19

Automatic power flat knitting

19.1 History

In 1867, *Henri Edouard Dubied* acquired the European rights for Lamb's machine (see Section 18) during the Paris Exhibition and established his knitting machine building company. Similarly, in 1873, *Heinrich Stoll*, a German engineer, began to build and repair Lamb machines and by the early 1890s he was not only building improved versions of the rib machine but also flat bed purl machines of a similar standard of perfection [1–3]. The company founded by Stoll continues to play an important part in the development of flat knitting machinery including: –

- 1926, the first motor-driven jacquard flat machine.
- 1975, the first fully-electronic flat machine.
- 1987, the first of the CMS series machines.

In the 1960s, the Japanese company *Shima Seiki* under its president *Masahiro Shima*, pioneered the development of the automatic V-bed seamless glove-knitting machine. Experience gained in that field has been applied to the development of a comprehensive range of electronic V-bed flat machines, including the very latest techniques for knitting whole garments. CAD systems have also been up-graded and refined to complement developments in knitting technology.

19.2 The MacQueen concept

In the early 1960s, *Kenneth MacQueen* unsuccessfully attempted to develop a revolutionary electronic computer-controlled V-bed flat machine having compound needles [4]. The idea was to use the Basque beret technique of knitting wedge-shaped garment parts in a sideways manner with held loops, part course knitting, and sections separated by waste yarn segments.

The machine was to use a variable carriage traverse, magnetically-energised raising cams to lift the needle butts, tape control for the design selection and garment sequence, with centralised computer control of up to six 'slave machines'. Although MacQueen's concept failed through being too ambitious, the advent of micro-electronic technology, computer programming, and major advances in shaping techniques have enabled the major part of his far-sighted dream to be realised.

19.3 Power flat machines

The basic principles of V-bed flat knitting have already been outlined in Chapter 18. The main difference between the simple hand-controlled flat and the automatic power flat is that the latter can be programmed to automatically knit a garment length sequence with little or no further human intervention. The term *flat bar* or *power flat* has been retained as the generic name for both rib and purl flat machines. Both types originally were designed to knit garment-length blanks of constant width for cut-and-sew knitwear.

19.4 The versatility of V-bed power flat knitting

As the facilities of the mechanically-controlled V-bed flat machine improved, its patterning versatility became such that it could not be equalled:

- It was able to knit rib or plain garment panels in jacquard, racked stitches, rib loop transfer, links-links, cable stitch, needle-out, and relief designs.
- Jacquard steels provided individual needle selection across the whole needle bed (with the possibility of selection on the back as well as on the front needle bed).

However, in cut-and-sew knitwear it faced competition from the less versatile but more highly-productive circular garment-length knitting machines. Additionally, in the production of classic, plain, fully-fashioned knitwear it was unable to challenge the shaping facilities of the straight bar frame.

Over the last thirty years, many innovations and refinements in knitting technology have gradually evolved and combined to transform the mechanically-controlled V-bed machine into a computer-controlled, highly efficient and versatile knitting machine, not only for cut-and-sew knitwear but also for integrally-shaped panels and whole garments.

In this process of evolution it has rendered the flat bed links-links machine superfluous, blunted the productive challenge of the circular garment-length machines, surpassed the straight bar frame in shaping potential both in types of shapes and knitted structures, and has extended its own gauge range capabilities. Its biggest challenge occurs when fashion swings away from knitwear to tee shirts and sweatshirts cut from jersey fabric.

19.5 Electronic controls replace mechanical controls

The electronically-controlled power flat machine offers quick response to size, style and pattern changes with versatile and infinitely variable adjustment of its electronically-controlled functions under the guidance of the main computer software programme and the back-up support of its memory. It is therefore more able to efficiently meet the exacting requirements for knitting shaped garments [5].

In contrast, the mechanically-controlled power flat machine is time-consuming and costly during machine changes and its more limited facilities provide less scope for adjustment.

19.6 The garment sequence programme

The garment sequencing programme is the most important requirement of a garment-knitting machine because it has overall control of the functioning of the machine whose automatic operation follows the specified programme.

On mechanically-controlled power flats, it is the pasteboard movement-card mechanism that provides the programme controlling and co-ordinating the machine's functions throughout the garment-length knitting sequence.

The positions of holes punched in the cards determine movement functions such as yarn carrier selection, positioning of knitting cams, needle bed racking, and overall control of the jacquard mechanism.

The cards are expensive and time-consuming to assemble, shaping programmes would require many extra cards and sequential knitting would require the equivalent of four programmes – for the front, back and two sleeves.

19.7 Mechanical jacquard selection

Figure 19.1 illustrates the arrangement of elements in the needle bed of a machine having full mechanical selection. A separately-controlled arrangement may also be available on the other needle bed. In the tricks beneath each needle are selectors (two in the case of the double-cam system machine) whose tails are supported by a jacquard steel that extends across the full width of the needle bed.

There is a possible punched-hole position for each selector on every jacquard steel. The steels are hinged together to form an endless 'chain loop' which passes over the prism. The prism can turn whilst the cam-carriage is clear of the needle bed at the end of its traverse. This brings another steel onto its upper surface and thrusts it upward into contact with the protruding tails of the selectors. This produces a simultaneous selection at every needle trick, ready for the next carriage traverse. The prism can dwell to repeat a selection, or rack forwards or backwards by one or two positions.

An unpunched portion in a steel causes the corresponding selector to be pushed upwards in its trick, aligning its butt with a raising cam in the cam-carriage so that eventually the needle above it will be lifted, possibly to knit. A punched hole allows the selector tail to sink into the groove of the prism and thus be unaffected by the thrust of the prism so that its needle is left at an inactive level.

19.8 The Shima Seiki electronic selection system

Figure 19.2 illustrates the front (F) and back bed (B) cam systems of a *Shima Seiki* two (knitting) system model SEC. It is indicated that the cam carriage is traversing

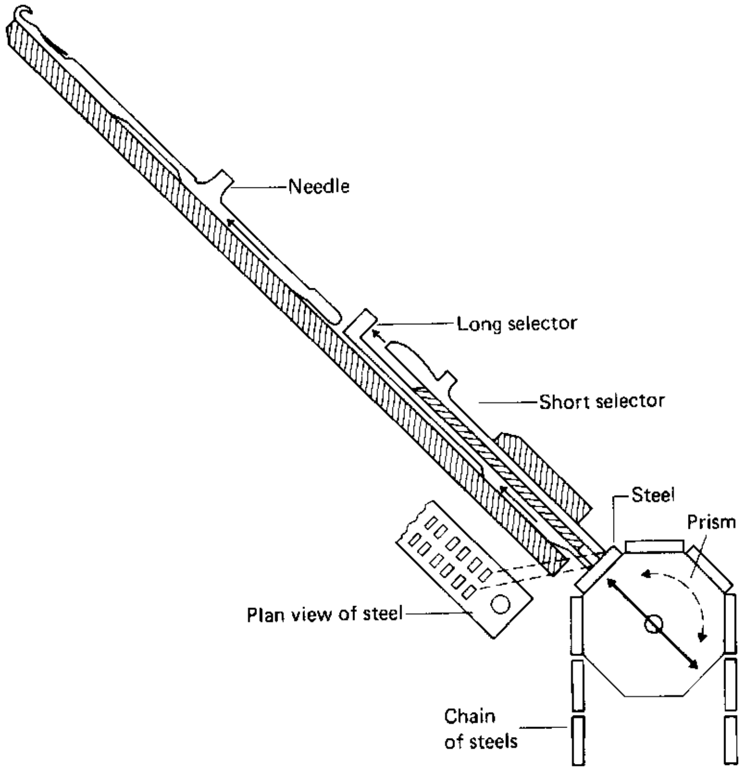

Fig. 19.1 Mechanical jacquard selection on a V-bed flat machine.

from right-to-left so that the butts of the knitting elements enter from the left, passing through four systems:

1 From the left, the first system is transferring loops from the back bed to the front bed. '4' is a loop transfer cam and '6' is a loop receiving cam.

2,3 The next two systems contain knitting cams, '2' being clearing cams and '3' being stitch cams.

4 Finally, the right system is transferring loops from the front bed to the back bed. Delivering cam '5' is introduced to raise butts onto transfer cam '4'.

The *Shima* model SES provides the same facilities but with only two systems, each of which contains full camming for knitting and two-way transferring; this virtually halves the width of the cam-box.

Figure 19.3 illustrates the arrangement of elements in one needle bed, e.g. the front bed; the back bed has an identical arrangement.

Latch needle (a) has a spring clip for rib loop transfer.

Needle jack (b) is pivotally connected to the needle and provides the single position knitting butt that can be selected to follow the raising cam (2) (Fig. 19.4) profile, lifting the needle from miss to tuck or knit.

When the tail of the needle jack is depressed by the head of the re-positionable *presser jack* (c), the knitting butt is sunk out of contact with the raising cam (2) and the needle remains at the height it has already reached.

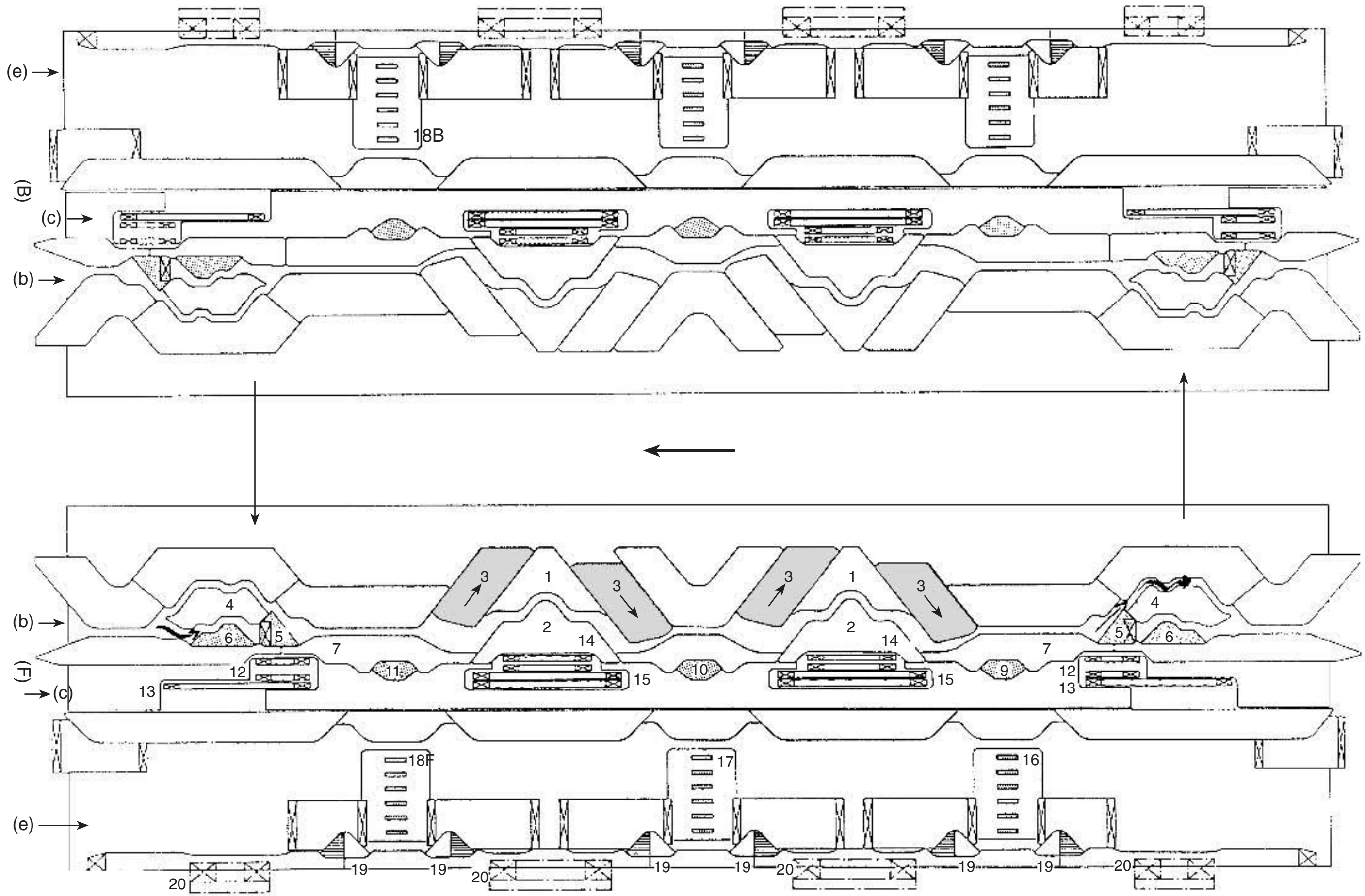

Fig. 19.2 Shimatronic SEC cam system [Shima Seiki].

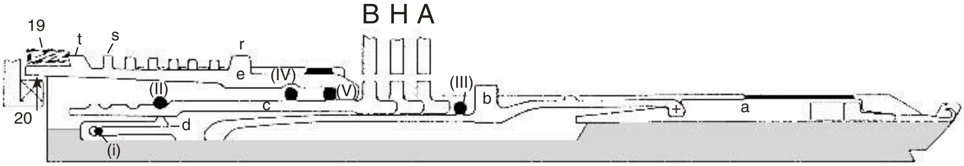

Fig. 19.3 Knitting elements.

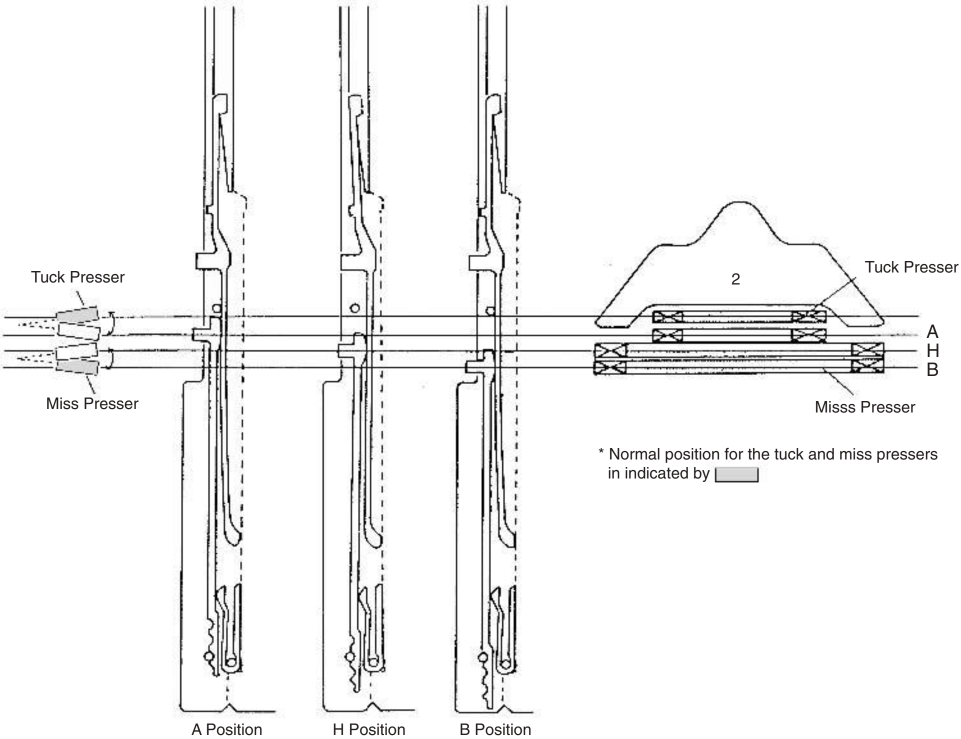

Fig. 19.4 Presser cams.

The presser jack is selectively positioned so that its pressing butt is aligned with one of three presser cam paths (A, H or B), where it can be pressed downwards by a *presser cam* in the cam-carriage. The needle jack can also be sunk out of action by manually pushing it under wire (iii).

The presser cam is a flat plate actuator in the cam-carriage that can be tipped so that it presses down onto the butt of a presser jack placed in its path. There are two presser cams (Fig. 19.4) projecting from beneath each raising cam (2):

The *lower presser* (the *miss presser*) covers the full width of the raising cam for presser jacks in either the H or B positions, causing the knitting butt to be out of action at miss before it can be lifted to tuck height.

The *higher presser* (the *tuck presser*) covers the top of the part of the raising cam and when in action will cause needles in the A track to remain at tuck height. When the tuck presser cam is tilted slightly, it will miss the presser butts in the A position and those needles will continue to follow the raising cam profile and be lifted to knit height.

There are 4 possible combinations of knit, tuck and miss:

1 Tuck presser cam tipped (A knit). Miss presser cam untipped (H knit, B miss).
2 Tuck presser cam tipped (A knit). Miss presser cam tipped (H miss, B knit).
3 Tuck presser cam untipped (A tuck). Miss presser cam untipped (H knit, B miss).
4 Tuck presser cam untipped (A tuck) Miss presser cam tipped (H miss, B knit).

The head of the *pattern selector jack* (e) rests on top of the presser, against its butt. When the selector is cammed forward, it moves the presser from position B to forward position A. Cancellation cams (9, 10, 11) move the presser from A to B. When the cam is out of action, the presser is guided only to intermediate position H for re-selection.

The selector has a tail butt (t) for raising it. Butt (r) is used to return the selector to the start position for re-selection. Selection butt (s) corresponds to one of 6 positions of the bank of actuator-selecting cams. The selection butts are set-out in descending echelon order.

19.9 The take-down system

The conventional V-bed machine relies on the two sets of needles, together with the takedown rollers, to hold the fabric down. The fabric is drawn downwards from the needle beds and passes between the grip formed by the roller and counter roller. The roller is composed of freely-turning sectional rollers on a common shaft. Each roller is pre-set spring-tensioned as the shaft turns under the influence of a racking pawl controlled by a lever and weight arrangement. Adjustable pressure rollers maintain the pressure grip.

The conventional mechanical takedown requires a continuous flow of knitted structure from the needles to the roller grip. The garment pieces must therefore be knitted in string formation, with each one joined to the next by a course knitted as a draw-thread that is removed later in order to separate the individual garment pieces.

The system operates most successfully on a fabric having a consistent knitting width, and a balanced course and knitted loop arrangement, both between the two needle beds and within each bed. As tension is exerted equally on all wales within the roller grip, those not gripped (at the selvedges if the fabric is being widened) will be untensioned, whilst held loops will receive excessive tension. Other wales, where more continuous knitting occurs, tend to receive insufficient tension. Thus, the mechanical arrangement tends to inhibit both shaping, and also types of designs that involve multiple tuck accumulation and holding loops over a number of courses.

19.10 The fixed-stroke carriage traverse

The distance a hand-powered cam-carriage is traversed can be varied as required. However, mechanically-powered cam-carriages are driven by a chain to traverse a constant width. This includes an 'over-throw' to take the cam-carriage clear of the needle bed so that striking plates controlled by the machine programme can contact the slides on the carriage to re-set the cams as required. There is thus wasted time if the knitting width is less than the maximum.

19.11 Meeting the requirements of a shaping machine

In order to knit shaped panels or integral garments, it is necessary to meet a number of exacting requirements which can only be achieved with a specially designed fully computerized V-bed flat machine having the characteristics set out in Sections 19.11.1 to 19.11.7.

19.11.1 The shaping control programme

The shaping control programme needs to have sufficient memory to include the data for all the parts of a garment, whether integrally knitted or sequentially knitted shaped-pieces, in the complete range of sizes.

Shaping in width can only be achieved on machines freed from the constraints of constant-width traverse. On electronic machines, the computer is linked to the cam-carriage whose variable traverse and speed is driven from a belt. The traverse distance is varied by the belt drive, which transports the yarn carriers so that they follow the selvedge edge.

19.11.2 Variable-width carriage traverse

One of the most important features of shaping is keeping the cam-carriage traverses to the minimum width using a lightweight compact cam-carriage and belt drive, combined with knitting/transfer cams, and needle butts that are sunk when out of action.

19.11.3 The shaping method

Fashion shaping using loop transfer is the most satisfactory method of introducing shape into garment blanks. It is employed on straight bar frames in the form of plain loop transfer, using a set of rackable fashioning points. Although separate loop transfer fashioning points are employed on some V-bed machines, the most common method is to use the needles to rib loop transfer from needle bed to needle bed, combined with needle bed racking to move the selvedge loops inwards or outwards. Care must be taken to ensure that receiving needles are empty of loops.

19.11.4 Modern take-down systems

Modern machines have a computer-programmed, positively-driven takedown system whose operation is synchronised with that of the requirements of the knitting programme and provides pre-determined fabric tension as required. Sometimes, small sub-rollers provide a nip immediately below the gap in the needle beds. The main control is provided by the nip formed by the takedown roller and the counter roller that presses against its surface. The counter roller is segmented, consisting of individual rollers that are each spring-adjusted.

The roller drive speed can be selected from as many as 31 possibilities and can be stopped during needle bed racking and rib loop transfer, or it can be reversed to achieve zero fabric tension whenever required during the knitting programme.

19.11.5 Control of the fabric during knitting

The production of width-shaped garment pieces requires different or additional facilities to those used when knitting constant-width garment pieces joined by draw-thread separation. No one device alone appears to provide for all conditions of fabric takedown when knitting to shape.

When changing from a narrow width at the end of one garment panel and recommencing on a wider starting width for the next panel, with normal takedown rollers there will be a lack of takedown tension and fabric control at the selvedges, even with a draw-thread connection. If the pieces are not connected together, there will be no takedown tension. The most common solution is to employ a takedown comb in addition to the conventional takedown rollers; this rises to engage its pins with the set-up courses of the new garment piece. As knitting continues, it guides the fabric until it engages with the takedown roller, which then takes over control of the knitted panel. With separated garment piece knitting it is also necessary to employ thread cutters and trappers, otherwise yarn ends will wrap around the rollers.

Shima have a new computer-controlled pull-down system for their *FIRST Whole-Garment* machines. The front and back of the garment each has a separate takedown panel of tiny pins, each section of which can be individually controlled for specific tension. This results in a more dimensionally-accurate garment; for example by allowing shoulder lines for set-in sleeves to be positioned over the shoulders and towards the back.

19.11.6 Stitch pressing-down devices

The object of the presser foot and other similar devices (such as knock-over bits and holding-down sinkers) is to keep the old (fabric) loops low down on the needle stems. They are thus prevented from rising ('riding-up') and staying on the latch spoons as the needles rise for clearing or yarn feeding. This ensures a 'clean' knitting action, irrespective of the variable tensions within the knitted structure or the lack of takedown tension operating onto the fabric from below.

Interest in this concept was regenerated in 1968 by the development work of *Frank Robinson* and *Max Betts* of *Courtaulds*, whose 'presser foot' patents were licensed by *Dubied, Bentley-Cotton* and *Shima Seiki* for use on their flat knitting machines. Other companies also employed stitch pressing-down devices of various types on their machines.

The original presser foot consisted of a piece of wire bent at either end to form a foot (Fig. 19.5). The centre of the wire is carried on the underside of a pivoted arm that hangs downwards from a cross member so that it brushes against the upper surface of the fabric loops as it moves with the cam-carriage. At the end of each traverse, the pivoted arm is tilted to incline in the opposite direction, lifting one foot out of action and lowering the foot on the other end to trail across the needle beds for the return traverse

There is a device working with each cam system and its yarn carrier. Different

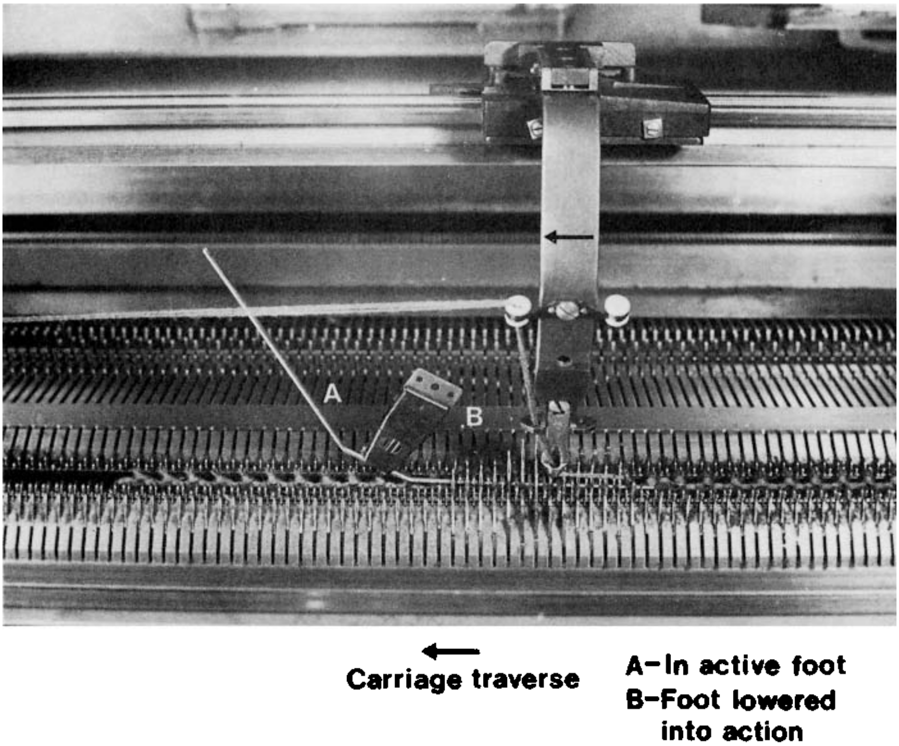

Fig. 19.5 Action of the presser foot. The foot is shown during a right-to-left traverse pressing down the loops on the needles in advance of the yarn carrier. (The cam carriage has been removed for purposes of clarity) [*Knitting International*].

diameters of wire can be employed for varying machine gauges and yarn counts, and it is possible to fit specially-angled feet of triangular cross-section for use during single-bed knitting or loop transferring, if necessary.

The foot acts slightly in advance of the yarn carrier and the rise of the needles for tucking or clearing. It enters the space between the needle beds to gently stroke the old loops down the needle stems as it trails, at a slight decline to their upper surface. Accommodation to differing degrees of knitting tightness can be achieved with a spring-loaded, self-compensating presser foot, which rides-up the support arm when the structure is knitted to a tighter quality.

As the presser foot does not create tension on loops already formed, loops may be held on inactive needles for many knitting cycles and stitch concentrations can be varied across the fabric width. It also enables separate garment panels to be commenced on empty needles and to be pressed-off on completion. The reduced take-down tension removes the problem of shape distortion and the bowing of courses caused by relaxation of the structure, often eliminating the need for first pressing. The structures tend to be heavier, and rib knitted on two-cam systems shows a slightly racked appearance because the presser foot causes yarn to flow into the first limb of each loop that it contacts. Two courses made in the same direction of traverse emphasise the inclination of the loops. To produce a conventional elongated loop instead of a round loop it is important to maintain some take-down tension.

The presser foot principle provides scope for the use of holding of loops, pressing-off, and part-course knitting in the production of unconventional integrally-knitted garments, which require less seaming and virtually no cutting. Amongst the garment shapes are cruciform, tubular plain articles, and garment parts in varying course lengths, knitted as shaped single pieces of fabric in a spiral formation, similar to the principles of the Basque beret or the ideas of *MacQueen* or *Pfauti*. Early attempts employing these techniques met with limited success until the development of computerised V-bed machines with full facilities for integral garment knitting, which could exploit the design potential offered in this area. The original presser foot was less precise than the modern computer-controlled stitch pressers and was susceptible to tension deflection and contact with the needles.

19.11.7 Needle bed racking

A maximum racking distance of 2 inches, in some cases on both beds, is available. This includes 1/4 pitch and 1/2 pitch. An over-racking facility stretches the loops, making their transfer easier.

19.12 The multiple-gauge technique

Sophisticated fashion tastes have, on occasion, required knitwear garments containing zones of both coarse and fine gauge stitches – which can now achieved on one machine using '*multiple gauges*'. This involves a combination of techniques, including half-gauging, using different numbers of yarn ends, intarsia zoning, and blocks of different gauges of needles each working with its corresponding count of yarn and yarn carrier (Fig. 19.6).

Stoll have a multi-gauge range:

The '5.2' with 6-gauge needle hooks gives a range from E 5 to E 10.
The '6.2' with 8-gauge hooks gives a range from E 6 to E 12.
The '7.2' with 10-gauge hooks gives a range from E 7 to E 14.

Stoll and *Shima Seiki* have demonstrated how an apparent range of gauge structures can be knitted all on the same E 6 gauge machine, using half-gauge and full-gauge needle set-outs, together with different numbers of ends of yarn.

Stoll have knitted a sample range on an E 6.2 gauge CMS 340 using Nm 2/32's yarn. In the finest gauge, every needle knitted a single end of yarn (resultant different count – Nm 16).

In the second sample, two ends of yarn (resultant count – Nm 8) were knitted.

In the third sample, half gauge knitting of three ends of yarn (resultant count – Nm 5.3) occurred.

Four ends (Nm 4) were knitted in the fourth sample.

Five ends (Nm 3.2) in the fifth.

Six ends (Nm 2.7) in the sixth and coarsest sample.

Stoll ready-to-wear integrates many of the laborious and time-consuming making-up processes into the knitting process; for example, pockets, button-hole panels, facings, overlapping collars, bows, and loops.

Fig. 19.6 Multi-gauge technique garment.

19.13 The split stitch

In Section 16.4.1 (Wale fashioning) it was mentioned that widening resulted in a needle losing its loop by transfer to another needle so that, when knitting recommences on the empty needle, a 'tuck stitch' type of eyelet hole is formed (Fig. 15.1). In straight bar frame knitting, the covering of this hole is termed '*filling-in*'. A similar technique has been developed for modern V-bed machines termed the '*split stitch*'. There are two methods (Fig. 19.7a and b):

- When knitting with a latch needle, a loop is transferred to an opposite bed loop but immediately, the delivering needle receives a new loop whilst at transfer height and this is drawn through the transferred loop. (Fig. 19.7a).
- When knitting with a compound needle, the receiving needle takes and shares half of a loop on a delivering needle in the opposite bed because that needle has an open hook during transfer and does not cast-off its loop (Fig. 19.7b).

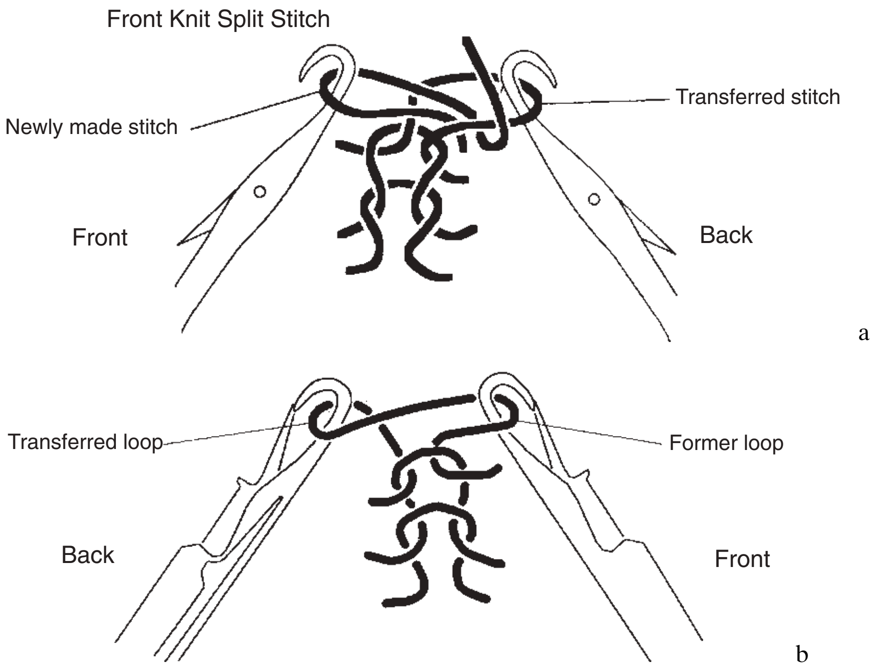

Fig. 19.7 (a) Split stitch using latch needles. (b) Split stitch using compound needles [Shima Seiki].

19.14 Multi-carriage flat machines

Introduced by *Textima* in 1950, the *Diamant* machine has two separate pairs of needle beds, each 72 inches (183 cm) wide, arranged parallel to each other on a rib basis. Each pair knits a straight cut edge garment blank by means of 15 to 18 cam-carriages that complete 10–15 clockwise circuits of the machine per minute, transporting their own yarn packages, stripers and selection drums.

19.15 Seamless glove knitting

The *Shima Seiki Company* has perfected a fully-automatic method of glove knitting in tubular plain on a small width V-bed machine (Fig. 19.8). Each finger is knitted in turn from its tip, with its loops then being held until the palm sequence commences. The glove is completed and pressed-off with an elasticated mock rib cuff. Control of knitting across the varying width is assisted by spring-controlled holding-down sinkers (now housed in the needle cylinder) and a variable traverse of the cam-carriage. A digital inverter provides infinitely variable speeds and smooth operation.

Machine gauges range from coarse gauge E 5, E 7, E 8 to fine E 10, for work, driving and fashion gloves. E 13 and E 15 are ultra-fine for precision work and special applications. Knitting speeds are approximately 1 minute 40 seconds for an E 5 glove to 3 minutes 7 seconds for an E 13 glove. An associated development is the five-toe sock-knitting machine in E 10 and E 13 gauges with 60 and 74 needles. It has a special picker mechanism for knitting the heel, and the step motor stitch control has 90 levels.

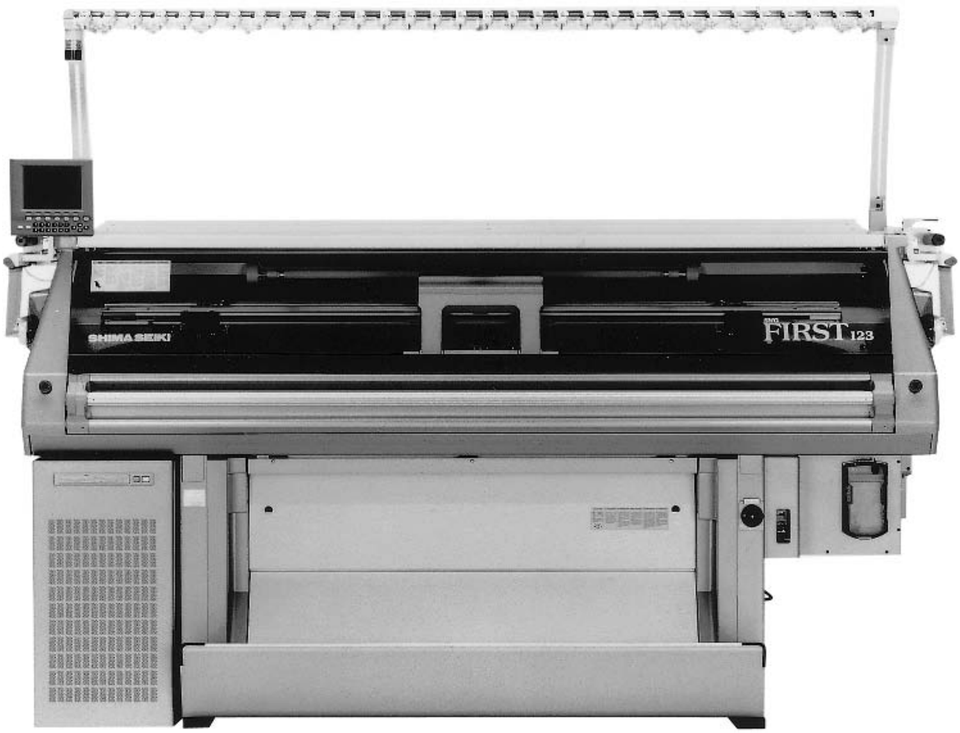

Fig. 19.8 The FIRST 123 three-system, short-bed computerised flat knitting machine [Shima Seiki].

19.16 The WholeGarment knitting technique

Shima Seiki launched their patented WholeGarment technique at ITMA'95 with two different V-bed models, each having unique features. These involve integrally and seamlessly knitting a complete tubular garment on a V-bed rib machine. A new feature of this technique is the ability to knit tubular rib with a high wale density and therefore improved extensibility and appearance.

WholeGarment knitting removes or reduces the need for subsequent making-up (and in some cases cutting) operations, consequently reducing the garment throughput time and work in progress. It also provides the potential for introducing novel styling features into knitwear garments.

The key concept of WholeGarment knitting is the facility to knit seamless body and sleeve tubes of virtually any type of plain, rib or purl construction, plus the ability to increase or decrease the sizes of the tubes and to move or merge them together as and when required during the garment knitting sequence.

The technique of knitting tubular courses of plain knit on a conventional V-bed flat machine is well understood and is used in the production of complete gloves on *Shima Seiki* automatic glove knitting machines.

In Fig. 19.9a, the running thread notations show the production of tubular plain in two traverses on a conventional V-bed flat machine. As the yarn passes across to the loops on the other needle bed, at each turn round of the cam-carriage a tubular course is knitted in plain fabric with the face loops on the outside and the reverse stitches on the inside of the tube. A number of tubular structures can be knitted at the same time (Fig. 19.9b); these can form the start of sleeves and a body.

Using loop transfer and other techniques to introduce or remove needles involved in knitting, it is possible to increase or decrease the size of the fabric tube, to move and merge it into other fabric tubes at a controlled rate, and to semi- or fully-close the tube either at the start or the end of the knitting sequence (Fig. 19.9b).

In order to integrally knit tubular-shaped garments, however, it is necessary to be able to knit tubular rib courses as and when required, particularly for the garment borders and the cuffs of sleeves.

The knitting of *tubular courses of rib* on a V-bed rib machine (Figures 19.10a and b) requires a carefully arranged sequence, particularly if a commercially acceptable wale density of rib is to be knitted. The problem is that in each traverse, front and back bed needles are required to knit the course of rib. The objective is for the front bed needles to eventually receive a complete traverse course of rib (face and reverse) loops and for the back bed to receive the return traverse course of rib loops.

The knitting of tubular rib on a conventional two needle bed flat machine does not, however, produce a rib that is very acceptable as far as extensibility and appearance is concerned because it is essentially knitted on only half the available needles (Fig. 19.11d). A course of 1 × 1 rib is first knitted using both needle beds (Fig. 19.11a) and is then transferred off onto one single bed (Fig. 19.11b).

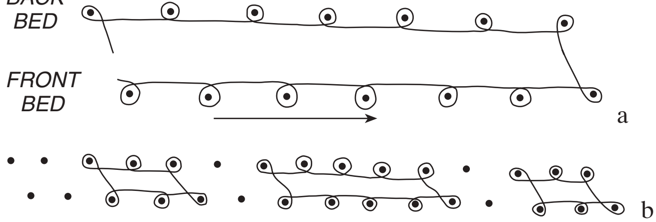

Fig. 19.9 Tubular plain knitting on a flat machine.

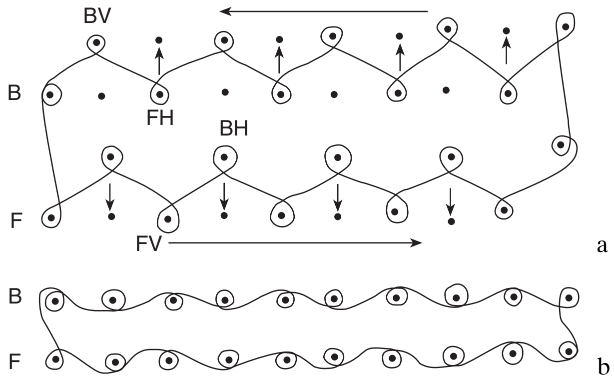

Fig. 19.10 Tubular rib knitted on a carefully arranged needle sequence.

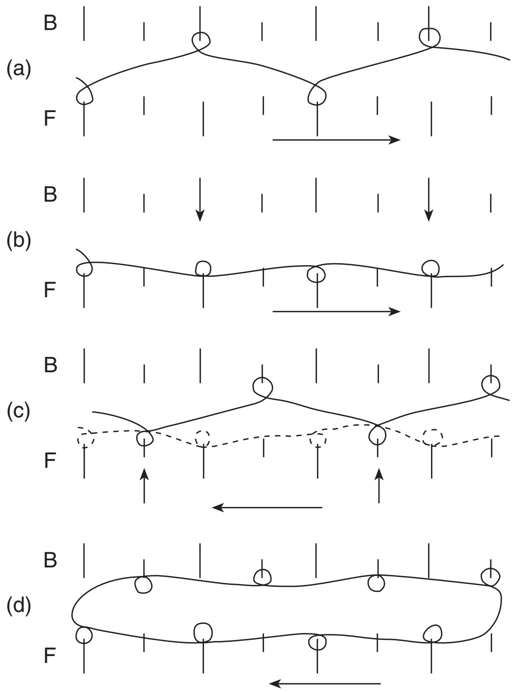

Fig. 19.11 Half gauge tubular rib.

In order to receive transferred rib loops, complementary needles in the opposite bed must be empty of loops whilst other needles in that bed retain their loops from the same rib course of knitting. Additionally, in order to shape the garment by widening and narrowing or joining, tubular courses of rib are required to be transferred laterally onto other needles in the same bed.

The needles that are active therefore require careful selection so that the maximum possible number are involved in knitting. The linear distance between adjacent needle loops must be kept to a minimum, otherwise the extensibility of the rib wales will be seriously impaired.

The *Shima* solution to the dilemma is to provide machines with four sets of needles, two sets for each traverse row of the tubular rib, instead of the two needle beds available on conventional V-bed flat machines.

Shima introduced two models each with a different needle bed configuration:

1 The model SWG-*X configuration* uses *four needle beds*, each having an identical arrangement of needles and selection elements providing for knit, tuck, miss and rib loop transfer. Two additional needle beds are positioned at an angle of 5 to 10 degrees from the horizontal, in a flattened V-bed arrangement above the conventional V-beds. Each needle in an upper bed is exactly aligned above a needle in the corresponding bed beneath it and can thus replace its action if required. Only *compound needles*, with their slim profile, short knitting stroke and sliding action, can perform efficiently in such a confined space. (The *Shima* model SES 122 RT introduced in 1993 also has four beds but the upper two beds contain loop transfer points instead of needles)

2 The model SWG-*V configuration* has *two needle beds* in the normal V-bed arrangement. The needles, however, are in a twin gauge arrangement offset in pairs. Thus on a 5-gauge machine there are 5 pairs of needles (10 needles per inch of needle bed). There is a normal gauge distance between each pair of needles, and a fine gauge distance between each of the needles in a pair in each bed. Thus, on the V model, the pair of needles can function in the same manner as the two aligned needles in the upper and lower beds of the X model. The V model has a simpler configuration but, because of twin gauging, its finest gauge is 7 (14 npi), whereas the X model is available in 7, 10 and 12 gauges, and now has an additional loop presser bed.

19.17 The Shima model FIRST

The name *FIRST* is an acronym representing F (fully fashioning), I (intarsia), R and T (rib transfer) and S (sinker). It employs a *slide compound needle* that has a number of unique design features. Its hook-closing slide is split to form a pair of loop-holding pelerine points at its forward edge. When the slide is advanced beyond its normal hook-closing position, it transports the loop on its shoulder across the beds to engage with the opposite bed and thus transfer the loop (Fig. 19.12).

This transfer action does not require the assistance of a transfer spring on the needle. The needle is therefore centrally positioned in its trick, thus reducing yarn stress.

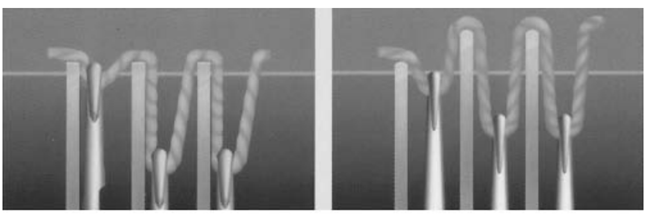

Fig. 19.12 Comparison of the new slide needle with the latch needle [Shima Seiki].

The outside shoulder of the slide is designed to retain a loop whilst another loop is inside the hook. Separate control of the two loops enables certain stitches to be knitted that were previously impracticable.

The slide needle has a thinner hook and a larger inside hook area, thus providing space for thicker yarns. The thinner hook is made possible because the hook does not receive the potentially damaging blows from a pivoting latch. *Shima* has three needle/needle bed arrangements designated small, medium and large. Small has fine needles and a small gap between the needle beds; medium has thicker needles but the same gap between the beds; and large has the same needles as medium but a larger gap between the beds.

In addition, there are four ranges of gauge based on *needle pitch* (the distance in millimetres between two adjacent needles in the same bed). '3.6' provides a gauge range up to E 7, '2.1' is the most popular giving a gauge range from E 6 to E 12, '1.8' provides a range up to E 14, and '1.4' provides the finest range up to E 18.

Three needle bed widths are available – 126 cm, 156 cm and 180 cm (50, 60 and 70 inches respectively). The short bed has 2 knitting cam systems; the other widths have 3 or 4.

Contra sinkers, moving in opposition to the needle movement, provide a knock-over surface and reduce the needle movement. The resulting lower yarn tension enables different sizes of loops to be drawn.

Above the V-bed are two horizontally-mounted beds containing ancillary elements. The upper front bed carries loop transfer jacks and is split into two sections that can be racked outwards for widening and inwards for narrowing to take place simultaneously at the selvedges, without the need for empty traverses and separate left and right racking of the transfer jack bed.

The upper rear bed holds special loop pressers that press down on selected individual loops in the front or back needle beds. With this arrangement it is possible to press an inlay yarn behind a non-knitting needle.

Conventionally, yarn carriers are moved into position by the cam-carriage. After a course of intarsia or integral knitting, the carriage must use an empty course to move the yarn carrier out of the way in order to knit the next course. The *Shima FIRST* machine has a motor-driven yarn carrier system that automatically '*kicks-back*' the yarn carrier into its field of knitting and out of the way of the carriage, thus eliminating the need for empty traverses.

19.18 The Tsudakoma TFK machine

The first automatic V-bed machine to operate *without cam boxes*, the model *TFK*, was demonstrated by the *Tsudakoma Corporation* at the 1995 ITMA exhibition. The *Asahi Chemical Industry Co.* supported its earlier development. The model *TFK* has a working width of 122 cm (48 in) in gauges 7, 8, 10 and 12, with a maximum variable speed of 1.2 m/sec.

Individual linear electric motors drive the needles in their tricks (Fig. 19.13) The computer and control system regulate the linear motors to simulate the conventional actions of the knitting and transfer cams.

As each course of knitting takes place, the knitting curves or *waves* of the needles are clearly visible. The machine is fitted with 12 or 16 yarn carriers on four double-sided rails. Each yarn carrier is driven by its own quick-start step motor, via a

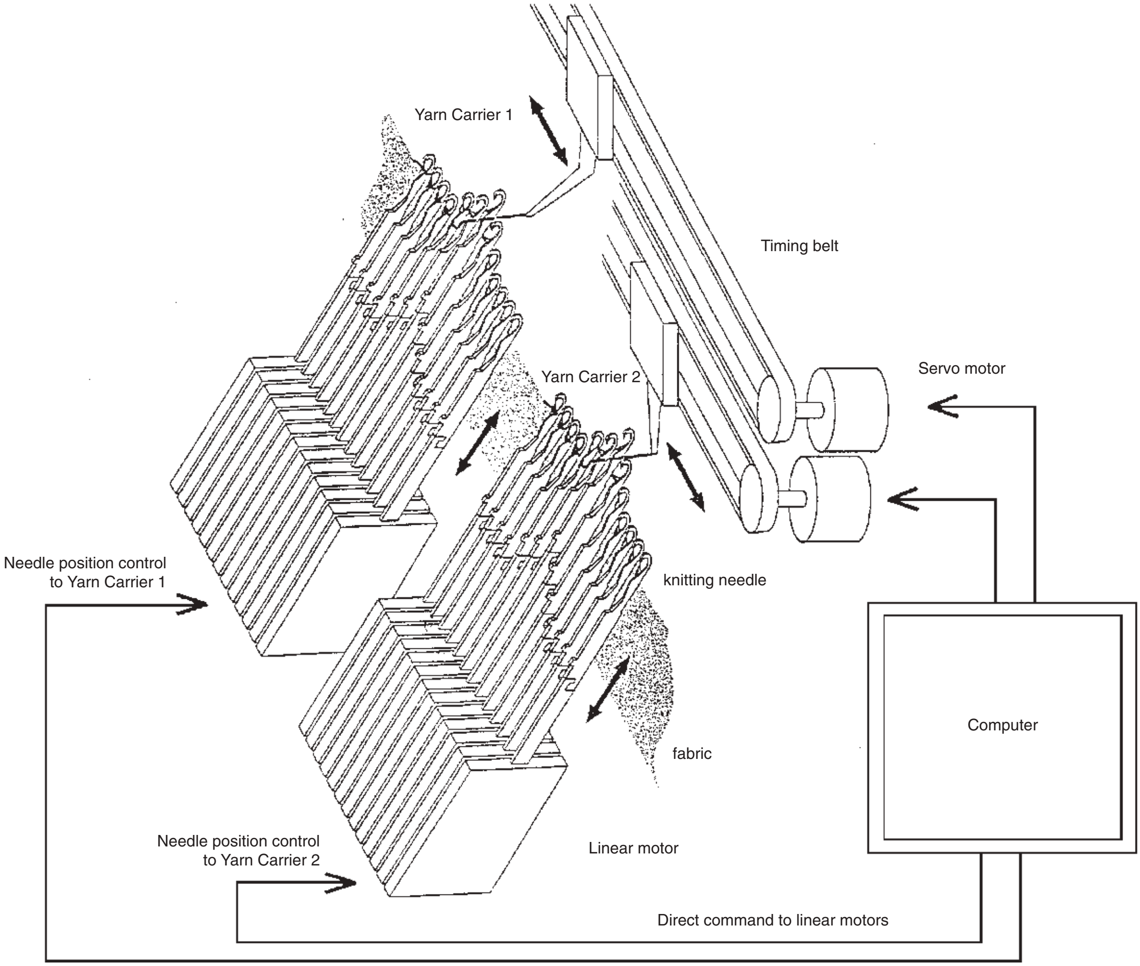

Fig. 19.13 The TFK driving system [Tsudakoma].

toothed belt. The yarn runs from the package to the yarn guide in a direct line via a yarn tensioner and knot catcher.

The machine computer synchronizes the needle clearing with the yarn carrier drive. Stitch length is programmed for each needle, with the linear motor allowing the needle to draw whatever loop length is required. Up to 30 different stitch lengths can be drawn across the knitting width. The stitch length ranges up to 8 mm in 0.1 mm graduations.

There is a moveable holding-down sinker between every two needles, each of which is driven by its own linear motor. They can be used for accumulated tuck stitch fabrics or, when knitting without the takedown system, needle bed racking by means of a step motor can take place over up to 7 needles in either direction.

Knitting begins with the start-up comb engaging the first course of the fabric, which is then taken over by the sub-assembly and final takedown mechanism. All have individually-programmed motor drives. When the garment component is completed, the yarn ends are clamped and severed by an automatic cutting device. The needles are then activated to press-off, without taking the yarn, and the component is ejected. Blanks or fully-fashioned garment pieces can be produced, including sequentially knitted fronts, backs and sleeves.

Various problems have been encountered, particularly due to the absence of brushes, latch openers or stitch pressers, which are usually attached to the cam-carriage. The greatest disadvantage is, however, the cost of the machine in comparison with conventional V-bed machines.

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20

Circular garment-length machines

20.1 Circular versus flat machines

On the basis of knitted stitches per minute against the capital cost of the machine, circular garment-length machines are generally more productive than V-bed flat machines for cut-and-sew knitwear. Prior to computer controls, the price/performance ratio was 1:3 in favour of body-width circular machines. Against electronic V-bed flat machines, however, circular machine builders had to move to less versatile large-diameter machines (33–36 inches) in order to achieve a ratio of even 1.2:1. There are large numbers of body-width RTR and SPJ mechanically-controlled machines still in operation, as well as some that have been retro-fitted with electronic controls.

Circular garment-length machines are mainly of the rib cylinder and dial type (Fig. 20.1) or of the double-cylinder purl type. Although more restricted in patterning capabilities than flat machines, they may offer advantages in productivity and fineness of gauge.

Many are of the revolving cam-box type whose cams, selection units and striper units are altered when their externally positioned levers are contacted as they pass by the control position on the periphery of the machine (Fig. 20.2).

The peg drum control unit for the garment-length programme is now tending to be replaced by an endless film loop that is driven by a horizontal perforated roller. The film is advanced by one row of holes for each feed or transfer section that passes per cam-box revolution. When no changes are required, an economiser rack-wheel operates.

On *Bentley* machines, the *Mechatape Pattern Control Unit* was introduced to replace peg drums or trick-wheels and provide a virtually unlimited pattern depth, faster running speeds, easier pattern preparation and more rapid pattern changes. The control unit consists of a drum whose perforations correspond to the staggered rows of punched hole positions on a plastic film loop. Each row operates through the bank of horizontal levers onto the levers of a passing selection unit. The arrangement in the selection unit is fixed for a complete circuit of the machine whilst it selects onto the jack pressers arranged around the cylinder.

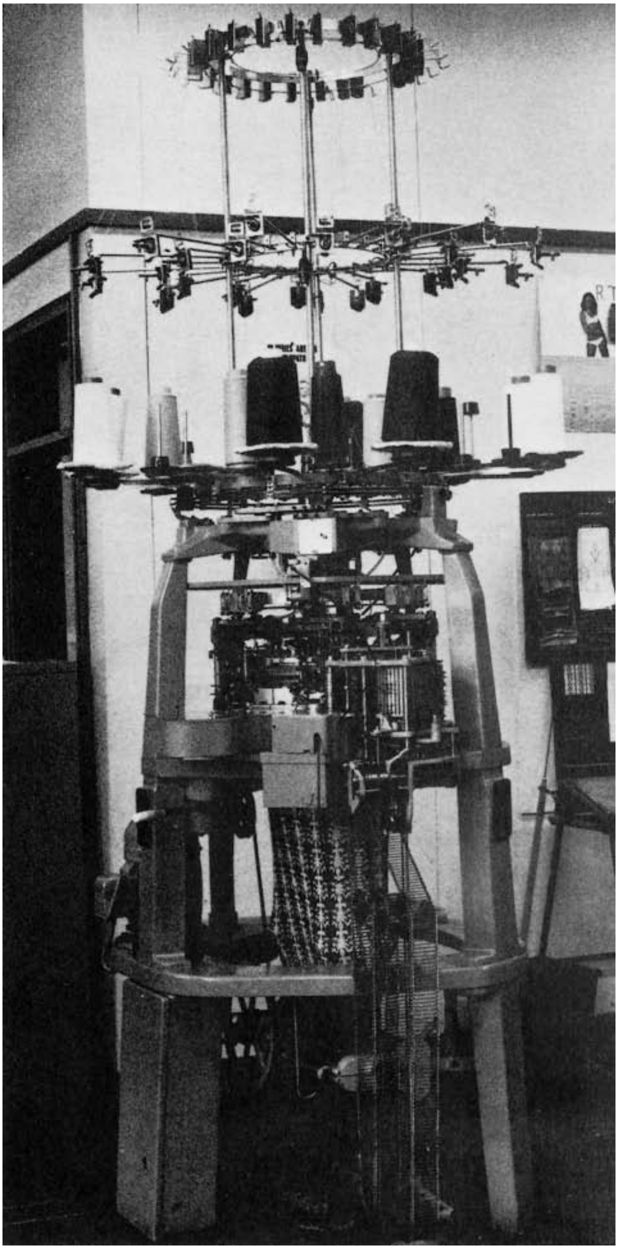

Fig. 20.1 RTR circular garment length revolving cam-box rib machine. The peg drum control unit and timing chain are clearly visible. Also note the slipping belt take-down mechanism which draws down the stationary fabric [Walter Bullwer].

The fabric take-down mechanism cannot be driven directly by the machine rotation as the length of fabric knitted per machine revolution can vary in different parts of the garment sequence. The slipping-belt system is an efficient arrangement that accommodates itself to the varying rates of fabric production.

The take-down rollers and the belt pulley that drives them via worm gearing are

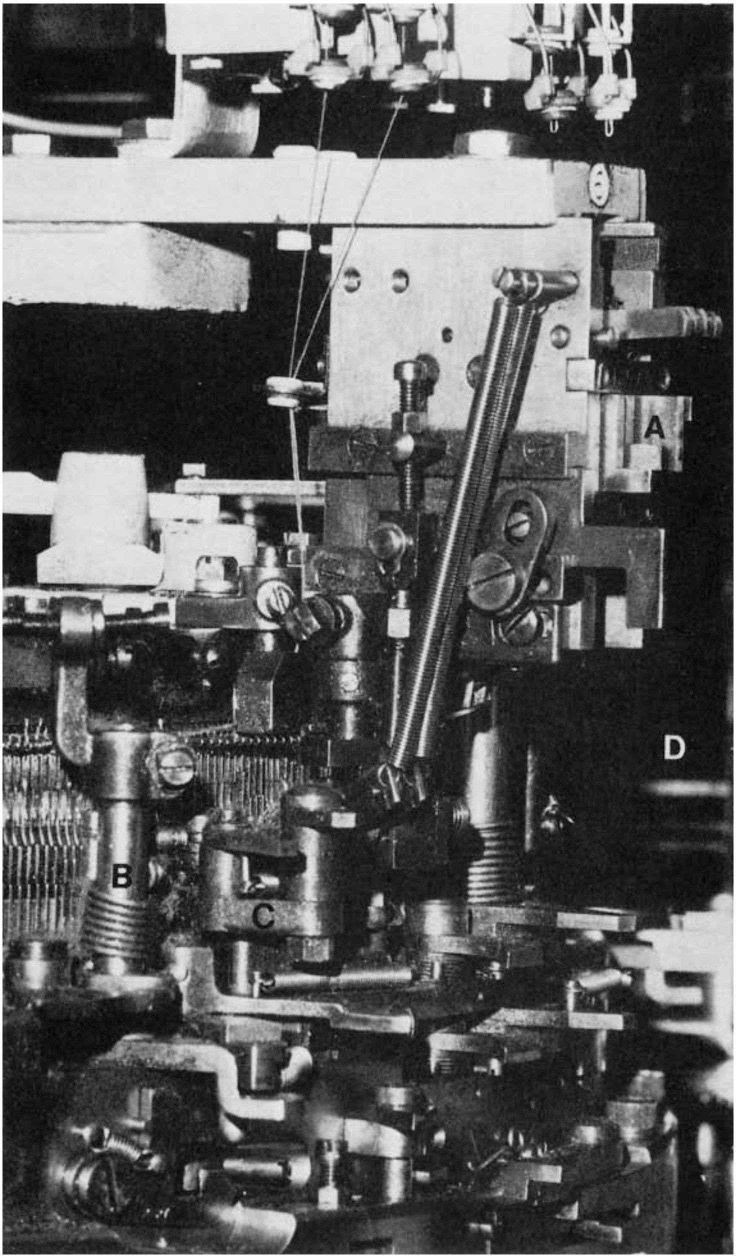

Fig. 20.2 Close-up of RTR revolving cam-box showing the exterior striking levers (A = striper box; B = dial stitch cam adjustment and levers; C = cylinder stitch cam and adjustment levers; D = stationary striking lever post) [Walter Bullwer].

attached to a pivoted lever. The rollers are driven faster than the rate of knitting so that, as soon as the surplus fabric has been drawn away, they tend to climb up the fabric, lifting the pivoted lever together with the belt pulley so that the belt becomes slack, stopping the drive to the rollers until sufficient fabric has been knitted to lower the lever again. This self-adjustment occurs so smoothly that a consistent take-down tension is ensured.

20.2 The double-cylinder garment-length machine

Spiers produced a successful machine of this type in 1930, termed the '*Spensa Purl*' machine. It has a revolving cylinder and internal sinkers and is capable of knitting garment-lengths with a tubular welt and rib border. In 1956, *Wildt (Mellor Bromley)* replaced it with the model SPJ, which has an anti-clockwise revolving cam-box, no dividing cams or internal sinkers, and sliders with pointed noses for opening the latches of needles knitting in the opposite cylinder. As well as being mechanically more reliable for purl knitting, the patterning potential of this model was improved over the years.

The main gauges are 6–12 npi with 2/16's (NeK) worsted being an average count for 10-gauge. Machine diameters are 16–20 inches (40–50 cm approx.) with six feeds; 22 inch (56 cm) (which replaced the 11 inch diameter for infantswear) with eight feeds; and a 33-inch (84 cm) model with twelve feeds.

The machine produces knitwear garments for adults, children and infants with a separating course, welt, 1 × 1 or 2 × 2 rib border, and a body or sleeve panel sequence. Stitch patterning may include any of the following in plain colour or striped-in colours: plain and purl, tuck rib, tuck purl, float stitch jacquard, and rib jacquard.

The machine has the standard knitting-element arrangement for a purl machine of one set of double-ended needles that can be controlled for knitting or transferring by either of two sets of sliders that operate from opposing tricks of the top and bottom cylinders. The tricks of the top cylinder are held in alignment with the bottom cylinder by a dogless head, whilst the cam-boxes for the two cylinders are rotated in unison by means of a vertical cam-shaft and two pinions.

Figure 20.3 illustrates the basic arrangement of the elements and cams, subject to the machine builder's modification. Each set of sliders has a single operating butt position and is controlled from a knitting cam-box. The butts are alternately arranged long and short, with long butts in one cylinder opposite to short butts in the other for obtaining a 1 × 1 needle arrangement.

Controlled by a cam-box below the bottom knitting cam-box is a set of jacks having single operating butts. Each intermediate jack is supported at its base by the ledge of a spring-tailed jack, placed behind and below it in the same trick, which has a tail butt controlled by raising cams when not selected (the indirect selection principle was described in Section 11.9). The intermediate jacks thus translate the selection into a movement causing the bottom sliders to be lifted for knitting or transferring their needles.

The presser selectors have 79 butt positions, corresponding to the pattern units (or presser brackets) that have batteries of 79 slides. Of these, 75 are available for patterning. Of the bottom four, which are used for isolation purposes, three are controlled by the *Cardomatic* film with set-outs of 1-out-1-in, 2-out-2-in and cancelling out the knitting selection, whilst the other line of all-in butts can be selected from the *Mechatape* for cancelling all transferring.

Two full-size pattern units may be provided for double selection on the bottom cylinder at each feeder. At selection I, needles are selected to remain at miss height whilst the remainder are raised to clearing (knit) height. At selection II, of those needles taken to clearing height, some are selected to remain at that height whilst the others are raised to be transferred to the sliders in the top cylinder.

Thus at selection I, the tail butts of non-selected jacks pass over the raising cam K to lift their intermediate jacks onto cam k. As the intermediate jacks pass over k

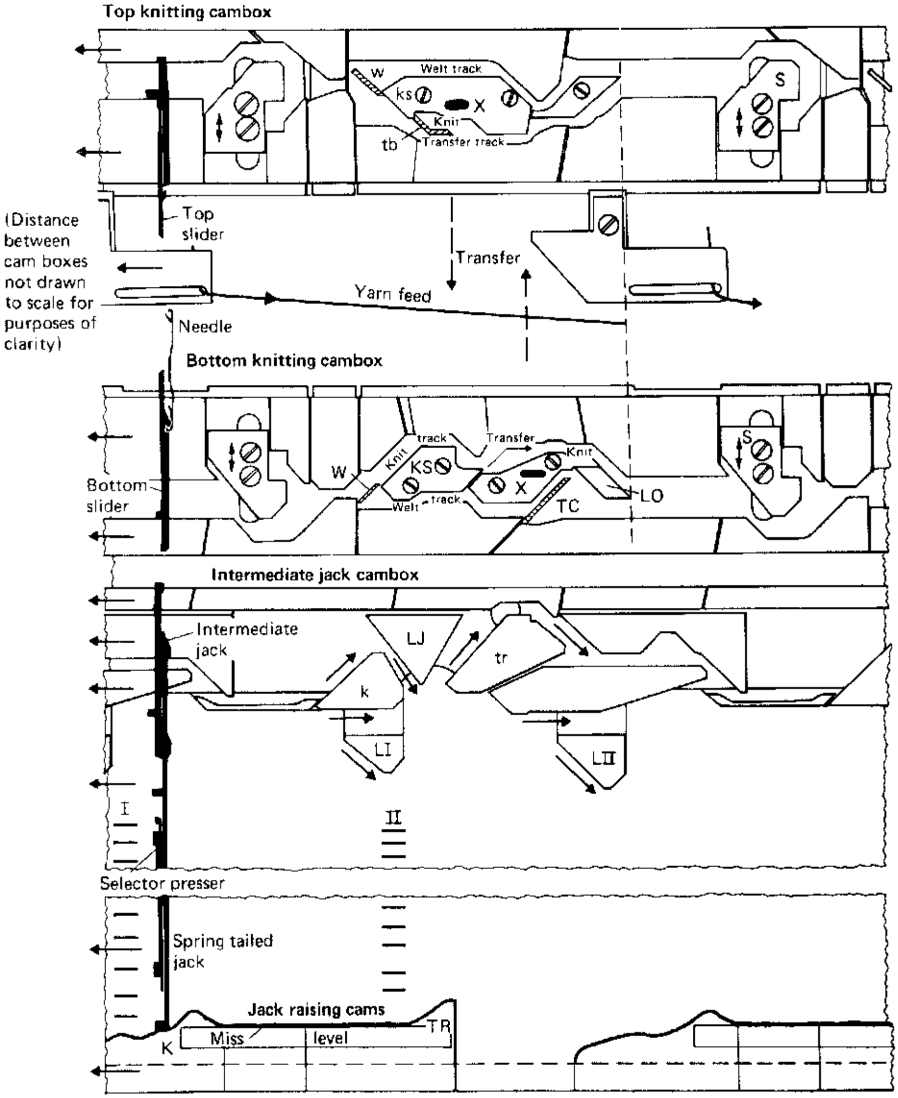

Fig. 20.3 Cam system elements of a circular purl machine.

they lift their bottom sliders onto the clearing cams KS putting them into the knitting track. The butts of non-lifted sliders will pass through in the welt (miss) track below the KS cams. S are the stitch cams for the knitting sliders, which can be automatically changed to any one of four pre-settings of 'quality' during the garment cycle.

Prior to selection II, the non-selected intermediate jacks are lowered by cam LJ and their spring-tailed jacks by cam LI. These jacks therefore have their bottom butt aligned with raising cam TR. If non-selected by selection II, they are raised over cam TR and lift their intermediate jacks over cam tr, raising their bottom sliders to transfer their needles to the top cylinder. At this moment, the tails of sliders that are transferring needles pass across the spring-loaded cam which presses down on them, causing the front of the slider to pivot upwards and unhook itself from the transferred needle. Needles of jacks non-selected at I but selected at II will pass through the upper cam track at knit height. Cam LII lowers the spring-tailed jacks ready for the next double-selection sequence.

In the knitting cam-boxes, certain cams are bolt cams of the plunge type, which are introduced or withdrawn out of the track as required for any cam-box revolu-

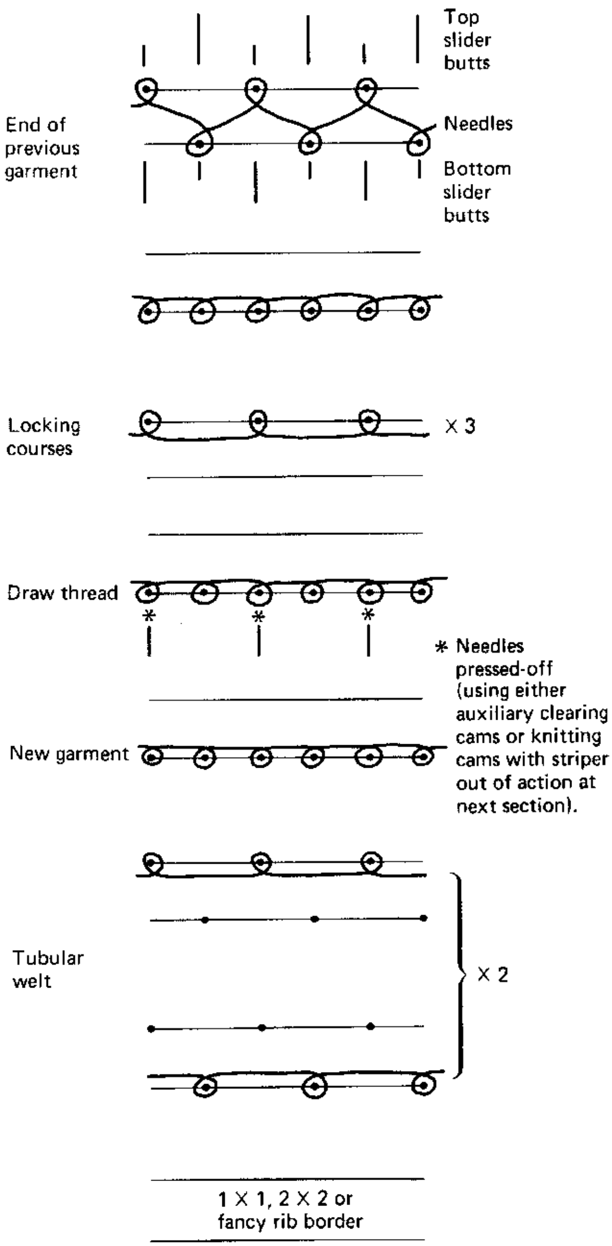

Fig. 20.4 Part of a purl garment knitting sequence.

tion. When fully in action, they deflect all sliders passing through, when half in action they only deflect long butt sliders, and when out of action the cam-track is clear.

Cams W are the welt bolt cams, which guard the entrance to the welt tracks and, when fully in action, cause all sliders with needles to knit. Cam W is in for knitting or the transferring of all needles in the bottom cylinder, but is out of action for selected knit miss or knit tuck stitches. In the top cylinder there is no selection so therefore those bolt cams are used during pattern selection. Cam W is employed when knitting, transferring down or receiving transferred up needles in the top cylinder. Half in action, it is employed for knitting or transferring on a 1×1 arrangement, and when fully out of action, needles in the top cylinder will miss. Cam tb is the bolt cam for transferring needles down from the top cylinder and works in conjunction with spring loaded cam x.

In the bottom cylinder, the bolt cam TC can be introduced to cause needles controlled by sliders in the welt track to be lifted to tuck. When employed in conjunction with cam L0, the needles are immediately lowered to miss but their latches are opened.

Figure 20.4 shows part of a purl garment knitting sequence.

20.3 The RTR garment-length machine

This fully-automatic garment-length rib machine was introduced in 1938 by *Wildt (Mellor Bromley)* as a replacement for their RSB model of 1936, which had no facilities for rib loop transfer. Its anti-clockwise revolving cylinder and dial cam-box has cam sections of equal size whether they are for knitting feeders or rib loop transfer. A unit set in advance of the section can select the cylinder needles for the knitting or transfer action. The original RTR has six cam sections, four for knitting (2 and 3; 5 and 6) and two for transfer (1 and 4). Section 4 also has facilities via the back butt set-out of the dial needles for changing the rib, either by collective dial-to-cylinder loop transfer or by dial needle loop press-off. Four *Brinton* trick-wheel units provide selection for the cylinder needles – one for each transfer section and one for every two knitting sections, with the selection at section 2 being repeated at 3 and the selection at 5 being repeated at 6.

In Figures 20.5 and 20.6, section 4 contains the cams for selective cylinder-to-dial loop transfer (cams R and Y) and collective dial-to-cylinder loop transfer (cams X, P and Q).

In section 1, cam T may be set to raise cylinder needles to clearing height and, as there is no feed position in this section, when lowered by cam U they will press-off their loops (for the end of the garment sequence). In a similar position at section 4 are raising and lowering cams P and Q, which act as receiving cams for the collective transfer of dial loops when cam I acts on the back transfer butts of dial needles.

It soon became apparent that the machine's garment-length knitting sequence of drawthread separation course, tubular welt, 1×1 or 2×2 rib border or waist, body panel section, and press-off locking courses could be used for knitting jacquard, double-jersey, or coarse-gauge knitwear as well as stitch-shaped underwear. A six knitting-section model, with each section having its own selection unit, thus became available for jacquard with interchangeable transfer sections. For double jersey, the dial shogging was adapted for interlock knitting. Depending upon the end-use of its

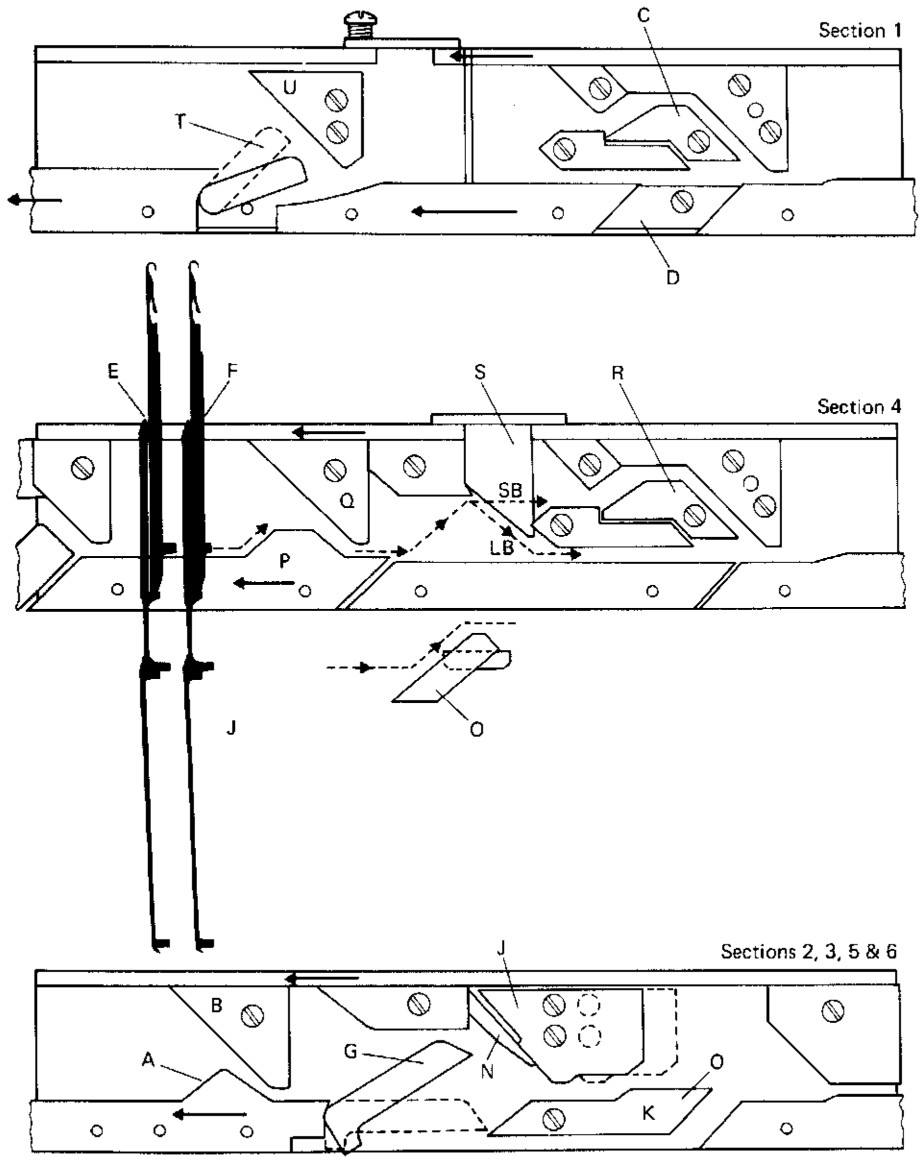

Fig. 20.5 Cylinder cam system of an RTR rib loop transfer machine.

model, panels can thus be knitted in 1 × 1 rib, dial-only knit, interlock milano rib, rib jacquard, or half- or full-cardigan, with selective patterning in rib transfer, coloured stitches, miss, tuck, knit or raised cloque relief stitch. Articles that can be knitted include vests and panties, cut and sewn sweater dresses and trouser suits, jumpers, coarse-gauge cardigans, and sweaters.

As well as the original 13- and 15-inch diameter models, other diameters were introduced, including 18, 20 and 22 inches to cater for more than one panel width (separated by a needle-out line) and the knitting of high-shrinkage synthetic yarns

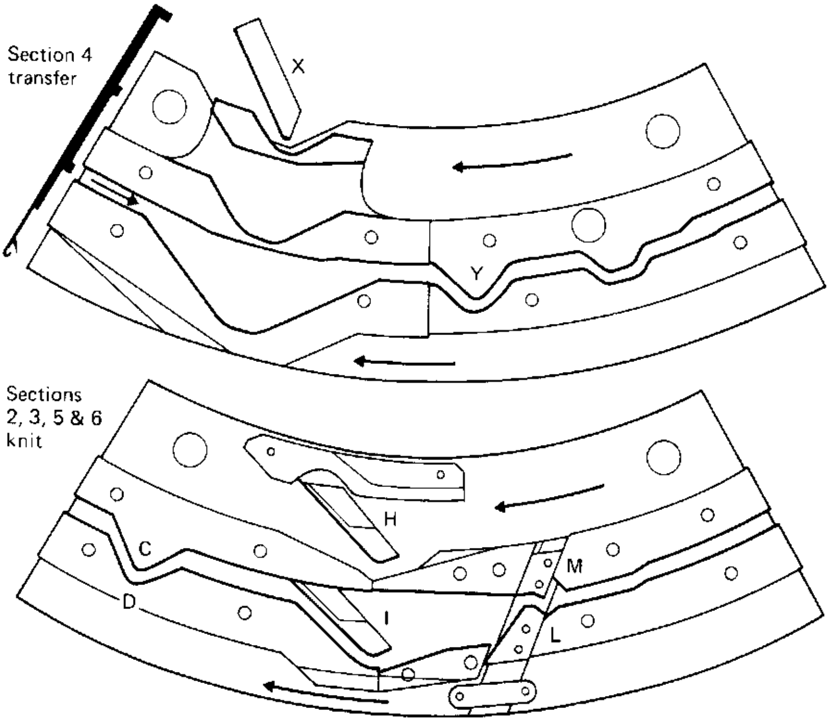

Fig. 20.6 The RTR dial cam system.

or coarse gauges. This concept was extended to a 33-inch diameter machine, with flexibility of knitting width and economy in cutting waste achieved by removing the block of needles not required, thus leaving a panel of floating threads.

Machine speeds range from about 16 to 32 rpm, according to machine design and type of stitch being knitted, with the cam sections being between eight and twelve in body diameters (and up to eighteen in the 33-inch diameter model). Gauges extend to 16 npi for underwear or jerseywear down to 7 npi for knitwear, with the coarse model having gauges of 3 and 6 npi.

20.3.1 The basic elements and camming arrangement of the RTR machine

The geometric selection employed on this machine has been previously described (Section 11.9). Figures 20.5 and 20.6 illustrate the arrangement of cams for a six-section machine; other models are similar. On the 33-inch diameter model, however, each presser has 79 butts, with a maximum of 73 available for patterning. One is removed to leave a gap. The remaining five are used for isolation purposes as follows: all butts on, 2 out of 3, 1 out of 3, odd needles only, even needles only. The dial needles are usually set-out with every third needle having a back butt for dial-to-cylinder transfers or press-off for achieving 2 × 2 rib. Cylinder needle butts may be set-out 1 short 2 long for 2 × 2 rib in the waist.

There is a jack-raising cam associated with each cylinder selection unit raising any jack butts whose pressers are not selected (Fig. 11.6). As empty needles may be required to re-start knitting, in sections 2, 3, 5 and 6, cams A and B, C and D raise and lower the cylinder and dial for latch opening. Cylinder cam G is a swing-clearing cam that can be set for knit or miss and is split into two sections; the top section acts on all butts, the bottom section acts only on long butts. In the dial, odd needles usually have long back knitting butts and are raised by cam H, whilst cam I raises even needles with long front knitting butts.

The front part of cam N is fixed, the back part J is shown in a solid line for delayed timing and in a dotted line for synchronised timing. The upthrow cam is K; L and M are the stitch and upthrow cams in the dial. The two cams L and M are adjusted together and have three pre-set positions for automatic alteration during the garment sequence for the welt, rib border and body panel.

In both cam sections 1 and 4, cylinder cam R is aligned with dial cam I as the delivering and receiving cams for cylinder dial rib loop transfer. In section 4, cam O in action will cause all cylinder needle loops to be transferred to the dial for dial-only knit, by means of the middle butt of the jack. If cam S is in action, long butt jacks will be lowered before transfer can occur. This is used for producing a 2×2 rib set-out for the waist at section 4.

20.4 Jumberca cylinder and dial and double-cylinder machines

The *Jumberca* cylinder and dial, and double-cylinder machines are electronically-controlled and have almost unlimited selection in the cylinder and dial and in the bottom cylinder of the links-links machine. Stitch length is infinitely adjustable in each bed. The programmable width device adjusts the fabric width to the accuracy of a single needle. Needles are taken out of action so that floating threads join the two fabric edges of the open width fabric; this can save up to 15 per cent on yarn. The fabric remains in tubular form through the take-down rollers, thus maintaining uniform tension around the circumference and throughout the garment sequence [1].

20.5 Mecmor Variatex machines

The *Mecmor Variatex* machines are a range of circular cylinder and dial, garment-length machines that knit garment-lengths in open-width on 300 degrees of the machine's circumference. The revolving cam-box model '180' has a diameter of 28 inches, providing a maximum knitting width of 70 inches (180 cm). The remainder of the machine's periphery consists of a command sector containing a multi-track *Mylar* film loop with insertable plastic studs and a master control drum to control each knitting or transfer station as it passes.

The knitting width may be reduced according to requirements, thus economising on yarn. The garment-length is of constant width, with fringes of yarn produced as each course is striped into and out of action for the knitting width.

The latest electronically-controlled models ('2500' onwards) have a revolving cylinder and dial with a 40-inch diameter. The maximum fabric width is 2.75 m. In a standard model there could be twelve knitting systems and six transfer stations.

Fig. 20.7 Body-size seamless garment [Santoni].

20.6 The 'seamless' bodywear garment machine

The *seamless bodywear garment machine* knits body-width underwear garments (Fig. 20.7) requiring little or no making-up and with no uncomfortable side-seams. The machine, whose simple construction owes much to knowledge gained from the development of hosiery and tights machinery, is produced in the *Lonati Group* by *Santoni*.

The model SM8-8 is an eight-feed, fully electronic, single needle selection machine that can produce a knitted-in welt, and structures such as openwork, stripes, jacquard, terry and plated fabrics. Spliced areas for shaping and figure-control can be incorporated using step-motor-controlled stitch cams. Diameters range from 10 to 15 inches in gauges E 16 to E 32.

An eight-feed cylinder and dial machine with four two-way transfer stations is being developed in a diameter range from 14 to 22 inches and gauges E 14 to E 16. The 20 and 22-inch diameter machines have twelve feeds and six transfer stations.

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21

The manufacture of hosiery on small-diameter circular machines

For centuries the production of hosiery was the main concern of the knitting industry. The prototype machines for warp, circular, flat and fully-fashioned knitting were all originally conceived for knitting hosiery. Nowadays, however, hosiery production is centred almost exclusively on the use of small-diameter circular machines. In single cylinder and fine-gauge hosiery particularly, much of the latest development is centred in Italy. One company – *Lonati* – has acquired a major portion of hosiery machine-building businesses, including their research and patents.

21.1 Types of hosiery

The term '*hosiery*' specifically refers to knitted coverings for the feet and legs, but it may be generically (but confusingly) applied to all types of knitted goods and fabric.

Most hosiery articles are knitted with integral tubular legs and feet. The welts and top are usually knitted first, the foot and toe last. Closing the toe also produces a secure finish.

The machines have a master *machine control* that automatically times and initiates the mechanical and electronic operations, and changes of stitch length necessary to produce the garment-length knitting cycle. Later making-up, such as toe-closing and finishing operations, off the machine may still be required.

Hosiery is usually available for a range of foot sizes. In the case of staple fibre spun yarns such as cotton or worsted, different foot lengths are obtained by knitting them with differing total numbers of courses. However, hosiery knitted from continuous-filament stretch nylon yarn may have an extension of 50 per cent so that a standard foot length is capable of accommodating itself to various foot sizes.

The following types of hosiery articles are particularly common:

- *Hose*, which have a leg-length extending above the knee;
- *Three-quarter hose*, which are of knee-length (approximately twice the foot length);

- *Men's half-hose*, which are usually in two leg-length ranges of 7–9 inches and 11–15 inches (18–23 and 28–38 cm);
- *Stockings*, which are designed to fit the leg up to or above the knee and may or may not be self-supporting;
- *Tights*, particularly in fine gauge, which are termed *panty-hose* in the USA. They may have a body section of the same knitted structure as the legs and an inserted gusset and elasticated waist-band.

21.2 Classes of hosiery machines

Except for the few *Griswold* type hand-turned machines (Fig. 4.4), all hosiery machines are of the *revolving cylinder type*. This arrangement offers the advantages of high revolution speeds, a simplified drive, and the possibility of selectively striping-in yarn from stationary packages placed at fixed feed positions around the cylinder. The garment sequence control must, however, be linked by means of cables and rods (or electronics), using the shortest possible routes, to the various mechanisms at the knitting positions around the needle cylinder without interfering with accessibility to the machine (Fig. 21.1).

The three types of hosiery machines, in order of their increasing complexity and needle bed arrangement, are *single cylinder*, *cylinder and dial* and *double cylinder*.

Ladies' fine-gauge seamless hose and tights are knitted in plain base structure on single-cylinder machines with holding-down sinkers.

Men's, ladies' and children's socks and half-hose in broad rib or purl (links-links) base structure are knitted on double-cylinder machines. Men's dress socks are broad

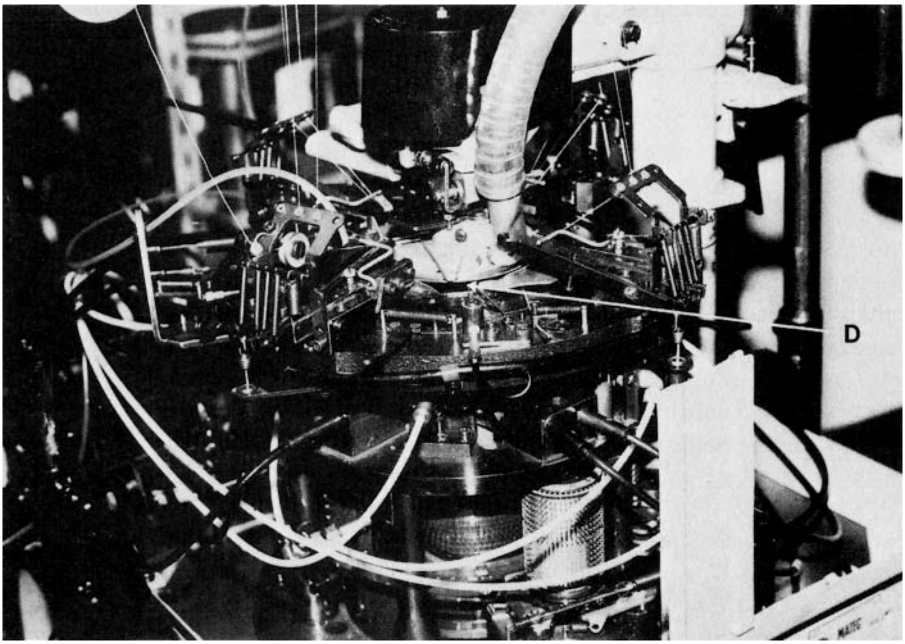


Fig. 21.1 Close-up view of the knitting head of a 4-feeder seamless hose machine (D = Dial) [Walter Bullwer].

rib socks with a reciprocated heel and reciprocated toe that has been closed by linking. A typical machine specification would be 4-inch diameter, 168 needles.

Sports and casual socks in a plain base structure are now usually knitted on single-cylinder machines with holding-down sinkers.

More formal simple rib socks may be knitted on cylinder and dial rib machines termed '*true-rib*' machines. These machines have half the number of needles in the dial as are in the cylinder, with every second cylinder needle opposite a dial needle. For that reason only simple ribs such as 1 × 1, 2 × 1, 3 × 1, etc. can be knitted, not broad ribs such as 6 × 3 rib. True rib machines knit a more balanced 1 × 1 rib than double-cylinder machines, whose needles in the top cylinder do not draw their loops with as strong a yarn tension as those in the bottom cylinder.

21.3 Gauge

On hosiery machines the *gauge* is usually expressed as *diameter and total number of needles*:

A 4 inch × 400 needle *single-cylinder* ladies' seamless hosiery machine will have 400 needles to knit plain. (NB: the number of needles may be slightly more or less than 400 in order to fit a particular mesh structural repeat exactly around the leg).

A 4 inch × 200 needle *cylinder and dial* machine will have 200 cylinder needles and 100 dial needles. Every second cylinder needle is gated in line with a dial needle and can only knit as 200 cylinder needles in plain structures. For 1 × 1 rib, the 100 dial needles knit in co-operation with the alternate 100 cylinder needles.

A 4 inch × 200 needle *double-cylinder* machine will have a total of 200 needles to knit plain stitches in the bottom cylinder, or, when arranged for 1 × 1 rib, will have 100 needles knitting plain in the bottom cylinder and 100 needles knitting rib in the top cylinder.

As well as the machine gauge, the *needle gauge*, i.e. thickness and size of needle hook, is also a consideration.

21.4 The early development of ladies' fine-gauge hosiery machines

Circular machinery entered hosiery production inauspiciously during the nineteenth century, knitting fabric that was then cut and seamed into cheap 'leg bags', onto which heels, soles and toes were later hand-frame knitted.

The development of specifically designed circular hose machines followed from patents such as those of *Newton* in 1857 and *McNary* in 1860. These described how seamless heel and toe pouches could be knitted as part of the tubular leg structure by selectively taking needles in and out of action during reciprocation.

During the 1870s, the patents granted to *Henry Griswold* virtually perfected the hand-powered sock machine. This world-famous small-diameter latch needle machine has a single rotating cam-system (and yarn feed) that can be oscillated (reciprocated) for heel and toe pouch knitting, and an attachable dial needle holder for knitting the integral rib tops at the start of the sock.

Much of the early development of large- and small-diameter *single-cylinder* latch needle machinery occurred in the USA. For many years, both in Britain and the rest of Europe, the products of these machines were considered to be inferior in quality to those knitted on bearded needle machinery or (later) latch needle machines with two needle beds.

Important developments in circular hosiery machinery included:

- the introduction of power;
- the use of holding-down sinkers;
- the automatic control of mechanical changes and operations;
- a change of machinery design from rotating cam-boxes to revolving cylinders; and
- the gradual replacement of bearded needles by latch needles as their fineness and reliability improved.

The first powered circular hose machine was produced by *Shaw* in 1879, and in 1887 pickers were added to automatically knit heel and toe pouches. By 1900, most mechanical operations could be automatically controlled by the machine, apart from welt turning and toe closing. *Scott and Williams* patented the former on their Model 'K' machine in 1915 and the latter, less successfully, over forty years later in 1967.

21.5 The advent of nylon

With only yarns such as rayon, silk, cotton and worsted available for knitting, bagginess (particularly around the ankle) of ladies' fine gauge circular knitted seamless hose caused them to be regarded as a cheap but inferior rival to the more shapely fully fashioned hose knitted on the straight bar frame. The former was even provided with an imitation of the fashionable seam at the back of the leg. There was thus little encouragement for circular hose manufacturers to re-equip and, in 1946, only a quarter of circular hose machines knitting in British factories could produce an automatic in-turned welt; and most machines had only a single feed.

In the same year, nylon, the ideal stocking yarn, became plentifully available. Not only was it a cheap, strong, fine and uniform yarn, it had the major asset of being thermoplastic so that articles knitted from it could be heat-set into shapes whose form they would permanently retain, provided that the setting temperature was never exceeded during washing and wearing.

21.6 Trends in fine-gauge hosiery since 1956

The straight bar frame was, at first, the main beneficiary of the huge demand that was unleashed for nylon stockings. This caused machine gauges to become progressively finer, and productivity to rise dramatically, as operations became more automated and efficient and knitting speeds increased.

For the circular hose machine, the advent of nylon meant that a combination of stitch- and heat-shaping could now produce a stocking with satisfactory leg-fitting properties, provided ladies' fashion would accept it.

Fashion intervened in the late 1950s, when, with skirts getting progressively shorter, the younger and then all generations, opted for the *'bare leg' look* in preference to the seamed leg.

Similarly, in 1966, the advent of the mini skirt brought the welted tops of seamless stockings into view and the conversion from stockings to more comfortable and less-noticeable *self-supporting tights* began.

For the seamless hosiery industry, the period from 1956 became one of dramatic and revolutionary changes in knitting, making-up, dyeing and finishing, marketing, and fashion. Although hiccups are produced by swings of fashion, the following trends are noticeable:

- the simplification of styles, knitting machines, and making-up;
- the increasing automation of making-up operations, handling, and transportation; and
- higher knitting speeds and/or numbers of feeders.

In twenty years there was a five-fold increase in productivity per knitting machine. Increasingly fierce competition and drastic reductions in the prices of stockings and tights have transformed the overall image from one of fashionable luxury and glamour (only about 8 to 10 per cent of ladies' tights production is patterned) to that of a mass-produced commodity article.

Some of the specific developments that occurred during this period are now discussed.

The slow and expensive reciprocated and linked-closed toe was replaced on a twin-feed machine in 1956 by all-circular knitted courses of spliced fabric, which was later cut and seam shaped into a toe.

In the same year, the *Reymes Cole* patent described how the reciprocated heel might also be replaced, in this case, by part-circular knitted splicing courses on selected heel section needles.

In 1961, the four-feed *Billi Zodiac* machine popularised the tube stocking with a patch heel by knitting a stocking in 2 minutes 10 seconds, compared with the 12 minutes taken to knit a stocking with a reciprocated and heel toe on a single-feed machine in the early 1950s. Speeds and numbers of feeds were then gradually increased, with a six-feed machine running at 210 rpm in 1963 and, by 1971, a twelve-feed machine running at 260 rpm.

Today, demands for higher quality and more versatility led to a reduction in the number of feeds so that machines now generally have 4 or 6 feeds and commercial operating speeds of 1000–1200 rpm. Electronic controls have reduced the number of mechanical parts so that less mechanical attention is necessary. At the same time, machine manning has been improved so that one person may now run 60–80 machines, whilst 5 kilogram yarn packages can reduce yarn package replacement to 5-day intervals.

The *Matec* HF range of fine-gauge tights machines do not select needles by using levers. Instead, knit or miss selection is obtained by means of a high-frequency current that changes the polarity of a metal plate which, through another element, moves the selector jack into either the knit or the non-knit camtracks. Needle-by-needle selection is achieved at a speed of 1000 rpm.

On a 6-feed machine, it is possible to knit tights with 5 colours and any structure in the ground at a speed of 800 rpm [1].

Recently there has been an increasing use of *Lycra* and other elastane yarns, in bare or in covered form, at every course or at alternate courses, either by knitting, laying-in or plating. This has not only improved fit and comfort, it has improved wear and thus reduced consumption.

Elasticated medical support hosiery with *graduated compression* has long been available. It allows the blood to flow back more easily in the leg. Advances in the knitting of fine-gauge elasticated hosiery, such as finer yarns and electronic-control of the graduated knitted leg shape, have led to the development of the *Lycra Leg Care* scheme for the fashion side of ladies' fine-gauge hosiery. The scheme is based on objective and measurable standards using *Lycra* yarns. This enables fine-gauge stockings and tights to be made with smooth, comfortable, graduated compression for body-shape control and improved blood circulation. There is a choice of three compression levels – light, medium and firm – based on pressure gradient levels.

One rather unsuccessful development has been the *automatically knitted closed toe*, which was almost immediately replaced by the *cut-and-sew toe* produced by the automatic toe-sewing equipment used during making-up operations.

In seamless hosiery finishing equipment, the dye-boarder, introduced in the early 1960s, replaced, in a single cycle, the separate operations of scouring, pre-boarding, dyeing and post-boarding, thus reducing labour content as well as *pull threads* caused during handling. Today, ladies' hosiery ranges from 7 denier ultra sheers to 70 denier opaques, in such forms as tights, stockings, hold-ups and knee-highs.

21.7 Ladder-resist structures

The fine smooth filaments in plain knit ladies' hosiery structures make them very susceptible to *laddering*. It is therefore important to reduce this tendency without impairing either the appearance or the extension and recovery properties of the structure too greatly [2].

Any stitch that reduces the likelihood of one loop being withdrawn through another (for example tight knitting), or that spreads the tension (knitting on alternate needles), will produce ladder-resist properties from the end knitted last. An alternate knit-and-miss or knit-and-tuck structure will be ladder-proof from the end knitted first.

Float-plated fishnet (Fig. 9.3) is one popular ladder-resist structure; all needles take the fine yarn (for example 15 denier) whereas alternate (or in the case of patterned fishnet – selected) needles rise high enough to take the thicker yarn (for example 30 denier). The two yarns are knitted in *a plating relationship*. This structure is popular for use in stockings to produce an anti-ladder band that prevents ladders from running down from the top of the leg.

1 × 1 Cross tuck is another ladder-resist structure, where alternate needles tuck at alternate courses.

Micromesh is similar although less effective because it contains less tuck stitches. In this structure, the tuck stitches spiral around the leg, reducing light reflectance and presenting an attractive appearance. There is usually a course of all-knitting in between each course of tuck stitches; the notation given in Fig. 21.2 shows the popular *3 × 1 micromesh*.

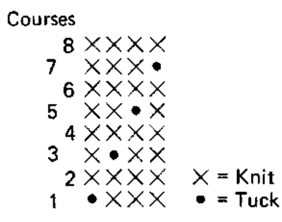


Fig. 21.2 Notation of 3 × 1 micromesh.

21.8 The development of the double-cylinder machine

The first double-cylinder machine was the model XL, patented by *Stretton and Johnson* of Leicester in 1900, which employed double-headed latch needles patented by *Townsend* in 1849 and internally-controlled sinkers patented by *Spiers and Grieves* in 1895. Using dividing cams for disengaging the sliders from the needles, it eliminated the need to knit the rib tops on a separate machine and then to transfer the fabric on a quill ring to the needles of another machine in order to knit the leg.

In 1912, the machine was converted to a *revolving cylinder* type, and in 1920 the first of over 100 000 *Komet* machines was produced. From that year onwards, a wide range of double-cylinder machines has been developed, from high-speed plain models to highly complex machines with extensive patterning capabilities [3,4]. Amongst the range of patterning effects available are three-feed jacquard, links-links, embroidery plating, and terry.

The robust reliability of mechanically-controlled double-cylinder machines has ensured their continued use despite competition from new computer-controlled machines.

21.9 Single-cylinder sock machines

Mechanically-controlled double-cylinder machines of the *Bentley Komet* type used to dominate the manufacture of socks but, with the encroachment of microprocessor controls, the simpler and cheaper single-cylinder machines now account for two thirds of new machinery sales. Factors influencing this trend include:

- Greater pattern scope at increased speeds using mono-magnetic needle selection.
- More colours per course when using motif embroidery plating, with up to 7 colours per course or a total of 21 colours in the sock.
- Ability to knit imitation links-links designs.
- Possibility of knitting new design features such as 4-colour intarsia with terry sole.
- Ability to knit tights with pelerine transfer stitch designs.

21.10 Timing and control of mechanical changes on circular hosiery machines

The application of microprocessor controls has removed the need for mechanical timing chains and control drums on the latest electronically-controlled hosiery machines. The machine's microprocessor memory can accommodate a range of sizes and styles that can be quickly recalled when a change is required.

On mechanically-controlled machines, the changes are timed by the links of a *timing chain* that also control the racking of a *control shaft* to which are attached the control cam-drums and wheels that initiate the major mechanical machine changes (Fig. 21.3).

One complete racking of the chain together with one complete revolution of the control shaft is necessary to produce the length knitting sequence for each hosiery

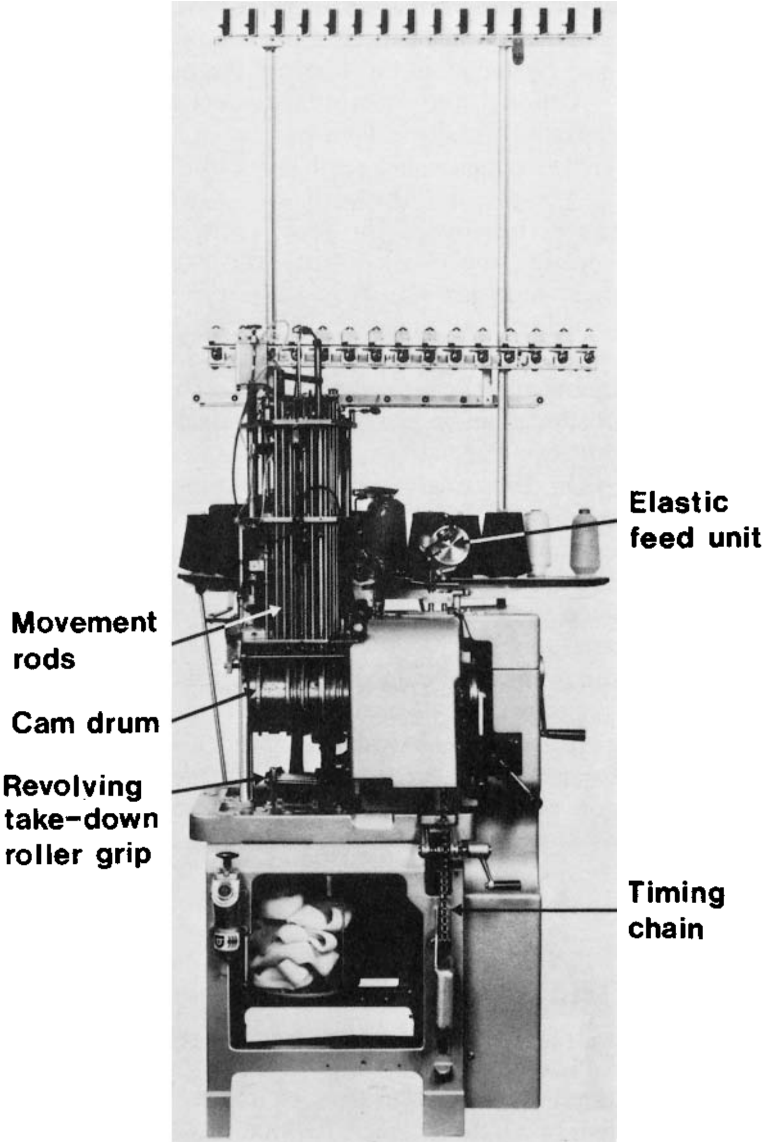


Fig. 21.3 Double cylinder half hose machine [Bentley].

article. Plain links are used purely for providing knitting time between changes whereas movement links have projections or studs to initiate mechanical changes, usually as a result of racking (turning) the cam shaft and its cam drum. Chain saver links have a pin that turns an economiser wheel, saving 23 plain links.

The control cam drum revolves with the control shaft and is divided into a number of tracks, each corresponding to a lever or rod that scans its section. Amongst functions that may be controlled from the tracks are: speed changes, knitting cam changes, pickers, the verge, take-down splicing, and pattern drum racking.

21.11 Adjustment of loop length

On hosiery machines without positive feed, the distance between the top of the needle head at knock-over and the loop-supporting belly of the sinker will determine the length of loop that is drawn.

On single-cylinder machines, the sinkers are in a bed fixed to the head of the needle cylinder so that any raising or lowering of the cylinder will affect the loop length.

A gradual lowering of the cylinder produces *graduated stiffening*. On electronically-controlled machines, this is achieved by step motors which are employed to raise and lower the stitch cams and also for introducing the stitch cams. This is particularly useful on tights machines for precisely placed spliced areas of elastane yarns to give selective comfort support whilst saving expensive yarn.

In single-cylinder tights production, *Matec* has developed the VPS (Variable Profile Stitch Cam). The angular position of the step motor-controlled stitch cam is adjusted to the speed requirements in different parts of the tights. A ten degree difference can enable an increase in speed by 130 rpm in that section of the tights.

On mechanically-controlled machines, levers scanning tracks on the control drum operate through adjustable set-screws to raise or lower the cylinder. Separate tracks on the drum may be responsible for adjustment of the loop length for the waste courses, toe, heel, panel, ankle and foot, graduated stiffening, etc. Graduated stiffening is operated from a rotary eccentric cam that is racked independently of the control shaft and allows the cylinder to be gradually lowered during the knitting of the calf, so that loops gradually become smaller and the leg tube is narrowed.

On double-cylinder machines, loop length adjustment is achieved by adjusting the stitch cams and thus the needle height.

21.12 The double-cylinder slider butt set-out

If a broad rib set-out is used whose repeat is not an exact factor of the total cylinder tricks, the extra non-standard rib panels must be carefully arranged to balance at the heel centre (back of the leg) so that they are less noticeable. It may also be necessary for the foot bottom to be slightly less or slightly more than half the cylinder tricks, in order to balance the rib panels on either side of the foot.

As previously mentioned (Section 7.5.1), sliders have a needle *knitting butt* towards their head and a needle *transfer butt* towards their tail. Generally, the knitting butts are long in the instep half (these are raised out of action during reciprocation) and short in the heel half, in both cylinders.

When arranging the transfer butts it is necessary to understand that the *transfer bolt cams* are gradually introduced in stages so that the longest butts will be used for the first transfer actions, whilst the shortest butts will be unaffected until the cam is fully in action for the last required transfer.

The 1 × 1 rib top arrangement is obtained by transferring up alternate needles using alternate long butts in the bottom cylinder. When a broad rib leg is required, a second up-transfer may be necessary using short butts on the bottom sliders. In a minimum movement only the necessary needles will be transferred up, whereas with a links-links movement all needles are transferred up. The broad rib wales are achieved by transferring down using long top cylinder butts. Medium butts are used to transfer down for the heel. Later, short butts are used to transfer down the instep needles still in the top, in order to finish by knitting the toe in plain.

21.13 Production of heels and toes

Three-dimensional 'turned' heel and toe pouches (Fig. 21.4) are knitted in plain so that, in the case of double-cylinder machines, the heel section needles must be *transferred down* to knit from the bottom cylinder. A spring take-up holds the surplus yarn as the needles traverse towards the feed on the return oscillation, whilst a pouch tension equaliser ensures that the pouch fabric is held down on the needle stems.

The pouch is preferably knitted in single feed so that the other feeds (if there are any) are taken out of action, but an additional splicing yarn is striped in for reinforcement. The shape and extent of the spliced section may extend beyond the pouch. Reciprocation of the cylinder is produced by the drive at this point, being taken from the forward and backward oscillation of the quadrant. As the changeover is mechanically complex, oscillatory knitting takes place at approximately two-thirds of the speed of circular knitting.

In socks with reciprocated heels and toes in single feed, over a third of the courses will be in oscillatory knitting and may require over 60 per cent of the machine's operating time, thus making this operation time-consuming and expensive.

During the oscillatory knitting of the pouch, the remaining needles (approximately half) are raised into a high inactive cam-track by the introduction of a cam. This operates only on the long knitting butts allocated specifically to them, so that they retain their loops (for the instep) from the last course of circular knitting.

During narrowing, the leading needle in each direction of oscillation is lifted up to join the other needles in the inactive track by the action of one of two side pickers

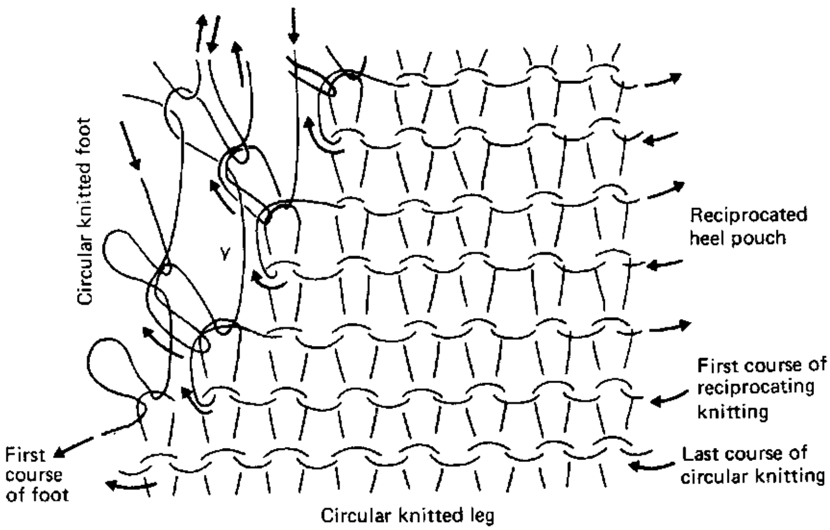


Fig. 21.4 Heel produced by reciprocation.

that are alternately in action according to the direction of oscillation. These pickers operate throughout the oscillatory motion.

During widening, a down picker is introduced that lowers two needles at a time, thus cancelling the effect of the up picker and putting an extra needle into action.

Each of the side pickers has an L-shaped recess and these are positioned facing outwards at the approach into the cam system so that in either direction of oscillation, the knitting butt of the leading heel needle or slider is caught by the recess. The continued movement of the cylinder causes the picker to be moved backwards and, as its movement is restricted, it pivots upwards in its holder to place the butt into the high inactive track; the spring attached to the picker then pulls it down again.

The down picker, when brought into action, moves down from the inactive track bringing two needles down with it each time. It has a recess on each side of its under surface so that two butts can be accommodated in each direction of oscillation. *Lonati* use only one type of picker, which is turned over to act as a down picker during widening. Some machines knit a twin-feed heel and toe. During narrowing two needles at a time are lifted. During widening, up picking continues with only one needle at a time whilst three needles are lowered into action at each side. With this method, a twin-feed heel or toe with acceptable sutures can be knitted in 22 seconds.

In the production of a *standard small heel*, half the needles knit in the heel-section, with narrowing occurring at each side, until only one-third of the needles are left in action. As each needle is lifted out of action, the yarn is automatically wrapped over it in the form of a tuck stitch, which makes the heel join stronger. Widening then takes place until all the heel section needles are brought back into operation, when circular knitting recommences.

A *toe pouch* is knitted in a similar manner. If the heel section needles are used again, the seam will be on top of the toe (as is the case in most socks). If the instep needles are used instead, a reverse toe is knitted, with its seam being underneath (usually preferable in hose).

Many modifications to the basic pouch sequence have been employed, particularly on hose, in order to improve the fit and appearance. In the *Y-heel*, extra fabric is knitted in the centre of the inverted Y suture-line by widening for twelve courses after narrowing to the one-third needles. Narrowing then occurs to one-third needles before commencing normal widening.

The *gusset toe* is a reverse toe knitted in a similar manner except that, when the one-third needles are left, a group are re-introduced collectively. Single-needle narrowing then occurs for twelve courses and then the rest of the needles previously collectively widened are lifted out of action and the normal widening picker is introduced. In the *ballet toe*, all the needles are brought collectively into action for a few courses of circular knitting after the needles have been narrowed to one-third. All except the one-third are then collectively raised out of action as normal widening begins.

21.14 Automatic separation

Pneumatic take-down and automatic press-off of seamless hose and socks from single-cylinder machines was a comparatively easier problem to overcome than the automatic separation of half-hose on double-cylinder machines which was achieved by *Bentley* in 1967. Pressing-off occurs at the point where the draw-thread would normally be introduced when the needles are engaged with the bottom cylinder sliders. The first few needles are raised to non-knit height in advance of the loop-forming position of the main feed so that the yarn from the previous article passes across them under tension and is severed as the sinkers move radially inwards and kink it with their throats.

At the main feed, the yarn for the new article is taken into every needle hook in the bottom cylinder. To ensure that all hooks are open, the needles have extended latches that are opened by the extended pointed ends of the sliders, which receive a rocking motion from cams at the transfer position. During this revolution, alternate needles are transferred to the top cylinder where they knit one course whilst the needles in the bottom cylinder remain in the non-knit track. For the next course, the rib needles enter the welt track and the plain needles are cleared to knit at the main feed for the commencement of the welt.

The Bentley-Solis arrangement [5, 6] employs vacuum suction complemented by a mechanical system to withdraw the separated article from the knitting zone. For reversed take-up, an inner plastic delivery tube then sucks the article upwards through the top cylinder where it drops onto a hinged exit door that automatically opens to allow it to fall into a collection container. The revolving take-down arrangement consists of two independently-operated sleeves positioned, one within the other, at the lower end of the top cylinder, with the inner sleeve protruding below the outer. The fabric is alternately held and pushed downwards by the sleeves, which are lifted and dropped once per revolution by cam action. The inner plastic delivery tube is slightly shorter than the inner sleeve so that it can suck the article upwards and away from the sleeves.

21.15 Seamed toe closing

Linking is the conventional method of toe closing that occurs after knitting during making-up. A slacker course of loops on the instep is joined loop-to-loop to a similar course in the toe pouch, by stitching on a linking machine. This is, however, an expensive, relatively slow and skilled operation.

In *Rosso linking*, the fabric to be joined is guided by a conveyor guide onto dial points and is seamed from opposite sides, but the join is not exactly on one course nor is there an individual ‘loop-to-loop’ join.

In the case of the *run-down toe*, the toe fabric is knitted in normal circular knitting (possibly with 40-denier instead of 15-denier yarn); it is later seamed from under the foot in an upward curve towards the top of the toe in a single or two-needle three-thread seam. Automatic toe seaming units can turn the hose inside out by means of compressed air, position the hose leg, and then convey it to a seaming head. After seaming the hose on the inside, it is turned back to its correct side. The complete cycle occupies only a few seconds.

21.16 Automatic toe closing on the knitting machine

Many novel methods have been devised for closing toes during the knitting operation. Generally, they have been restricted to single-cylinder sock machines, in coarser gauges, and not double-cylinder sock machines or seamless stocking and tights machines. They have achieved only limited success against conventional toe closing during post-knitting operations where automated seaming and handling techniques have considerably reduced labour content, time, and costs involved.

The main disadvantages of toe closing on the knitting machine have been one or more of the following: the necessity for a complex adaptation of the knitting machine and its knitting sequence with high capital costs; reduced production speeds; lower patterning potential; poor comfort; unsatisfactory wearing properties; and unconventional appearance. The following methods have been devised to overcome some of these disadvantages:

1 *The rosette toe*. Two types of toe that achieved some success in the late 1960s, were the *Scott and Williams* and the *Duravent* closed toes. Both commenced at the toe with circular knitting to produce a double thickness welt that was restricted to form a *rosette closed toe*, either by twisting the fabric tube or by wrapping yarn around it. These methods failed because of the unconventional appearance of the toe and the insecure finish to the welt, which was knitted last.
2 *The true-linked toe*. The appearance and comfort of a *true-linked toe* can now be achieved on a linking machine supplied directly from the knitting machine. The linking machine is either directly mounted on the knitting machine or it is supplied from a bank of machines. One sock is linked whilst the next is knitted. On the knitting machine, the open toe circle of fabric is held on a split dial that folds over to transfer and double-up the loops onto half the dial ready for loop-to-loop linking. Time and costs are saved by not having pre-linking courses, but the unit can add 30 per cent to the cost of the machine.
3 *The Sangiacomo Lin Toe*. This method (Fig. 21.5) uses the standard knitting sequence of *welt first*, *toe last*. It can be fitted to cylinder and dial true rib machines. The dial with its double loops is transferred to a *Frullini* patented, flange-mounted linking machine at the same time as the next sock is being knitted. The time required to transfer a sock for linking is 6–7 seconds. Knitting of the next sock occurs virtually immediately. Also, time and yarn are saved by not having additional pre-linking courses.

   A true stitch-by-stitch single-course linked seam is on the outside and a flat seam is next to the foot. The finest gauge limit is probably 200 needles × 4 inches diameter. The toe-closing unit, which can be retro-fitted to some sock machines, costs approximately 30 per cent extra. To reduce the cost of linking, after the sock has been knitted it can be robotically transferred to an *off-machine mini-linker* which can close the toes of socks from a number of machines [7].
4 *The knitted closed toe.* Knitted toe closure involves commencing at the toe and joining the instep needle loops to the toe loops. As the welt is knitted last, there is a problem in obtaining a neat, secure finish. Patents for a swivelling transfer dial to produce loop-to-loop knitted toe closure were first taken out by *Giulano Ugolini* in the early 1960's [8].
5 *The Matec Closed Toe*. With this system, the closing line on the outside of the sock is practically invisible and the result is equal to that achieved by hand linking. The time taken to close the toe is 5–6 seconds. All yarn waste is eliminated. It is possible to retrofit this to all *Matec* single-cylinder machines.

   The toe set-up course is picked up by the half-dial transfer elements and is knitted in a reciprocating manner on the sole half needles. As soon as the toe is

Fig. 21.5 Lin Toe toe-closing on the machine [Sangiacomo].

knitted, the dial rises further and swivels, bringing its set-up course over the cylinder needles of the instep half of the foot. The loops are then transferred from one half of the cylinder to the other. An externally-mounted crochet hook closes the toe. The foot length is then knitted on the full diameter.

6 Another method employs the dial as the transfer element, enabling the set-up course to be run by the dial, stitch-by-stitch, as the toe pouch is knitted by reciprocation. The toe fabric is then transferred to the other half of the needles that knit to close the toe. Afterwards, circular knitting commences for the foot.
7 *The Conti Florentia Air Toe*. This system produces a random linked appearance, not exactly loop-for-loop. It is therefore most suitable for coarser gauge sports socks. It is simple and virtually invisible on the outside of the sock. At the start of the toe, two courses of covered elastic are knitted by reciprocation. Sufficient fabric is then knitted to transfer across to the other half of the cylinder. Special hooked sinkers engage with the fabric aided by air jets which blow down onto the fabric. As the cylinder turns, the new yarn is knitted into the elastic yarn course.

21.17 Tights

Early versions of tights were made by seaming a hose leg to each leg of a pair of panties. Today, the conventional method of constructing tights is to knit two long seamless hose legs (having about 2000 courses). In the making-up operation, the legs are '*toe-closed*'. A slit is then cut vertically down the centre of the inner side of the upper (body) section of each leg. The slits are then opened so that the left side of one leg slit can be seamed to the right side of the other leg slit in a single operation. This is termed the '*line closing*' or '*U-seaming*' operation and it converts the top of the two tubular legs into one large tubular tights body. The top of the legs may contain the knitted-in *elasticated waist-band* or this may be seamed on later. The crotch area may then be cut or burned out so that a shaped gusset (often of knitted cotton fabric) can be inserted and seamed in its place.

21.17.1 Automated seaming

The cost of manual handling and seaming, combined with the static price of the finished article, has encouraged the search for alternative methods of production in the form of *one-piece tights* knitted on the machine. However, at present, increasingly automated tights seaming techniques have proved to be more successful. Unfortunately, there are considerable problems involved in automatically picking-up, orientating, guiding, handling, and sewing one of the lightest, flimsiest, most extensible and unstable of knitted structures. It is therefore essential that the hose legs are in a smooth, flat, undistorted state when they are removed from one operation and presented to the next. With the making-up operations being separate modules serviced by robotic handling devices, it is possible to incorporate different makes of machine as modules and to introduce and remove them as and when required, without interfering with previous or subsequent modular operations.

Whereas previously the hose legs were presented to the automatic seaming operation by a skilled operative, the '*pick and place*' system automatically picks-up and '*double positions*' the garment using two reference points on it [9].

The *Detexomatic pick and place* system uses a pick-up probe involving suction and gripping fingers to collect legs from a revolving basket. A second picker presents the leg to an orientation device, either toe-to-waistband or waistband-to-toe. If it is the wrong way, it will be reversed.

On the *Esox system*, vision detection is used to align the legs for automated tight assembly by detecting and aligning a colour marker in the waist band and the six wales of mesh that indicate the cutting line.

21.17.2 One-piece tights

The various knitted one-piece tights methods normally involve using a hose machine of $3\frac{3}{4}$ to 4 inches (9.5–10 cm) diameter with approximately 400 needles, and knitting a modified tube of fabric. It is necessary to obtain a width of 4 to 5 inches (10–12 cm) for the ankles and a lateral stretch of 16 to 20 inches (40–50 cm) for the body, which may be achieved with textured yarn.

The main problems have involved fit, quality, and the time and cost of the knitting sequence. More specifically, fit and quality problems have included insufficient depth in the body, fabric breakdown under tension at the leg joins, insufficient extension of fabric at the thighs, and an excess of fabric in the crotch section.

Although smaller sizes can be achieved, larger sizes are more difficult and larger machine diameters such as $4\frac{1}{4}$ inches may be used for these.

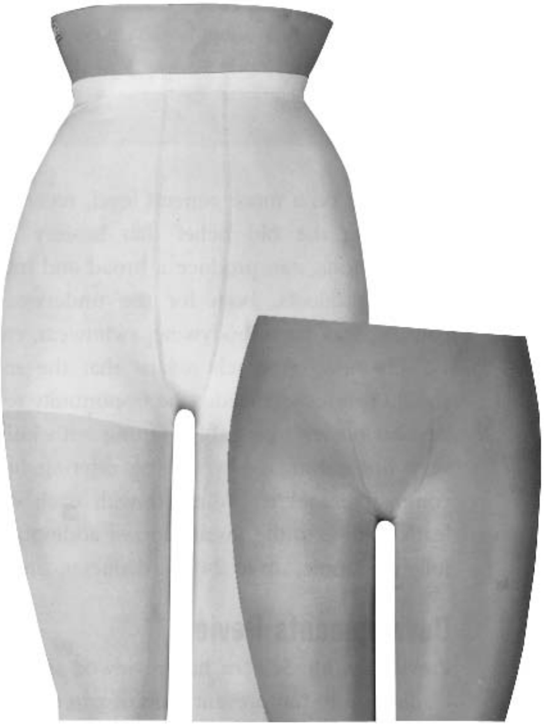
One of the first types of commercially-produced one-piece tights was patented by *Pretty Polly* in 1968. It consists of a tube started at one toe and leg, with a wider body section in the centre, and terminated by knitting the other leg and toe. A slit is made down the wales on one side of the body section, which forms the opening for the elasticated waist section, whereas the other side of the body section becomes the under leg-crotch section as the tube bends into a *banana* shape.

Billi (*Matec*) modified this concept to achieve a better shape by introducing part course sections on the crotch side of the body section. This was combined with graduated sections of multiple tucks on a 1 × 1 knit/ tuck basis, which decrease in number towards the waist opening, which is a rectangle with a knitted-in elastic waist band. With this technique, a 'complete' panty-hose (pair of tights) can be knitted on a *Zodiac* eight-feed machine in approximately 3 minutes.

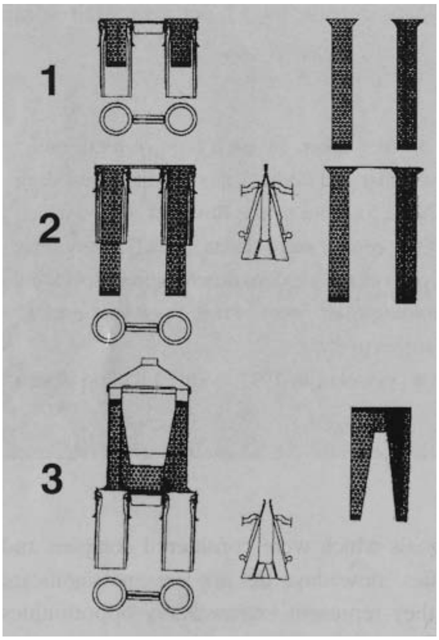
Other methods have involved reciprocation in the body section and in the case of the *Samo Panty-Sol*, one half of the waist band and panty is knitted in each of the two cylinders of a special double-cylinder machine; afterwards one leg is knitted in each cylinder with normal circular knitting.

The prototype *GL one-piece tights* system is the most recent development, taking 2 to $2\frac{1}{2}$ minutes to knit a pair of tights without closed toes. The Italian hosiery manufacturer *Golden Lady* holds the international patents and know-how to the GL one-piece knitted tights project (Fig. 21.6). The machine consists of two needle cylinders, each of 400 needles, and 4 feeds separated by a V-bed flat needle bed with 200 needles. It starts by knitting the two legs simultaneously, one on each cylinder. When knitting reaches the crotch portion, the body is knitted in tubular form on 1000 needles on all eight feeds, which includes the two cylinders and the V-bed.

In the standard 'made-up tights' there are only 800 needles in the body and a portion of this is cut-away during line-closing. The tights have a better fit and, being seam-free, are more comfortable. Single wale needle lines show in the body where the feeders pass between the flat and circular beds. Production rates are comparable with conventionally made-up tights but the cost of seaming machinery and labour is saved.



a



b

Fig. 21.6 GL one-piece tights. Production is started by knitting the two legs simultaneously. When the crotch portion is reached, the body is knitted continuously, in tubular form, either on the sets of cylinder needles or on the flat needle beds. This means that the leg portions are knitted with 4 + 4 feeders (4 feeders for each cylider) and that the body portion is knitted with 8 feeders throughout [*Knitting International*, Nov. 1998].

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