from the straight line path of the yarn, an excess of yarn at very low tension must be available in the region between the jet and the fabric at the time immediately prior to, and during, the yarn collection. Additionally as the weft insertion needle retracts from the far selvedge, an excess of yarn must be drawn back from the fabric, as described in section 7.6.3. Therefore a variation of yarn feed and tension must be achieved over the weaving cycle. The form of this is shown in Figure 7.11.

This cyclic variation was achieved by means of a spring mounted on a shaft, as shown in Figure 7.10. This spring is caused to oscillate back and forth, and, as it does so, it effectively lengthens and shortens the yarn path between the tensioner and the jet.

The yarn feed cycle was as follows:

0 - 90^{o} Main Shaft Rotation: The insertion needle advances to the selector jet, the back robbing spring advances, and the excess yarn is drawn forward by the main air jet to form an arch, either downwards to select or upwards to miss;

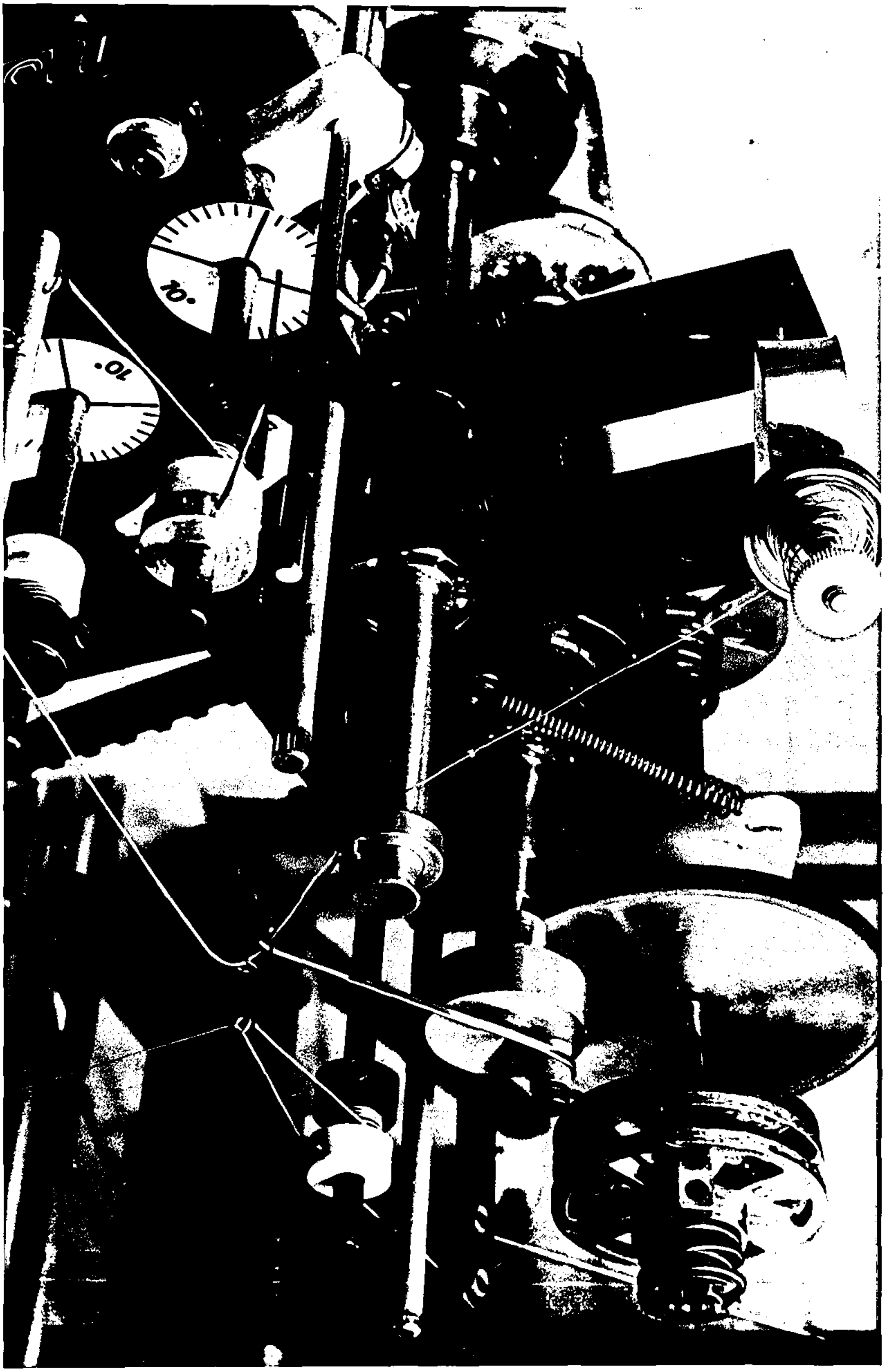


Fig. 7·12 The Modified Weft Back Robbing Device.

90^{o} - 180^{o} Main Shaft Rotation: The insertion needle enters and crosses the shed, carrying the selected yarn with it. As the yarn is pulled, its tension rises to that set at the cymbal tensioner; then additional yarn is drawn as required through the tensioner from the yarn feed unit.

180^{o} - 270^{o} Main Shaft Rotation: The insertion needle retracts, leaving the weft yarn looped around the selvedge - forming latch needle. The back - robbing spring retracts, pulling excess weft yarn from the selvedge area and, if necessary, drawing a small reserve of yarn from the supply to be fed forward on the next cycle and

270^{o} - 360^{o} Main Shaft Rotation: The weft needle is fully retracted, the beat up reed is advanced, and the back robbing spring completes its back stroke.

The input drive to the back - robbing spring is derived from the drive to the original positive feed unit, the round section drive belt having been replaced by a timing belt and pulleys for greater security of timing relationships. Originally, the shaft supporting the spring was reciprocally driven by a simple crank mechanism, the resultant motion being of slightly modified sinusoidal form with approximately equal time periods in both the forward feed and the back - rob modes. In practise, it was found that a dwell period in the back position was desirable to limit the amount of yarn available at the moment of collection. This was achieved by restraining the spring by a link attached to a suitably timed excentric. This is shown in Figure 7.12. Adjustment of the timing and strokes of the two input motions achieved a yarn feed that would select and weave satisfactorily.

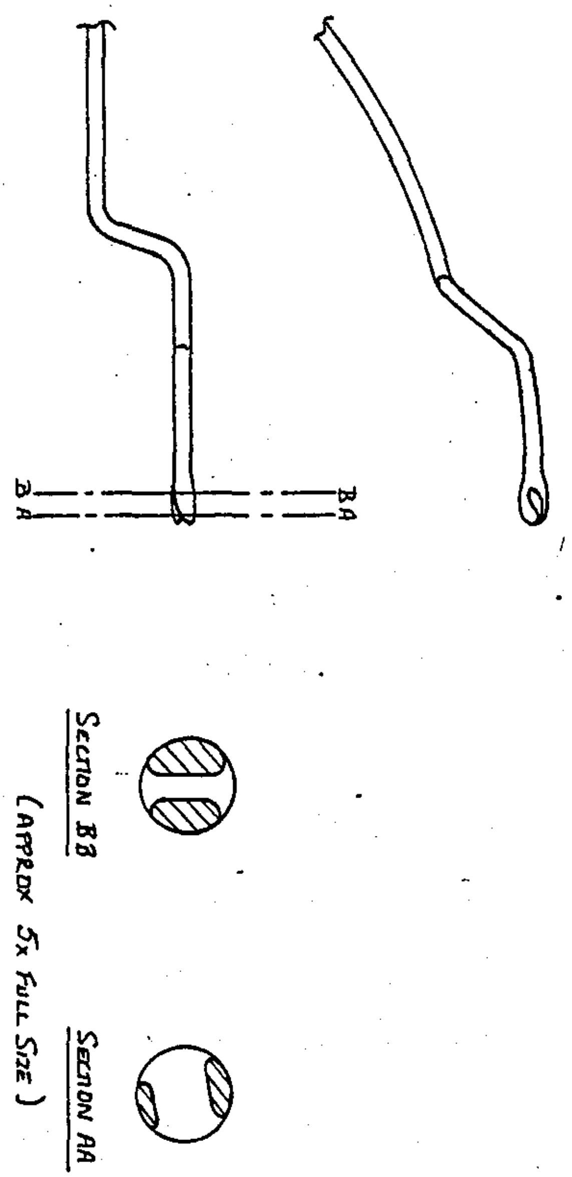


Fig. 7.13. The First Weft Needle.

7.7.1.3 The Weft Insertion Needle

The form of the weft insertion needle used was found to be critical. The yarn was presented, by the jet, at an angle of about 45^o to the weaving plane and along a path which varied to the order of ± 1 mm. For effective interaction with the selvedge - forming latch needle, the weft yarn must leave from the lowest point of the insertion needle. The insertion needle must also enter and pass through the slot provided in the jet block and traverse the warp shed space without fouling warp yarns.

The shape of needle, which, it was hoped, would satisfy these criteria is shown in Figure 7.1 3. It performed with limited success. The entry to the fork was at 45^o to the weaving plane for weft collection, but the root of the fork was perpendicular to it so that the weft would be presented correctly to the latch needle. The smooth narrow shape of the nose of the needle was able to pass through the warp shed, only fouling warp yarns in the most severe cases of shed separation failure. The double crank in the shaft of the needle was needed so that only the tip of the needle passed through the slot of the jet. The needle holder could then pass safely below the jet block.

In practise the weft collection performance was disappointing, the reason being the relative size of the needle cross section compared with the jet 'trumpet'; this resulted in the air flow in the jet, and with it the yarn, being substantially affected by the presence of the needle.

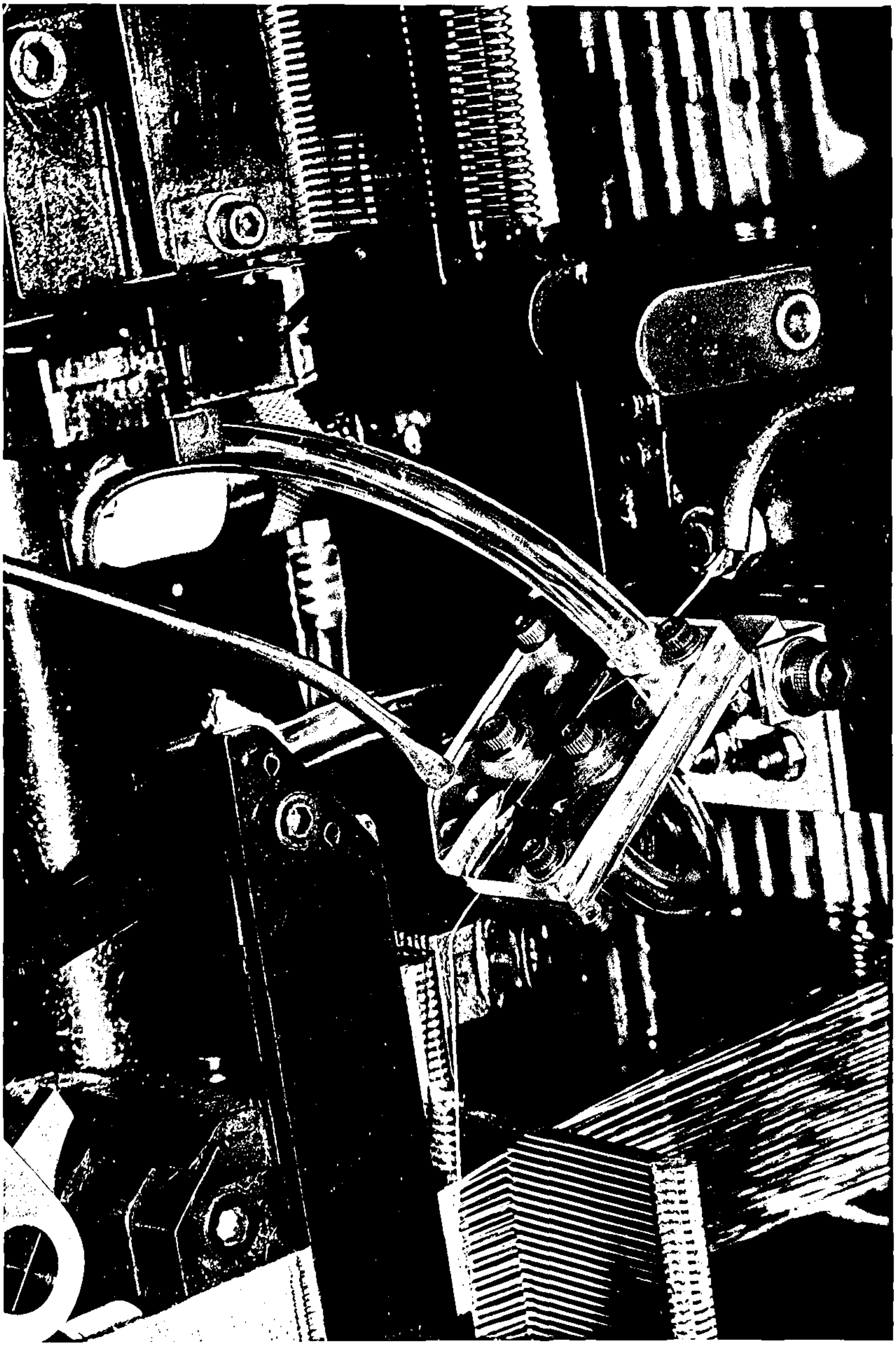


Fig. 7·14 The Insertion Needle And Jet Machine Mounted For Trials.

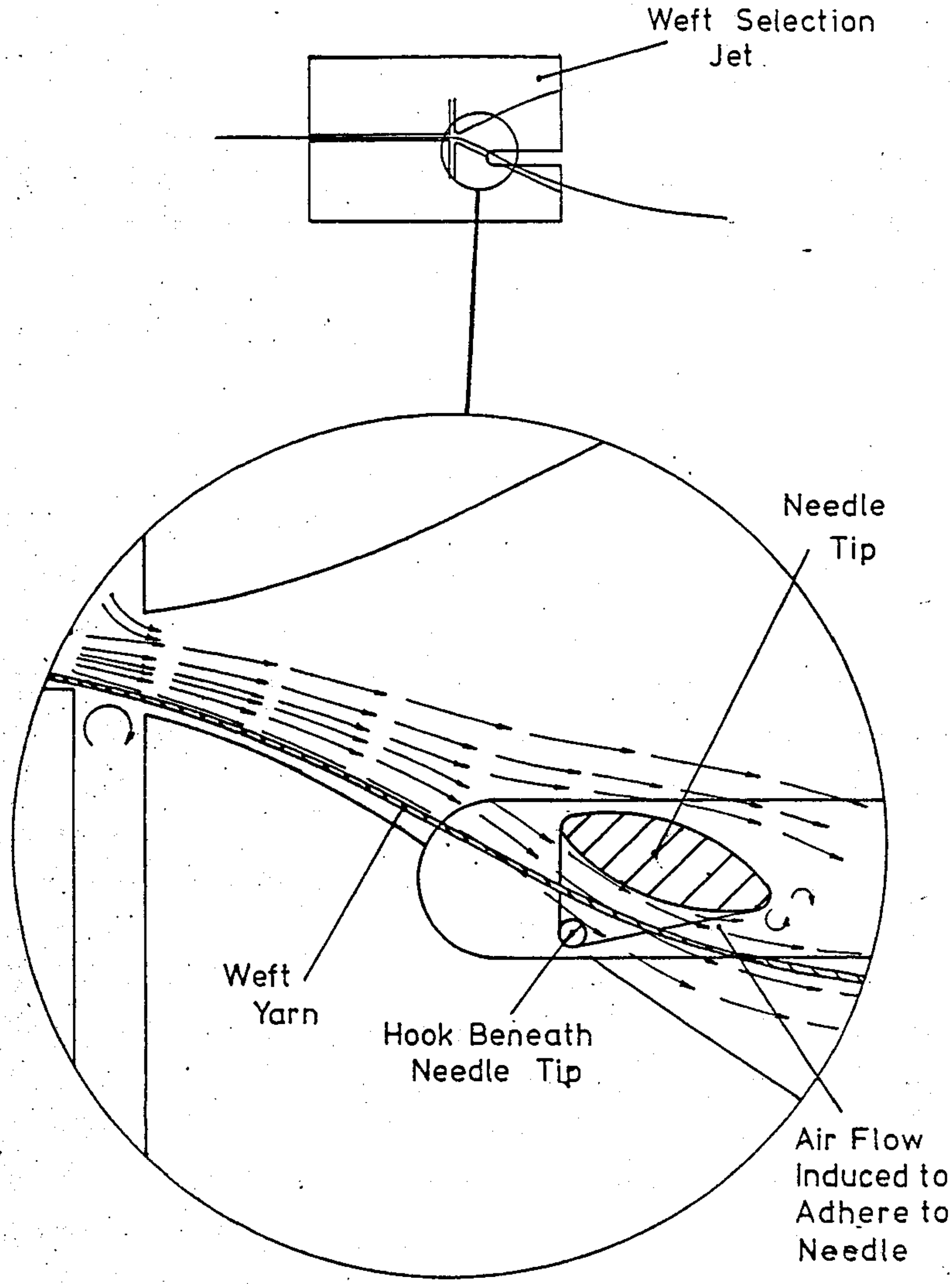


Fig. 7.15 Modified Needle Tip

A modified needle was designed and manufactured. This can be seen set up for use on the machine in Figure 7.1 4. The nose of the needle was shaped such that it would enter the jet above the selected yarn; the jet shape would be changed by the presence of the needle such that the air flow, and the yarn with it, would be drawn up against the underside of the needle (see Figure 7.1 5). Set back, a small distance along the back of the needle, was a hook which would collect the yarn. The hook was made sufficiently small and as to be effectively shielded by the larger nose of the needle as it entered the warp shed, thereby preventing the fouling of any warp yarns which had failed to separate.

7.7.1.4 Performance of First Machine-Mounted System

With the modified needle shapes, and the jet and yarn feed as described above, the system performed satisfactorily and produced an acceptable fabric.

Nevertheless, failures did occur and they fell into one of two categories:

(i) Failure to collect the weft yarn due mainly to poor interaction between the needle and air jet; the hook was too small to tolerate variations in the yarn presentation position; and

(ii) Fouling of warp yarns by the insertion needle, owing to the shape of the needle and to poor selvedge formation. This problem was compounded by the type of warp used namely a 62- end, 300- denier viscose rayon which proved intolerant to even slight contact between yarn and needle. Procurement of a polyester warp helped alleviate the problem for trial purposes although the undesirable contact remained.

7.7.2 Second Machine-Mounted System

7.7.2.1 Aims of Second System

The first system, as previously described, was limited to a single weft yarn, obviously the next stage was to produce a system which controlled several weft yarns.

The performance of the first system was considered carefully before its successor was designed. The principle of operation had been proved to be basically sound but the yarn collection, as it had been achieved to date, was insufficiently reliable. In an attempt to improve the reliability of the weft collection it was decided to modify the insertion needle to provide larger fork, such that a greater area would be swept by the advancing needle thereby increasing the tolerance on the position of the weft yarn as presented to the needle. The shape of the needle as used in the first system also created problems regarding fouling of the warp yarns, and so a redesign of the needle was required on these grounds also.

If a needle with a larger, and more particularly wider, fork was to be used,the way that it interacted with the jet had to be reconsidered; it appeared that the presence of the needle was adversely affecting the flow of air in the jet, therefore to increase the dimensions of the needle would require an increase in the dimensions of the slot through which the needle passed and this would also increase the disturbance of the air flow.

7.7.2.2 The Redesign of the Selector Jet

The inspiration for the design of the first jet was the fluidic bistable device of the wall - attachment type. For fluidic logic purposes, an essential feature of the jet was the ability to set the 'condition' of the jet by means of small input pulse of air, the output selected then being stable and remaining constant until reset.

It was initially hoped that, despite the modification necessary for the air jet to carry a yarn, ie the removal of the flow 'splitter', the jet would retain a bistable characteristic. Thus the controlling input required to select one yarn would be a short pulse of air rather than a continuous flow. In practise it was found unwise to rely on the bistability of the jet which was adversely affected by several factors, namely:

(i) the absence of a flow splitter;
(ii) the presence of a the yarn;
(iii) the intermittent yarn feed; and
(iv) the passage of the weft needle through the output area of the jet.

Consequently the controlling inputs to the jet were used in a continuous mode; this resulted in a greater consumption of air, especially at lower machine speeds, but as the majority of the air was passed continuously through the main jet, in either mode of control, the difference in consumption was negligible.

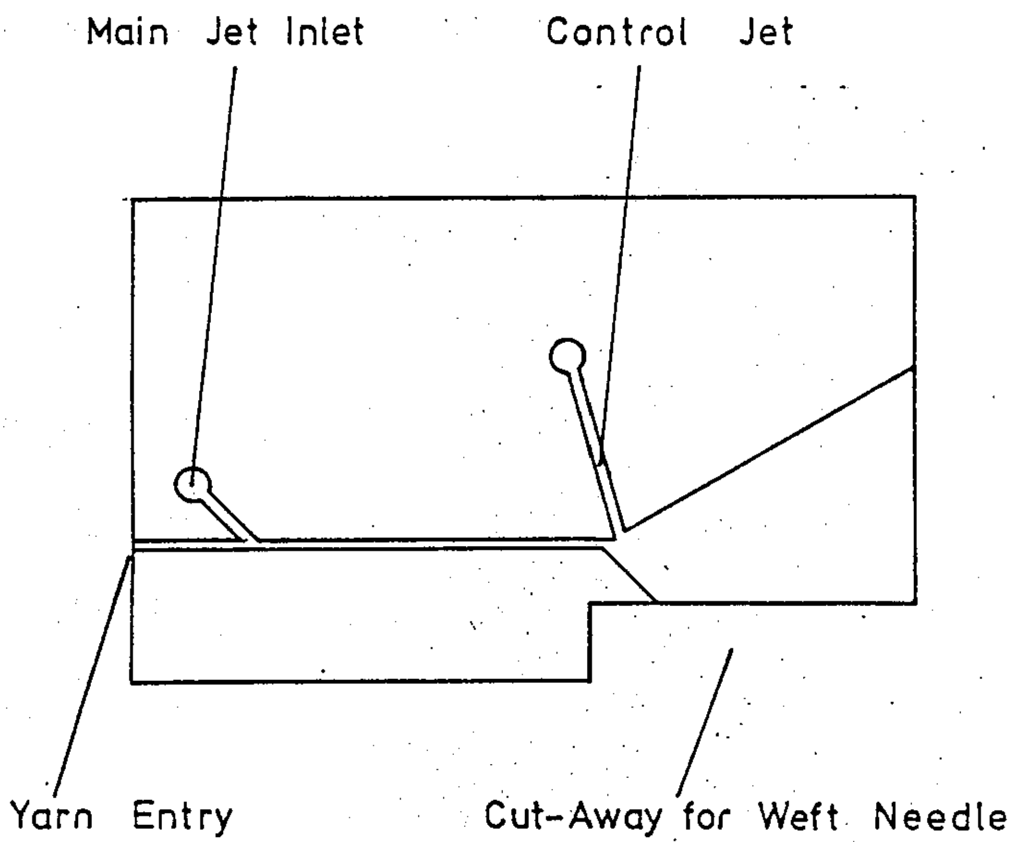


Fig. 7.16 The Simplified Jet

When the jet was redesigned, it was therefore decided to produce a monostable jet, which was easier to produce and more positive in action as the careful balancing of two air flow paths was no longer required. Selection, when required, was achieved by switching a second, unstable, output by means of a continuous control jet which served to detach the air flow from one wall and deflect it along a second path. The jet, and its input, were consequently simplified since the two carefully balanced inputs were replaced by one.

The form of the redesigned jet is shown in Figure 7.1 6. The shape of the jet was further simplified, the curved walls of the bistable jet being replaced by straight walls which were much easier to manufacture accurately. The absence of the lower control jet permitted the removal of much of the lower body of the block such that the slot, which previously facilitated the entry of the weft insertion needle, was no longer required, the needle merely passing immediately below the jet, thus collecting any yarn leaving the jet block from the lower face due to action of a pressurised upper control jet detaching the main jet, and the yarn entrained in it, from the upper jet wall and deflecting it downwards. If the control jet was not pressurised the main air flow and the yarn entrained in it left the block, from the front face, well clear of the path of the weft insertion needle.

This improved form of the jet was checked for its air flow paths by means of a model made from Perspex. This was fed with air in a bench test situation, the air paths being indicated by a length of yarn entrained in the air flow. As far as could be ascertained the performance was satisfactory.

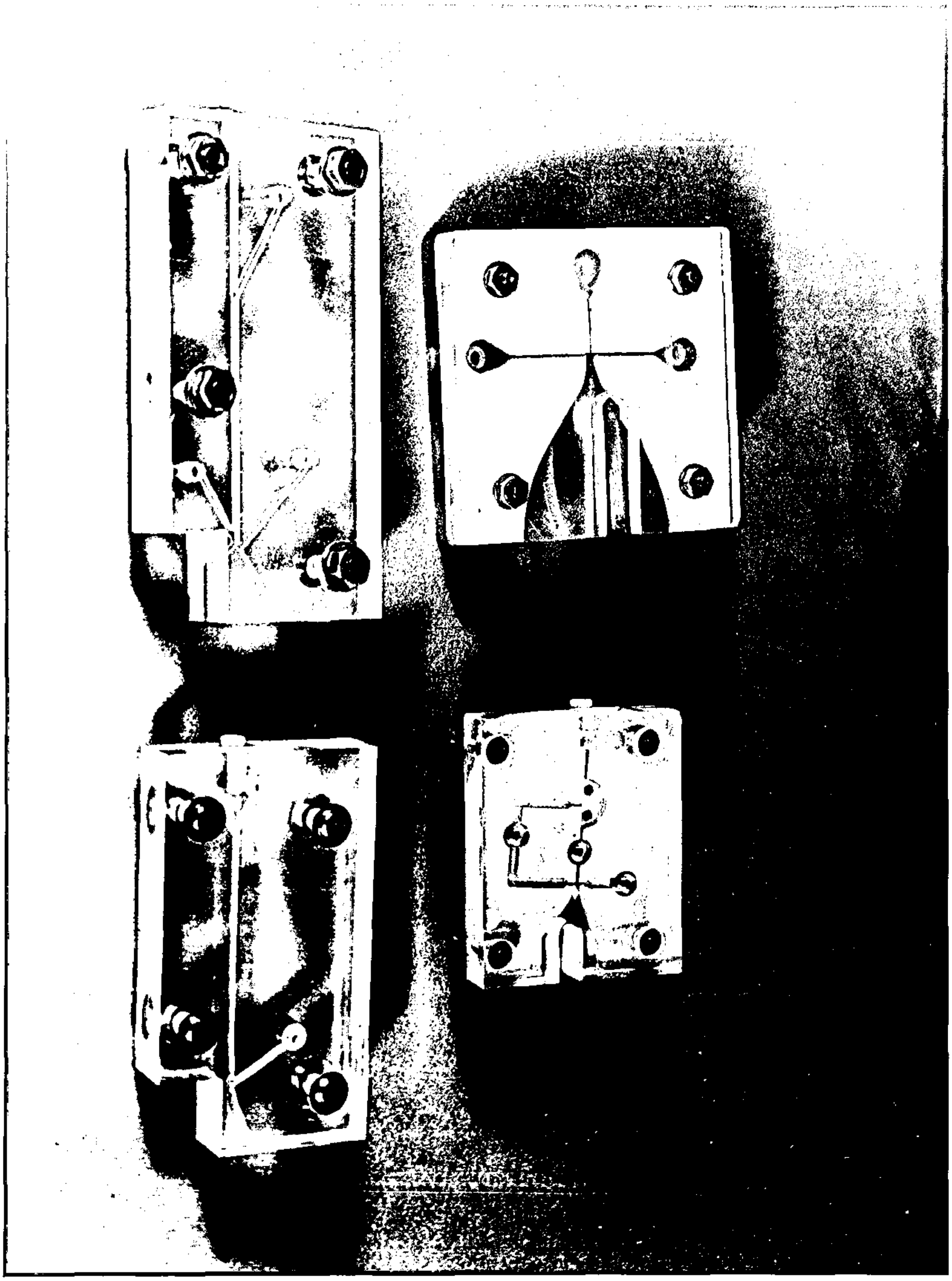


Fig. 7·17 Perspex Models Used In Jet Development.

A jet block, containing two jets so that two yarns could be selected, was made by cutting the jet form in two pieces of Perspex. These were joined together with a shim steel plate between the jets to separate the air flows (See Figure 7.9b).

The controlling signal for the electrically - operated pneumatic values was derived as before, i.e. optically from a disc attached to a shaft on the machine. The shaft rotated at one - half machine speed, and the cut-outs on the disc were such that each yarn was selected on alternate machine cycles. This represented the most severe selection rate possible with a two - yarn system.

Figure 7.17 shows some of the Perspex models used in the development of the jet shape.

7.7.2.3 Redesign of Insertion Needle

To co-operate with the redesigned air jet a modified weft insertion needle was designed. Because the needle was now required to pass underneath the jet, rather than through it, the fork was made larger, the object being to improve the weft yarn catching reliability. The shank of the needle could also be simplified, the cranked form previously employed to give added clearance of the slot being no longer required and the shape adopted being much closer to the original eyed needle. (This needle shape is described in Chapter 6, see Figure 6.5).

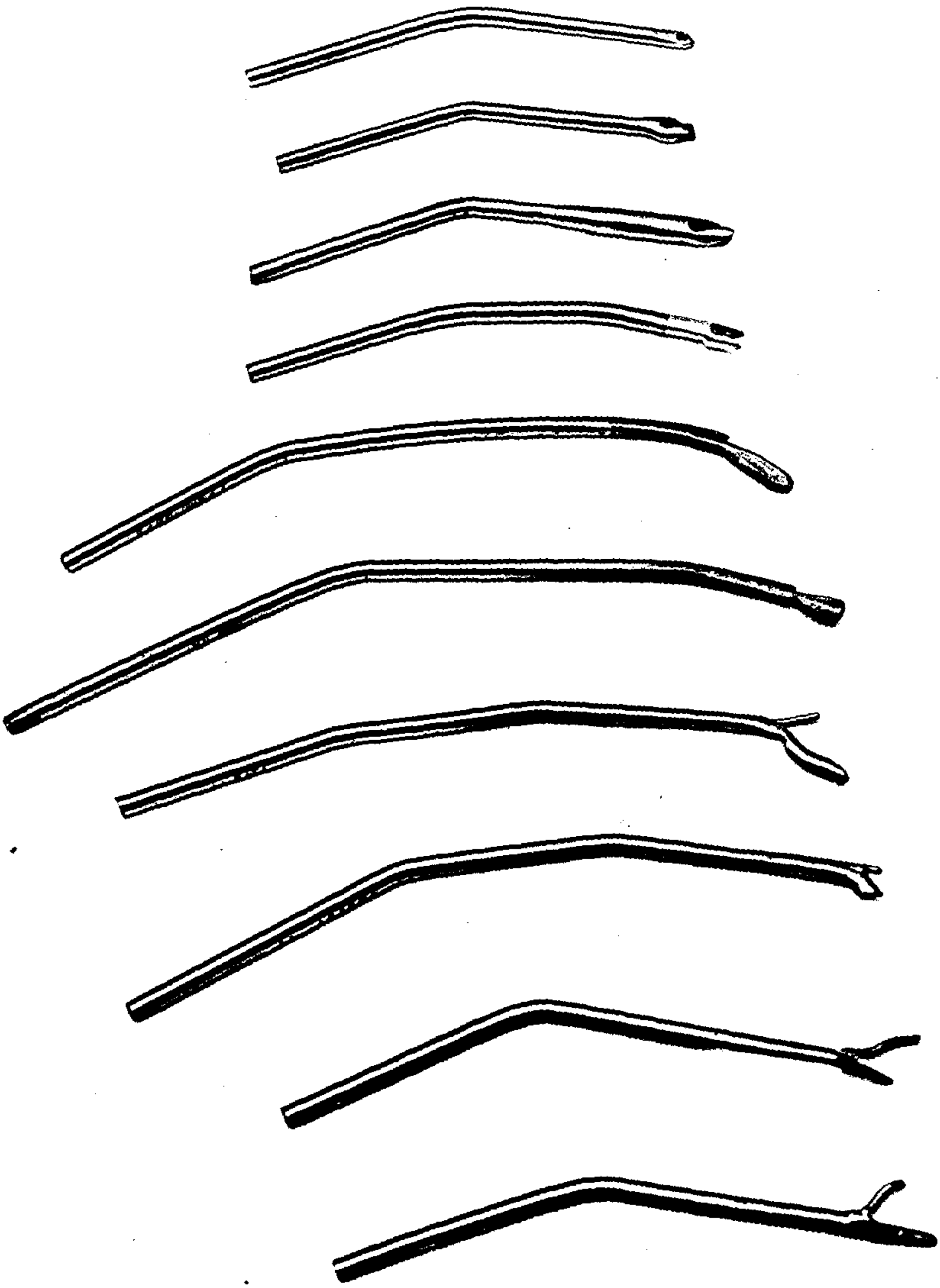


Fig. 7·18 A Selection Of The Weft Insertion Needles Used In The Study.

7.7.2.4 The Weft Supply

The weft yarn supply arrangement was similar to that described in Section 7.7.1.2., this being merely duplicated. However it was found that, due to the new arrangement of selection jet and insertion needle, the yarn collection was more tolerant to the variation of excess length of yarn available at the jet. Consequently it was no longer necessary to produce a compound motion of the back-robbing spring, a simple sinusoidal reciprocating motion being sufficient to produce satisfactory weaving.

7.7.2.5 Performance of Second Machine-Mounted System

The performance of the system, as it then existed, was good. The failure rate, as compared with the first system was very much improved ; both types of fault as previously described still occurred but at a much lower incidence rate. Weft yarn tension, in particular affected the fault rate and most faulting occurred in the period of initial trials of yarns, i.e. whilst experience of use of the system was being gained with a particular yarn.

7.7.3 The Third Machine-Mounted System

7.7.3.1

This system was virtually an extension of the second system, such that up to six weft yarns could be conveniently accommodated. A description of the system as a whole, and also the individual components, is given in Chapter 6.

For the purpose of experimental trials the input signals required for the valves which control the jet block were derived from a circuit employing electronic logic to access a repeatable sequence of signals to the valves. To facilitate a reasonably thorough testing of the system, the sequence, which in its most basic form is a serial actuation of the six valves, was capable of modification by adjusting switch positions, in the following manner:-

(i) Each valve could be operated for any number of machine cycles, up to nine before the next valve was operated;

(ii) Each valve could be operated on its own for an indefinite number of cycles; and

(iii) The number of valves in the sequence could be limited to any number from 2 to 6.

Details of the circuit used to provide the controlling signal are given in Appendix 4. However, one point worthy of note here, is that all six of the pneumatic valves were driven directly from a single integrated circuit; this contained all of the driving transistors, which responded to the logic level signals fed to them. The total power consumption of the circuit, including the power used to drive the valves was less than 100 mA,

7.7.3.2 Performance of Third Machine-mounted System

A series of tests was made with the system to explore its capabilities. Only the most extensible of the yarns failed to weave satisfactorily; this was due to the considerable distance between the back robbing mechanism and the selector jet.

Bringing these components closer together should improve the handling of elastic yarns.

The system was able to handle all other yarns tried at speeds up to the maximum achievable by the loom i.e. 2400 picks/min. Yarns of differing types and tex values required only very slight differences in settings and could be incorporated in a single fabric without any difficulty.

CHAPTER 8: THE PATTERN CONTROL SYSTEM

8.1 INTRODUCTION

The warp and weft selection systems developed during the period of this study, and described in Chapters 4 and 6, are designed to respond to electrical input signals corresponding to the configuration of yarns which is desired in the fabric to be produced. (For the reasons for the choice of a signal that is electrical in nature see Section 8.3). Without the provision of these control signals neither system could function.

In basic terms the warp selection system requires a two-state signal for each warp yarn being controlled; this would be true whatever the nature of the signal and the system being controlled by it, since each warp yarn has the possibility of occupying two positions. Because the specification calls for control of 400 warp yarns, the control system must provide 400 "bits" of information for each pick of fabric produced.

The weft selection system also requires a number of controlling signals and, since each weft yarn is either selected or not, the number of "bits" of information required equals that of the total number of weft yarns being controlled. It will be shown later that,because of the relatively small number of weft yarns being controlled, compared with the number of warp yarns, it is not necessary to define the number of control signals needed at this stage.

In the traditional forms of machinery used to introduce patterns into woven fabric, the signals required to control both warp and weft selection are mechanical in nature, e.g. pegs in a belt or chain in Dobby systems and holes in cards in Jacquard systems.

The limitations of these mechanical systems are discussed in Chapter 2. To enable the proposed warp and weft selection systems to perform at the high speeds for which they are intended some other, faster form of data storage and retrieval must be employed.

8.2 CONTROL SYSTEM REQUIREMENTS

The primary object of the control system is to provide the signals, as required, which are to be implemented by the warp and weft selection systems.

Whatever form of control is chosen it must fulfil the applicable requirements of the Specification of the entire system as laid down in Chapter 3. In particular the system must be such that it is:

i) commercially viable. The cost at which this would occur is difficult to define but it is probably of the order of cost of the basic, plain fabric producing loom;

ii) capable of providing 400 "bits" of information for warp selection and 12 "bits" of information for weft selection for each pick at speeds up to 3000 picks/min;

iii) able to provide a prearranged sequence of data corresponding to many picks such that a pattern may be produced, this sequence to be reproduced many times consecutively, and possibly after a long period of disuse, during which other sequences may be required. Thus some form of memory is required for short term and long term use;

iv) able to receive the date initially, either previously 'digitized' or preferably from a more readily available source, e.g. a drawing; unfortunately the data required is not merely a straightforward binary

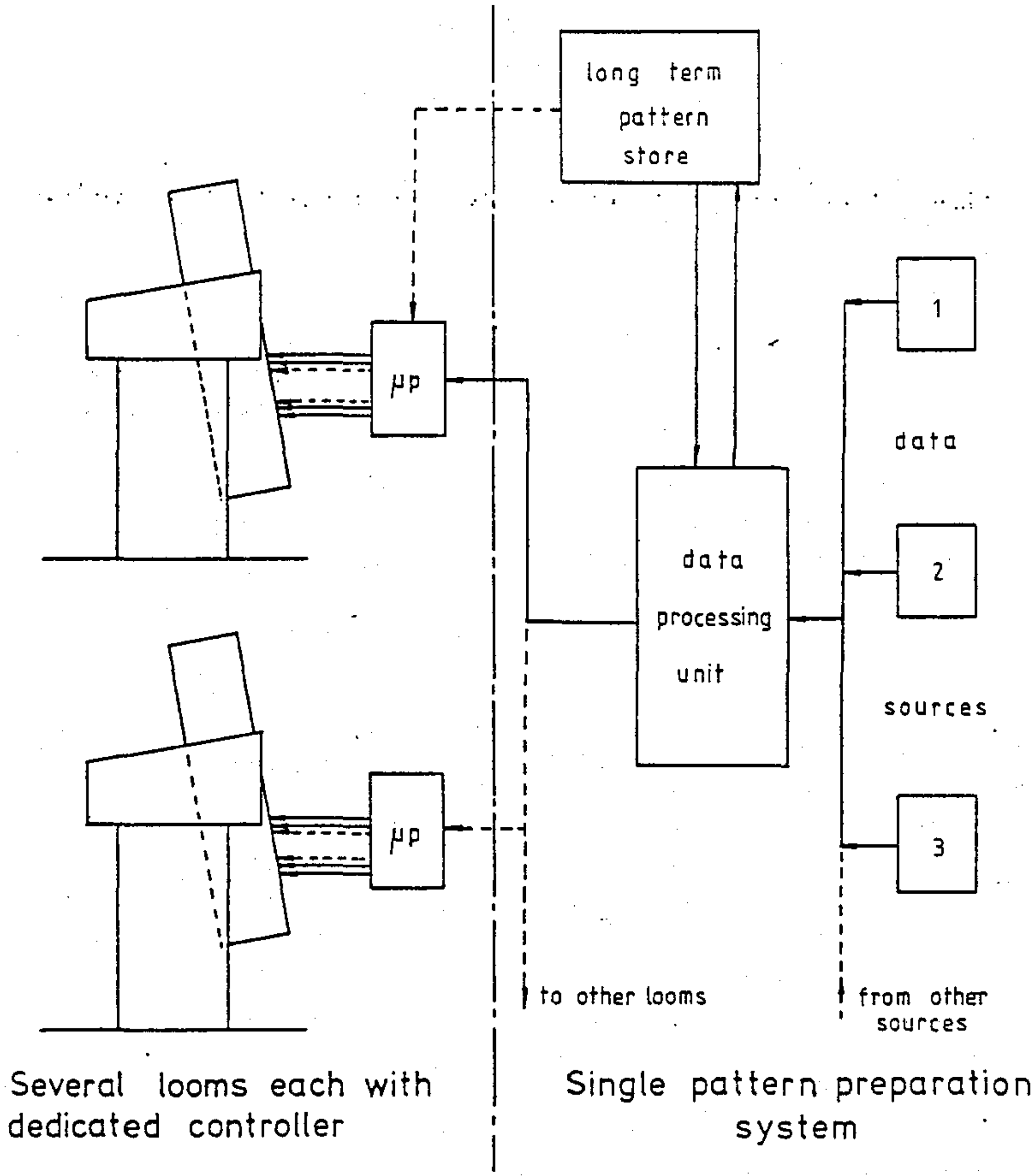


Fig. 8.1. Division of System into Preparation and Control

equivalent of the design, since a satisfactory fabric must be formed by the interlacing of warp and weft yarns.

v) In a great many instances where the patterning system would be used, there would be several machines similarly equipped. To provide flexibility in production scheduling it would be useful if the sets of pattern data could be exchanged between machines and also reproduced so that more than one machine could produce fabric corresponding to one data set, possibly at the same time.

There are conflicting aspects of these requirements i.e. a simple function to access the data to the machine as it is required by the machine , and which operates during the whole time the machine is running, and a more complex function to derive the data, a task which is only required once and which is not required to perform at production machine speed. These requirements are considered to be best satisfied by developing two separate systems (see Fig 8.1). This former,simpler system is dedicated to the fabric producing machine; it reads the data from some form of storage and provides it to the machine at the rate at which it is required. The latter , more complex system, would work in its own time to generate the pattern data, possibly from several sources; it would provide any manipulations on the data required to ensure a satisfactory fabric or to "edit" the design. It should be capable of feeding the data to the machine dedicated systems of several machines and also provide a permanent or semi-permanent record of the data for later use.

This proposed sharing of the functions of the overall system should also provide economic advantages, especially in installations comprising several machines, since that part of the system essential to each machine would be kept as simple, and therefore as inexpensive as possible.

Conversely the more complex, and hence more expensive, part of the system would be required only intermittently; it could be shared between several fabric producing machines and would not impede their performance whilst fulfilling its own function.

The considerations given to each of these sub-systems are described in Sections 8.4 and 8.6.

8.3 THE NATURE OF THE CONTROL SIGNAL

In order to permit the concurrent development of both the selection systems and the control system, a decision was made early in the study to determine the nature of the signals which would pass from the control system to the selection mechanisms. The limitations of the traditional mechanical signal have been discussed previously (See Section 5.1), and the decision was made to adopt an electrical form of signal. The exact characteristics of the signal were not specified at that stage as some degrees of freedom would be useful in all the systems and, generally speaking, it is relatively easy to condition electrical signals and so match the input and output characteristics of the systems.

The reasons for the choice of an electrical signal were:-

i) a preliminary survey of data storage and retrieval means, taking into account the constraints of speed and capacity required, suggested strongly that the means employed should be electrical, in some form, in order that compatibility with an electrical interface could be readily achieved;

ii) a vast range of technology exists to modify and condition electrical signals into virtually any required form at moderate cost;

iii) the frequency response and bandwidth required through the interface is well within the capabilities of electrical signals;

iv) electrical power supplies are readily available;

v) electrical signals are easily and efficiently transmitted from one location to another via cables; and

vi) should the need arise, due to factors unforeseen at the time of the decision, to use principles of operation which required an input or output which is other than electrical in nature, there exist a vast range of devices to convert electrical signals to or from, virtually any other form of signal.

8.4 THE MACHINE CONTROL SUB-SYSTEM

8.4.1 The Detailed Requirement

The characteristics required of the system dedicated to a narrow-fabric equipped with a warp selection system, as proposed in Chapter 4, and a weft selection system, as described in Chapter 6, are as follows:

i) The system must be able to store a minimum of 81,200 bits of information. This corresponds to a 200 pick repeat pattern comprising 400 warp yarns, to be positioned either 'up' or 'down' for each pick, and a a selection of one from six weft yarns for each pick;

ii) during each pick of the machine, the system must be able to 'recall' 400 bits of data for warp selection, these signals to be made available simultaneously and held for a minimum of 25% of the machine cycle time. (Note that the actual timing of the signal must be from 0^{o} to 50^{o} of main shaft rotation during the insertion time of the pick immediately preceeding the pick. corresponding to the supplied data(see Section 4.3 and Fig 4.9).

iii) in addition to the above stated data requirement, the system must provide a signal to one of six control valves incorporated in the weft selection system. This signal must be provided for a minimum of 50% of the cycle, the timing being from 270^{o} of main shaft rotation during the preceeding pick to 90^{o} of the current pick.

iv) the signals must be synchronised to the machine cycle so that fluctuations in machine speed, acceleration of the machine during starting, and deceleration during stopping,will not affect the registration of the signal from the control system with the machine operating.

v) the range of machine speeds with which the system must be compatible, is from a maximum of 3000 picks per minute to a minimum of zero, i.e. the system must retain its integrity during machine stoppages and to be able to cope with the manual "inching" of the machine.which is required during fault rectification and machine set-up.

vi) the system must be able to recognise the end of a pattern data set and automatically return to the start of the set for the next pick in a manner which is identical to that of passing between consecutive picks.

vii) as the pattern date must be repeated a large number of times, the system must be such that any deterioration of the pattern data due to its having been read must be sufficiently minimal that renewal of the data is only required after long periods of use e.g. 10^{5} pattern cycles.

viii) the system is to be capable of receiving the set of pattern data from a co-developed pattern preparation sub-system.

iv) as the system is to be dedicated to the fabric producing machines on a one-to-one basis, the cost of the system should be as inexpensive as possible whilst still retaining a high reliability characteristic.

8.4.2 Possible Forms of the Machine Sub-System

A survey of the principles on which data and storage and retrieval systems could operate was undertaken. The characteristics of each form of system were compared with the requirements listed in the previous section. The most significant techniques considered are listed below together with brief comments on their suitability.

8.4.2.1 Mechanical Jacquard, as currently used in the weaving industry.

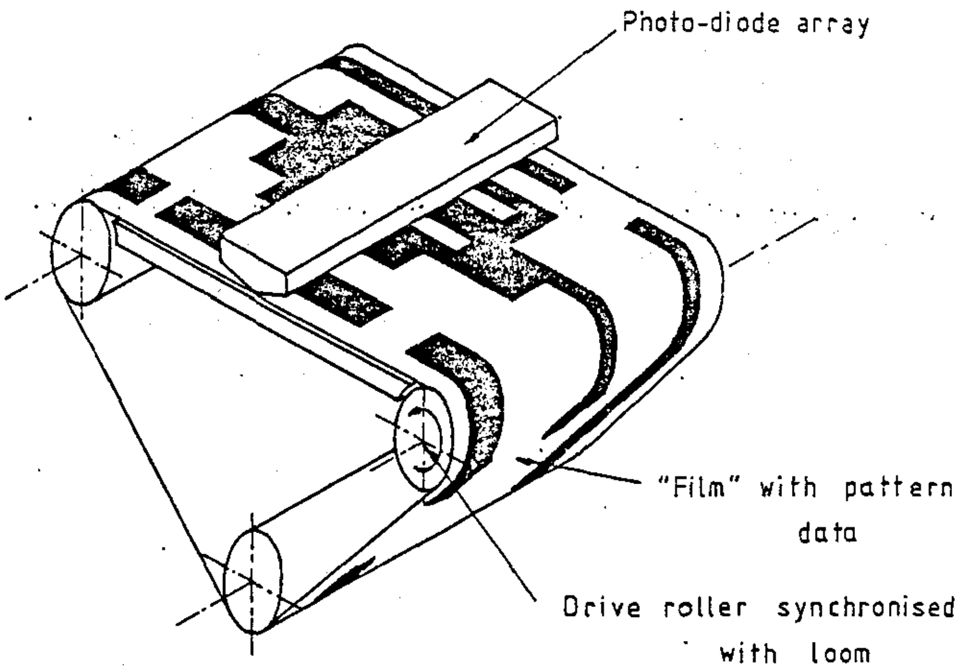
The speed limitations, capital costs, maintenance costs and "programming" problems of this type of system have already been discussed in Section 2.

8.4.2.2 Pattern Wheel, as currently used in 'Jacquard' Knitting

The quantity of information that can be stored by this type of device is limited. The cost of the many such wheels that would be required would be prohibitive as would the cost of pattern preparation.

8.4.2.3 Punched cards, of the computer type

These represent a cheap and convenient means of storing data. The speed of reading these cards though fast is likely to be below the requirement. Cards of this type are liable to damage and wear.



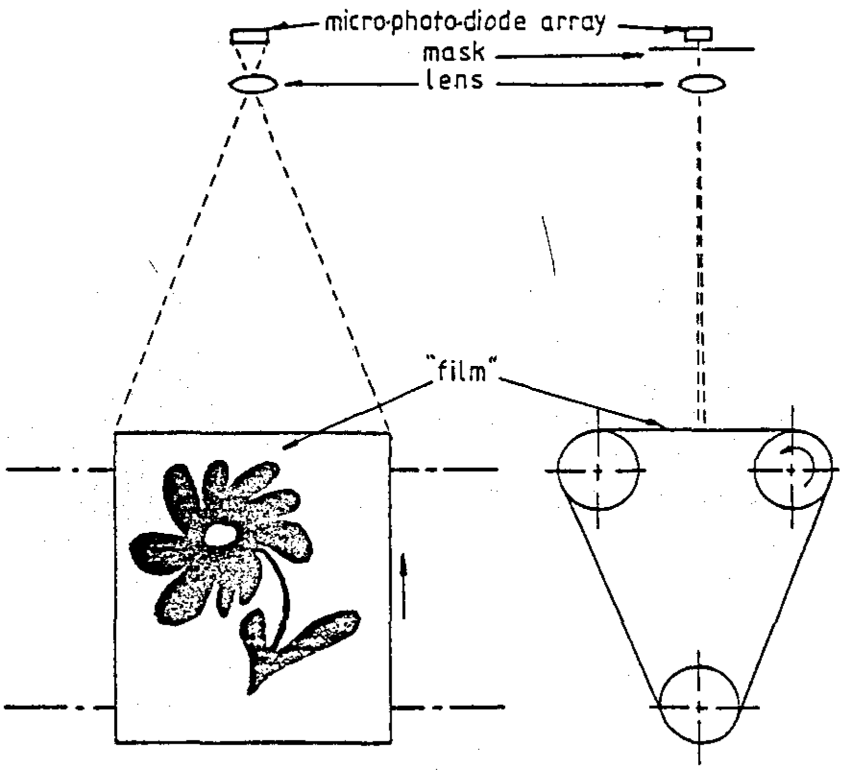


Fig. 8.2. Optical Control Systems

Cyclic reading of a deck of such cards should be possible but would require careful engineering.

8.4.2.4 Punched Paper Tape

The rate of reading information from a paper tape is lower than from cards. The tape is just as liable to damage as are cards but the cyclic reading of tape could be realised very easily.

8.4.2.5 Magnetic Tape/Magnetic Disc

This is a form of data storage commonly used in computer systems. The rate at which data could be read from such a medium is sufficient for this application but difficulty could be experienced in synchronizing the data retrieved with the machine operation, and would probably be expensive in practice.

8.4.2.6 Optical Sensing from Film or Tape

(See Fig 8.2)

The use of arrays of photo-sensitive electronic devices reading encoded information from a continuous loop of film or tape, is a possible solution, in that the speed of response is sufficient and it would be simple to synchronise the tape with the machine. Devices, such as photo-diodes, are available in arrays of up to 12. To simultaneously read over 400 channels of data would however require many such arrays and the tape would have to be of the order of 2.4 metres wide. Similarly the length of film required for each pick of pattern information would be of the order of 15 mm. Thus the film would be large and difficult to handle.

An alternative could be another type of array in which photo-sensitive devices have been formed on the same chip of semiconductor material. The result is a much more compact unit but at a very much higher cost. Another problem incurred by the use of this type of device would be the production of the 'film' carrying the encoded data as this would need to be of very fine resolution. Photographic reproduction could be used but the process would not be straightforward and would involve equipment and skills not normally available in a typical weaving company.

8.4.2.7 Microprocessor controlled semi-conductor memory

The advances made over recent years in micro electronic technology in terms of cost, availability and computing power, make the use of a dedicated microprocessor-controlled system an alternative well worthy of consideration. There are many features of such a system which are very attractive for this application:-

i) there are no moving parts to wear out or fail and so reliability should be high;

ii) the unit would be compact and have very low power requirements;

iii) the system would be easily matched to pattern preparation systems which use electronic logic principles;

iv) a variety of means exist to store the data for use at a later date;

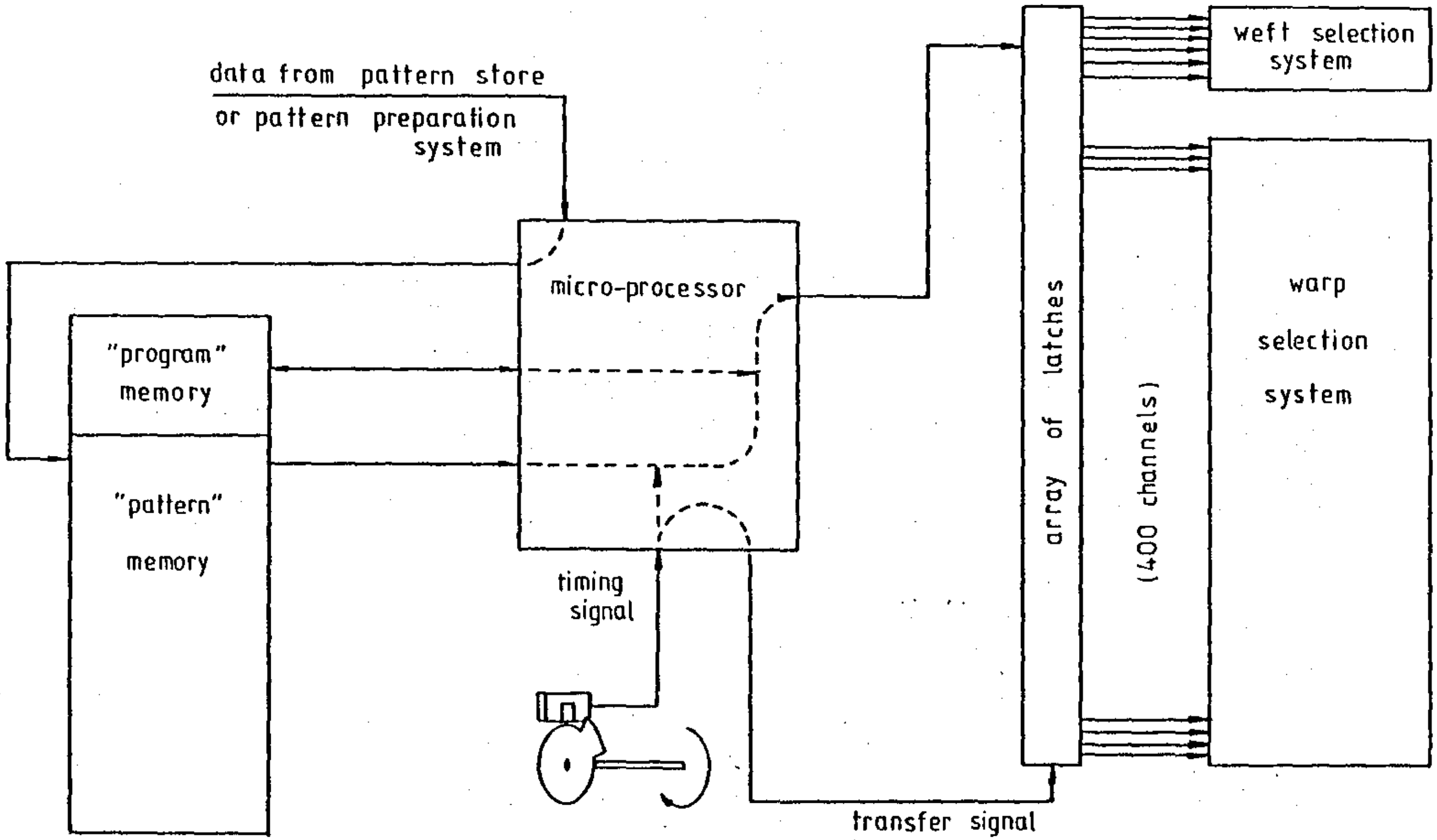


Fig. 8.3. The Machine-Based Control System

v) the cost of the system would depend upon the number of such systems produced, the approach to the organisation of the system, and the facilities provided by the system, but is liable to be very competitive with any other form of system considered. Unlike most other components and materials, the cost of micro-electronics is falling and is expected to continue to do so, at least for some appreciable time.

8.5 FURTHER INVESTIGATION OF A MICROPROCESSOR BASED SYSTEM

Having considered the alternative forms of machine control sub-system it was apparent that a microprocessor controlled semiconductor memory offers a potentially satisfactory system at moderate cost. There remained however two vital aspects of this type of system which had yet to be proved satisfactory.

i) Speed of response. Would such a system be able to access the data held in the memory in the time available?

ii) Memory capacity. Would such a system be able to store sufficent data to reproduce a reasonable size of pattern area?

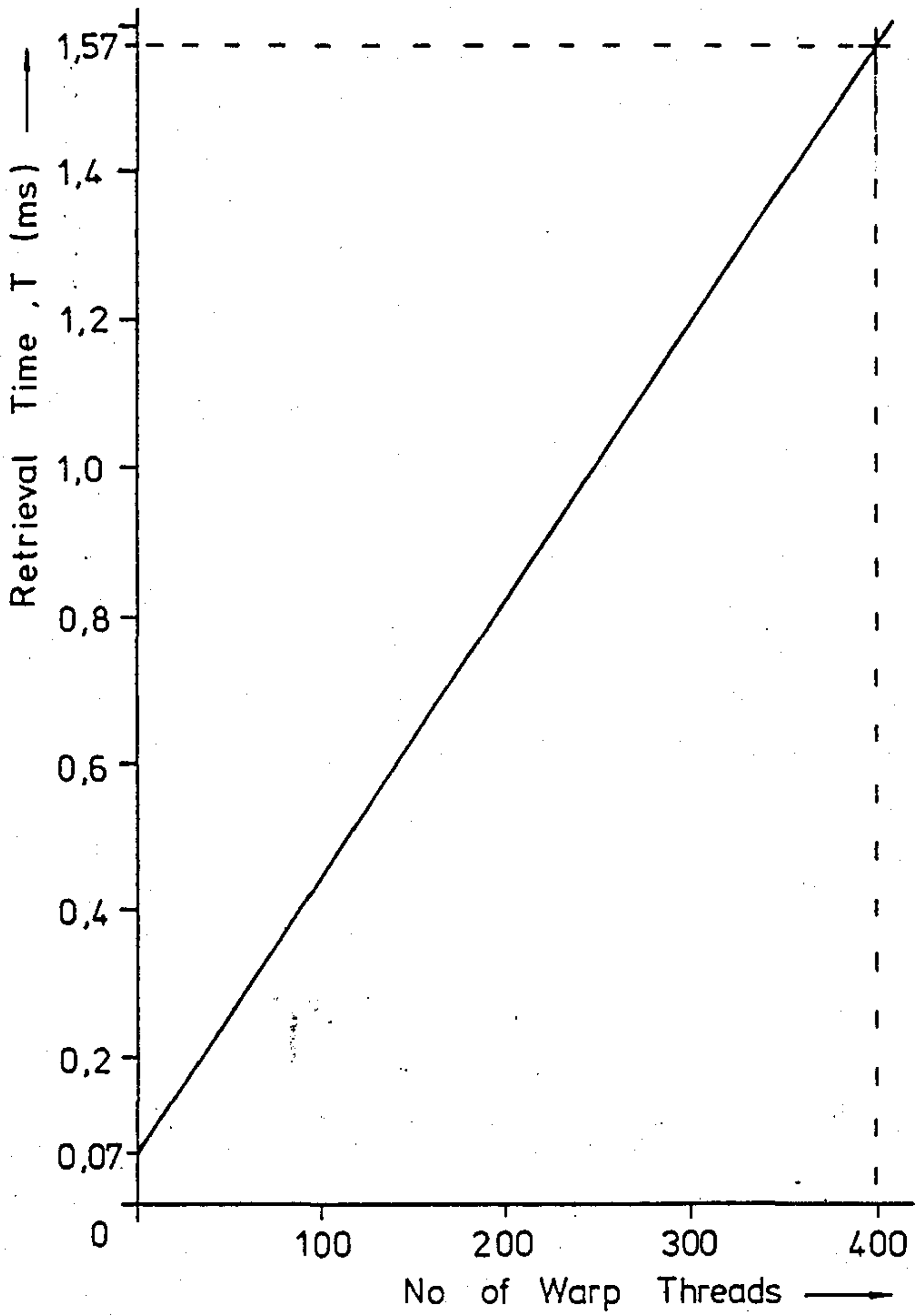
In order to answer these questions some work was undertaken by D.R. Lambert, as an Undergraduate Final Year Project in 1979 [12] which was jointly supervised by the author. This work is summarized here.

The type of system envisaged is shown in Figure 8.3 The pattern data is assumed to be in the memory of the system. The microprocessor locates the start of the pattern data and transfers it, 8 or 16 bits at a time, dependent on the type of components used, to an array of electronic "latches".

The data held in the array corresponds to one pick of selection information. After it has filled the array, the microprocessor awaits a signal from the loom which indicates that it is in the correct part of its cycle to accept the new data. The data is transferred to the warp and weft selection systems. Once this has been achieved the microprocessor proceeds to transfer the next "pick" of data from the memory to the array to await the next signal.

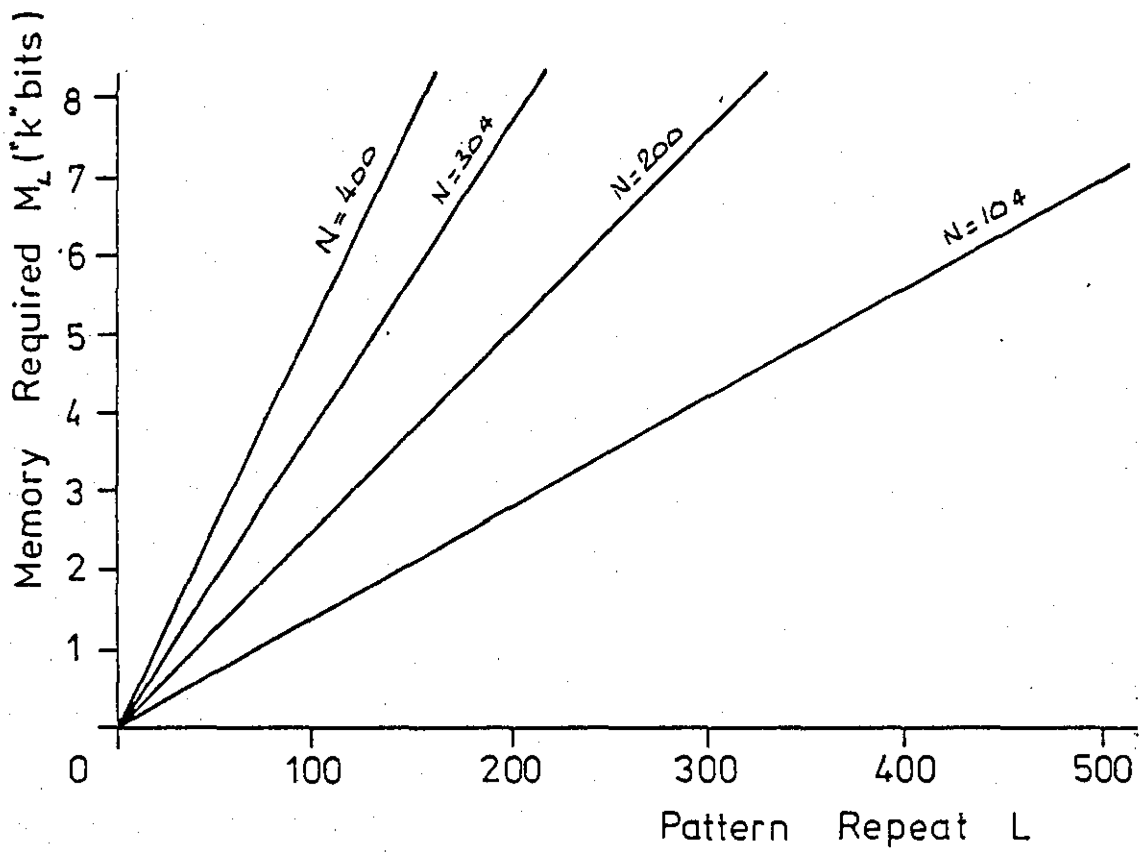
In the tests performed, a microprocessor module sold under the name of KIM 1 was used. This incorporates, on one board, the microprocessor, the memory, and the other circuits needed to allow the system to function. The power supplies and the array of latches were external. It would be quite feasible to use a general purpose system such as this for a production machine; all that is required is the correct programme to control the operation of the microprocessor. This programme is stored along with the pattern data in the memory of the system. However, since , for general use, it is desirable to be able to change this control programme easily, the memory used is of a type such that its contents can be changed (Random Access Memory). This type of memory is volatile , i.e. when the power supply is removed the information held in it is lost. It is because of this undesirable feature that it may be preferable to develop a system specifically for this particular application, in which case the programme could be held in a form of permanent memory (Read Only Memory or ROM). However, this choice does not affect the operation of the system and the validity of the results of the tests being described here.

A programme was written for the KIM 1 based system which controlled the data as previously described with the addition that, when the last of the pattern data had



$$T = \frac{40 + 30(N/8 + 1)}{1000} \text{ mS}$$

Fig. 8.4 "Loom 1" Retrieval Time



$$M_L = \frac{L}{1024}\left(N/8 + 1\right) \quad \text{kbits}$$

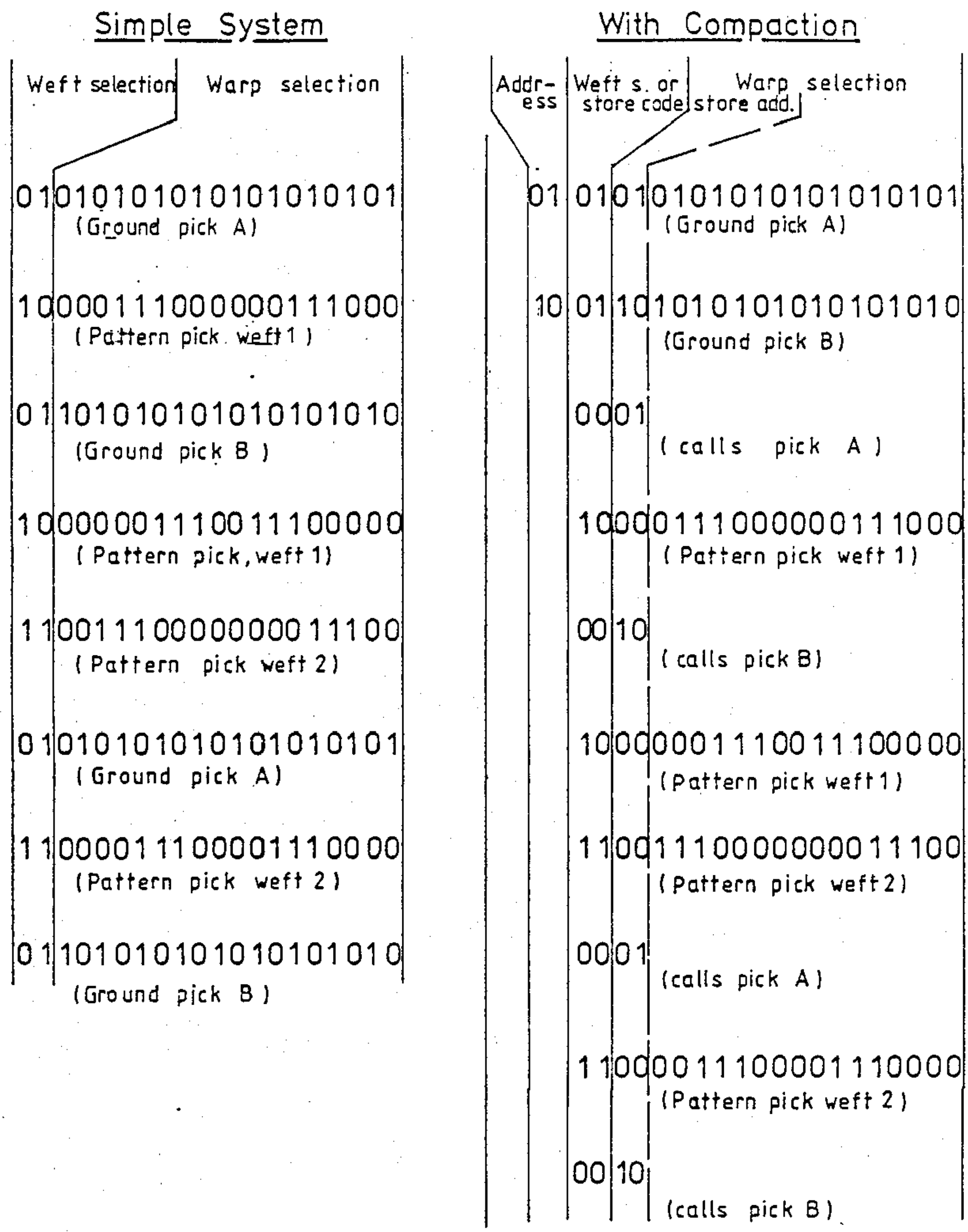
Fig. 8.5. "Loom 1" Memory Requirements

been transferred to the array, the microprocessor returned automatically to the start of the data set to provide a continuous cycle of operation.

This system was run in a bench-test situation to ensure that the programme was "bug-free". The time taken by the system to perform a cycle of operations corresponding to one pick was obtained by analysis of the programme. This can be done since it is known how long each type of operation takes in terms of pulses from the clock incorporated in the system. The clock rate is known, therefore the cycle time can be calculated. Since the programme length depends on the number of yarns being controlled, and hence on the number of bits of information required per cycle, the data retrieval time varies accordingly. The time corresponding to the maximum of 400 warp yarns and six weft yarns was found to be 1.47 ms (see Fig 8.4) i.e. well within the minimum time available.

The second area of investigation was that of the data storage capacity. The KIM I module is capable of addressing up to 64K of memory, although this amount is not actually provided on the single board. The amount of memory occupied bears a simple relationship to the pattern area. This is shown in Fig 8.5. At present the memory components are amongst the most costly items of the microcomputor module and, whilst the memory can be expanded by the addition of components, this would greatly increase the cost of the system. The interim conclusion was that memory of sufficient capacity to store even very large patterns could be provided and controlled but only at considerable cost.

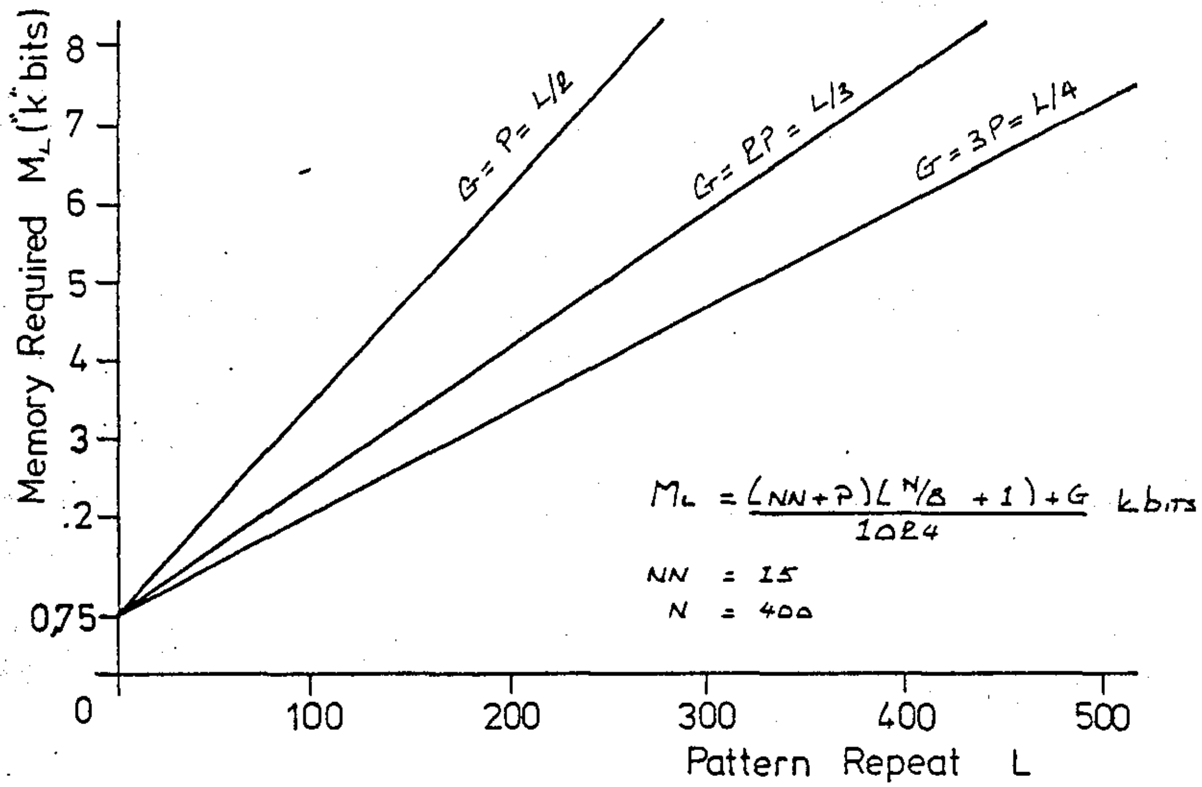
The control programme used up to this stage organised the memory in perhaps the most straightforward manner, i.e. the required position of each warp and weft yarn for each pick occupied one location in the memory in a serial arrangement.



Memory Requirements

Simple System	With Compaction
4 pattern picks (20 bits) = 80	4 pattern picks (20 bits) = 80
+ 4 ground picks (20 bits) = 80	+ 4 ground picks (4 bits) = 16
	+ 2 stored picks (20 bits) = 40
total 160	total 136

Fig. 8.6. Comparison of Memory Requirements



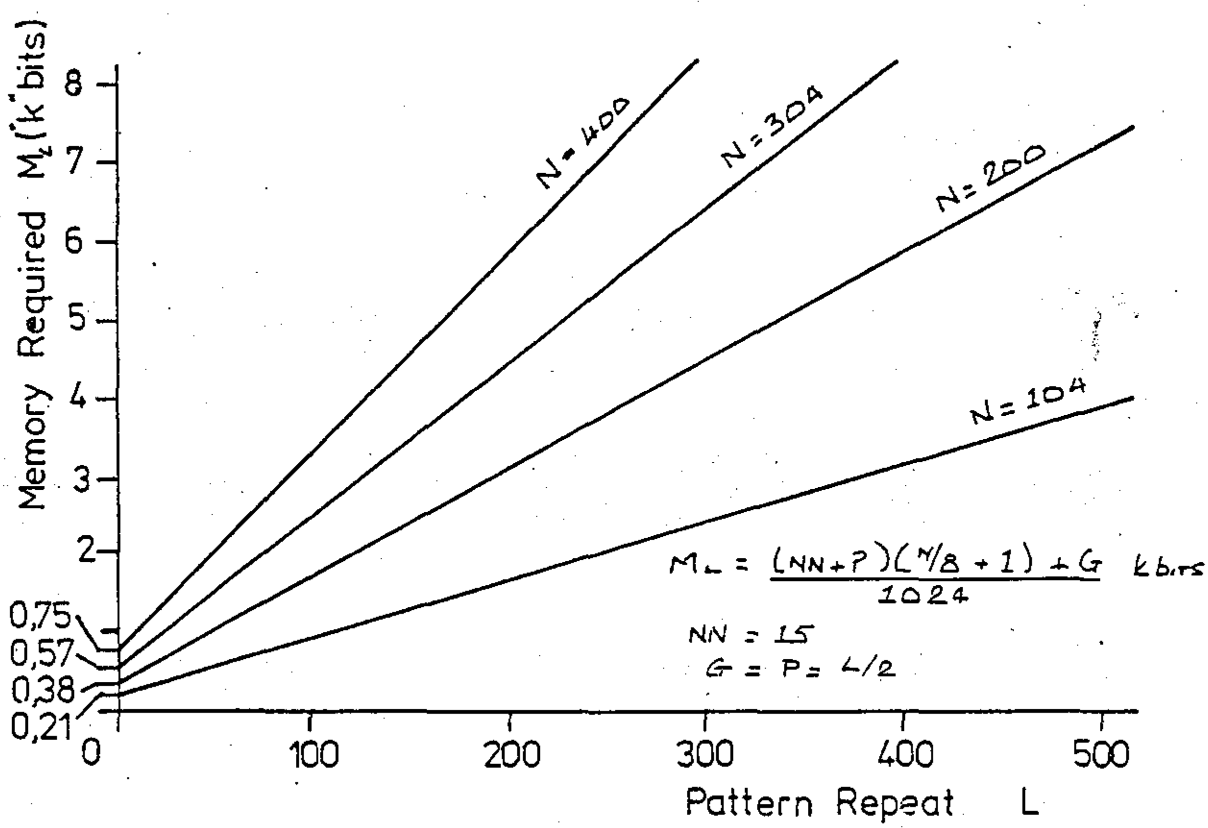


Fig. 8.7. "Loom 2" Memory Requirements

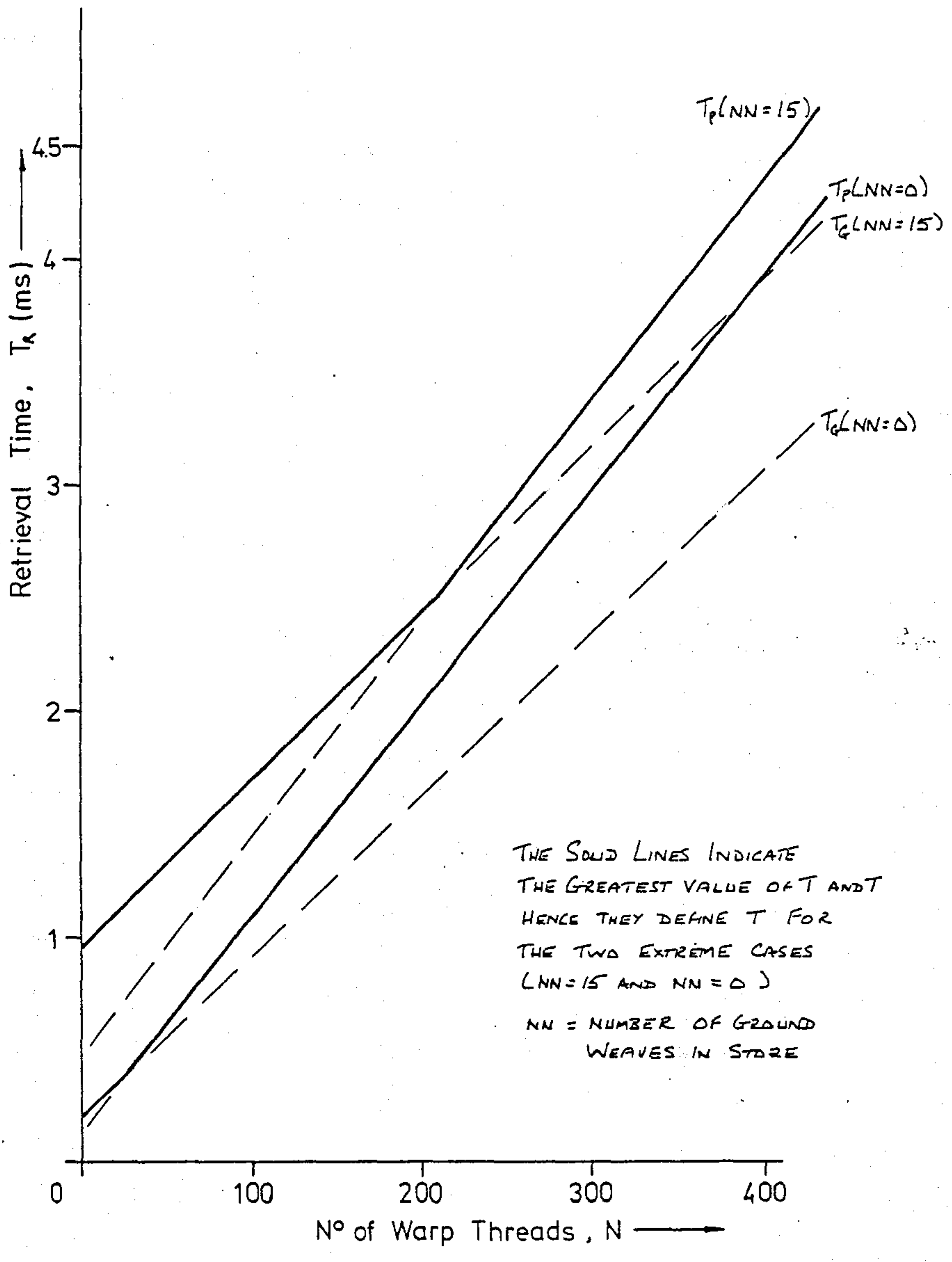


Fig. 8.8. Retrieval Time for "Loom 2"

Thus the number of memory locations occupied is equal to the total number of warp and weft yarns multiplied by the number of picks in the pattern. It was noted that, in practise, many picks of a patterned fabric are in fact identical, especially when these picks correspond to the base fabric. For example, if the base fabric was of 1 x 1 weave, then each pick of the base fabric would comprise one of two alternatives, either 01010101... or 10101010.. If the fabric contained many base fabric picks, as most do, a great deal of memory would be used to store the same sequence many times over. Consequently , much of this memory could be saved by referring to a small 'library' of basic sequences when one of these base fabric picks is required rather than listing each pick in full.

This concept was incorporated into a second programme. As the microprocessor starts to retrieve a row of data from the memory it checks the first digits of the row for a code which, in the case of the illustrative example shown in Fig 8.6, is 00; if this is present it causes the next two digits to be read as an address for one of several base fabric picks stored elsewhere in the memory. This is then transferred into the array. If the code had not been present, then the data is transferred from the memory located immediately after the test digits as in the first programme.

The results of this more sophisticated programme are two fold:

i) The memory requirements are reduced (see Fig 8.7) and therefore the cost of the hardware is similarly reduced.

ii) The time taken to retrieve the data is increased, due to the greater number of operations undertaken by the microprocessor (see Fig 8.8).

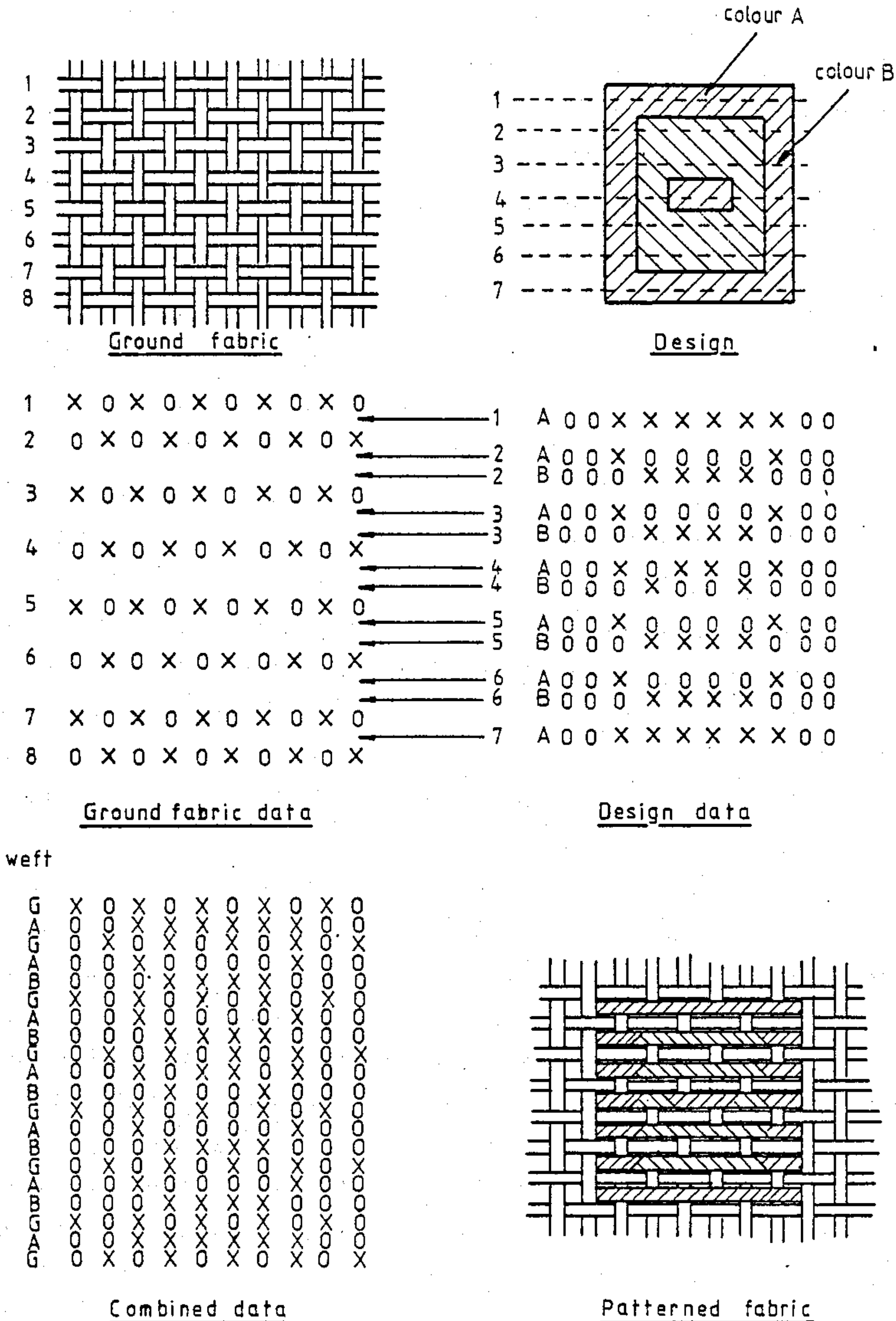


Fig. 8.9. Data Set Combination

The time taken is dependent on the number of threads controlled and on the number of base fabric picks that are stored apart from the pattern. In the case of 400 warp yarns and 15 stored base fabric picks, the maximum time taken is 4.285 ms; that is still well within the time available.

It was concluded that a system comprising a microprocessor controlled semi-conductor memory would fulfil the requirements of the machine control sub-system conveniently and economically. The experience gained from the work undertaken showed that such a system would be reasonably straightforward to assemble. The possibility of further sophistication of software and hardware could provide better performance and lower costs.

8.6 THE REQUIREMENTS OF A PATTERN PREPARATION SUB-SYSTEM

The function of the pattern preparation system is to provide the data set corresponding to the required construction of the patterned fabric to be produced. This data must, of course, suit the machine control system which will access the data to the selection systems.

The data set can be considered to comprise a combination of two sub-sets, one corresponding to the figured design as it would appear on the face of the fabric, and the other corresponding to the base fabric construction. The most common manner of combining these sub-sets is demonstrated by the example illustrated in Fig 8.9 and described below.

Assume that the last pick to have been inserted corresponds to the last of the base fabric picks immediately prior to the colour appearing in the design. For the next pick (1 in Fig. 8.9), a weft yarn is selected which is the colour required by the design(A) ;

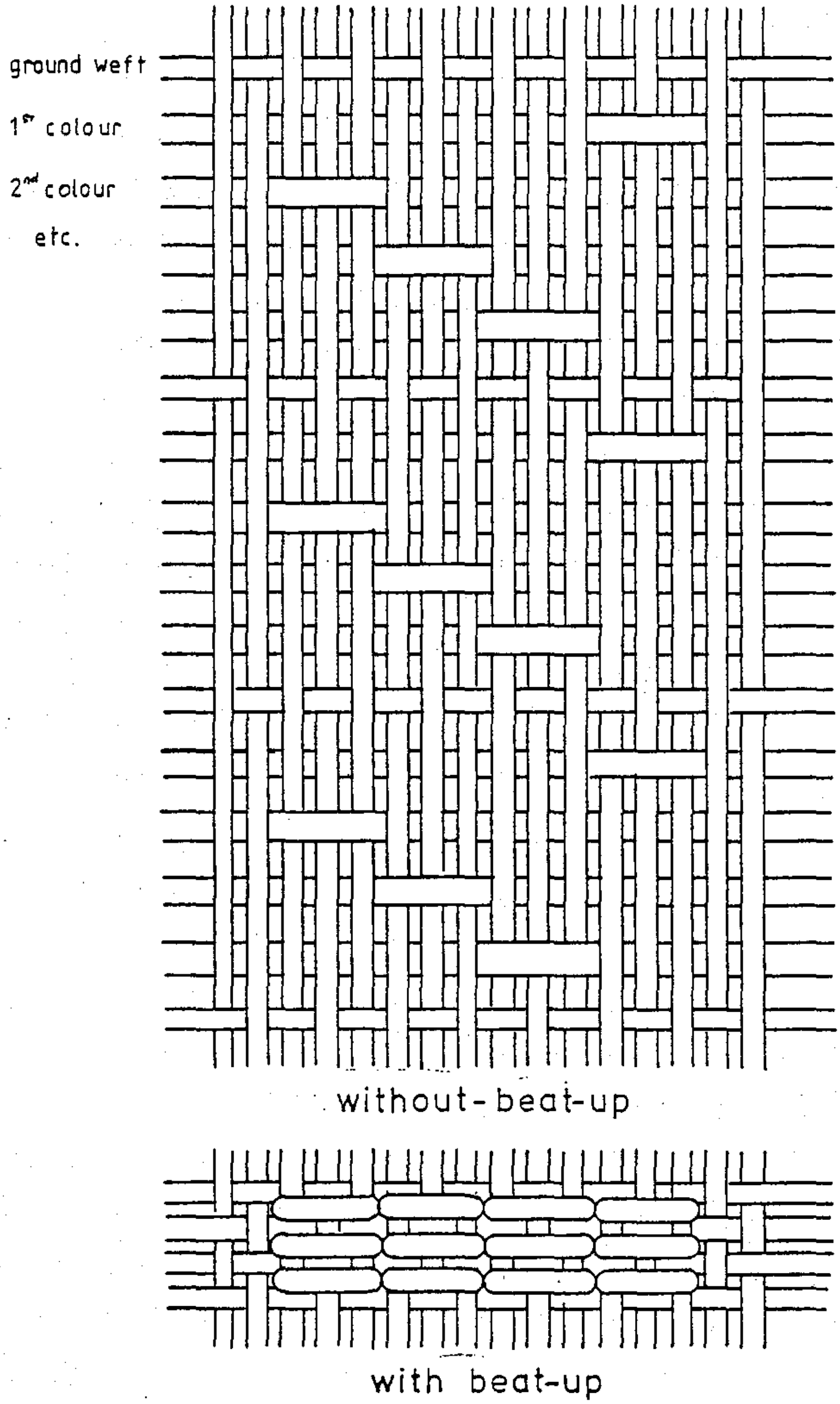


Fig. 8.10. Multicolour Pattern Formation

this is inserted into a warp shed which has been arranged so that the weft appears on the face of the fabric where the colour is required. Because no other colour is required elsewhere across the fabric at this point, the next weft selected is the base fabric weft (ground fabric 2) and this is inserted into a base fabric shed arrangement. The next line of the fabric requires two different colours (A and B). This is achieved by first selecting one of the coloured wefts (A) and inserting it into an appropriate shed (2A), then selecting and inserting the second weft (B) into a shed which has been re-arranged to show the second colour where required (2B) The next weft selected would be that of the base fabric (3).

This sequence may be summarised thus:-

1.i) base fabric weft inserted into 1st base fabric shed;

ii) 1st coloured weft inserted into design shed; and/or

iii) 2nd coloured weft inserted into design shed; and/or

iv) 3rd coloured weft inserted into design shed; and/or

last coloured weft inserted into design shed; and

2.i) base fabric weft inserted into 2nd base fabric shed

ii) etc.

It is worth noting that the order in which the figuring, or coloured, weft yarns are selected between any two base fabric picks, is unimportant. This is because two figuring yarns would not normally appear over the same warp thread; consequently when the fabric is beaten up by the reed, all of the figuring yarns would adopt positions along a single line across the fabric (see Fig 8.10).

Thus, between each base fabric pick the requirement for each of the coloured wefts may be tested in the same order each time. This simplifies the compilation of the data, which, as a generalised routine, may be used thus:

i) Ground fabric pick;

ii) Test for each colour in turn;

iii)2nd ground fabric pick;

iv) Test for each colour; etc.

8.7 POSSIBLE COMPONENTS OF A PATTERN PREPARATION SYSTEM

The source of the pattern data sub-set could be one, or more, of many. Some examples are listed below:-

i) a "scanner", which could directly read a design from a drawing and convert it into digital form, would therefore replace the manual digitizing of a pattern using 'point paper';

ii) a mini- or micro- computor could be used to generate data by means of the mathematical algorithms , which would normally correspond to geometirc shapes;

iii) a library of designs could be stored, eg. on tape or in a semi-conductor memory, and recalled as required to be combined with other sources of data - this could prove to be very useful when considering designs which incorporate alphabetic characters, numerals, trade marks, laundry-care symbols, etc., all of which occur frequently in labels as attached to garments and for the production of which the patterning system as developed would be ideally suited; and

iv) a manual entry of data could prove to be useful for some applications.

Whatever the source of the data it would be useful if, before being combined with the base fabric data, it could be checked either manually , or automatically for certain undesireable conditions. These would vary according to the materials used in manufacture of the fabric and the end use for which the fabric was intended. The most common example is float length. There is normally a limit to the length of unsupported yarn which can be tolerated on the face, or rear of a fabric. A computor al^gorithm could be used to test and correct for this condition.

The base fabric data defines the construction of the fabric into which the figured design is incorporated. This is usually a fairly simple construction, especially when compared with the design data. The source of the base fabric data could also be one of many but, for most applications, could be the same as items (ii) , (iii), or (iv) as listed above as sources of pattern data.

In addition to the sources of the data sub-sets, some means of combining them is required . The sequence of operation is straightforward and could most probably be achieved by a suitable microprocessor or microcomputor. The choice of data sources will depend on many factors particular to every user. However, it is likely that, for most applications, a suitable microcomputor and some form of design scanner would provide all the required facilities. At this stage of the work it has been decided not to attempt to define a suitable microcomputor for use with the system as the hardware available, and the technology within it, is changing so rapidly that specification of this component is best left to the latest possible time.

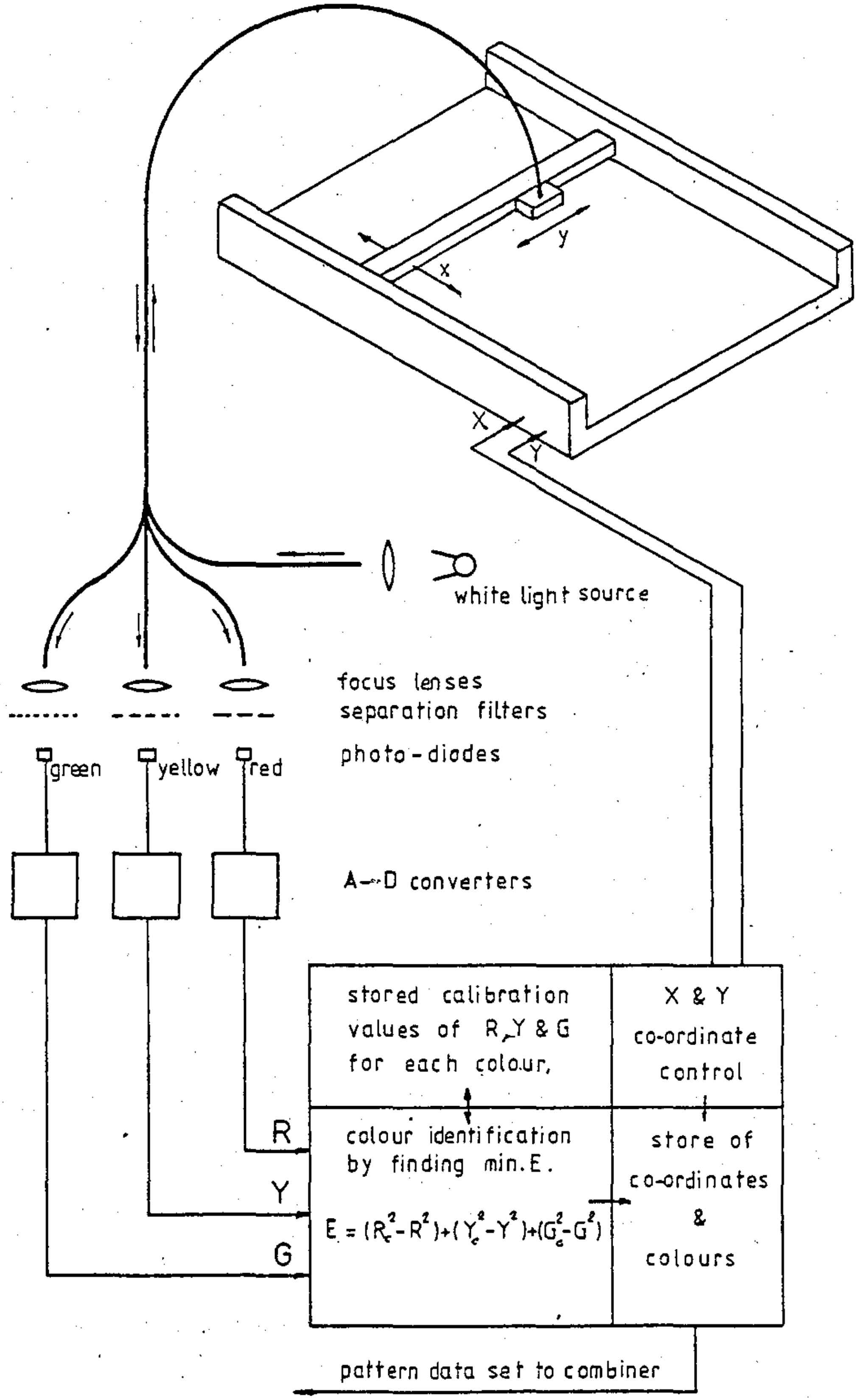


Fig. 8.11. Schematic of a Pattern Scanner

8.8 THE FURTHER INVESTIGATION INTO A DESIGN SCANNER

One component of the pattern preparation system which would be useful in most applications, and which would require a fair degree of development, is a design scanner and digitizer. The provision of such a device which, within the capital cost restraint, can detect and differentiate colours is not a simple matter.

A team of workers in Japan have been looking at this problem and working on a solution using a colour TV camera;[13] the cost of this is high compared to the cost of the rest of the patterning system which has been developed during this study.

A second, Final Year Undergraduate, T. Blackler,[14] is currently investigating alternative approaches to fulfilling this function.

The method on which he is working at present is to use a standard XY plotter (see Fig 8.11), the only modification having been to replace the pen with the end of a light guide and a focusing lens. The design to be digitised is placed on the table of the plotter and white light from a remote source is directed onto a point of the design via the light guide. The frequency distribution of the reflected light is dependent upon the colour of the design at that point. The light guide also serves to carry a proportion of reflected light to three different filters. Behind the filters are photo-sensitive electronic devices. Thus the magnitudes of the three electronic signals provide a representation of the colour of the design at the point being inspected. To identify the colour, the signals obtained are compared by a 'least squares of errors' method with a set of reference signals. These have been obtained at the start of the scan by centreing the light guide on a sample of each colour in the design.

The design is completely scanned by the light guide, the position of which is controlled by, and hence known by, a minicomputor, or microcomputor, which is also used to identify the colours. Thus the design is fully encoded, as a series of coloured spots.

In practice, it may be found that a slightly different approach is required. If a line of the design is scanned several times, each time only comparing the signals to one reference colour, then the information is in a form closer to that which would be required by the loom, i.e. for a particular pick in which a single colour weft is inserted, all the points along the line of that pick at which the colour is required to be seen are identified. This is then repeated for the same line of the design with the other available colours.

Another feature which would be required, and which can easily be provided is to be able to vary the spacing between the scan lines and the sample points. This is to allow the design to fit the warp and weft packing densities being used in the fabric.

8.9 THE FUTURE OF PATTERN PREPARATION

It may appear that the proposed form of pattern preparation system is sophisticated and expensive. It must be remembered, however, that its function is much greater than that provided by the weaving machines of today. It will replace a very labour intensive, and costly, part of the production of patterned fabrics. It will also allow the full explotation of a rapid patterning system which is also very conveniently changed from the production of one design of fabric to another.

The cost of the system need not be prohibitive. The decreasing price and the increasing computing power of micro-electronic devices are changing almost daily; therefore the actual cost of providing a data processing function is falling rapidly. It should soon reach the stage at which a fully-automated pattern preparation system for woven fabrics is very attractice, especially when the comparison is made with the knitting industry, where even several years ago, firms found it attractive to invest in large computing facilities to reduce pattern preparation costs.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

9.1 FULFILMENT OF OBJECTIVES

In Chapter 3 a specification was produced for a combination of systems to allow patterns to be incorporated into woven narrow fabrics during manufacture. The work des-described in this thesis was directed towards fulfilling this specification.

The systems which have been developed and described mainly satisfy this specification, but some further work is required to completely fulfil it, in particular the very high speed demanded of the warp selection system. This, in the state of development described in Chapter 4, the system has achieved a speed slightly in excess of 1600 picks/min and whilst this is below the specified 3000 picks per minute, it is well above the speeds achieved by existing patterning mechanisms used in weaving. The system has yet to be built in a form that can actually be fitted to a loom and thus be tested whilst producing fabric. Some recommendations for the way in which it could best be applied to a loom are given in Chapter 4.

As the result of an assessment of this system by N R D C it was considered to be capable of commercial exploitation, therefore the principle of operation of the warp selection system is the subject of a British Patent Application[15] filed by National Research Development Corporation on behalf of Loughborough University of Technology.

The weft selection system would seem to satisfy the specification. The system has been built onto a Bonas Varitex 2/65 loom situated in the Department of Mechanical Engineering. This machine, although amongst the fastest looms available at the onset of the research, is capable of running at only 2400 picks/min compared with the 3000 picks/min called for in the specification. The weft selection system functions satisfactorily at this speed and tests performed on the selection block suggest that an operational speed in excess of 3000 picks/min is possible. The range of yarns tried in conjunction with the system, whilst wide, is not comprehensive and this is an area requiring further work.

The weft selection system is also the subject of a separate British Patent Application.[16]

A control system for use with the warp and weft selection systems has not been produced, although the way in which it could be achieved has been proved in principle. The use of a micro-computer based system is recommended; the exact form it should take will depend on the specific requirements of a particular application and the finalised forms of the warp and weft selection systems. Therefore, it was considered appropriate to leave the detail design of the control system until the other systems had been fully developed, especially as the range of equipment available in this field is changing and expanding rapidly at the present time.

9.2 THE REACTION OF THE TEXTILE INDUSTRY

Due to the need for confidentiality prior to the two pending British Patent Applications, the systems were shown only to a few selected members of the Textile Industry. Of these Mr. W C Arnold, then Technical Director of the Bonas Machine Company, works in an area closest to the work here described. It was stated in Chapter 2 that the Bonas Machine Company manufacture and market a Jacquard mechanism for use with the narrow fabric looms that they manufacture.

These Jacquards are limited both in terms of speed and patterning capability, and yet they are powerful enough to be bought and operated by many commercial narrow fabric producers. The opinion expressed by Mr. Arnold was that the specification on which this work was based defines a very powerful and comprehensive patterning system; hence, if a system fulfilling even a 'derated' specification were produced it could perhaps exceed the capabilities of existing alternative systems and allow the economic production of a very wide range of patterned fabrics. Such a specification comprising, for example, 200 individually selectable warp ends working at a rate of 2000 picks/min, with or without weft selection, is within the reach of the demonstrated capabilities of the systems which have been devised.

As a consequence there are two alternative directions which any further investigations could follow, namely:

either (a) To accept the principles of operations of these systems, including the limited speed of warp selection, and thus apply them to a loom and offer a complete system satisfying the derated specification;

or (b) Further refine the warp selection system to achieve the 3000 picks/min required by the full specification before applying the system to a loom.

9.3 AREAS OF FURTHER WORK

Whichever of the above alternative approaches is followed for the continuation of this work, there are a number of areas where further work will be required. They are summarised here together with possible approaches.

9.3.1 Provision of "Lingoes" or Equivalent

The warp selection system as developed uses a positive push and pull action; however, the heddle elements are slender and should the distance between the latch mechanism and the yarn be excessive, it may be preferable to use some form of tensioned flexible link to connect the heddle element to the warp yarn. This is done in traditional Jacquard mechanisms, where flexible harness cords are tensioned by means of "lingoes", which are normally just weights. In high speed systems, where the accelerations required are greater than that due to gravity, these have been replaced by rubber extension springs[17] and some similar arrangement would need to be investigated.

9.3.2 The Provision of an End-Position Clamp

As mentioned in section 4.5.9 it may prove necessary to provide a means of positively holding the heddle elements in their upper and lower positions, during those machine cycles when they are not required to move. This would need to be effective at the time of maximum warp tension which occurs during "beat-up". This action could be achieved by various arrangements either purely mechanical or incorporating electro-magnets.

9.3.3 The Provision of an Intermittent Take-Down Clutch

To achieve a high quality patterned woven fabric, it is normal to advance the fabric only on machine cycles corresponding to base fabric picks. The reason for this is that weft figuring picks do not normally contribute to the 'body' of the fabric, and if a normal pick space is allocated to it, the fabric produced is loose and unstable.

Again there are a number of ways in which this could be achieved, one of which is the inclusion of an electro-magnetic clutch in the take-down drive; another being the use of a stepper motor to drive the take-down mechanism. The control for either could be simply derived from the pattern control system. An added benefit of the second suggestion is that the input to the stepper motor could be altered whilst the machine was running; this may be useful in setting up a new fabric on the loom especailly for short run situations.

9.3.4 The Improvement of the Weft Yarn Path

The path and feed arrangement of the weft yarn as it is currently applied to the experimental loom is not ideal for use with all yarn types. In particular, the length of yarn subjected to the back robbing tension is too great for the more extensible yarns tested. It would be feasible to reposition the feed units and so reduce the length of the yarn path. This should increase the range of yarns that can be handled by the system and increase the reliability of operation with all yarn types.

The function of the I R O yarn feed units could be reviewed with the object of replacement by a cheaper and perhaps more compact unit.

9.3.5 The Design of Interface Circuitry

Once the design of the coils in the warp selection system, and the choice of the valves in the weft selection system, are finalised, then the electronic circuits needed to drive them in response to the T.T.L. level signals obtained from a micro-processor can be developed.

Since one of the objects of the design of the systems has been the utilisation of techniques to minimise the power levels required by the coils and valves, these circuits should be small and cheap, to manufacture.

9.3.6 The Control System Component Selection

When a specific application of a complete patterning system has been identified it will be possible to specify the features required of the control system. Subsequently, the input devices can be selected, e.g. pattern scanner, teletype, digitizing table, disc audio type cassette, together with the microcomputor system best matched to the requirements.

The programmes used to manipulate the data can be developed to provide the required functions based on the principles outlined in Chapter 8.

When the above recommendations for further work are followed, the result will be a complete patterning system for woven fabrics capable of operating at speeds many times greater than any existing technique. The added benefits of rapid pattern change and machine set-up would make the system extremely attractive to the short run fabric producer and perhaps do much to reverse the trend towards inferior quality printed pattern on plain fabric, as well as opening up new markets for competitively priced fancy narrow fabrics.

APPENDIX A1

THE PRINCIPLES OF WEAVING

APPENDIX 1

A.1.1 PRINCIPLES OF WEAVING

A woven cloth is defined[6] as a cloth formed by "interlacing warp and weft yarns" i.e. yarns which run essentially along the length of the fabric and are interlaced with yarns passing across the width of the fabric. In order to produce a woven fabric three basic machine operations are required, shedding, picking, and beating-up.

Shedding is the term given to the action of separating the warp threads into upper and lower positions, those over which the weft yarn is to be passed are lowered and those which the weft will pass below are raised. The space between the separated yarns is termed the shed. Conventionally the movement of the warp yarns is achieved by heddles (alternatively known as healds) and heddle frames. The heddles are looped cords, shaped wires or flat steel strip with an eye in the centre through which a warp yarn is threaded. The upper and lower ends of a number of the heddles are fixed to the rails of a heddle frame. Thus when the frame is raised or lowered all of those warp yarns are moved together. It is usual that several heddle frames are used, all of the warp yarns pass through all of the heddle frames but each yarn is attached, via a heddle, to only one frame. Thus the shed arrangements are determined by the motion of the heddle frames. The complexity of the fabric construction is therefore limited by the number of heddle frames and the means by which they are moved.

Picking is the act of passing a weft yarn through a warp shed. This can be achieved by the traditional shuttle and also many other means. The use of a needle weft insertion is discussed later in this appendix since this is the principle of operation on which the weft selection system described in this thesis is based.

Beating-up is required to press the inserted weft yarn uniformly into the corner of a separated warp yarns (the fell) to produce an even and firm fabric. It is normally achieved by a reed, i.e. a closed comb like arrangement of wires or slots which pass between the warp yarns. The weft yarn is inserted in front of the reed and so as the reed is brought up to the fabric the weft is pressed firmly into the fell of the fabric. The speed at which this is done leads to the term beating-up.

In addition to these basic weaving mechanisms some means of control over fabric and yarn tensions are required. The different ways in which each of these fundamental weaving actions can be achieved leads to a wide variety of weaving machines, or looms, each with its own particular characteristics; consequently some looms are better suited to certain yarns and fabrics than others.

A1.2 THE LOOM AND ITS WORKING PARTS

A loom is defined[6] as a machine for making woven cloth. In modern texts the phrase weaving machine is often used to imply a machine which posses some novel feature to distinguish it from the traditional form of loom. However these novelties are usually concerned with only part of the machine, the rest remaining substantially similar to the traditional design. For the purposes of this report the working parts of the traditional loom will be defined and any other newer feature mentioned only if relevant to the report.

In its most basic form a loom has 5 mechanisms. These are:-

A1.2.1 The warp let off system. The warp threads are previously wound in a parallel form on to a storage roll, the warp beam, as the warp threads, or collectively the warp sheet,are drawn off the rotation of the beam is braked to provide a tension in the warp threads.

A1.2.2 The shedding system. The warp threads traditionally pass through an eye in a heddle which in turn is attached to one of several heddle frames, which is moved up and down this forming the shed of the warp threads. The motion of the heddle frames is derived from cams or tappets if there are 10 or less, or from a Dobby mechanism if there are more, up to a maximum of 36.

A1.2.3 The weft insertion system. On traditional looms this is the shuttle and the picking mechanism the shuttle is a projectile which carries a small store of the weft yarn, the tail of which is held either in the fabric or in a special gripper so that as the shuttle passes through the shed the yarn is drawn from the store inside. The motion is imparted to the shuttle by a wooden picking stick, driven by a cam. The shuttle is brought to rest on the opposite selvedge in a shuttle box which normally contains some form of brake. As the shuttle moves in both directions there has to be a picking stick and a shuttle box on both sides of the loom.

A1.2.4 The beat-up mechanism. In order to obtain an even fabric, each weft yarn has to be placed in the same position on every cycle, in the case of dense fabrics a high level of force may be required. The beat up is accomplished by the reed, a comb-like component positioned such that one or more warp yarns pass through each dent, i.e. the gaps between the wires of the reed. The reed is brought forward after each pick to the fell of the cloth positioning the weft in the fabric.

A1.2.5 Fabric take down. Finally the finished fabric is drawn from the loom at a definite fixed rate. This determines the weft density of the fabric measured as the number of picks per inch or centimetre. It is this motion which draws the warp yarns right through the loom and rotates the warp beam.

In recent years a large number of new techniques have been incorporated into the design of looms, but they mainly are concerned with the weft insertion system. The variants now available include rapier insertion, multiple gripper looms, air jet looms, water jet looms, and in the area of narrow fabrics,needle looms.[8] Description of these newer techniques can be found in many standard texts. The operation of the narrow fabric needle loom will be briefly described here as it is this type of loom on which the experimental work was based.

A1.3 THE NARROW FABRIC NEEDLE LOOM (With particular ref to Bonas Varitex 2/65)

A narrow fabric needle loom performs exactly the same functions as a normal width loom, the only difference being that the fabric produced is by definition no wider than 450 mm. In the case of the Bonas Varitex the maximum width of fabric that it can produce is 65 mm.

Due to this restricted width it is possible to carry the weft across the fabric with a rigid needle. In the case of the Varitex machine, the needle is pivoted about a point beneath the fabric already produced such that the eye of the needle describes an arc which starts outside the left hand selvedge, passes through the shed approximately perpendicular to the warp thread and protrudes 10 to 15 mm from the right hand selvedge. The weft yarn is continuous and held at the left hand selvedge where it emerges from the previous pick. As the eye advances across the fabric, yarn is drawn from the weft supply and a loop of yarn is taken through the shed to the right hand selvedge where it is caught on the hook of a latch needle lying parallel to the warp, so that as the weft needle retacts it leaves a double lay of weft in the shed. Once the weft needle is clear of the fabric the reed advances and beats up the yarn in the usual manner and the shed changes. The weft needle is continuously moving and now advances through the new shed.

The latch needle on the right hand selvedge is also continuously moving and as the weft insertion needle advances so does the latch needle to catch the new weft. As a result the previous weft loop passes down the shank of the latch needle over the latch. Thus as the new weft yarn is caught and the latch needle starts to retract the old loop passes back up the shank, closing the latch over the hook and the new loop, until the needle has retracted far enough to actually cast off the old loop, the needle then starts to advance to catch the next weft and the cycle repeats. The ends of the loops of the weft are therefore knitted with each other to retain them at the selvedge.

An alternative to this knitted selvedge is the catch thread selvedge. In this case the latch needle when it advances rather than catching the weft loop, passes through it and a second yarn, the catch thread is passed around the hook and drawn back through the weft loop and it is the catch thread loops that are knitted to form the selvedge. The advantage of this system is that a finer yarn can be used as the catch thread making the selvedge less bulky and therefore the difference between the two selvedges less noticeable, or a yarn of the base fabric colour can be used thus avoiding the coloured loops of figuring weft yarns being so visible in the selvedge.

The weft supply system is worthy of mention at this stage. Due to the predictable motion of the weft insertion needle, and the uniform requirement of weft yarn, the supply can be of a positive feed type. This supplies a fixed length of yarn for each pick by means of a rotating reel geared to the machine around which the yarn is passed several times. By adjusting the diameter of the reel the length of yarn supplied per pick can be fixed and the uniformity of the resulting fabric greatly improved.

To allow a variation of yarn take up rate during the loom cycle the yarn is passed through two 'pigtail' type springs which can temporarily store a small length of yarn and consequently buffer the yarn feed reel from the weft needle resulting in non extremes of yarn tension.

This system is only applicable when exactly the same length of yarn is required for every pick.

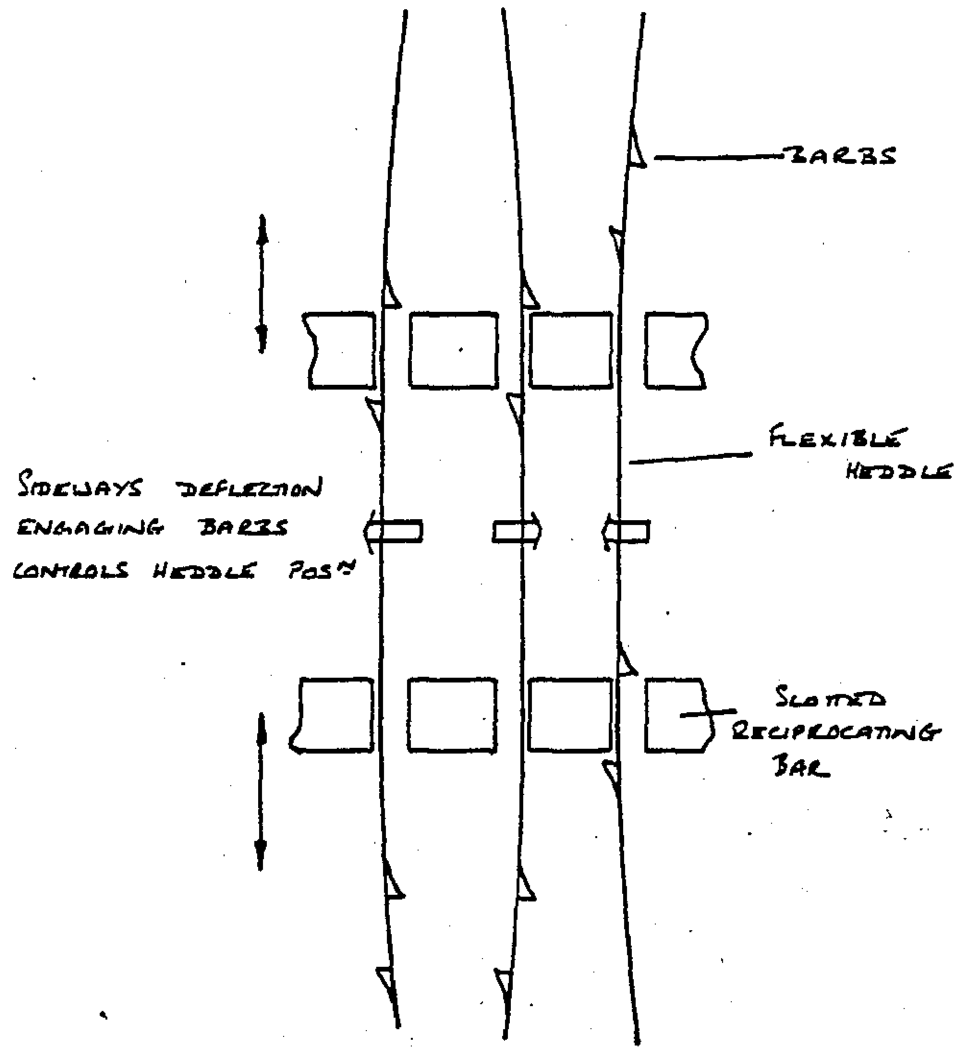
One very important consequence of the system on which this type of loom works is due to the simple motions of component travelling through relatively small distances By careful design and engineering the speeds at which these looms can operate greatly exceed conventional looms, in many cases by a factor of 10 or more e.g. a conventional shuttle loom may achieve a speed of 250 ppm, an air jet loom may achieve 500 ppm but the Bonas Varitex machine can produce fabric at 3000 ppm.

There are some disadvantages with this system of operation. The pick which is inserted is a 'double' pick i.e. it consists of two lengths of weft yarn. This increases the weight of fabric produced for a given weft yarn. When a fabric of given area density is required the weft yarn which must be used is finer than that which would be needed for a 'single pick' fabric; so although the same total weight of weft yarn would be consumed it would have to be more finely spun which would make it more expensive.

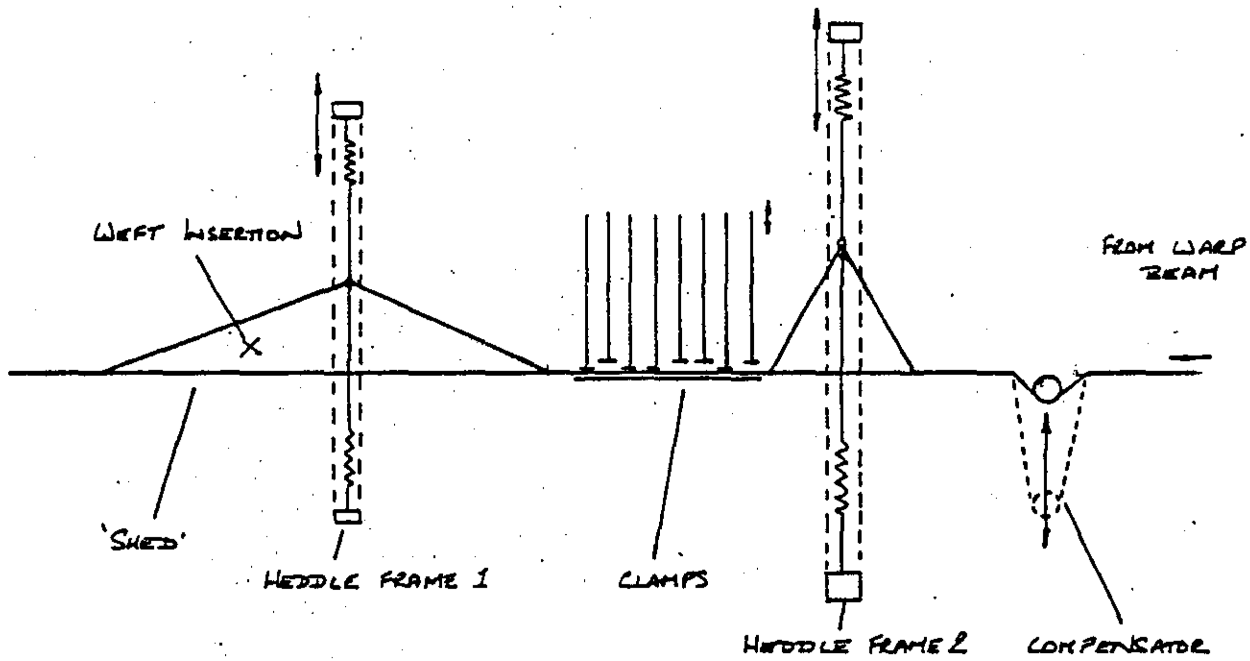
The second disadvantage is due to the nature of the selvedge formed on the side opposite the mounting of the needle. The ends of the weft loops are normally knitted together by the latch needle to form a selvedge in which the weft yarns are locked. There are many ways in which this can be modified by the use of catch threads, locking threads and picot shedding action but this selvedge always differs to that on the other side of the fabric which is essentially the same as that found on conventional shuttle - woven fabrics.

APPENDIX A2

POSSIBLE WARP SELECTION OPERATING PRINCIPLES



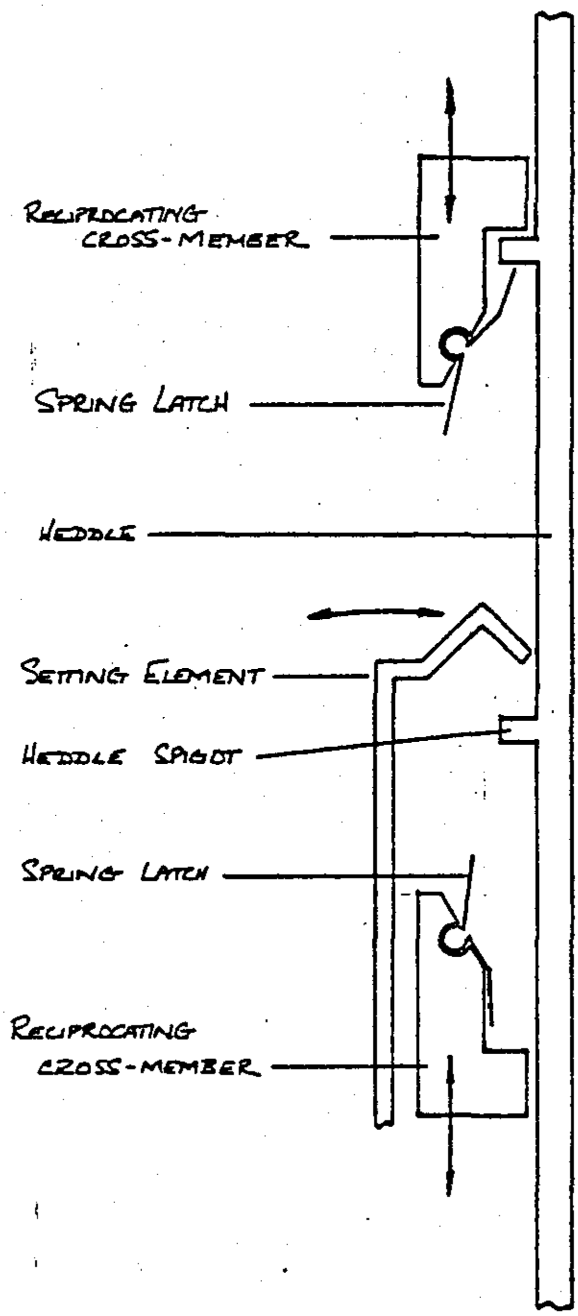
THIN FLEXIBLE HEDDLES WITH 'BARBS' ARE DEFLECTED SIDEWAYS TO ENGAGE RECIPROCATING SLOTTED BARS AND ARE THUS MOVED. DEFLECTION TO BE BY SOLENOID OR BY PASSING CURRENT THROUGH HEDDLE IN THE PRESENCE OF A STRONG MAGNETIC FIELD.



HEDDLE FRAMES 1+2 RECIPROCATE CONTINUOUSLY IN UNISION. THE HEDDLES ARE CONECTED TO THE FRAMES BY 'SPRINGS', THOSE IN FRAME 1 ARE STRONGER THAN THOSE IN FRAME 2. THE CLAMPS ACT EACH ON ONE THREAD, AND ARE OPERATED BY SOME MEANS UNDEFINED.

IF A THREAD IS CLAMPED THEN AS THE FRAMES RISE INSUFFICIENT YARN IS AVAILABLE FOR IT TO RISE WITH FRAME 1. IT DOES RISE WITH FRAME 2. IF A YARN IS NOT CLAMPED THEN THE PULL OF SPRING IN FRAME 1 IS STRONGER THAN IN FRAME 2. YARN RISES WITH FRAME 1 + NOT FRAME 2. THE COMPENSATOR TAKES UP SLACK YARN AS FRAMES 1+2 FALL BETWEEN PICKS.

DISADVANTAGES: THE SPACE REQUIRED IS GREAT
THE ACTION IS THAT OF A BOTTOM RETURN DOBBY.



THE RECIPROCATING CROSS-MEMBERS MOVE IN OPPOSITION. THE HEDDLE SPIGOT IS HELD IN ONE CROSS-MEMBER BY THE SPRING LATCH. THE POSITION OF THE TWO SPRING LATCHES IS SET BY THE SETTING ELEMENT AS THE CROSS-MEMBERS COME TOGETHER.

DISADVANTAGE: THE ACTION IS SIMILAR AS A CENTRE RETURN DOBBY I.E THE HEDDLE IS RETURNED TO THE CENTRE OF THE SHED BETWEEN EACH PICK

APPENDIX A3

THE SELECTOR COILS

APPENDIX 3: THE SELECTOR COILS

A.3.1 The interface between the electrical signal produced by the Pattern Generation System and the mechanics of the Warp Selection System was achieved by small coils producing magnetic fields. As described in Chapter 4 the coils were not used to perform mechanical work, but to retain a ferrous component as part of the magnetic circuit. The coils were developed to perform this type of duty rather than that of a solenoid.

The development coils were made from enamelled copper wire wound on a cast iron core. The coils were located in closely fitting holes in a cast iron block, and retained by epoxy adhesive. By using a block in this way a high packing density could be achieved and the relatively large mass of the block acts as a heat sink for the coils. Two arrangements of core and surrounding block were experimentally tested, a straight coil (see Fig A.3.1) and an 'L' shaped coil (see Fig A.3.2). In both arrangements a magnetic circuit was formed in ferrous material leaving an air gap which could be bridged by a ferrous object placed against the face of the block.

When the magnetic circuit is completed in this way, a high magnetic flux as generated by a relatively small electrical current. The forces required to pull the loose component away is very high compared with that generated by a solenoid of comparative size as the solenoid has an air-gap in its magnetic circuit reducing the magnetic flux.

Both forms of coil were tested on the rig and individually in bench tests. The dimensions and performance obtained are tested in the following table.

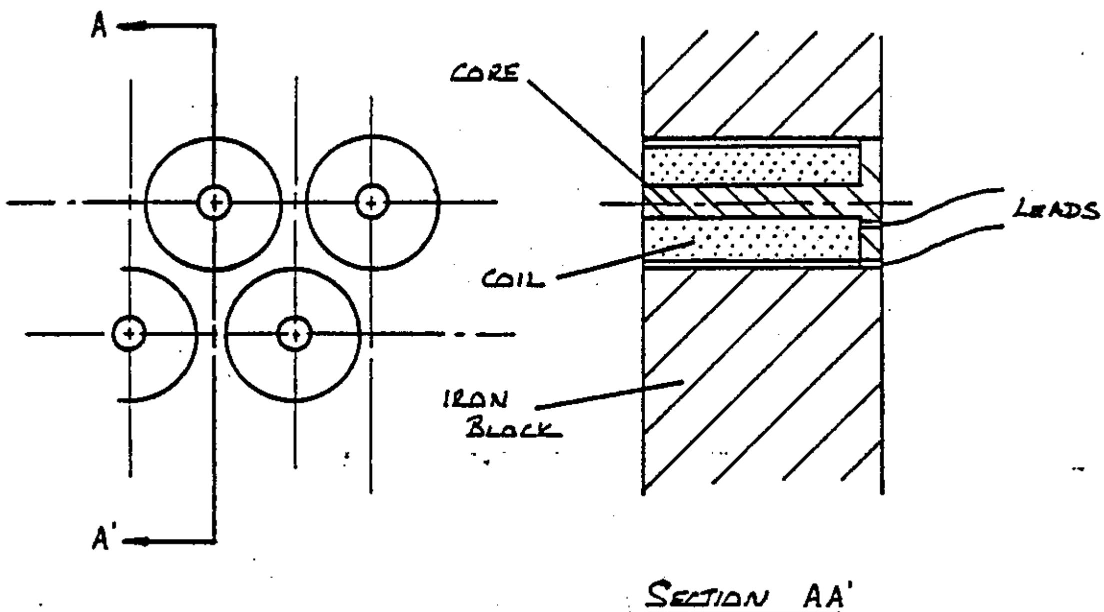


Fig. A3.1

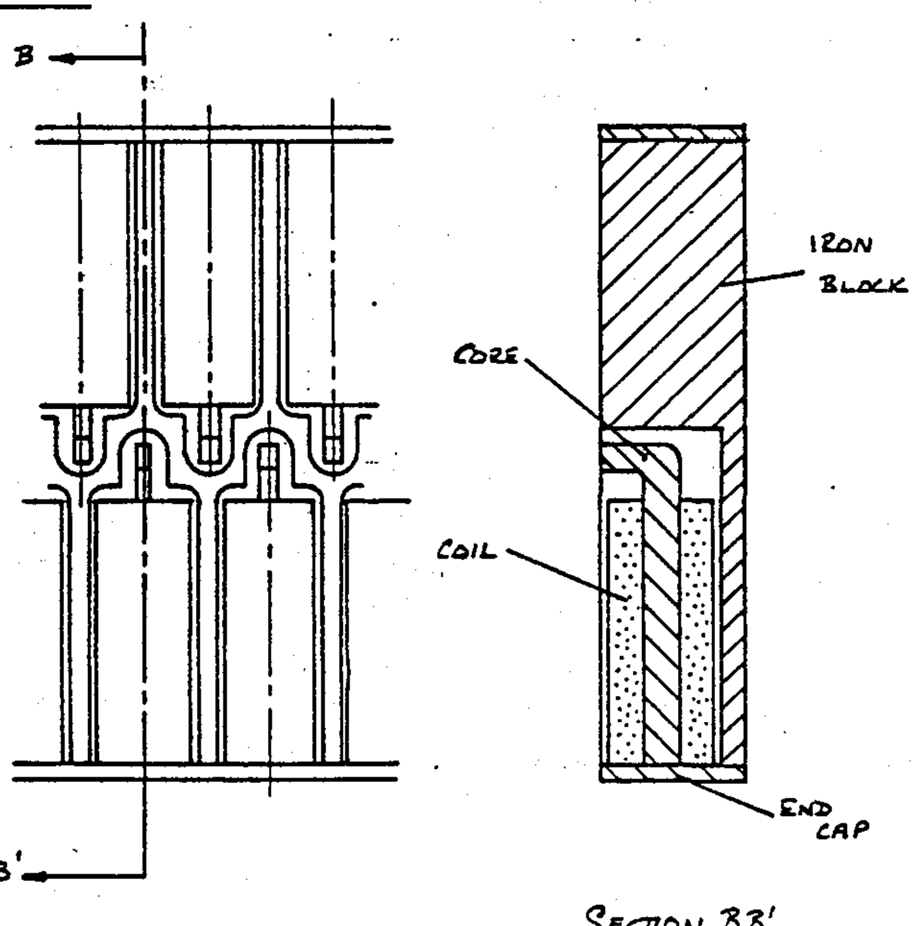


Fig. A3.2 .

COIL PARAMETERS

COIL N°	1	2	3	4	5	6
FORM	STRAIGHT	STRAIGHT	'L'	'L'	STRAIGHT	STRAIGHT
WIRE GUAGE (Ø MM)	40	36	40	38	40	40
N° OF WIRE TURNS	1200	750	2250	2000	1500	1100
CORE DIMENSIONS (MM)	Ø1.5	Ø2.0	1.0×2.0	1.0×2.5	Ø3.0	Ø3.0
CORE AREA (MM^2)	1.77	3.14	2.0	2.5	7.1	7.1
COIL OUTER DIMENSIONS	Ø7.0	Ø7.5	7.0×9.0	7.0×9.0	Ø7.5	Ø7.5
COIL LENGTH (MM)	10	15	25	23	17	12
COIL D.C. RESISTANCE (Ω)	22.3	4.4	57.1	36	34	24
COIL INDUCTANCE (mH)	23	1.3	41	-	27	40
BREAK AWAY FORCE (gm)	47	60	25	15	145	100
AT INPUT POWER (WATT)	0.75	1.0	3.0	3.0	2.4	1.5

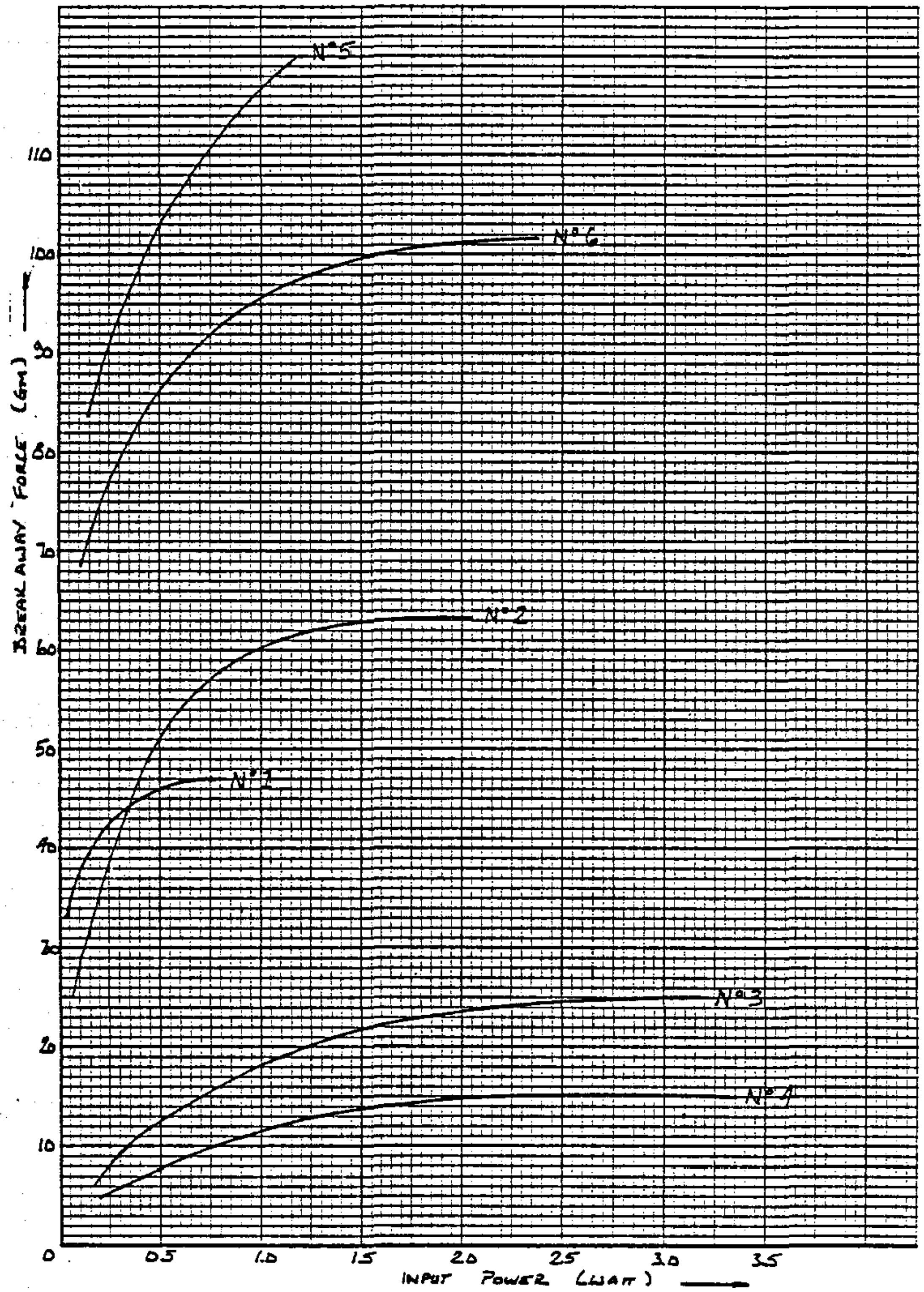
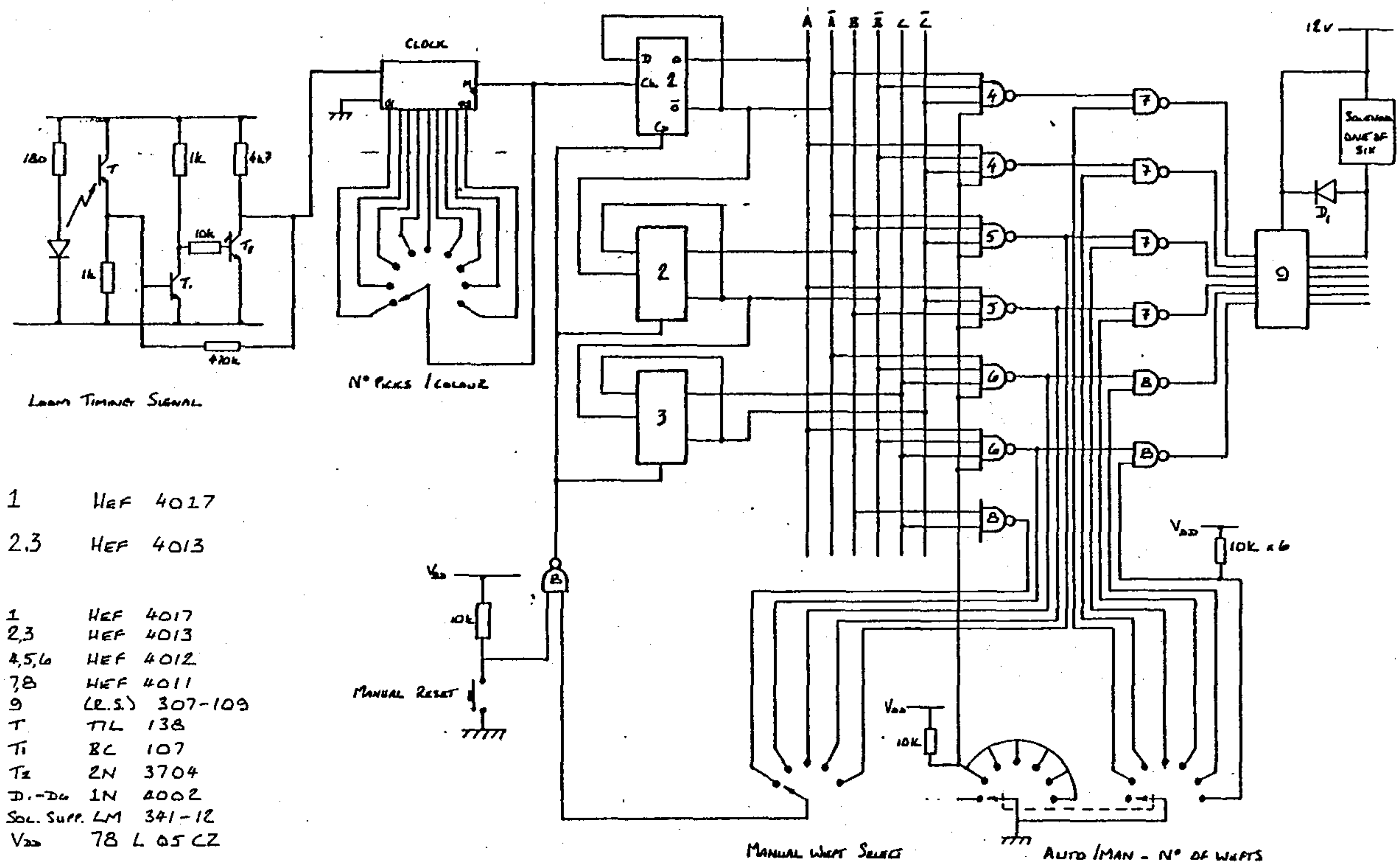


Fig. A3.3 Breakaway Force / Input Power

The breakaway force, i.e. that force which applied to the ferrous bridging component just caused it to come away from the face of the block, was measured for each coil manufactured and plotted as a function of the electrical power supplied to the coil. The resulting curves are shown in fig A.3.3.

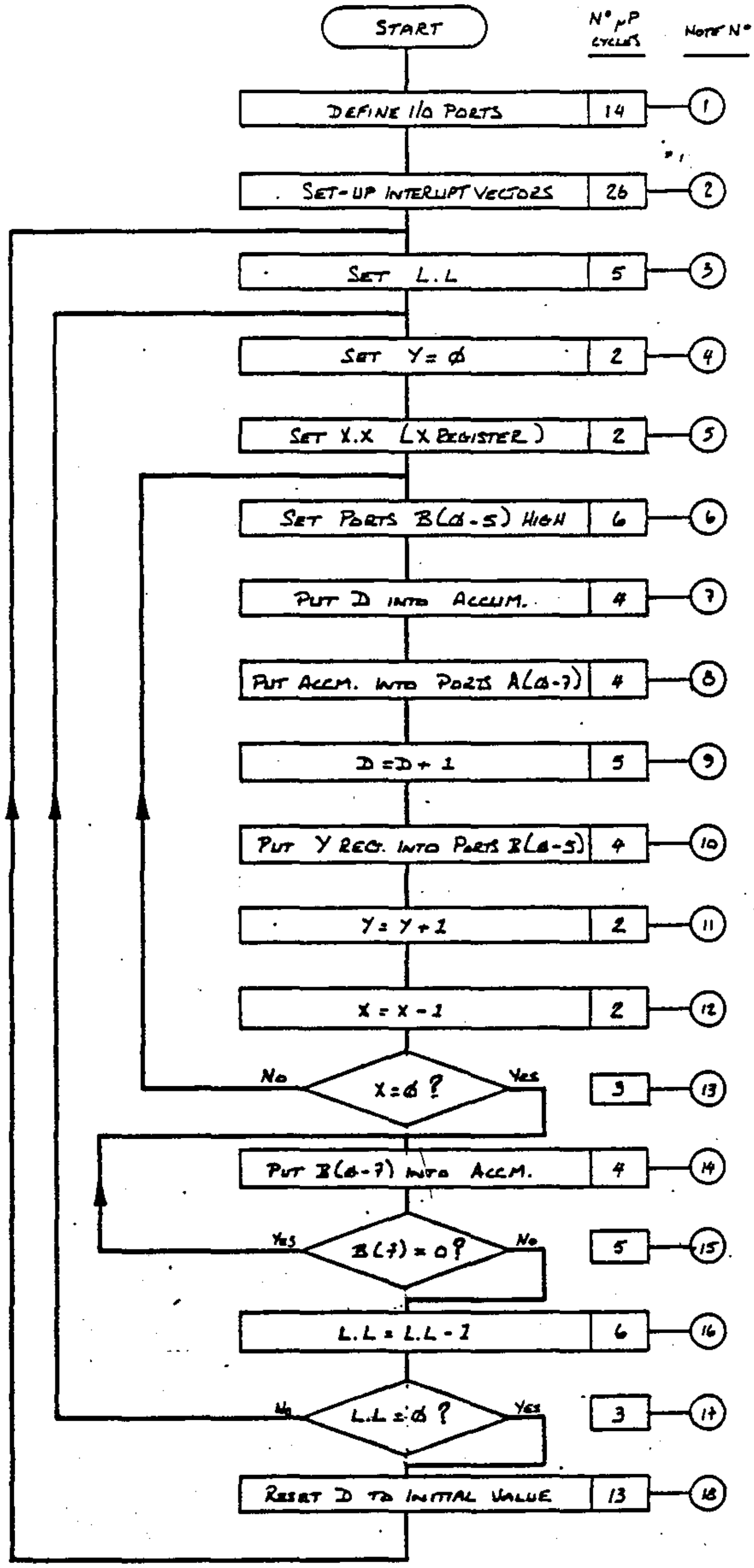
APPENDIX A4

THE WEFT SELECTION CONTROL UNIT USED IN THE STUDY


12V
Solenoid one of six
D1
9
CLOCK
1
D
Q
Ck
Q̄
Cp
2
3
A Ā B B̄ C C̄
4
5
6
7
8
180
1k
10k
4k7
470k
T
T1
T2
Loom Timing Signal
N° Picks / Colour
VDD
10k
Manual Reset
10K x 6
Manual Weft Select
Auto / Man - N° of Wefts
1 HEF 4017
2,3 HEF 4013
1 HEF 4017
2,3 HEF 4013
4,5,6 HEF 4012
7,8 HEF 4011
9 (R.S.) 307-109
T TIL 138
T1 BC 107
T2 2N 3704
D1-D6 1N 4002
Sol. Supp. LM 341-12
VDD 78 L 05 CZ

APPENDIX A5

THE PATTERN DATA RETRIEVAL PROGRAMS (LOOM 1 AND LOOM 2)


START
N° μP CYCLES
NOTE N°
DEFINE I/O PORTS 14 1
SET-UP INTERUPT VECTORS 26 2
SET L.L 5 3
SET Y = Ø 2 4
SET X.X (X REGISTER) 2 5
SET PORTS B(Ø-5) HIGH 6 6
PUT D INTO ACCUM. 4 7
PUT ACCM. INTO PORTS A(Ø-7) 4 8
D = D + 1 5 9
PUT Y REG. INTO PORTS B(Ø-5) 4 10
Y = Y + 1 2 11
X = X - 1 2 12
No X = Ø ? Yes 3 13
PUT B(Ø-7) INTO ACCM. 4 14
Yes B(7) = 0 ? No 5 15
L.L = L.L - 1 6 16
No L.L = Ø ? Yes 3 17
RESET D TO INITIAL VALUE 13 18

"LOOM 1"

'LOOM 1' NOTES

1. Sets external connections as inputs or outputs.

2. Provides means of interrupting (and stopping) the program.

3. The number of rows in the pattern.

4. Resets the external buffer address.

5. The number of 'bytes' per row of pattern.

6. Prepares the external buffer for data.

7. Brings pattern data from address 'D' into accumulator.

8. Transfers pattern data to external buffer.

9. Increments the data address.

10. Addresses one byte of external buffer.

11. Increments external buffer address.

12. Decrements the 'bytes per row' counter.

13. Check for end of row.

14. Looks at input port (B7) for timing signal from loom.

15. Check for presence of timing signal.

16. Decrements row counter.

17. Check for end of pattern.

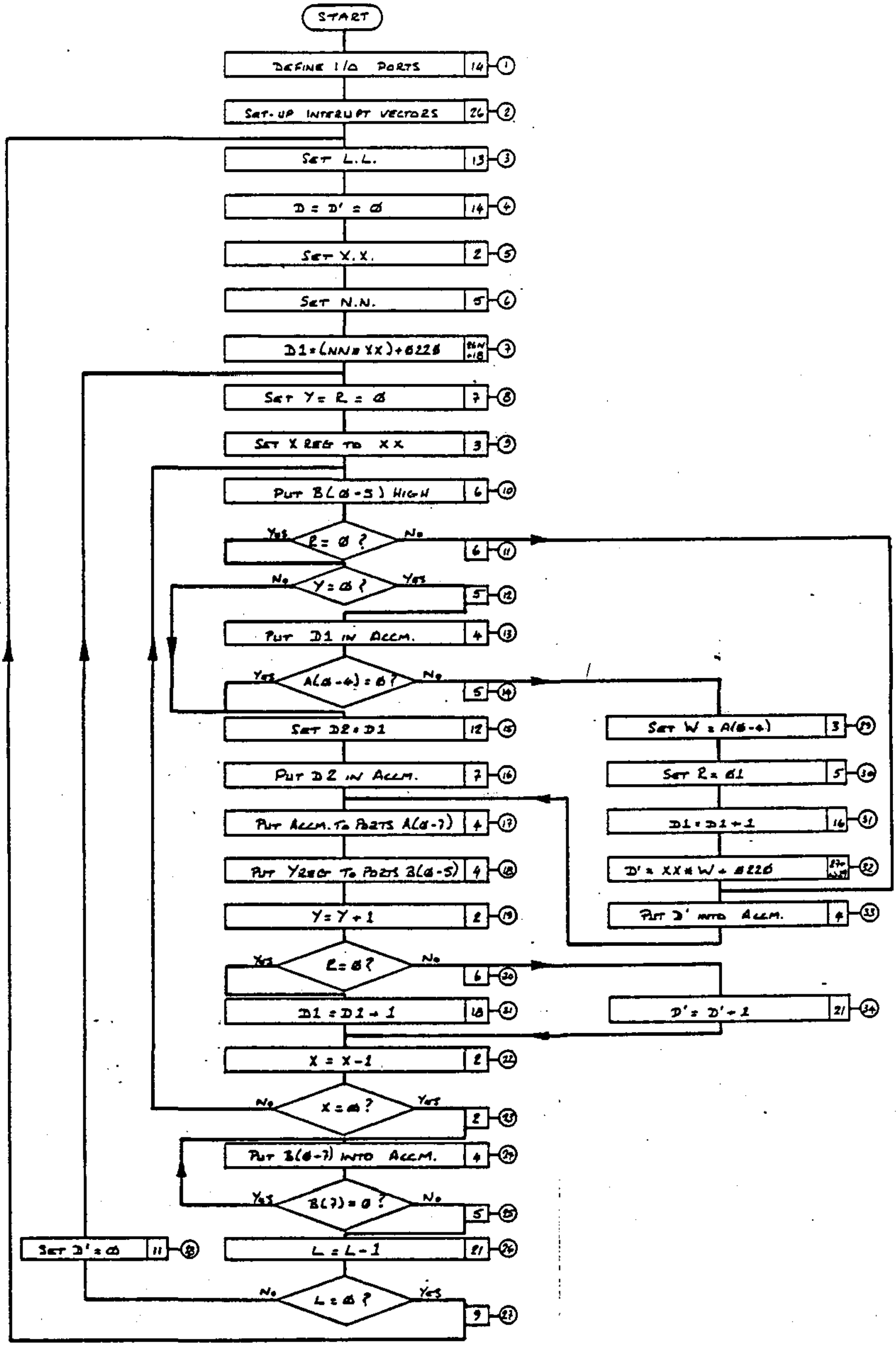
18. Return to start of pattern and repeat.

LOOM 1 LISTING

ADDR.	OP. CODE	M/C CYCLES	REMARKS
ØØØØ	D8	2	SET BINARY MODE
Ø1	A9	2	
Ø2	FF		
Ø3	8D	4	
Ø4	Ø1		SETS UP: AØ – A7 – OUTPUTS
Ø5	17		BØ – B5 – OUTPUTS
Ø6	A9	2	B6, B7 – INPUTS
Ø7	BF		
Ø8	8D	4	
Ø9	Ø3		
ØA	17		
ØB	A9	2	
ØC	ØØ		
ØD	8D	4	
ØE	F1		
ØF	ØØ		
1Ø	8D	4	
11	FA		
12	17		
13	A9	2	
14	1C		
15	8D	4	SETS UP INTERRUPT VECTORS
16	FB		
17	17		
18	A9	2	
19	ØØ		
1A	8D	4	
1B	FE		
1C	17		
1D	8D	4	
1E	FF		
1F	17		
2Ø	A9	2	
21	"XX"		PUT "XX" (Nº OF LINES IN
22	8D	4	PATTERN) IN
23	EE		ADDRESS ØØEE
24	ØØ		
25	AØ	2	
26	Ø1		
27	8C	4	INITIALISE Y AND BØ – B7
28	Ø2		
29	17		
2A	A2	2	"YY" (Nº OF BYTES PER ROW)
2B	"YY"		
2C	AD	4	
2D	ØØ		PUT CONTENTS OF MEMORY IN A.
2E	Ø2		

"LOOM 1" LISTING – CONTINUED

ADDR.	OP. CODE	CYCLES	REMARKS
ØØ2F	8D	4	
3Ø	ØØ		PUT CONTENTS OF A. IN AØ – A7
31	17		
32	A9	2	
33	FF		
34	8D	4	PUT BØ – B7 HIGH
35	Ø2		
36	17		
37	C8	2	
38	8C	4	INCREMENT Y BY 1 AND PUT IN BØ-B7
39	Ø2		
3A	17		
3B	E6	5	INCREMENT DATA ADDR BY 1
3C	2E		
3D	CA	2	DECREMENT X BY 1
3E	DØ	3	BRANCH NOT ZERO TO ØØ2C
3F	2C		
4Ø	AD	4	
41	Ø2		PUT CONTENTS OF BØ-B7 IN A.
42	17		
43	29	2	
44	8Ø		BRANCH TO ØØ43 IF B7 = Ø
45	FØ	3	
46	FC		
47	CE	6	
48	EE		DECREMENT ØØEE BY 1
49	ØØ		
4A	DØ	3	BRANCH NOT ZERO TO ØØ25
4B	D4		
4C	A9	2	
4D	Ø2		
4E	8D	4	SET ADDR FOR DATA TO Ø2ØØ
4F	2E		
5Ø	ØØ		
51	4C	3	
52	2Ø		JUMP TO ØØ22.
53	ØØ		


START
DEFINE I/O PORTS
SET-UP INTERRUPT VECTORS
SET L.L.
D = D' = Ø
SET X.X.
SET N.N.
D1 = (NN * XX) + 6226
SET Y = R = Ø
SET X REG TO XX
PUT B(Ø-5) HIGH
R = Ø ?
Y = Ø ?
PUT D1 IN ACCM.
A(Ø-4) = Ø ?
SET D2 = D1
PUT D2 IN ACCM.
PUT ACCM. TO PORTS A(Ø-7)
PUT YREG TO PORTS B(Ø-5)
Y = Y + 1
R = Ø ?
D1 = D1 + 1
X = X - 1
X = Ø ?
PUT B(Ø-7) INTO ACCM.
B(7) = Ø ?
L = L - 1
L = Ø ?
SET D' = Ø
SET W = A(Ø-4)
SET R = Ø1
D1 = D1 + 1
D' = XX * W + 6226
PUT D' INTO ACCM.
D' = D' + 1
YES
NO

"LOOM 2"

'LOOM 2' NOTES

1. Sets external connections as inputs or outputs.

2. Provides means of interrupting (and stopping) the program.

3. The number of rows in the pattern.

4. Resets both data address counters.

5. the number of 'bytes' per row.

6. The number of stored ground weave rows.

7. Calculates the address of the first byte of pattern data.

8. Resets the external buffer address (y) and ground weave flag.

9. Loads the number of bytes per row into the x register.

10. Prepares the external buffer for data.

11. Checks for ground weave being requested.

12. Checks for first byte of a pattern row.

13. Copies first byte of data from memory.

14. Checks data for weft code - if absent ground weave called for.

15 & 16. Transfers data prior to output.

17. Outputs data to external buffer.

18. Changes address of external buffer.

19. Increments address of external buffer.

20. Check for ground weave row.

21. Increments data address.

2. Decrements 'bytes per row' counter.

23. Checks for end of row.

24 & 25 Waits for timing signal from loom.

26. Decrements row counter.

27. Check for end of pattern.

28. Resets ground weave data address.

29. Sets which ground weave row called for.

30. Sets ground weave flag.

31. Increments data address.

32. Calculates address of start of ground weave row required.

3. Saves ground weave data address.

34. Increments ground weave data address.

"Loom 2" Listing

Addr	Op. Code	Cycles	Remarks
0000	D8	2	Set Binary Mode
01	A9	2	
02	FF		
03	8D	4	
04	01		
05	17		Sets up A0 - A7 outputs
06	A9	2	B0 - B5 outputs
07	3F		B6 - B7 inputs
08	8D	4	
09	03		
0A	17		Sets Up Interrupt Vectors
0B	A9	2	
0C	00		
0D	8D	4	
0E	F1		
0F	00		
10	8D	4	
11	FA		
12	17		
13	A9	2	
14	1C		
15	8D	4	Sets Up Interrupt Vectors
16	FB		
17	17		
18	A9	2	
19	00		
1A	8D	4	
1B	FE		
1C	17		
1D	8D	4	
1E	FF		
1F	17		
20	A9	2	Set 'LL' the N° of Rows in
21	"LL"		Pattern Repeat (Low order
22	85	3	byte). Store At 00ED
23	ED		
24	A9	2	Set 'LH'. The N° of Rows in
25	"LH"		Pattern Repeat (High order
26	85	3	Byte). Store At 00EE
27	EE		
28	A9	2	Set Acc. To Zero
29	00		
2A	85	3	Set D(LL) To Zero. Stored At 006C
2B	6C		
2C	85	3	Set D(HI) To Zero. Stored At 006D
2D	6D		
2E	85	3	Set D'(LL) To Zero. Stored At 00B2
2F	B2		

"Loom 2" Listing – Continued

Addr.	Op. Code	Cycles	Remarks
0030	85	3	Set D'(H) to zero. Stored at 0033
31	B3		
32	A2	2	Set "XX" the N° rows in pattern rpt.
33	"XX"		
34	A9	2	Set "NN" the N° of ground weave rows
35	"NN"		
36	85	3	To be used. Store at 00EC
37	EC		
38	F0	3	Branch to 004A if NN is zero
39	10		
3A	8A	2	
3B	18		
3C	65	3	
3D	6C		
3E	85	3	
3F	6C		
40	A9	2	
41	00		
42	65	3	
43	6D		
44	85	3	
45	6D		
46	C6	5	
47	EC		
48	D0	3	Calculate the first pattern data address D(L), D(H). (Low and high order bytes). Store at 006C and 006D. First location for pattern data assumed to be 0220
49	F0		
4A	A9	2	
4B	"20"		
4C	18	2	
4D	65	3	
4E	6C		
4F	85	3	
50	6C		
51	A9	2	
52	"02"		
53	65	3	
54	6D		
55	85	3	
56	6D		
57	A0	2	Set Y register to zero
58	00		
59	A9	2	Set Accm. to zero
5A	00		
5B	85	3	Set R to zero. Stored at 00EB
5C	EB		
5D	A6	3	Set X reg. to XX at 0033
5E	33		
5F	A9	2	Set Accm to "3F"

LOOM 2 LISTING — CONTINUED

ADDR.	OP. CODE	CYCLES	REMARKS
ØØ6Ø	3F		
61	8D	4	
62	Ø2		PUT ACCM. INTO B PORTS
63	17		
64	A5	3	PUT R INTO ACCM.
65	EB		
66	DØ	3	RELATIVE BRANCH TO ØØB1 IF R NOT ZERO
67	49		
68	98	2	PUT Y REG. INTO ACCUM.
69	DØ	3	RELATIVE BRANCH TO ØØ72 IF Y NOT ZERO
6A	Ø7		
6B	AD	4	
6C	D(L1)		PUT CURRENT DATA ADDR. INTO ACCM.
6D	D(H1)		
6E	29	2	
6F	ØF		"AND" DATA WITH ØF (HEX). RELATIVE BRANCH IF RESULT NOT ZERO TO ØØ8Ø
7Ø	DØ	3	
71	ØE		
72	A5	3	
73	6C		SET D(L2) = D(L1). STORE AT ØØ7B
74	85	3	
75	7B		
76	A5	3	
77	6D		SET D(H2) = D(H1). STORE AT ØØ7C
78	85	3	
79	7C	-	
7A	AD	4	
7B	D(L2)		PUT CURRENT DATA ADDR INTO ACCM.
7C	D(H2)		
7D	4C	3	
7E	B4		JUMP TO ØØB4
7F	ØØ		
8Ø	85	3	STORE RESULT G AT ØØEA
81	EA		
82	A9	2	
83	Ø1		
84	85	3	
85	EB		
86	18	2	
87	65	3	
88	6C		
89	85	3	INCREMENT CURRENT DATA ADDR.
8A	6C		
8B	A9	2	
8C	ØØ		
8D	65	3	
8E	6D		
8F	85	3	

"Loom 2" Listing – Continued

Addr.	Op. Code	Cycles	Remarks
ØØ9Ø	6D		
91	C6	5	Decrement G (ØØEA)
92	EA		
93	FØ	3	Relative branch to ØØA4 if G is Zero
94	ØF		
95	BA	2	
96	18	2	
97	65	3	
98	B2		
99	85	3	
9A	B2		Calculation of XX (G – 1)
9B	A9	2	
9C	Ø6		
9D	65	3	
9E	B3		
9F	85	3	
AØ	B3		
A1	4C	3	
A2	91		Jump to ØØ91
A3	ØØ		
A4	A9	2	
A5	2Ø		
A6	18	2	
A7	65	3	
A8	B2		Calculation of the first memory
A9	85	3	location for the ground weave
AA	B2		subroutine. XX (G-1) + Ø22Ø
AB	A9	2	
AC	Ø2		
AD	65	3	
AE	B3		
AF	85	3	
BØ	B3		
B1	AD	4	
B2	D'(L)		Put ground weave data addr in Accm.
B3	D'(H)		
B4	8D	4	
B5	ØØ		Put Accm in A Ports
B6	17		
B7	8C	4	
B8	Ø2		Put Y Reg to B Ports
B9	17		
BA	C8	2	Increment Y Reg
BB	A5	3	Put R (ØØEB) in Accm.
BC	EB		
BD	FØ	3	Relative branch to ØØCF if R is Zero
BE	1Ø		
BF	A9	2	(See over)

"LOOM 2" LISTING — CONTINUED

ADDR.	OP. CODE	CYCLES	REMARKS
ØØCØ	Ø1		
C1	18	2	
C2	65	3	
C3	B2		
C4	85	3	INCREMENT CURRENT GROUND WEAVE SUBROUTINE DATA ADDRESS (D')
C5	B2		
C6	A9	2	
C7	ØØ		
C8	65	3	
C9	B3		
CA	85	3	
CB	B3		
CC	4C	3	JUMP TO ØØDC
CD	DC		
CE	ØØ		
CF	A9	2	
DØ	Ø1		
D1	18	2	
D2	65	3	
D3	6C		
D4	85	3	INCREMENT CURRENT PATTERN DATA ADDRESS
D5	6C		
D6	A9	2	
D7	ØØ		
D8	65	3	
D9	6D		
DA	85	3	
DB	6D		
DC	CA	2	DECREMENT X REGR.
DD	DØ	2	RELATIVE BRANCH TO ØØ5F IF X REG IS ZERO
DE	8Ø		
DF	AD	4	PUT B PORTS IN ACCM.
EØ	Ø2		
E1	17		
E2	29	2	RELATIVE BRANCH TO ØØDF IF B7 IS ZERO
E3	8Ø		
E4	FØ	3	
E5	F9		
E6	38	2	SET CARRY IN ACCM.
E7	4C	3	JUMP TO Ø2ØØ
E8	ØØ		
E9	Ø2		
EA	'G'		STORAGE OF VARIABLES
EB	'R'		
EC	'N(N)'		
ED	'L(L)'		
EE	'L(H)'		
EF			NOT USED.

"LOOM 2" LISTING – CONTINUED.

ADDR.	OP. CODE	CYCLES	REMARKS
0200	A5	3	
01	ED		
02	E9	2	
03	01		
04	85	3	
05	ED		DECREMENT ROW COUNTER (L)
06	A5	3	
07	EE		
08	E9	2	
09	00		
0A	85	3	
0B	EE		
0C	D0	3	RELATIVE BRANCH TO 0215 IF L(H) NOT ZERO
0D	07		
0E	A5	3	PUT L (LOWER) INTO ACCM.
0F	ED		
10	D0	3	RELATIVE BRANCH TO 0215 IF L(L) NOT ZERO
11	03		
12	4C	3	JUMP TO 0020
13	20		
14	00		
15	A9	2	SET ACCM. TO ZERO
16	00		
17	85	3	SET D'(L) TO ZERO
18	B2		
19	85	3	SET D'(H) TO ZERO
1A	B3		
1B	4C		JUMP TO 0057
1C	57		
1D	00		
1E	EA		NO OPERATION
1F	EA		
20	–		
21	–		
22	–		
23	–		START OF PATTERN DATA
24	–		
25	–		
26	–		
27	–		
28	–		
29	–		
2A	–		

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improvement with the available experimental data. Comparison of the pattern formed by ellipses based on experimental data with those predicted by the CMC(1:1) formula showed systematic discrepancies. (D52287/84)

35-2490 An investigation into the release and effects of toxins in certain paints on marine fouling organisms. Malpass,P.M, *Manchester*, M.Sc, 1983. *L7c*

A number of supplied antifouling formulations were evaluated to determine their effectiveness in marine fouling control. The paints were combinations of ablative resins (organotin methacrylate) with soluble and insoluble pigments.

Field trials of treated panels took place in a static dock environment, supplemented by laboratory rotor testing of the same panels in a simulated erosional environment. An evaluation of the leaching rate, utilizing Atomic absorbtion spectrophotometry, as well as analysis and inspected by scanning Electron microscopy of the paint layers before and after leaching were also carried out. These latter evaluations were to investigate the possible mechanisms involved in toxin release from the various resin and pigment combinations.

The results are used in an attempt to indicate th best paint combinations in preventing and/or controlling fouling communities.

L7d : Textile Technology

35-2491 The development of a high speed patterning system for a narrow fabric weaving machine. Davies,H.R, *Loughborough*, Ph.D, 1981. *L7d*

The needs for, and requirements of, a patterning system capable of matching the high speeds (up to 3,000 cycles/minute) attained by modern machines used for producing plain woven narrow fabrics are identified and a specification derived.

The warp selection system as developed is described; it comprises a collection of small electromagnets which each act upon the resilient part of a control element. This determines the position assumed by the control element which in turn controls the motion of a heddle element by causing it to latch onto one, or neither, of two continuously reciprocating members. The electrical input power requirement of the electromagnets is kept to a minimum by using the electromagnets to only retain the element and thus they do no mechanical work.

The weft selection system as developed is described; each weft yarn is streamed in a small jet of air within a selector block. The path taken by each air jet is controlled by smaller secondary jets and, using wall attachment phenomena. By switching these secondary jets by small fast electronically operated valves the desired yarn is caused to enter the path of the specially designed weft insertion needle of the loom. Details of the weft feed and tensioning system developed are described.

The development of both selection systems to the present form is outlined.

The capabilities and compatibility of a microprocessor based system for driving the selection systems are investigated. It is shown that this approach is feasible in terms of speed of response and data capacity. In order to reduce capital cost it is recommended that the system is divided into two parts; that for machine control and that for data preparation. The latter which is more complex and expensive may then be shared between a number of weaving machines.

Recommendations for the further development of the systems are given. (D53493/85)

35-2492 The properties of continuously shrink-resist treated wool. Greaves,P.H, *Bradford*, Ph.D, 1983. *L7d*

The effects of three commercially important continuous shrink-resist treatments (the Chlorine Hercosett, Kroy Hercosett and Dylan Fullwash processes) on a batch of 70's quality wool have been compared.

The wool tops were processed into knitted fabric and evaluated at each successive processing stage, i.e. top, singles yarn, two-fold yarn and knitted fabric.

Significant differences between the properties of the wools were found in the following areas:-

Fibre Tenacity;
Alkali Solubility;
Yarn Strength and Extension at Break;
Pilling Properties of Knitted Fabrics;
Handle of Fabrics;
Yellowness Index;
Dimensional Stability to Washing of Knitted Fabrics;
Appearance of Fibres under the Scanning Electron Microscope.

The development of cockling in knitted fabrics was found to be related to the uniformity of chlorination in the wool.

A microscopical staining procedure was used to provide an assessment of the uniformity of the shrink-resist treatments. (D52368/84)

35-2493 The development of a novel high-speed fabric manufacturing process. Vitols,R, *Loughborough*, Ph.D, 1979. *L7d*

The manufacture of conventional textiles usually involves either weaving or knitting. The author and his colleagues have devised a completely new technology for textile fabric construction involving the use of simple elements. These elements are basically similar in shape to sewing machine needles which interact with each other in such a way that yarns "stitch-knit" themselves together to produce a fabric. As a result of this unique interaction the number of loops produced is double when compared to the time cycle of a conventional knitting action. Further enhancement of at least double fabric production rates should accrue from the dual effects of decreased yarn tensions and the lowered dynamic disturbing forces of the simplified knitting element manipulating system.

A survey has been made of the looped-type textile manufacturing processes and the most appropriate groups have been enumerated in order to form a basis of comparison for the novel process.

A basic study (including computer aided graphics) of probable textile structures, that could be produced by this technology, has revealed a substantial range of novel fabrics. These fabrics have been analysed and possible uses for them are suggested.

A powered research-rig has been designed and constructed on which the important yarn manipulation characteristics have been determined. This experimentation has facilitated a more positive yarn pick-up to be evolved. As a result of this, more practicable design tolerances may be given for the manufacture and setting-up of the manipulative elements. Moreover, narrow-width novel fabric samples have been produced from spun-staple yarns at rates exceeding the current commercially available maximum, thereby substantiating the earlier predictions.

Finally, the new technology and its resulting products are appraised and design proposals for a prototype machine are made; it is hoped that this will be offered to industry in due course for further development and potential exploitation. (D44434/83)

L7e : Polymer Technology

35-2494 Processing of UPVC in single and twin screw extruders. Covas,J.A.C.G, *Loughborough*, Ph.D, 1985. *L7e*

The processing characteristics of PVC compounds play a major role on the ability of the equipment to control the final properties of the product. Therefore, information on the effect of processing conditions on such characteristics, and its influence on the final properties can lead to an optimization of the extrusion process.

In this work, a statistically based experimental design was used in order to investigate the role of the operating conditions on the extrusion of a simple lead based PVC formulation. Both a single and a twin screw extruder were used - they were instrumented, and data collected by computer. A die was designed for the formulation used, with both shear and extensional flows being taken into account. These experiments produced both core samples along the screw(s) and final products with varying states of fusion.

The fusion mechanism on processing was monitored with the help of electron and light microscopy techniques, thermal analysis and density measurements. In both types of extruders the primary particles were found to fuse well before the grains, but the overall mechanism differs for each type of machine.

An experimental technique was developed for the study of the Residence Time (RT) and Residence Time Distribution (RTD) of the material in the processing equipment. These functions were related to the operating conditions and compared with the available models for extrusion.

The degree of fusion of the processed products was assessed by rheology and thermal analysis. A range of mechanical properties, relevant to the general end - use of rigid PVC formulations, was analysed: flexural, tensile and impact properties were found to be directly related with fusion level. Hardness, measured using a newly developed apparatus, proved to be a potential technique for the degree of gelation of PVC formulations. D56865/85

35-2495 Diatomaceous earth filled HDPE. De Sousa,J.A, *Loughborough*, Ph.D, 1984. *L7e*

The objective of this research programme was to study the influence of filler incorporation on the rheological, mechanical and morphological properties of high density polyethylene. Several compositions of general moulding grade of HDPE filled with increasing concentrations of diatomaceous earth, an amorphous silica-based particulate mineral of high porosity and friable nature, were compounded in a single-screw extruder. Good filler dispersion into the polymer matrix was achieved with complete polymer permeation through the porous structure of the diatomite particles,