16

Welts, garment sequences and knitting to shape

As previously mentioned (Section 8.2), the production of a firm starting welt and the introduction of shape during knitting are often features of garment-length knitting sequences.

16.1 The welt

A *welt* is an attractive and secure edge of a knitted article that helps to prevent laddering or unroving of a structure. It is formed either during the knitting sequence (usually at the start, and parallel to the courses), or as a later seaming operation during making-up.

16.1.1 The plain fabric welt

On machines with no facilities for rib welt sequences, the plain fabric is formed into either a turned-over *inturned-welt* or a *mock rib welt*. The ability to produce a knitted welt sequence usually distinguishes an article-producing machine from a fabric-producing machine. Some machines start at the closed toe end or finger-tip and finish with the welt end of the article. The last knitted course will unrove backwards from the last knitted loop unless it is secured.

Sometimes the curling edge of plain fabric is used as the start of a garment or the curl of a collar instead of a welt.

16.1.2 The inturned welt

The *inturned welt* is used particularly for manufacturing ladies' hose and sports socks on circular machines (Fig. 16.1) and some knitwear on Cottons Patent machines (Fig. 16.2). Jacks or hooks collect the sinker loops of the third course or the set-up course and hold them, drawing the fabric away until sufficient has been knitted for the double-thickness welt.

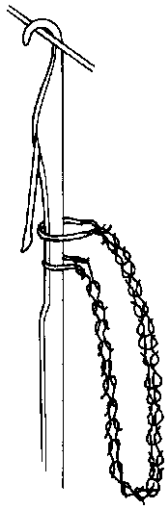


Fig. 16.1 Turned welt on latch needle machine.

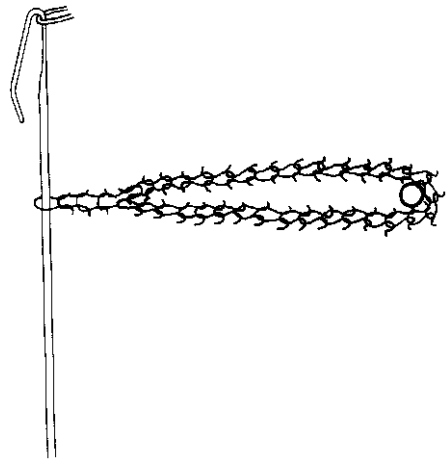


Fig. 16.2 Turned welt on bearded needle machine.

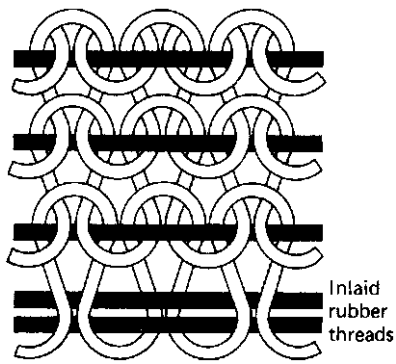


Fig. 16.3 Accordion welt top.

The welt is then turned by transferring the held course back onto the needles that knit it into the structure. A *picot edge* at the turn of the welt is achieved either by an alternate needle tuck sequence or by alternate needle loop transfer.

Cottons Patent plain machines often produce garment panels by knitting onto a rib border that has been run onto the needles, having been previously knitted on a V-bed rib machine.

16.1.3 Accordion top

An *accordion top* (Fig. 16.3), welt and mock rib, can be produced on single-cylinder half-hose and sock machines, and on other machines using a single set of needles in a tubular arrangement. Elastomeric yarn is laid-in to odd needles only for a few courses so that when the first plain course is knitted by the textile yarn, the straight contracted elastomeric yarn lies through its sinker loops, forming a neat roll edge. The elastomeric yarn is then usually inlaid on a two-tuck two-miss or a one-and-one basis at each course or alternate courses for a number of courses. As the elas-

tomeric yarn relaxes, it causes alternate wales to be displaced into a mock rib configuration. Sometimes, the second course of textile yarn is knitted only on alternate needles.

16.2 Rib welts

Most fully-fashioned and stitch-shaped underwear and outerwear garments, half-hose, and socks have ribbed borders containing a welt sequence that is produced by causing the sets of needles to act independently of each other after the 1×1 rib set-up course.

When the rib border is to be knitted in 2×2 rib, the needle bed is either shogged to form a skeleton 1×1 rib needle arrangement or it is knitted on a normal 1×1 rib needle set-out followed by rib loop transfer to achieve 2×2 rib for the border.

Three types of welt are possible when needles are arranged in 1×1 rib set-out. These are:

1 The tubular or French welt.
2 The roll or English welt.
3 The racked welt.

16.2.1 The tubular welt

The *tubular welt* (Fig. 16.4) is the most popular welt because it is a balanced structure that is reversible, lies flat, can be extended to any depth and is elastic. Its only disadvantage is that it can become baggy during washing and wear unless knitted tightly. Apart from old Cottons Patent Rib Frames, most garment-length knitting machines can knit this welt.

The *split welt* is actually a tubular welt knitted at the end of the garment sequence instead of at the beginning. It is used as an open tube for a collar or stolling, to fit over the cut edge of a garment to which it is then linked by a through stitch.

16.2.2 The roll welt

The roll welt (Fig. 16.5) is produced by knitting approximately four courses on one set of needles only whilst continuing to hold the setting-up course of loops on the other set of needles. It is bulkier and less elastic than the tubular welt and has the disadvantage of long held loops. This welt is knitted particularly on half-hose and links-links garment-length circular machines.

A *reverse roll welt* is knitted for sleeves with turn-back cuffs and for turn-over top socks. To obtain this welt, the opposite set of needles (the bottom set of needles on half-hose machines) are caused to hold their loops so that the roll of the welt appears on the other side of the structure, but it is on the face when the fabric is folded over.

16.2.3 The racked welt

The *racked welt* (Fig. 16.6) is neat and inconspicuous, rather like the set-up course of hand knitting in appearance, and is favoured for collars and other trimmings. It

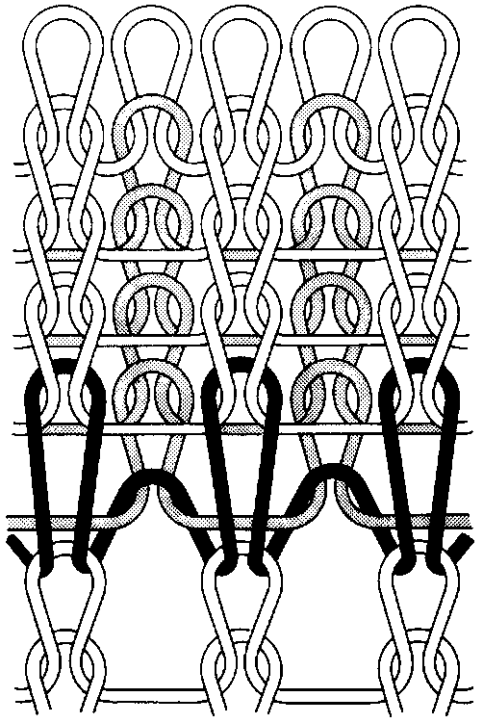


Fig. 16.4 Tubular welt.

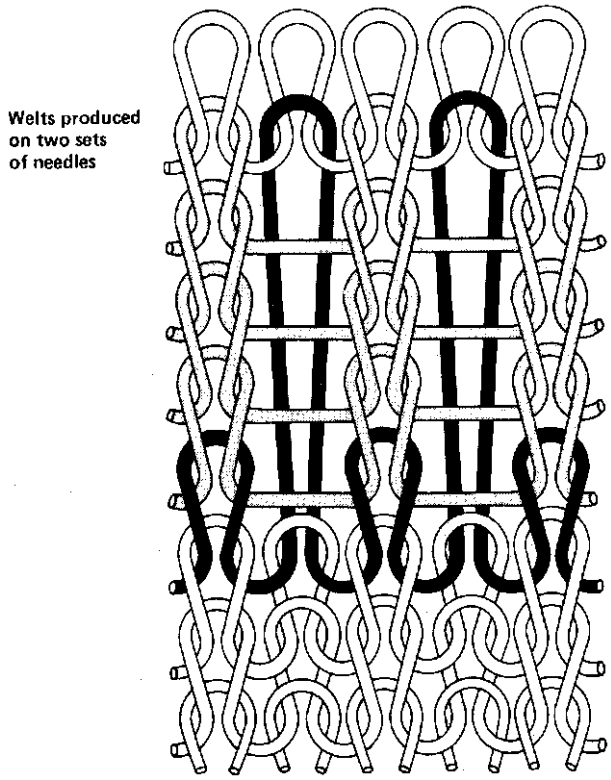


Fig. 16.5 Roll welt.

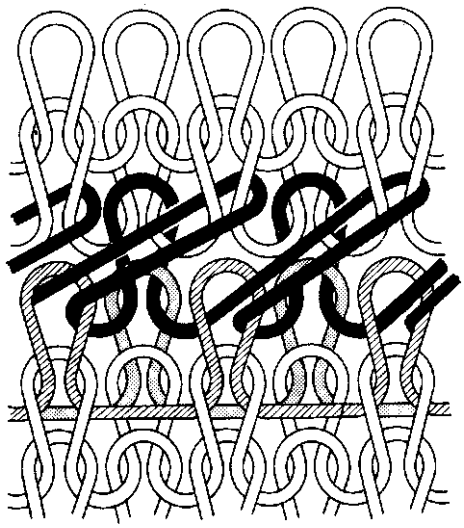


Fig. 16.6 Racked welt.

is not as elastic as the other two welts and is normally only knitted on V-bed flat machines. It is produced by racking the needle bed by one needle space after the set-up course and retaining this arrangement.

16.3 Separation

Knitted articles are often produced separately on single-cylinder machines, Cottons Patent machines and some flat machines. Others are knitted in continuous string formation on many flat and circular rib and purl machines because fabric tensioning is dependent on a continuous length of fabric between the needles and the take-down rollers. Also, there would be a danger of latches not being open at the start of a new garment sequence.

If the string of garments is separated by cutting, there is a danger of either the welt being damaged or of unwanted yarn not being removed. For these reasons, some form of separation course is usually provided, normally in the form of a *draw thread course*, preceding the first course of the new garment.

The draw thread is usually a smooth strong yarn that may be knitted as a slack, plain tubular course to facilitate easy removal. The tubular draw thread course does not unrove accidentally during wet processing.

A second method is the press-off draw thread construction, which, although more expensive in time and yarn, tends to be more popular. The course preceding the start of the new garment is knitted in 1×1 rib and then one set of needles presses-off its loops, leaving a single plain course of extra long drawthread loops that can be quickly and easily removed. Prior to the press-off course, locking courses are produced by knitting three or more additional courses, only on the set of needles that are to press-off. These help to reduce tension in the structure after pressing-off and thus reduce the possibility of laddering back.

A popular alternative to a draw-thread, employed on half-hose and sock

machines, is to knit a number of courses in a soluble yarn such as alginate. The socks are separated by cutting, and the remaining courses of yarn are dissolved away during finishing to leave a neat edge to the welt.

Most garment-length machines using two needle beds have a butt arrangement of two long, one short for each bed, enabling 2×2 rib knitting after pressing off the loops of a 1×1 rib set-out and recommencment of knitting on only long butts on each bed in turn.

16.4 Imparting shape during knitting

In addition to facilities for garment-length sequence knitting, weft knitting provides unique opportunities for width-wise shaping during knitting, with the sequence being initiated and co-ordinated from the same central control mechanism.

The three methods of width shaping are:

1 varying the number of needles in action in the knitting width,
2 changing the knitting construction, and
3 altering the stitch length.

16.4.1 Wale fashioning

Wale fashioning is the normal manner of shaping (symmetrically or asymmetrically) on straight bar frames (Figures 16.7 and 16.8). It involves the transfer of loops from one needle to another within the same needle bed, either transferring onto selvedge needles that are to start knitting (*widening*) or transferring from needles that are to cease knitting (*narrowing*).

The fashioning technique has, in the past, been generally restricted to plain fabric structures although there were a few rib straight bar frames. There is now an increasing number of automatic V-bed flat machines with additional beds of fashioning points or rib loop transfer needles. Each transfer bed operates onto a specific needle bed (Fig. 16.9).

Fashioning can also be achieved by needle-to-needle rib loop transfer, racking

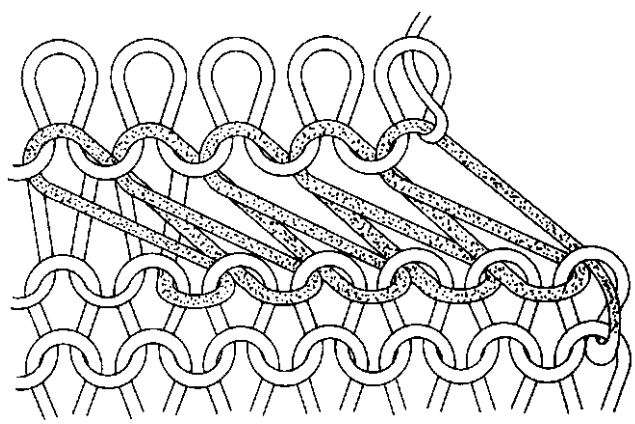


Fig. 16.7 Wale fashioning (narrowing).

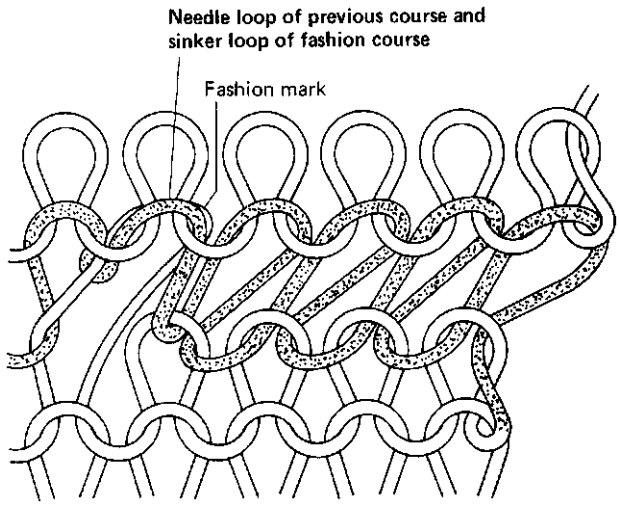


Fig. 16.8 Wale fashioning (widening).

one bed, and transferring back to the original needle bed, but this technique requires receiving needles to be empty of loops.

The firm, fashioned selvedge edges can be point- or cup-seamed together, without the need for cutting and seaming to shape involving loss of expensive fabric. The shaping angle is varied by changing the fashioning frequency (i.e. the number of plain courses between each fashioning course), aided by the possibility of four-needle or two-needle as well as single-needle narrowing. A block of loops is transferred at a time, so that the transferred loop effect (*fashion mark*) is clearly visible in the garment, away from the selvedge, as this is a hall-mark of classic fully-fashioned garments.

Widening involves transferring the loops of a group of needles outwards by one needle, thus leaving a needle without a loop that would produce a hole if it was not covered by the action of filling-in.

Figure 16.8 shows the effect of using a single filling-in point that is set slightly in advance of the innermost fashioning point. It has an independent vertical movement and takes a stitch from the previous course, placing it onto the empty needle. Another technique in order to cover the hole is to use two half-points to transfer the half limbs of two adjacent needle loops sideways.

A similar technique as been developed for automatic V-bed machines, when it is termed a *split stitch* (Fig. 16.10).

16.4.2 The calculation of fashioning frequencies

Using the details shown in Fig. 16.11 as an example, the following sequence is necessary in order to calculate the required fashioning frequencies from the dimensions of a garment part:

1 Convert the length dimensions in each section to total number of courses by multiplying the length measurement by the cpi. Thus, $7 \times 20 = 140$; $4 \times 20 = 80$; $5 \times 20 = 100$ courses.

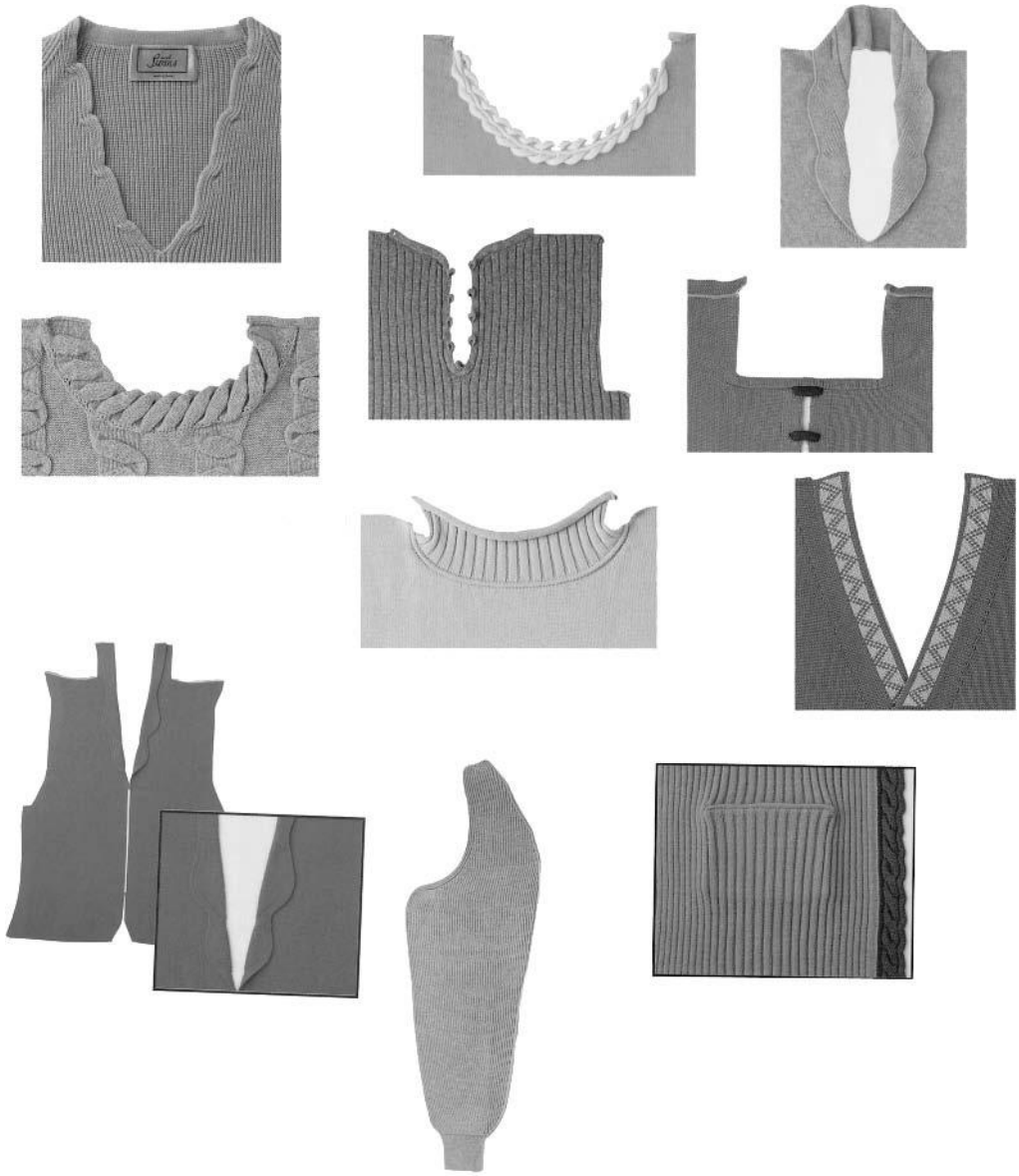
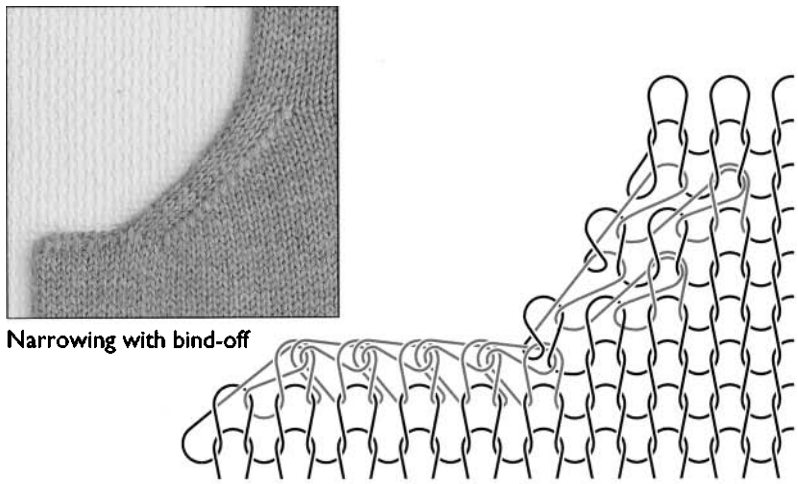
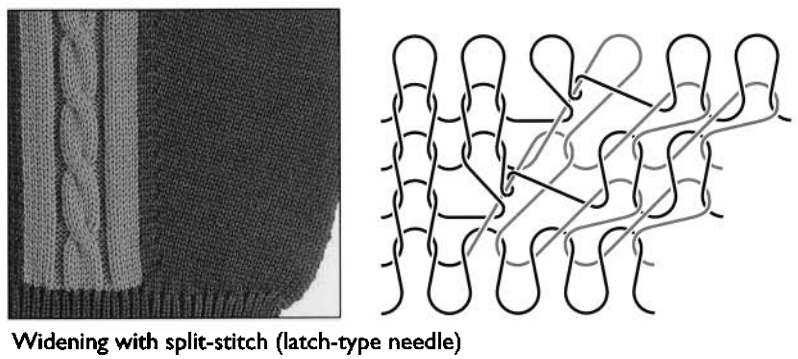


Fig. 16.9 Integrally shaped rib garment pieces. The machine has an additional bed containing the transfer points [Shima Seiki].

2 Convert the width dimensions at the start of each section to total numbers of needles by multiplying the width measurement by wpi. Thus, 16 × 16 = 256; 18 × 16 = 288; 8 × 16 = 128 needles.
3 Calculate the total number of needles increased or decreased from one section to another by taking one total from the next.
4 Divide the totals obtained by 2 in order to obtain the increase or decrease of needles at one selvedge. Thus, 288 – 256 = an increase of 32 needles. 32/2 = 16





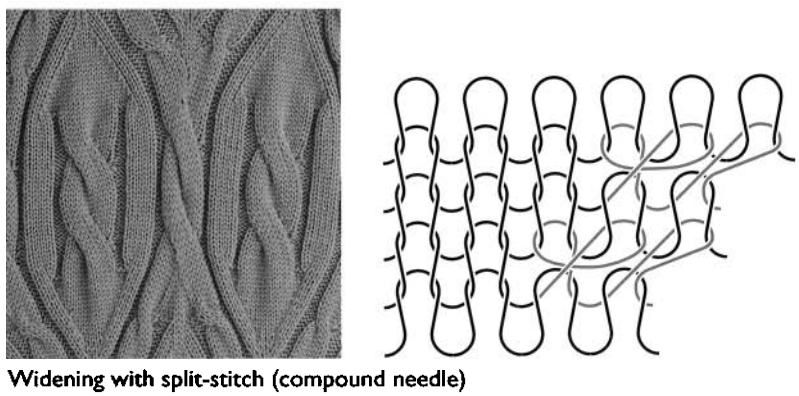


Fig. 16.10 Modern integral garment technology assures precisely-formed loops which are crucial to the production of shaped garments [Shima Seiki].

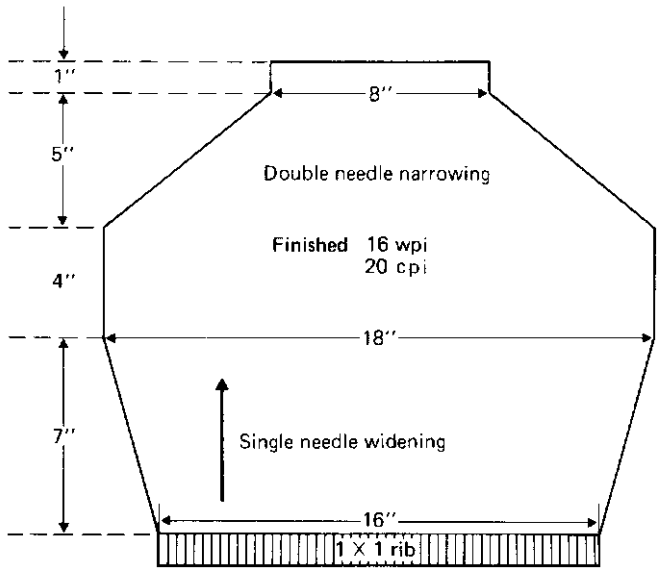


Fig. 16.11 Full-fashioned shaping calculation.

single needle widenings; 288 – 128 = 160; 160/2 = 80 needles, 80/2 gives 40 double-needle narrowings

5 There are 16 single-needle widenings occurring during the knitting of 140 courses; assuming the first fashioning occurs in the first course, there will be 15 fashionings in 139 courses; 139/15 = 9 with a remainder of 4. Thus 4 fashionings must occur at 10 course intervals and the remaining 11 at 9 course intervals.

6 Forty double-needle narrowings occur during 100 courses, again assuming the first fashioning occurs in the first course; 99/39 = 2 with a remainder of 21. Thus 21 fashionings occur at 3 course intervals and the remaining 18 fashionings occur at 2 course intervals.

16.4.3 Three-dimensional wale fashioning

Shaping by three-dimensional wale fashioning occurs within the width of needles, using an additional pair of independently-controlled fashioning boxes to shape stocking heels or bosom pouches. In the centre of the pouch, a number of needles knit plain fabric whilst on either side of them the extra sets of points widen outwards and later narrow again.

During widening, each needle that loses its loop and does not receive a new loop will commence a new wale in the next course, whereas, during narrowing, when a needle receives two loops, two wales will be caused to converge into one.

16.4.4 Needle selection shaping

In *needle selection shaping*, the selvedge needle(s) is introduced or withdrawn from the knitting width by means of needle selection. It is more convenient on automatic

V-bed flat machines to employ the jacquard selection to introduce empty needles for widening and to take needles out of action for narrowing

(i) by transferring and re-transferring rib loops in conjunction with needle bed racking,
(ii) by pressing-off loops, or
(iii) by causing needles to hold their loops for large numbers of traverses (Fig. 16.12) [1].

It is even possible to introduce or remove a selvedge needle from the knitting action during tubular plain knitting on a V-bed flat machine, thus achieving a certain amount of shape in the tube.

The full shaping potential of the V-bed flat machine can only be exploited if the conventional roller take-down system is replaced by an arrangement capable of accommodating itself to varying rates of production and fabric widths and even to separated garments or garment pieces.

16.4.5 Reciprocated knitting of pouches

Three-dimensional shaping of pouches can be achieved on small-diameter hosiery machines by using held loop shaping in a similar manner to flat knitting, so that the number of courses knitted by adjacent needles is varied in order to knit a pouch for a heel and, if necessary, for a toe.

During pouch-knitting, the rotating movement of the cylinder changes to an oscillatory movement. In the first half of the pouch-knitting sequence, only half the needles continue knitting, and during the reciprocating knitting, a needle at each edge is lowered out of action (narrowing) to join (in the case of heel-pouch knitting) the instep needles, which are already holding their fabric loops. When only one-third of the needles remain in action, widening commences so that needles are successively brought back into action at the edge of the pouch. When all the pouch-half of the needles have recommenced knitting, the cylinder returns to rotary knitting and circular courses are knitted, with all needles in action.

A small-diameter garment machine was developed to produce shaping for the bust or shoulder section of integrally-knitted garments using the *reciprocated pouch* principle but has not been utilised to any extent [2].

As *oscillatory knitting* is a much slower and more complicated process than circular knitting, the toe is produced as an open tube on many stocking and tights machines. It is later seamed to shape. The heel may also be knitted as a part of the leg tube, being boarded out and heat-set shaped during finishing.

One method of producing a stocking heel pouch in completely circular knitting is to knit circular courses at the first feeder and to select needles for heel section knitting at the second feeder in conjunction with striping, cutting and trapping of yarn. With this method, a part circular course is sandwiched between each full circular course for the heel section.

16.4.6 Shaping by changing the knitted stitch structure

Stitch shaping is the imparting of shape into selvedged or tubular weft knitted structures by changing the nature of the stitch structure without altering the total number of needles that are in action. It may be used for garment-shaping sequences in

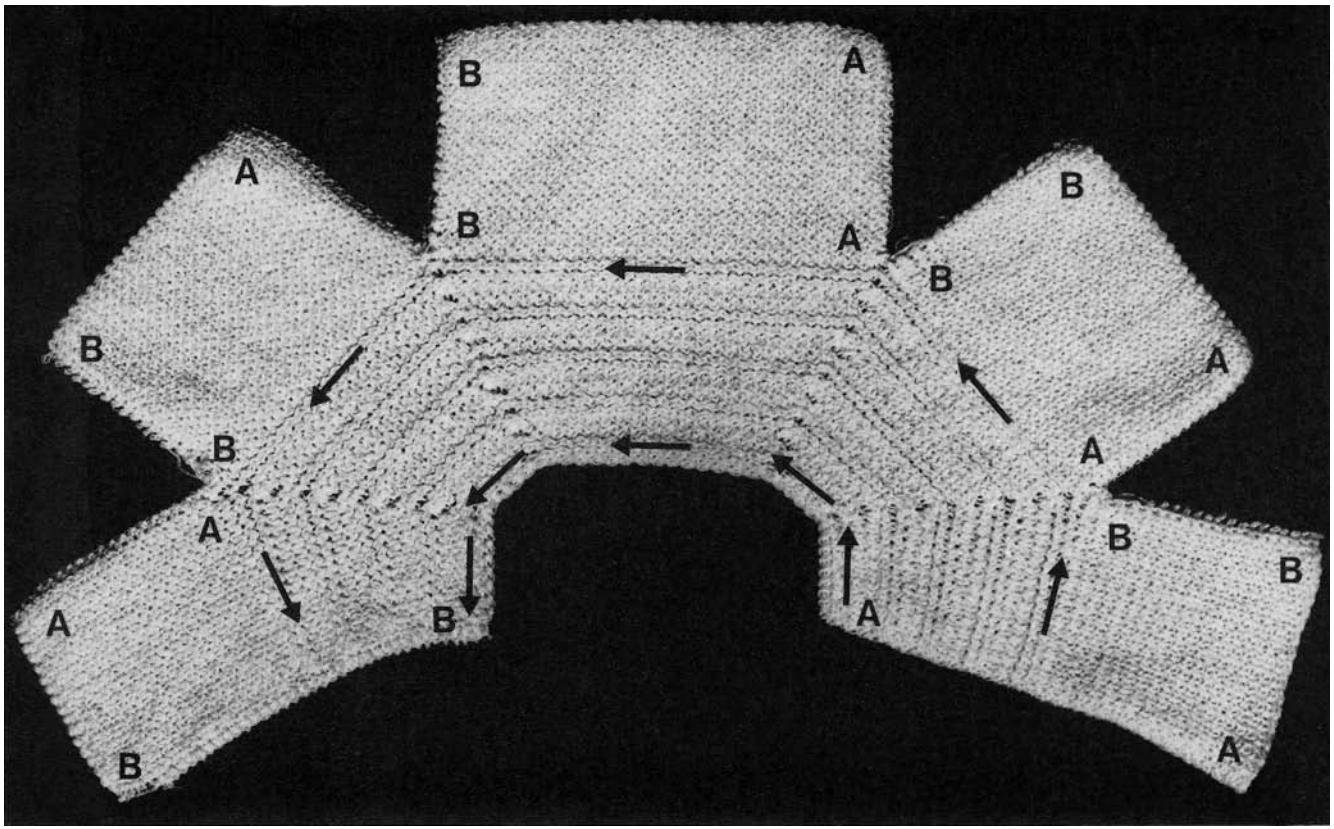


Fig. 16.12 Garment shaping by holding loops on a V-bed flat machine thus knitting wales with different numbers of courses. (A) is the commencing course and (B) the pressed-off course. A presser foot device was employed [*Knitting International*].

knitwear, jerseywear and underwear produced on latch needle machines. It is a simpler and faster method than fashioning and does not require specially-shaped elements, but it can only be used for a few definite step-changes of shape rather than the graduated shaping technique of fashioning.

In the sleeve and body panels of knitwear, the tuck stitches will cause half and full cardigan to throw out wider than the 1×1 rib border (Fig. 16.13). In ladies' stitch-shaped vests, patterned rib eyelet will produce a similar effect in the bust and skirt sections, compared with the 2×2 rib waist and border (Fig. 16.14).

In plain tubular fabric articles such as some socks and gloves, elastic may be inlaid on an alternate tuck/miss basis on the same needle sequence, so that the fabric concertinas into a narrower elastic 'mock rib' effect for the tops.

16.4.7 Shaping by altering the stitch length

Changes of stitch length by alteration of stitch cam positions are carried out at particular points in a garment-length knitting sequence. Even mechanical V-bed power flat machines have at least five pre-set positions that can be automatically obtained during traversing of the cam carriage. On both circular and flat machines it is also possible to change from synchronised to delayed timing in 1×1 rib knitting and thus produce tighter and more 'elastic' rib courses suitable for rib borders. In ladies'

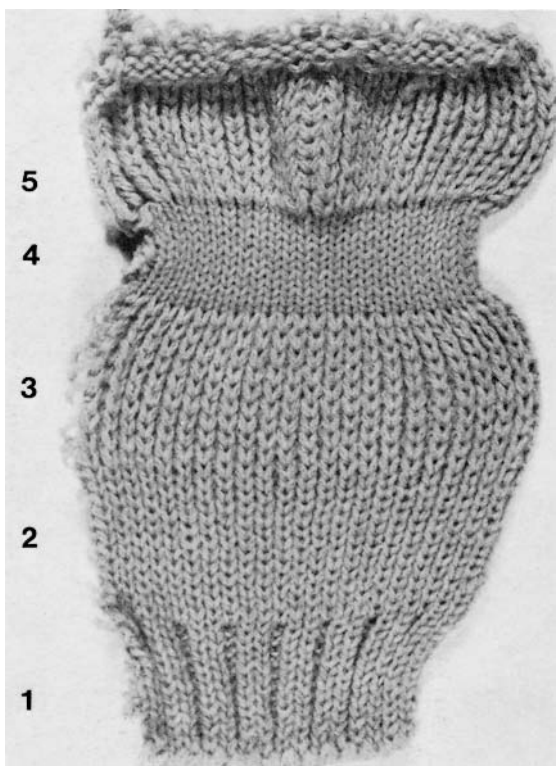


Fig. 16.13 Stitch shaping (1 = 2×2 rib; 2 = 1×1 rib; 3 = half-cardigan; 4 = tubular courses; 5 = full cardigan).

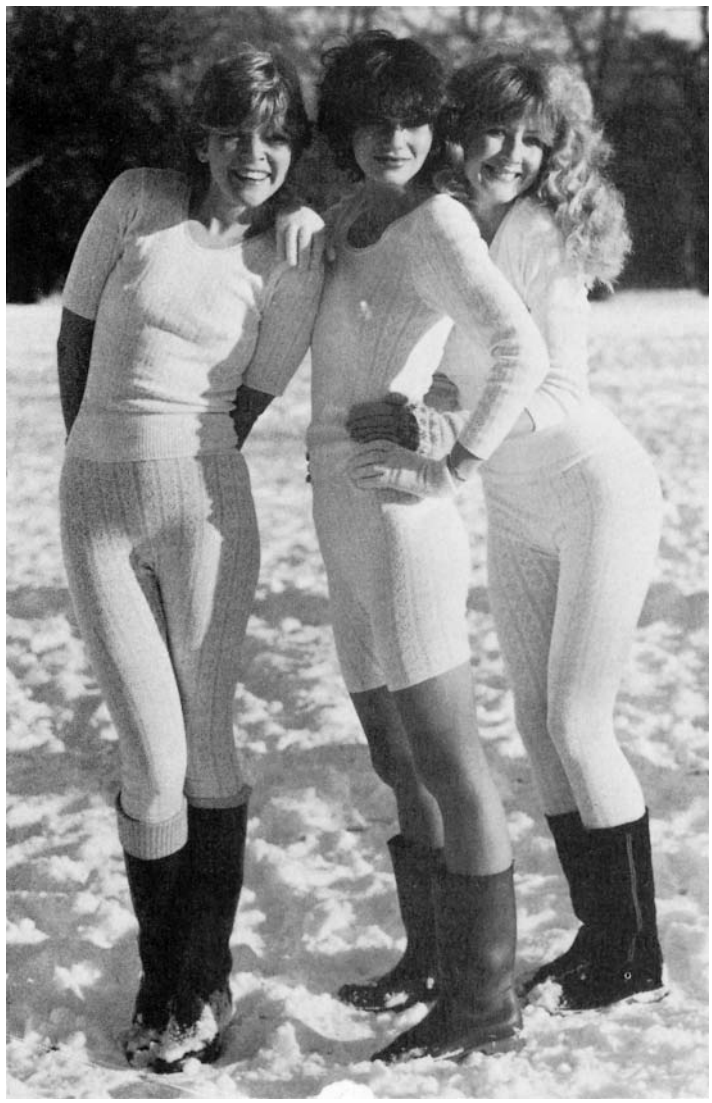


Fig. 16.14 Stitch-shaped thermal underwear in 1×1 rib with rib loop transfer and cylinder needle pick-up design knitted in 1/28's cotton spun 50/50 Viloft/polyester on a 10-gauge RTR (13-, 15-, and 17-inch diameters) by Twinlock [Courtaulds, Henrietta House, London].

hosiery, a *graduated stiffening* or tightening of the stitch length occurs to obtain a certain amount of shape between the thigh and the ankle.

The introduction of a certain percentage of elastane yarn into the construction of a weft or warp knitted fabric improves extension and recovery properties and therefore its form-fitting properties. The percentage elongation of the elastane yarn may be controlled during fabric finishing by heat-setting [3].

16.5 Integral garment knitting

An *integral garment* is one whose various parts have been knitted and knit-assembled by the knitting machine. It thus requires minimal make-up attention on leaving the knitting machine.

Integral garment knitting lowers make-up costs (including cutting), shortens throughput times, reduces work in progress and provides the opportunity to introduce new styling features. The knitting machines, however, are more complex and expensive and may be more restrictive in their operation and patterning scope. *Shima Seiki*, the Japanese V-bed machine builders, use the term *WholeGarment Knitting* to cover their own particular patented technique.

Despite the fact that integral garments are tubular and seamless, few are produced on circular machines except for hosiery and underwear (where making-up operations such as toe closing are still required). The reason is that knitting to shape generally involves wale fashioning achieved by selective loop transfer to and from needles in the same bed – a technique not readily available on circular machines.

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17

The straight bar frame and full-fashioning

17.1 The development of the straight bar frame

The straight bar frame is, with a number of later improvements and developments, recognisable as a direct descendant of *William Lee's* hand frame.

Credit for the development of the first acceptable power-driven rotary frame is given to *Samuel Wise* who, in 1769, replaced the foot pedals with a power-driven rotary shaft whose tappets caught against arms and levers to move the working parts. To increase productivity it was necessary to simplify the knitting action and introduce automatic mechanisms to replace hand-controlled operations. In 1857, *Luke Barton* replaced hand-controlled loop transfer points used for fashion shaping with a self-acting narrowing mechanism, and in 1861, *Paget* invented a movable needle bar.

It was, however, *William Cotton* of Loughborough who transformed the hand-controlled power-driven rotary frame into the high-speed automatic fashioning multi-head straight bar frame. This speeded the transition of knitting from a cottage-based to a mass-production industry. Between 1846 and 1864, he obtained patents which have caused the term '*Cottons Patent*' or '*Cotton Machine*' to become synonymous with that of the straight bar frame.

Cotton invented the vertically moving needle bar, developed the use of screw-controlled fashioning points for automatically widening and narrowing, and placed the driving shaft for the elements towards the base of the machine to reduce vibration.

The replacement in 1953 of the end controls by a central control unit paved the way for the modern automatic straight bar frame with its fully-programmed garment-knitting sequence (Fig. 17.1). Balanced and simplified motions, together with variable draw, have increased knitting speeds, whilst automatic actions have reduced standing time and labour supervision [1].

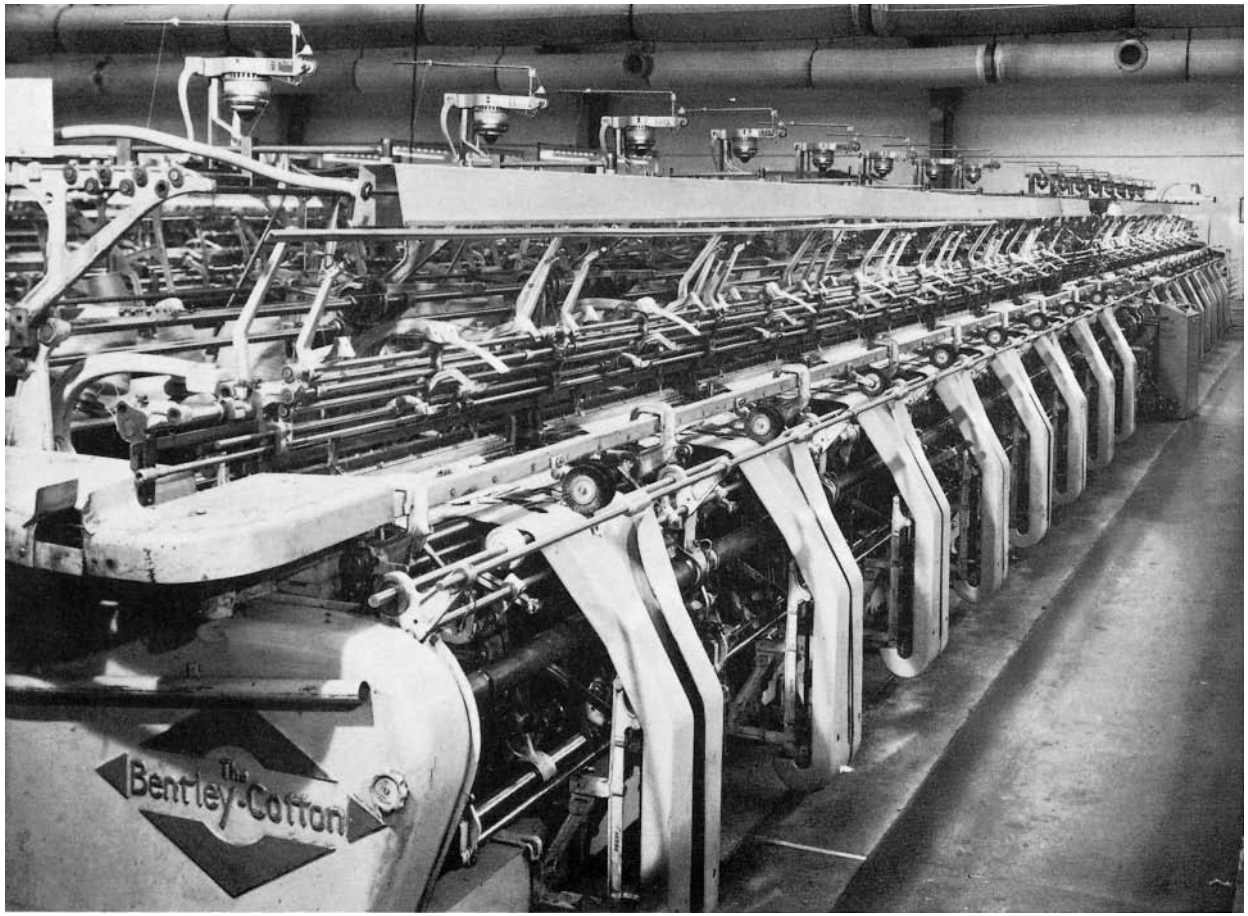


Fig. 17.1 Sixteen-head plain straight bar frame having a conveyer for transporting the rib ends to each head [Iropa].

17.2 Fully-fashioned articles

Excepting *knitwear*, which is a comparatively recent development, fully-fashioned or wrought products have suffered a considerable decline in fashion demand during the twentieth century as a result of the improvement of cheaper manufacturing techniques in other sectors of weft knitting including, more recently, the development of heat-set shaping based on the use of thermoplastic fibre yarns such as nylon.

Fully-fashioned half-hose and socks were the first to be replaced by circular knitted products between 1900 and 1920.

17.3 Stocking production

Fully-fashioned nylon stocking-production reached a peak in the 1950s, with automatic machines having up to forty divisions, each 15 inches (38 cm) wide, in popular gauges of 51 G and 60 G (needles per $1\frac{1}{2}$ inches/38 mm). Each stocking blank, which has a turned welt top, shaped leg and foot, round heel pouch, and diamond point toe, was completed in 30 minutes and pressed off from the few needles still knitting. The stocking blank selvedges were then *cup-seamed* (joined together with a seam that passed straight down the back of the leg and underneath the foot). By the end of the fifties, however, fashion was swinging over to the bare leg look of the cheaper, heat-shaped, circular knitted, seamless stocking, and production of fully-fashioned stockings declined rapidly during the early 1960s.

Today, fully-fashioned stockings provide a niche market for a handful of specialist knitters [2].

17.4 Underwear and knitwear

Fully-fashioned underwear, such as men's undershirts and pants (union suits) and women's vests, panties and combinations, were popular until fashion changed during the 1920s; from then onwards the surplus machine capacity was used for knitting outerwear. Attention was concentrated on women's twin-sets and men's pullovers. Classic knitwear styles became very fashionable after the Second World War and production was aided by new machine attachments such as that producing the V-neck shape [3].

Today, outerwear straight bar frames with 16 knitting sections, each 32 or 34 inches wide, may be as long as 77 feet (23.5 metres), and weigh 70 tons. The gauge is still expressed in needles per $1\frac{1}{2}$ inches so that the popular 21-gauge is actually $21 \times 2/3 = 14$ needles per inch. The normal gauge range is from 9 to 33. Typical yarn counts for 9, 21, 24 and 33 gauges respectively are 2/10's, 2/24's, 2/28's and 2/40's worsted count (NeK) or 175, 74, 64 and 44 tex. Knitting section widths range from 28 to 36 inches (71–91 cm) for bodies and 20 to 22 inches (51–56 cm) for sleeves, the wider sections being useful when using higher shrinkage synthetic yarns.

17.5 Knitting motions of the straight bar frame

The three directions of motion required for the knitting action are provided from two separate sources. The rotary motion of the cam-shaft produces the vertical and

horizontal movement of the fashioning points and the needle bar. The sideways reciprocating movement for the yarn carriers and for introducing the sinkers in serial sequence via the slurcock is obtained from a coulier or draw cam attached to a shaft, set at right angles to the main cam-shaft at the back of the machine, which oscillates a draw lever. A variable draw ensures that the stroke of the draw is related to the varying knitting width. Thus, more courses per minute are knitted on narrower widths. Operating speeds of a hundred courses per minute can be achieved.

17.6 Knitting action of the plain straight bar frame

Figure 17.2 shows the cross-section of the knitting head containing the following elements:

A *Bearded needle*, having a cranked end for location in the tricked and drilled needle bar.
B *Sinker* – only one between every other needle space – with a reinforced back and, at the front, a 'catch' to sink the yarn around the needles, and a 'neb' to separate the old and new loops until knock-over.
C *Divider*, occupying each remaining space, usually having the same shaped front as the sinker but with an extended tail at the back.
D *Knocking-over bit* – one directly beneath each sinker and divider – having a 'throat' for holding the loops and a 'nose' for knocking-over.
E *Needle bar*, having a compound horizontal and vertical movement.
F *Striking jack*, fulcrummed at its lower end, each one with its 'nose' resting on a sinker back, and a 'spring' exerting pressure on its 'tail'.

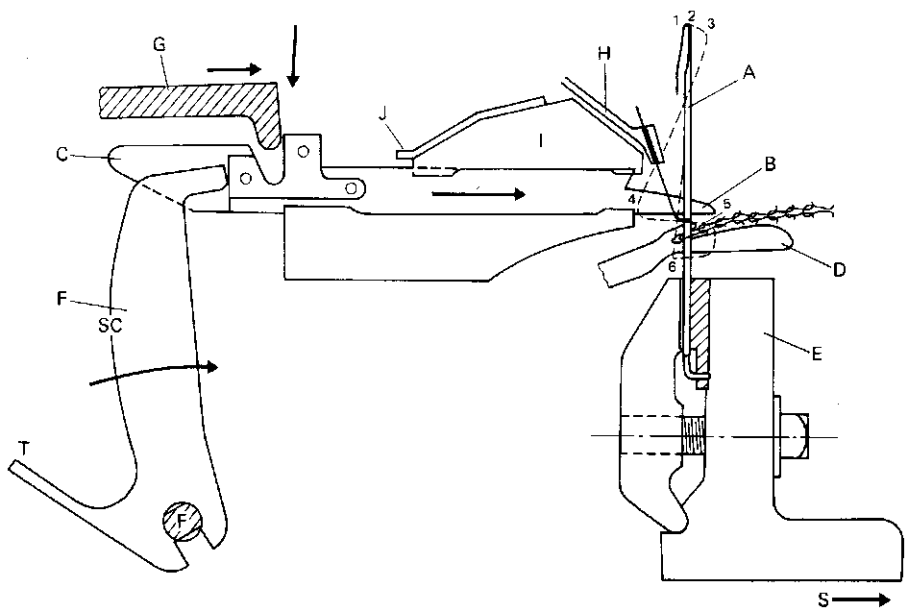


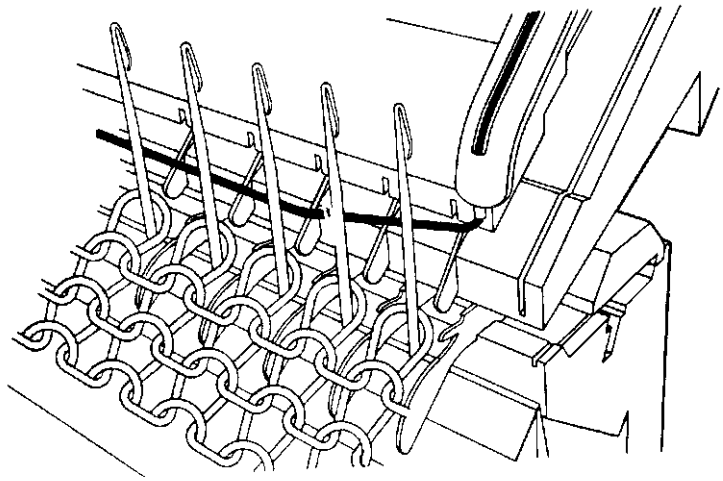
Fig. 17.2 Knitting head of the straight bar frame.

G *Catch bar*, extending the full width of the knitting head, having forward and backward, as well as vertical, movement.

H *Yarn carrier*, which traverses in alternate directions across the head from one course to the next – up to six carriers may be available. The carrier is connected to a reciprocating carrier rail by friction, and when the carrier is arrested by its carrier stop, the carrier rail completes its full traverse, driven by the coulier cam and punching through the carrier friction.

J *Falling bar*, which is a stop that cushions the advance of the sinkers and dividers.

Figure 17.3(a–f) shows the movement of the knitting elements to produce one course of loops:



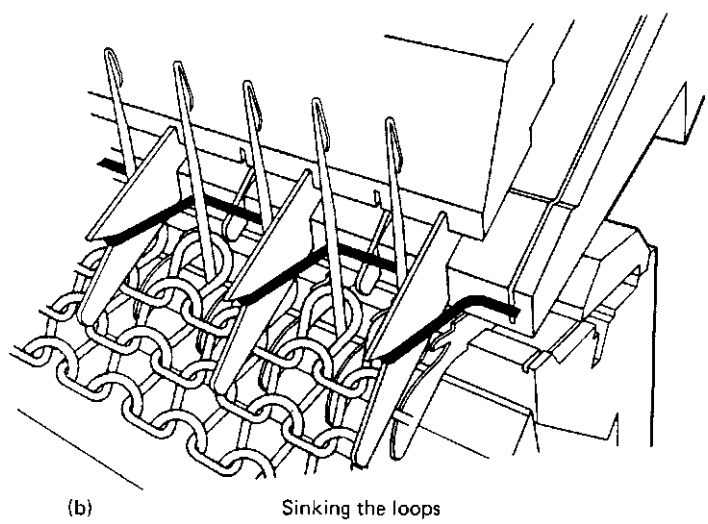
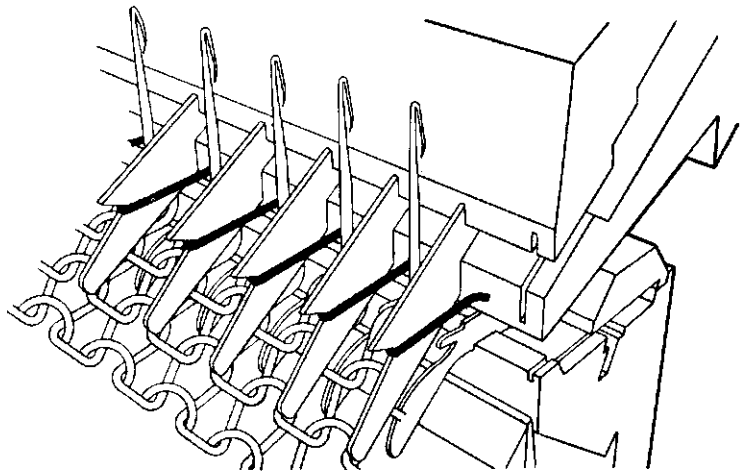
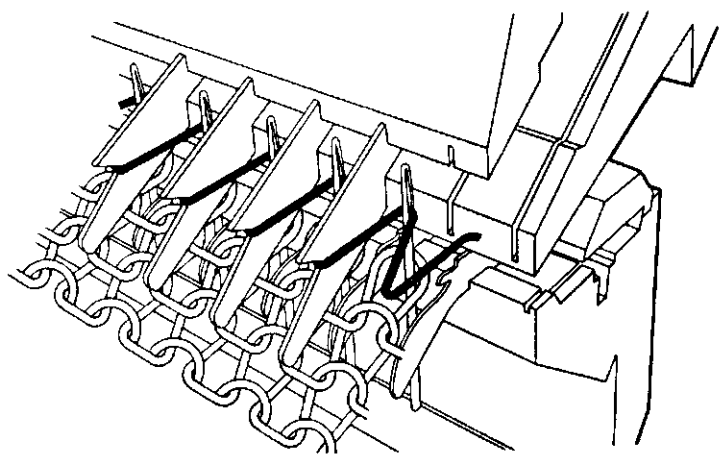


Fig. 17.3 Movement of knitting elements.



(c) Dividing the loop



(d) Pressing

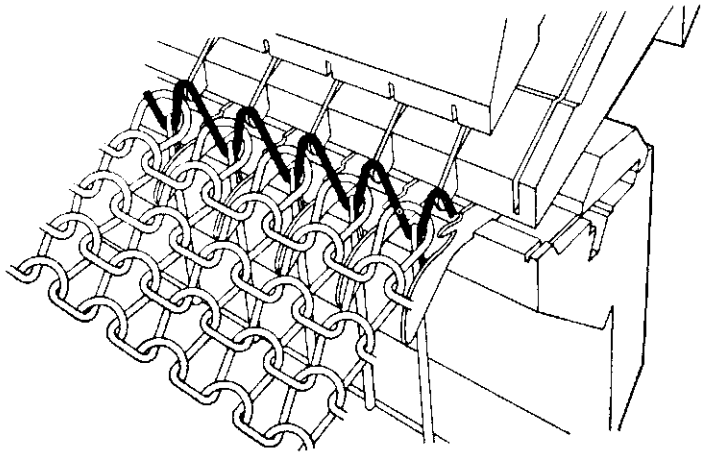
Fig. 17.3 cont'd.

Thread laying (a). The carrier moves across the knitting head, laying the yarn on the noses of the sinkers and dividers and on the beard side of the needles.

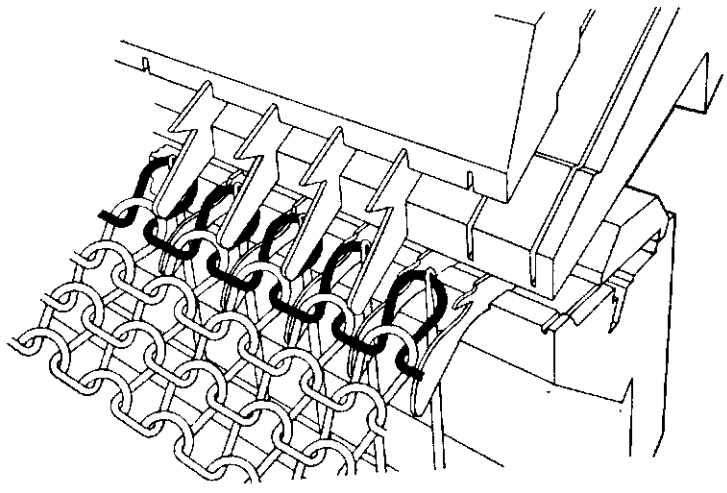
Sinking (b). The slurcock (one for each knitting head), travelling behind the carrier, contacts the jacks (Fig. 17.2); it is shaped so that each jack in turn pushes the sinker forwards to kink a loop around every two adjacent needles.

Dividing (c). The catch bar moves the dividers forwards, collectively, whilst the needle bar tips slightly outwards to allow the double loops to be divided into equal-sized needle loops around every needle.

Pressing (d) and *landing* (e). The needle bar descends, placing the new loops inside the hooks of the beards. The catch bar is now lowered so that the sinkers, as well as the dividers, are collectively controlled by it for the rest of the knitting cycle. They now start to withdraw. The needle bar moves towards the sinker verge, causing the beards to be pressed. A further downward movement of the needle



(e) Landing the loops



(f) Knocking-over the loops

Fig. 17.3 cont'd.

bar 'lands' the previous course of loops, resting on the knock-over bits, onto the closed beards.

Drop-Off. As the needle bar moves away from the pressing-edge, the sinkers and dividers withdraw so that the newly-formed course of loops drops off their noses onto the knocking-over bits.

Completion of knock-over (f). The needle bar descends to its lowest position. As the heads descend below the belly of the knocking-over bits, the old course of loops is collectively knocked-over.

Holding-Down. As the sinkers and dividers move collectively forward to hold down the fabric, the needle bar rises to the thread-laying position. The catch bar is slightly raised to release the sinkers for individual movement at the start of the next course.

On coarser gauge machines it is possible to accommodate sinkers with reinforced butts between every needle space, thus eliminating dividers and their action. Some machines have selvedge dividers with a lower forward ledge so that when the yarn carrier stops over one divider, the next divider inwards from it will be the last to take that traverse of yarn, which will slide into its specially-shaped lower throat and form a tight selvedge.

17.7 Loop transfer

Loop transference is used not only for fully-fashioned shaping on straight bar frames, but also for making lace stitch patterns and for introducing marking or drop stitch effects. The positioning and sideways traverse of the points will depend upon the effect required. This sideways traverse of the points is usually achieved by some type of screw thread (Fig. 17.4).

To produce a drop stitch, the tip of the point is turned away so that, for example, when knitting a cardigan front, the loop is collected from the centre needle towards the end of the cycle sequence and is cast-off from the point to form a ladder as a guide for cutting.

A fashioning course or '*dip*', like the knitting action, requires one revolution of the main cam-shaft, but the speed of production is lower with about 50–60 rpm being achieved during fashioning instead of 60–100 rpm during straight knitting.

Fashioning involves a set of points being positioned to cover the needles of each selvedge and the cam-shaft being shogged sideways to present a set of fashioning cams to the cam followers or lever rollers, in place of the knitting cams. The fashioning cams only take the needle bar to an intermediate height and the needles are slightly tipped to allow the points to descend to cover them. At the same time, the coulier motion that drives the yarn carriers and slurcock is disconnected.

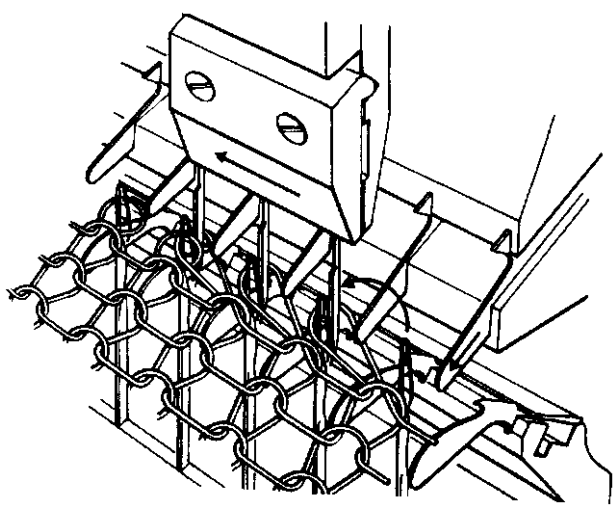


Fig. 17.4 Fashioning points.

17.8 The fashioning action

Figure 17.5(a–f) illustrates the fashioning action for either narrowing or widening:

(a) The fashioning points descend and the needle bar tips backwards to clear them.

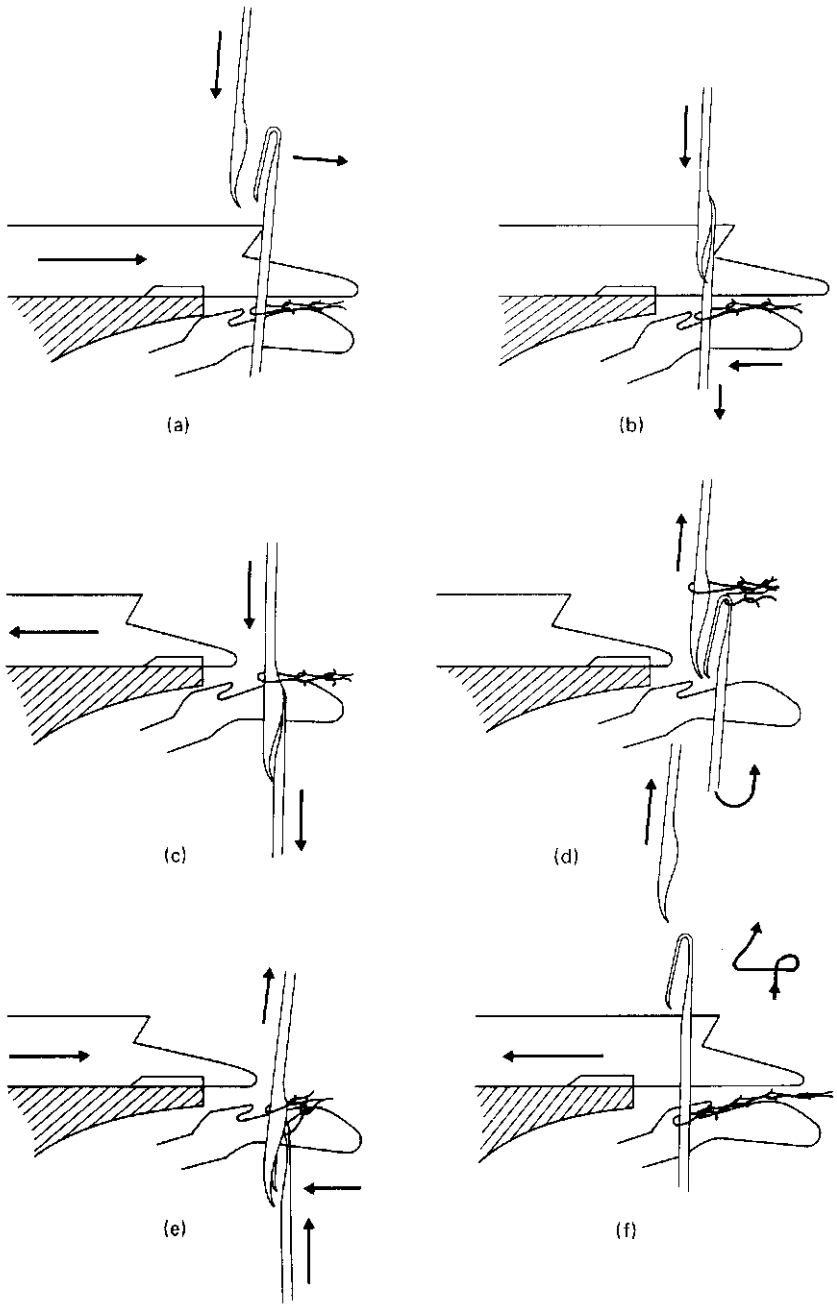


Fig. 17.5 The fashioning action.

(b) The needle bar moves towards the points, causing the beards of the needles engaged with points to be pressed and '*boxed*' or located in the grooves of the points.
(c) The sinkers and dividers, which are collectively controlled by the catch bar, retire, and the needles and points descend together below the knocking-over bits, so that the loops are cast-off onto the points.
(d) The needles and points now rise and move clear of each other so that the points can make the sideways 'fashion rack' at each selvedge, either by one needle for widening or by one, two, or four needles for narrowing.
(e) The needles and points now descend and the needles 'box' with the points again so that they receive the transferred loops. As the needles and points descend below the sinkers, the sinkers and dividers move forward to hold down the loops.
(f) Once the needles have slid up into the grooves of the points to receive the loops, the points rise to their high inoperative position. The needle bar rises, causing the transferred loops to slip down onto the stems and the cam-shaft is shogged back to the left again so that knitting can restart.

17.9 Automatic control

On straight bar frames, a ratchet selector was employed which could, through the introduction of racking pawls and a choice of rack wheels having different numbers of teeth, turn a shaft to produce (usually) two fashioning actions during each of its revolutions. Each rackwheel thus produced a different fashioning frequency. The operator, however, had to set the machine for widening or narrowing, choose the frequency, count fashionings, and terminate the action.

A control chain was later introduced that could automatically initiate the fashioning, insert a slack course, control the machine speed, and operate a chain saver. Soon, the demand for a cheaper, simpler and quicker method of changing styles or sizes led to the development of an electronic console unit, programmed from a punched plastic card film. On the card film there is provision for 23 punched-hole positions across its width, each position being scanned by a dropper pin.

To become fully automatic, control of the following was necessary: courses and fashioning; changing from widening to narrowing; initiating the rib transfer or welt turning; stopping the machine on completion of the set; racking back the carrier and stops for the next starting width; laying the yarn for the start of the next garment; controlling the machine speed; inserting the initial draw-off; and severing connecting yarns after pressing-off the previous garment piece.

17.10 The welt

The turned welt of doubled plain fabric that is produced on stocking frames is usually less acceptable for the start of a garment panel – a rib border is often preferred. Straight bar rib frames have been built but they have proved to be complex and uncompetitive against faster and more versatile V-bed rib flat machines.

A popular technique is to knit the rib borders or cuffs on a specific-purpose

V-bed flat machine and then to transfer them, using the last required course, loop-by-loop onto the points of a special '*topping-on bar*' ('*running-on*'). The fabric is then transferred onto the needles of the straight bar frame ('*barring-on*'). Six ribs may be transferred at a time but only the topmost is placed on top of the knocking-over bits and underneath the sinkers, ready for knitting the plain onto it. It is a common practice to employ '*doubling*', i.e. to have more wales in the rib than in the plain so that, during running-on, two rib loops are sometimes run onto the same points. In this way, the rib is in a more relaxed state and gives a better fit.

Rib transfer has been automated by using a conveyor to transport loaded rib transfer bars from one end of the machine to the individual knitting heads (Fig. 17.1). Each bar is transferred to the holders of the automatic rib transfer mechanism, in readiness for rib transfer at the start of the next garment cycle. Arms then advance the rib transfer holder and present the new rib to the needles. Empty bars are replaced on the conveyor, which automatically returns them to the loading station for refilling.

This operation has reduced standing time from an average of five minutes to a matter of a few seconds and has enabled the knitter to supervise more knitting heads. At the start of knitting on the straight bar frame, an initial draw-off engages the ribs or welt rods whilst sufficient courses are knitted for them to be engaged by the main draw-off arrangement.

Special V-bed flat machines have been designed for automatic rib knitting and magazine bar loading. A four-head machine can knit an average body rib in 1 min 25 sec at 60 courses per minute (cpm), or in less time without doubling. The machine is pre-programmed to knit a cotton course, which is taken by the hook-up bar of the take-down mechanism, followed by the tubular welt and rib in 1×1, 2×1 or 2×2.

On completion of the rib, a separate mechanism actuated by a cam on the main cam-shaft causes the front bed loops to be transferred to the back bed. A transfer bar then descends to collect these loops and transfer them onto the points of the magazine bar. A maximum of sixteen ribs can be accommodated. Doubling on every seventh needle on a 14 npi machine can be achieved, if desired, for a 21 G garment.

17.11 The rib-to-plain machine

Despite automation in transferring rib border fabric from the V-bed flat machines onto straight bar frames, the operation requires the co-ordination not only of the fabric but also of extra labour and machinery, and involves additional factory space. The rib-to-plain technique [4] pioneered by *S. A. Monk* tried to overcome these problems. It involves a straight bar frame that can knit an integral rib border start with a less complex mechanical action than that of the conventional rib frame. During rib border knitting, an ancillary set of horizontally-arranged latch needles ('*machine needles*') co-operates with only the even needles of the vertical bearded needle bar ('*frame needles*'). At the commencement of the fully-fashioned panel, the machine needles transfer their loops onto the re-introduced odd frame needles so that a full set of plain needles is in action (Fig. 17.6). Unfortunately, this and the Bentley Cotton CRP were capitally expensive and complex, and never seriously challenged the existing method of automatic rib transfer.

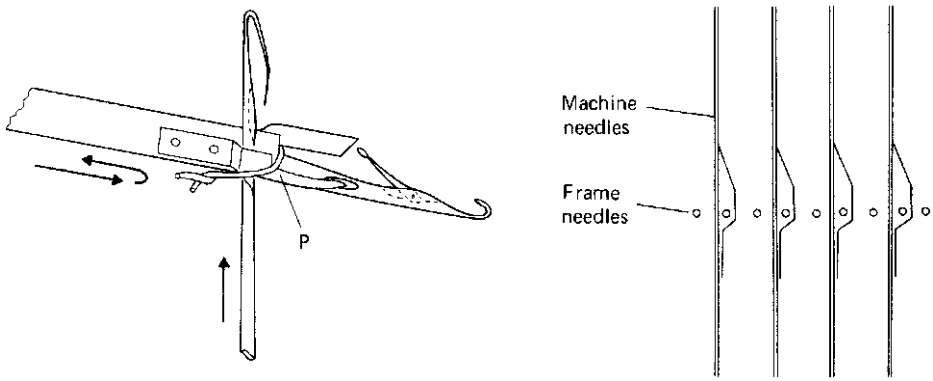


Fig. 17.6 Rib to plain.

17.12 Patterned structures

Although noted for the production of plain, classic, fully-fashioned knitwear, the straight bar frame is capable of utilising stitch patterns whose scope is dependent upon the particular machine's facilities. These may include lace, coloured designs, tuck stitches and combinations of these stitches [5].

Lacing points operate in a similar manner to fashioning points. Sets of points fixed in boxes will produce symmetrical effects, whereas individually-controlled points may be used to produce motifs. Between transfer actions, the points are racked sideways for re-positioning. Lace effects are determined by the type of pattern control, the number and type of points available, the point set-out, the direction and extent of the transfer movement, and the number of plain knitted courses between transfer actions [6].

Cable stitch designs in two-cord cross-over of three wales are possible on some machines, with the cord being emphasized by removal of a number of needles on either side of it, leaving a gap up to the adjacent wales.

Coloured designs are achieved with a number of carrier rods having different coloured yarns. The designs range from simple horizontal stripes to plating and elaborate intarsia patterns. One machine also uses guides in order to make *tartan designs* [7].

Tuck stitch designs are generally achieved by replacing the leading pressing edge of the sinker bed with individual presser bits, one for each needle beard. The presser bits are carried on slides that receive their forward pressing movement from steel strips on a tambour (drum). Punched positions in the steels do not advance their slides and thus produce tuck stitches. After each course, a different selection may be produced by racking the drum.

17.13 The challenge of latch needle machinery

Few new straight bar frames are now being built. Instead, existing machines are being 'recruited' (up-dated) to meet the challenge of the V-bed machines, with their ever-improving patterning and shaping facilities. New frames tend to be in fine

gauges, with patterning capabilities not easily achievable on V-bed machines, such as 30 gauge (30 E) intarsia [8].

The *Steiger Vesta Multi* is a multi-head V-bed flat machine designed along simple lines to knit shaped garment pieces in rib or plain. The machine has four double-system knitting heads, each with a width of 106 cm (42 inches), and between 8 and 16 individually-driven yarn carriers, in a machine length of only 703 cm (23 feet). The bed tricks have only two elements; a retracted stitch transfer needle and a spring-less jack. Bi-stable mono selectors individually select the needles.

Each cam system has three-way selection and stitch transfer facilities in both directions, independently of direction of carriage traverse. The cam carriage is open and yarn feed is direct. The take-down is positioned directly below the loop-forming area so that only a few or all the needles can knit on the same setting. After narrowing-down to only a few needles, it is possible to widen-out to the full-width, knitting a short interlock structure sequence in order to start a new fabric piece.

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18

Flat knitting, basic principles and structures

18.1 History

The first *flat bar machine* (Section 8.4.2) was demonstrated in 1862 and patented in 1865 by the *Rev. Isaac Wixom Lamb*, an American clergyman. He later changed the arrangement to the inverted V-bed shape patented by *Eisenstuck*.

18.2 The two types of flat machine

Two types of flat machine evolved. The widely used *V-bed rib* machine and the slower, more specialised *flat bed purl* or *links-links machine.*

V-bed machines have two rib gated, diagonally-approaching needle beds, set at between 90 and 104 degrees to each other, giving an inverted V-shape appearance.

Flat bed purl (links-links) machines have horizontal needle beds. They have been employed mainly in knitting simulated hand-knitted constructions of a speciality type, such as cable stitch, basket purl, and lace patterning. They use *double-headed latch needles* that are transferred to knit in either of two directly opposed needle beds. The non-knitting hook is controlled in the manner of a needle butt by a *slider* that hooks onto it. There is a set of sliders in each needle bed whose butts are controlled by the traversing cam-carriage to produce knitting or transfer of the needles (see Section 7.5).

These complex and slow machines are no longer built because the modern electronic V-bed machines can knit all the links-links designs using the facilities of rib loop transfer and needle bed racking.

Early *intarsia* machines employed a different approach, using only one needle bed to knit solid colour designs. Now, however, many modern V-bed machines have intarsia-patterning facilities and are no longer restricted to geometrical designs because the mechanically-controlled carrier stops have been replaced by more versatile electronic controls.

18.3 Flat machine gauges

Flat machines (Fig. 8.2) are normally gauged on the *English system* (*E*) of *needles per inch* (npi). The *Metric system*, which is based on the distance in tenths of a millimetre from the centre of one needle to the next, is rarely used. The latter is a direct system, with a higher gauge number indicating a coarser gauge – the opposite of the English system.

Generally, flat machine gauges range from E 5 to E 14, with the main gauges being 5, 7 and 10, but there are machines as coarse as E $2\frac{1}{2}$ and as fine as E 18 or even finer now being built.

NB: All flat machines can be *half-gauged* by removing every alternate needle; thus, an E 10 gauge machine will become an E 5 gauge. Also, different needle hook sizes are available, and gauge conversion by changing needle beds is possible.

18.4 Conversion from Cottons Patent to V-bed gauge

To convert from Cottons Patent gauge (G*, needles per $1\frac{1}{2}$ inch) to V-bed gauge (E, needles per inch)

1 Convert from $1\frac{1}{2}$ inches to 1 inch needle bed width.
2 In the gauge range G9 and below, reduce the resultant E gauge by 1. Above G 9 reduce the resultant E gauge by 2. This is to fit commercial practice in flat knitting, where a slightly coarser gauge is preferred.

Example: Convert G9 and G21 fully-fashioned (needles per $1\frac{1}{2}$ inches) to V-bed flat E gauge (npi)

$$G9 \times 2/3 = 6$$
$$6 - 1 = E5$$
$$G21 \times 2/3 = 14$$
$$14 - 2 = E12$$

18.5 Knitting widths

Strapping machine needle bed widths tend to range from about 14 to 50 cm (5.5–20 inches); hand-operated garment-width machines range from about 80 to 120 cm (31–47 inches); power-driven automatic garment length machines range approximately in width from about 66 cm to 240 cm (26–95 inches).

Wider '*blanket width*' machines are approximately 244 cm (96 inches) wide, to knit unshaped garment pieces for cut-and-sew knitwear.

Narrow bed '*compact*' machines are approximately 127 cm (50 inches) wide for fashion shaped knitwear.

For *integral garment* knitting, the approximate width is 183 cm (72 inches).

* 'G' is sometimes expressed as 'gge'. For example, G 9 = 9 gge.

18.6 Yarn counts

An indication of an approximately suitable count for a flat machine may be calculated using the formula:

$$\text{worsted count (NeK)} = \text{gauge}^2 / 9$$

The following are typical NeK count ranges for particular E gauges:

12 npi – 2/26's to 2/42's
8 npi – 2/14's to 2/22's
5 npi – 6/14's to 6/18's
2 npi – 8/7's to 8/9's

It can be seen that a characteristic of the flat machine is the large number of ends of yarn that may be knitted at the same time. However, if light-weight structures are required, the number of ends may be much fewer (See multi gauges, Chapter 19).

18.7 Simple hand-manipulated V-bed rib flat machines

Figure 18.1 shows a cross-section of a simple hand-powered and manipulated V-bed rib flat machine. The trick walls are replaced at the needle bed verges by fixed, thinner, polished and specially shaped *knock-over bit edges*. In rib gating, a knock-over bit in one bed will be aligned opposite to a needle trick in the other bed. During knitting, the edges of the knock-over bits restrain the sinker loops as they pass between the needles and thus assist in the knocking-over of the old loops and in the formation of the new loops. The takedown tension and the needles in the other bed help to hold the old loops down on the needle stems as the needles rise to clear. Many modern electronic flat machines have movable knock-over and holding-down elements, which assists in the knitting of shaped and single-bed structures.

On hand flat machines, after the first or *set-up course* of rib is taken by the needles, a *fabric comb* is hand-inserted into it, upwards from under the needle beds, so that the eyelet holes of the comb protrude above the course. The comb wire is then inserted through the eyelets, over the set-up course, so that the comb is suspended from the course, and a takedown weight is attached to it.

The *cover plate* is a thin metal blade, located in a slot across the top of the needle bed tricks. It prevents the stems of the needles from pivoting upwards out of the tricks as a result of the fabric take-down tension drawing the needle hooks downwards, whilst allowing the needles to slide freely in their tricks. The plate can be withdrawn sideways out of the needle bed to allow damaged needles to be replaced.

Supporting the tail of each needle is a *security spring* that fits over the lower edge of the needle bed. When the spring is pushed fully into position, it locates into a groove on the under-surface of the needle bed. The butt of the needle that it supports is then aligned with the knitting cam track on the under-surface of the traversing cam-carriage. When a needle is not required to be in action, its security spring is not located in the groove, so that the needle is nearer to the lower edge of the needle bed and its butt misses the traversing cam-carriage.

On machines employing jacquard selection, the function of the security spring is replaced either by the thrust of a jacquard steel onto the tails of the elements or by

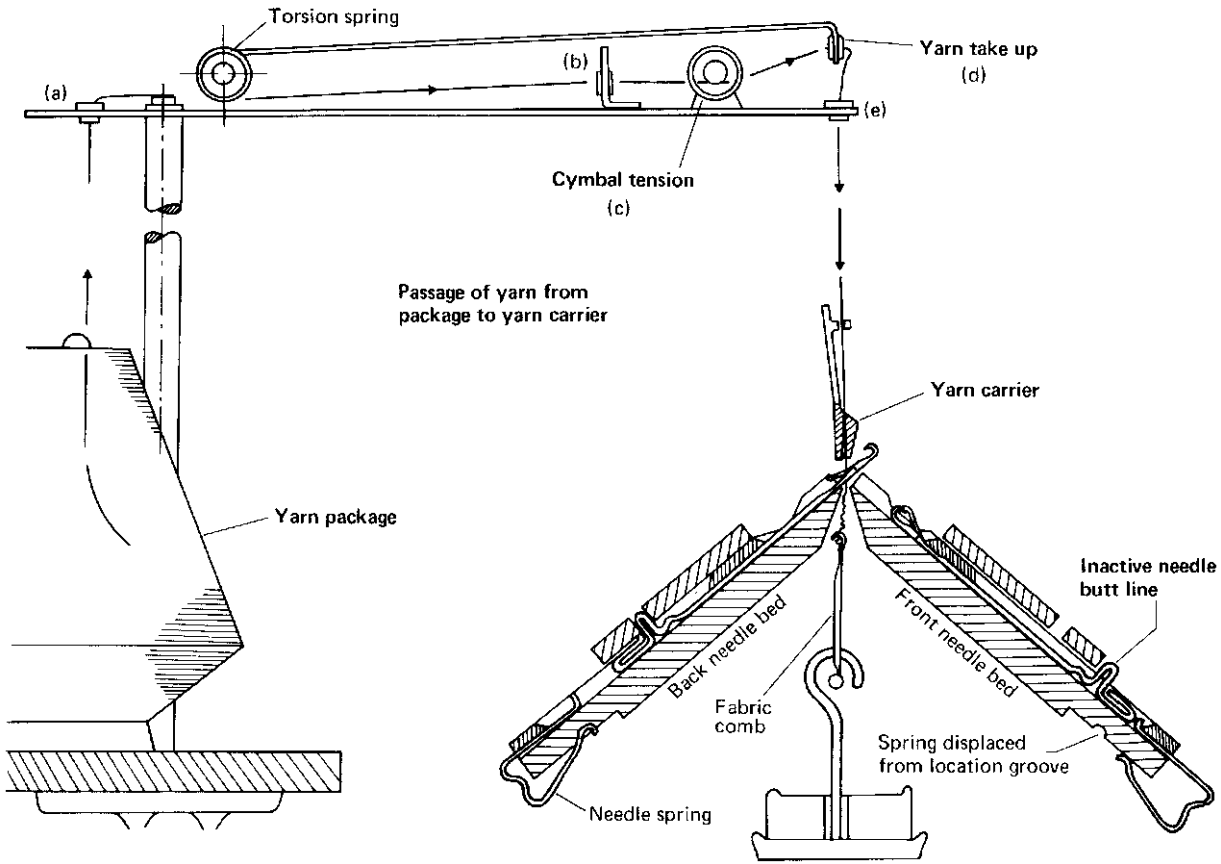


Fig. 18.1 Passage of yarn from package to yarn carrier.

the raising or depressing of the knitting butts into the tricks, in order to position the needle butts for each carriage traverse.

Latch opening brushes are attached to the cam-plates of both needle beds to ensure that the needle latches are fully opened. The supports of the brushes are adjustable to ensure precise setting of the bristles relative to the needles.

The cam-carriage either slides, or runs on ball-bearings or wheels, along *guide rails*, one of which is fixed over the lower end of each needle bed. It is propelled either by hand or from a motor-driven continuous roller chain or rubber belt.

Each *yarn carrier* is attached to a block which slides along a bar, which, like the carriage guide rails, passes across the full width of the machine. The carrier bar may be of the double prism type so that yarn carriers may be attached to slide along both the front and the back surfaces. The yarn carriers are picked up or left behind by the carriage, as required, by means of driving bolts or pistons that are attached to, and controlled either manually or automatically from, the carriage bow. There is a bolt for each carrier bar track that, when lowered, entrains with a groove in the shoulder of a yarn carrier block. Stop plates having inclined edges are positioned on the carrier bars at the knitting selvedges. On contact with a stop plate, the base of the bolt rises and is lifted out and disconnected from the groove of the carrier block so that the carriage continues its traverse without that carrier.

Two levers are usually provided, one at each end of the needle bed. One is for *racking the back needle bed*, to change the gating of the needle beds for changes of rib set-out or rib loop transfer. The other is to *open the gap* between the needle beds for easier access to the knitted fabric hanging from the needles.

18.7.1 The cam system of the V-bed hand flat machine

Figure 18.2 illustrates the knitting action of a V-bed hand flat machine and Fig. 18.3 shows the underside of the cam-carriage and the cams forming the tracks that guide the needle butts through the knitting system. The single knitting system cam-box is symmetrically designed for knitting a course of loops on both the front bed and back bed needles during a right-to-left traverse and a second course during the return left-to-right cam box traverse.

The needle butts will enter the traversing cam system from the right during a left-to-right carriage traverse and from the left during a right-to-left traverse. For each needle bed there are two raising cams (R), two cardigan cams (C) and two stitch cams (S).

In the direction of traverse, the leading raising cam is responsible for knitting and the trailing raising cam acts as a guard cam. The leading stitch cam is raised out of action and the trailing stitch cam is in operation. In the reverse direction of traverse, the roles of the two raising cams and of the two stitch cams are reversed.

A raising cam lifts the needle to tuck height, but if the cardigan cam above it is in action the needle is lifted to full clearing height. Thus, the cardigan cam is taken out of action if a tuck stitch is required. To produce a miss stitch, both the raising cam and the cardigan cam are out of action. To produce a course of tubular plain knitting, a pair of raising cams that are diagonally opposite each other in each bed (RL and RR) are out of action.

The arrangement as shown in Fig. 18.3 is referred to as a *knitting system*. A *single system* machine will knit one course of rib in one traverse whereas a *double system* machine will knit two courses of rib per traverse. Sometimes a set of cams in one bed is referred to as a *lock*.

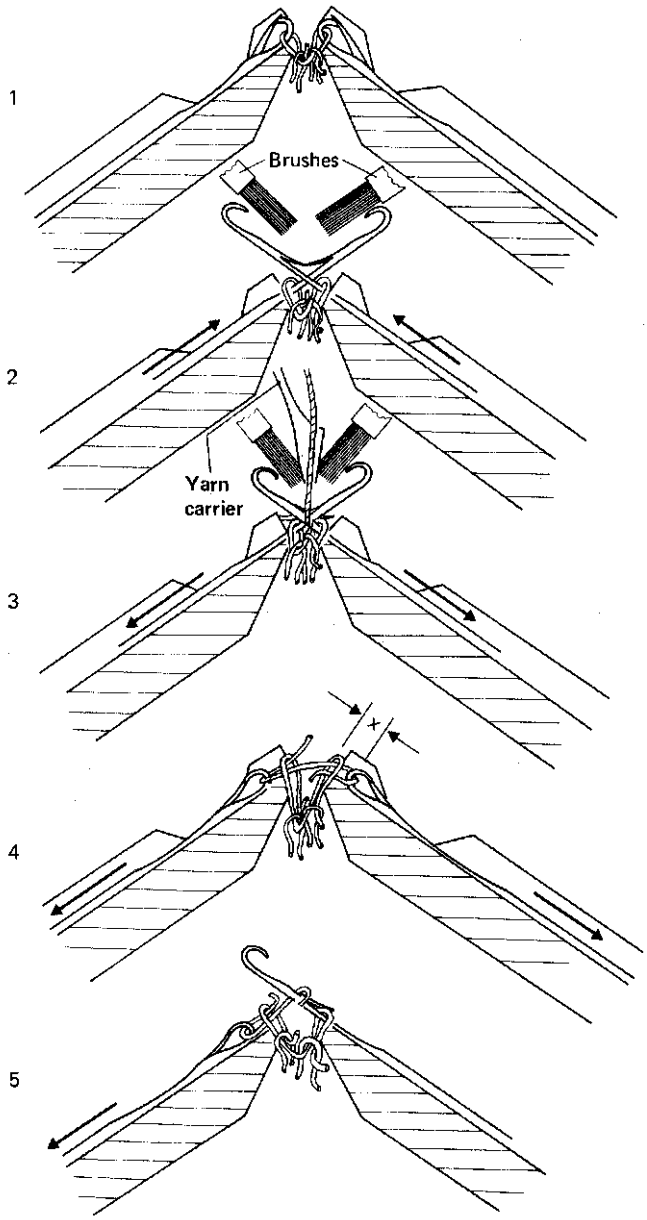


Fig. 18.2 Knitting action of V-bed flat machine.

18.7.2 The knitting action of the V-bed hand flat machine

Numbers 1 to 4 below correspond to the numbers in the knitting action illustrations (Fig. 18.2), assuming a carriage traverse from left-to-right. Similar positions may be plotted for the return traverse, using the cams given an (L) designation to provide the positive movements.

1 *The rest position*. The tops of the heads of the needles are level with the edge of the knock-over bits. The butts of the needles assume a straight line until

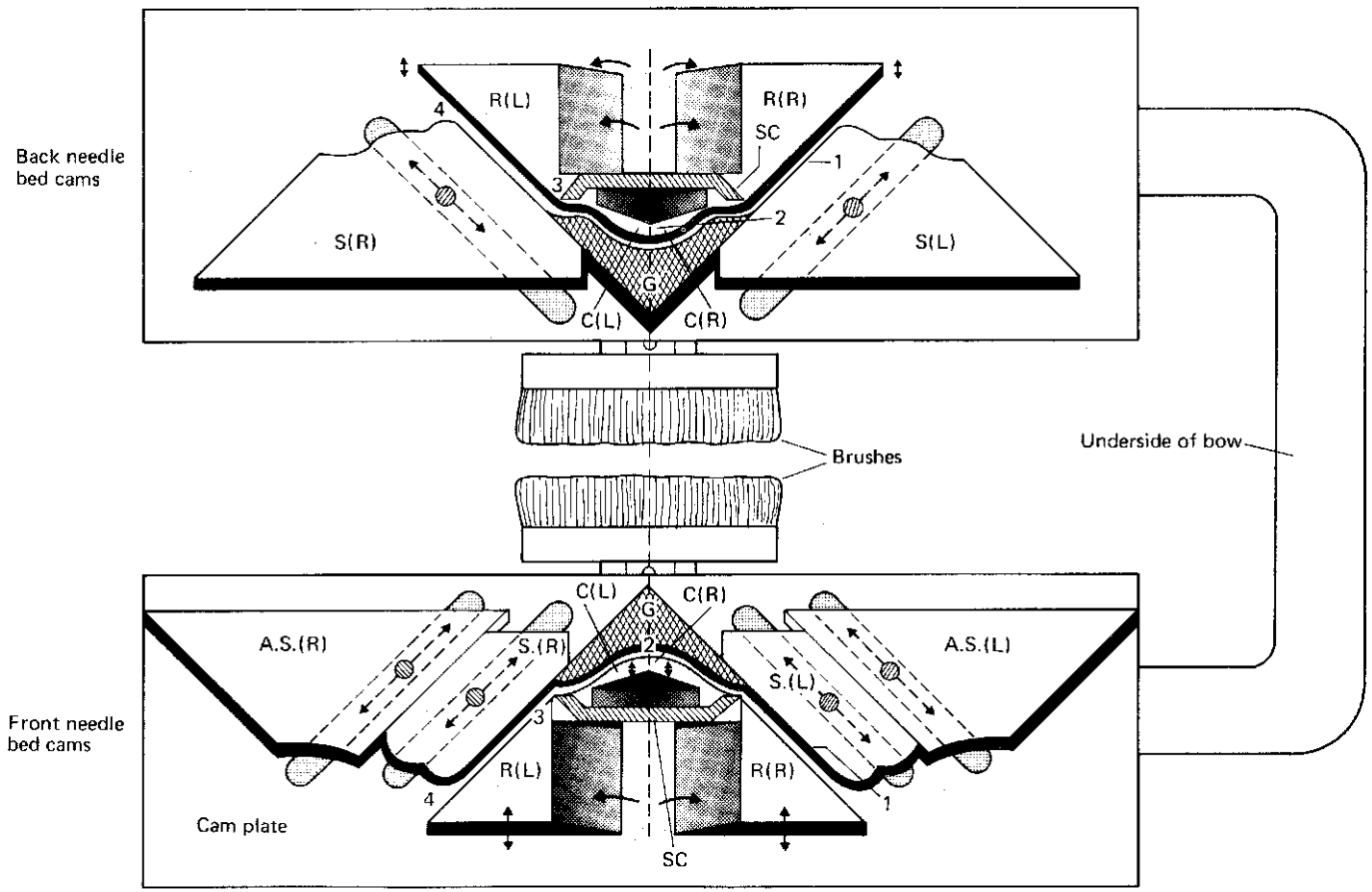


Fig. 18.3 Cam system of simple hand flat.

contacting the raising cams R (R) because the leading stitch cams S and AS (L) are lifted to an inactive position. The lifting action is an *alternating action* that always lowers the trailing stitch cams and raises the leading stitch cams in each system as the traverse commences. This action prevents needles from being unnecessarily lowered and a strain being placed on the old loops prior to the start-up of the knitting action.

2 *Clearing.* The needle butts are lifted as they contact the leading edge of cams R (R), which raises the needles to 'tucking in the hook' height with the under-surface of cams S (L) acting as guard cams. The needles are lifted to full clearing height as their butts pass over the top of cardigan cams C (R) and C (L).

3 *Yarn feeding.* The yarn is fed as the needles descend under the control of guard cam (G). The required loop length is drawn by each needle as it descends the stitch cam S (R).

4 *Knocking-over.* To produce *synchronised knocking-over* of both needle beds simultaneously, the stitch cam S (R) in the front system is set lower than the auxiliary stitch cam AS (R), so that the latter is rendered ineffective. If, however, *delayed timing of the knock-over* is employed, knock-over in the front bed will occur after knock-over in the back bed. In this case, stitch cam S (R) is not set as low as AS (R) (Number 5 in Fig. 18.2) so that the depth setting of the latter cam produces the knock-over action. Delayed timing is only normally used on gauges finer than 8 npi and cannot be used for broad ribs.

18.8 Stitch cam settings

The stitch cams are located in slots by studs and they may be raised or lowered to a different setting position by moving the stud along the slot (Fig. 18.3). Unless the rate of yarn feed is controlled, the setting of the stitch cam at knock-over will determine the *stitch length* because it controls the distance the head of the needle descends below the knock-over bit edge from the rest position. The alternating stitch cam settings are indicated by pointers on a calibrated scale on the outside of the cam-plate.

On hand flats, the adjustment of the settings is obtained by hand controls, whilst on modern electronically-controlled flats, each stitch cam is raised and lowered by its own *step motor*, so a wide range of stitch lengths can be achieved during the knitting of a garment.

18.9 Spring-loaded cams

Raising cams (R) and cardigan cams (C) (Fig. 18.3) are of the spring-loaded type that can be depressed into the under-surface of the cam-plate against the action of a spring. The leading edge of a leading raising cam is straight so that it causes the butts to follow its profile. However, the trailing inner edge of the cam, which is the leading edge when that cam is trailing, has a gently sloping edge. Needle butts deliberately not raised by the leading cam thus ride up the trailing cam, depressing the cam into the cam-plate and then follow an undisturbed path across its face. After the butts have passed, the cam springs outwards from the cam-plate to resume its active position for the return traverse.

On hand flat machines, the cams are often of the sinkable setting type so that they can be set either:

1 *fully in action* out from the cam plate so that they act on every needle butt,
2 *partly withdrawn* into the cam-plate so that they miss the low (short) butts, which pass undisturbed across their surface, or
3 *fully withdrawn* into the cam-plate so that all butts pass undisturbed across their surface.

The standard set-out when using different lengths of butts is two long and one short in each bed, with the short butt centred between the two long butts in the opposite bed. This enables changes from 1×1 to 2×2 rib knitting to occur.

Changes of cam settings are achieved by the movement of controls that are placed on the outside of the cam-plate. In the case of mechanical automatic power flats, these controls can consist of metal push slides, each corresponding to a different cam whose sideways movement produces the required change of cam setting. At each end of the machine is a contact post containing striking plates, aligned to contact the slides as the carriage reaches the end of its traverse so that the cams may be set for the return traverse. Control of the plates is achieved from the main garment (machine) control of the machine.

Electronic machines have continuous electronic contact with the cam carriage and therefore do not require the cam slide arrangement.

On hand flat machines it is useful to have split cardigan cams so that a different setting can be achieved in each direction without having to stop the carriage at the end of each traverse.

The automatic machine can change the cam settings for each traverse; split cardigan camming is unnecessary and these machines usually have a single cardigan cam for both traverse directions.

18.10 Two or more cam systems

Although hand flat machines have single cam system carriages, many automatic power flat machines have two, three or four cam systems, each with a complete set of knitting cams arranged side by side in the same cam-plate each working with a separate yarn carrier. Thus, in one cam carriage traverse, as many courses as there are cam systems can be knitted.

However, compared with a single system machine, the rate of carriage traverse is often reduced, firstly because of the heavier carriage, and secondly because it is longer and must traverse further, thus making the machine longer. There is also a problem of vertical floating threads at the selvedge edges of the fabric. Compact cam design and machine construction, together with the use of lightweight alloys and automatic thread cutters, have largely overcome these problems.

18.11 Split cam-carriages

Another useful development is the *split cam-carriage*. For example, a double system cam carriage operating across the full width might also be split into two single system (2×1) cam-carriages, each covering half the needle bed or both co-

operating in the knitting of wedge-shaped or other complex designs. Split cam-carriage machines have been built with a total of two (2×1), four (2×2), six (2×3), and even eight (2×4) systems.

18.12 Direct and indirect yarn feed

On mechanically-controlled flats, it is necessary to join the front and back needle bed cam-plates with a *bow* or *bridge* in order to drive the cam-carriage as a single unit. However, the traversing bow necessitates an unbalanced diversion of the yarn path down to the needles. This in turn produces unbalanced yarn tension, depending on whether the cam carriage is traversing towards or away from its yarn supply.

On some of the latest electronically-controlled power flats, the bow has been eliminated by driving the front and back needle bed cam-plates separately but in unison, thus giving the cam carriage an open construction. Additionally, the yarn carriers are no longer mechanically connected to the cam-carriage and are each individually driven. They need not be synchronised with the carriage traverse. A yarn carrier can be selected either for knitting, plating or laying-in. Precise placing is achieved both for selvedge shaping and intarsia, where swing yarn carriers are no longer needed (Chapter 19, *Tsudakoma*).

Direct yarn feed is often used on hand flat machines as it allows weak yarns to be knitted because the yarn is supplied directly down from the centrally-positioned yarn tensioner to the reciprocating yarn carrier, so that the tension is kept fairly constant at a minimum level. With this arrangement, the carrier must always remain on one side of the carriage bow, for example on the right, and not pass underneath it, as the yarn path would be disturbed. Yarn carriers can therefore only be collected and left by the carriage at the right side of the machine so that only double course striping can be produced. The pick-up device for the yarn carrier is located on the outside of the low bow.

Indirect yarn feed is used on power flat machines, and is characterised by a high carriage bow passing over the carrier bars, with the yarn path parallel to them, from guide eyes at the end of the machine to the yarn carriers. The yarn is deflected in its downward path from the yarn tensioners across to the guide eyes, thus increasing the tension on the yarn and tending to cause fluctuations depending upon whether the carrier is traversing away from, or towards, the yarn guide eye end of the machine. However, it does enable the yarn carrier to be picked up or left on either side of the machine, using plungers that operate down onto the carrier blocks from the underside of the carriage bow.

18.13 Yarn carrier arrangement

The yarn carriers are arranged to slide on both sides of double prismatic guiding bars and there are usually six or seven carriers operating on two or three double bars. When two carriers operate on the same track of the same bar, it is essential to arrange the sequence so that if the two carriers are deposited on the same side, the one nearest to the cam-carriage will be the one first required to traverse back in the opposite direction.

There are two methods of entraining carriers with cam systems on double system

machines: uncrossed and crossed. With the *uncrossed* arrangement, the same yarn carriers operate with the same cam systems in both directions of traverse. This simplifies the control and is essential when two carriers are on the same track, but it causes problems with vertical yarn floats at the selvedges because the yarn with the leading cam system will finish the first course but will not knit the return traverse.

With the *crossed* arrangement, one yarn carrier will always be entrained with the leading cam system and the other with the trailing cam system, so that if the carriers have different coloured yarns, each will knit alternate courses.

In carrier positioning and traversing for jacquard (Fig. 18.4), the yarn carriers

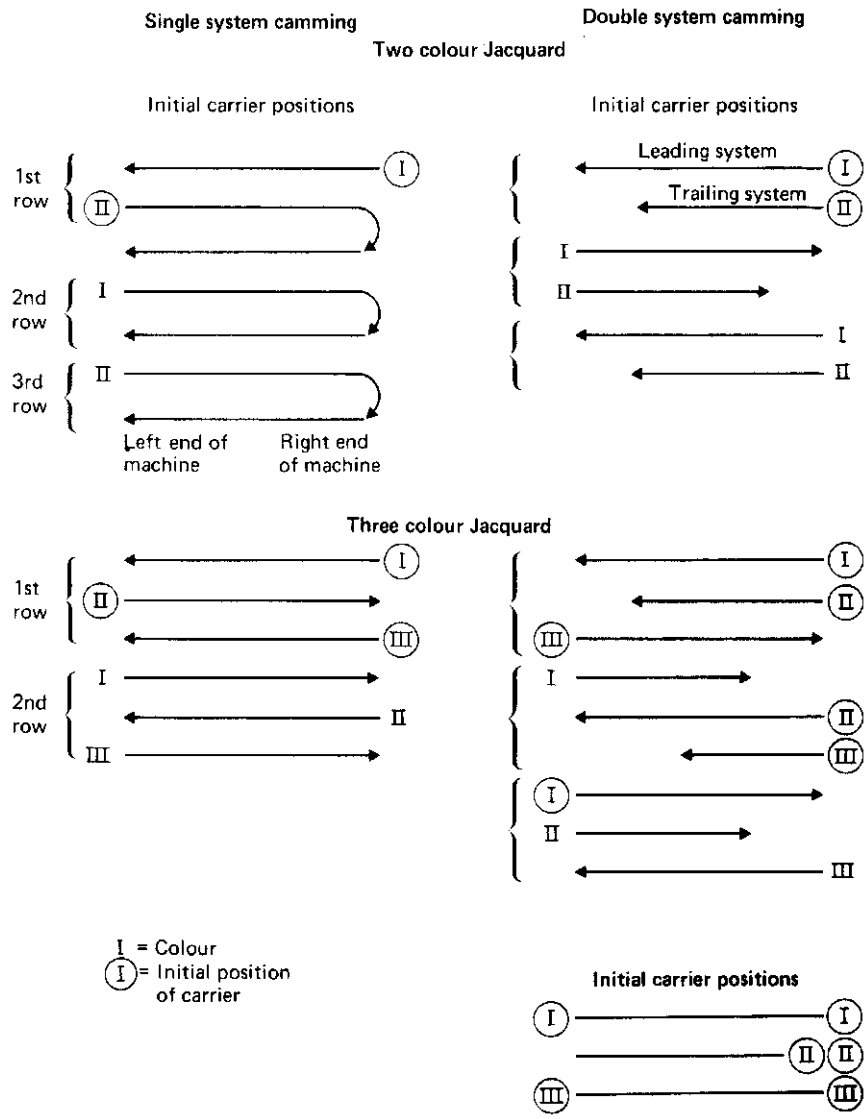


Fig. 18.4 Yarn carrier positioning.

must be carefully positioned initially in order to keep their number to a minimum whilst ensuring that empty traverses (without knitting a course) are avoided whenever possible, as they reduce productivity. By drawing a plan of traverses and colours, and indicating each time a new yarn is picked-up, the initial positions can soon be established. For double system knitting in two- or three-colour jacquard, each system will require as many carriers as there are colours, but two carriers of the same colour can use the same track. Only in the case of single-system two colour jacquard is it necessary to alter the sequence of coloured courses. This is because, after their first course, each colour is knitted at two consecutive courses.

18.14 Typical structures knitted on flat machines

Cardigan stitches are two-course repeat tuck rib knitwear structures, widely used in the body sections of heavy-weight stitch-shaped sweaters. The tuck stitches cause the rib wales to gape apart so that the body width spreads outwards to a greater extent than the rib border. The tuck loops increase the fabric thickness and make it heavier in weight and bulkier in handle, although the rate of production in rows of loops will be less than for normal 1×1 or 2×2 rib. The greater the proportion of tuck to cleared loops, the heavier and wider the finished relaxed structure (see Fig. 16.13).

In the production of a knitted stitch, the leading raising and cardigan cams for that bed and direction of traverse must be in action, whilst for a tuck stitch, the raising cams remain in action but the cardigan cam is taken out of action. It is important to arrange the camming for the needle beds so that, at the start of the traverse when tucking, the first needle is tucking and the last needle in action is in the opposite bed and is thus knitting. If the last needle is tucking, the selvedge tuck loop will withdraw from the needle hook as the reverse traverse commences.

Half-cardigan or *royal rib* (Fig. 18.5) is produced on a 1×1 rib base, having tuck loops on one bed only at alternate courses. It is therefore an unbalanced structure with a different appearance on each side and with twice as many cleared loop courses per unit length on the all-knit side as on the tuck loop side. On the all-knit

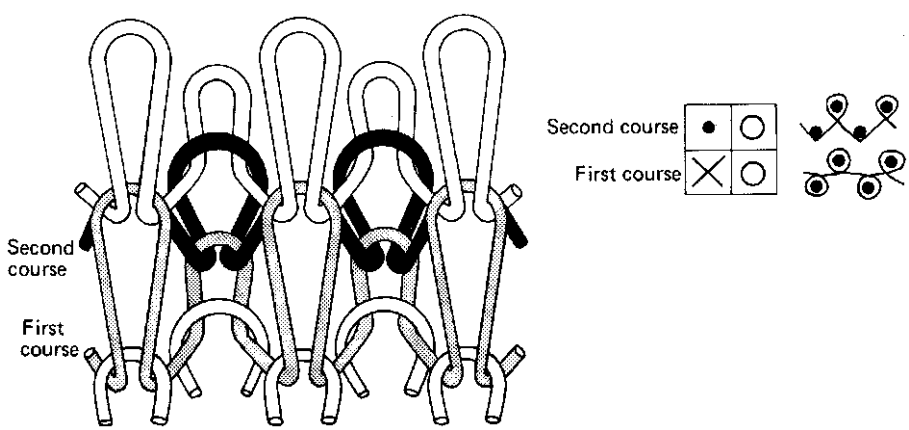


Fig. 18.5 Half-cardigan loop structure.

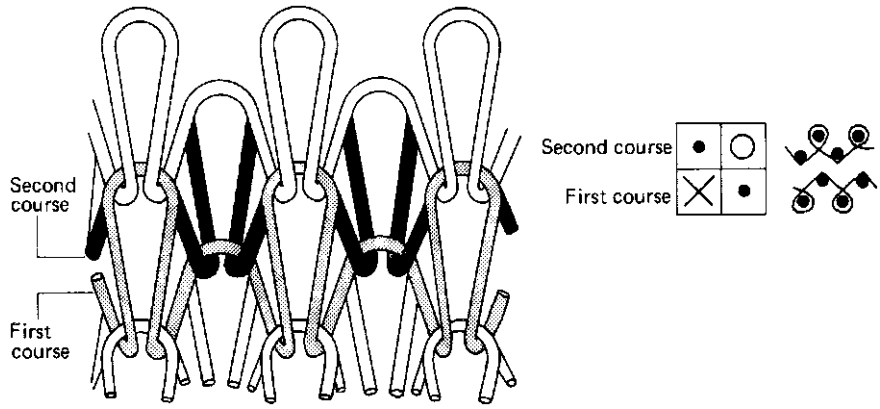


Fig. 18.6 Full cardigan.

side, one course of loops has very large and rounded loops. This is because they receive yarn from the tuck loops on the other side. The other course of loops on this side has, in contrast, extremely small and insignificant loops because they are robbed of yarn by the elongated held loops on the other side, which consists only of held loops as the tuck loops lie behind them.

A two-tuck variation of half-cardigan, based on a four course repeat with each repeat sequence repeated at two consecutive courses, is useful as it produces rounded loops on the knit side as a result of yarn passing into it from the second tuck course.

Full-cardigan or *polka rib* (Fig. 18.6) consists of one course of loops knitted on the front bed and tucks on the back, and the second course with the sequence reversed, thus producing a balanced 1×1 tuck rib structure with the same appearance on both sides. If different coloured yarns are knitted at alternate courses, a '*shot rib*' will be produced which in the relaxed state will show one colour on one side and the second colour on the opposite side.

In open width, a 1×1 rib fabric will relax by about 30 per cent, half-cardigan by only 5 per cent, and full-cardigan will show no width shrinkage compared with its original knitting width.

To knit half-cardigan on a single-system hand-flat, one of the four cardigan cams is taken out of action so that in one direction of traverse a tuck stitch will be knitted on one needle bed only.

To knit full-cardigan, diagonally opposite pairs of cardigan cams are taken out of action so that in one direction of traverse the front needle bed will tuck and in the return traverse the back needle bed will tuck.

The 2×2 rib version of half-cardigan is termed *fisherman's rib* and the full-cardigan version is termed the *sweater stitch*.

18.14.1 Racked rib structures

The V-bed flat machine is capable of knitting a unique range of racked rib structures (Fig. 18.7), based on the facility of racking one needle bed by one or more needle tricks past the other needle bed, either towards the right or the left as and when required. Usually, the needle set-out is 1×1 rib, or a modified version with

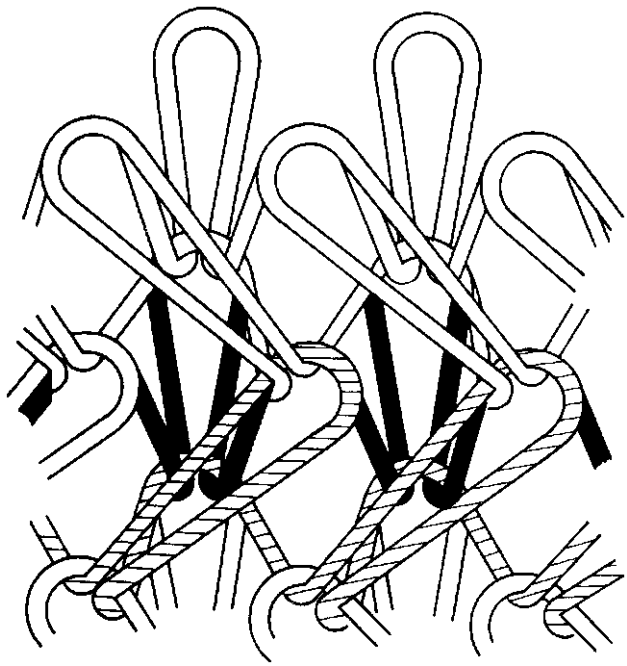


Fig. 18.7 Racked rib.

selected needles taken out of action, and a knitting sequence of half- or full-cardigan [1].

The *basic principles of racked rib structures* are as follows:

1 A loop on a needle in one bed must be racked past a loop from the same course on a needle in the other bed. The structure must therefore be rib based.
2 After an all-knit course of 1×1 rib, the 45 degree angle of inclination of a single needle rack would be shared by the loops in both beds and the appearance would be insignificant. A two-needle rack is thus required.
3 After a course with tucking on one bed and knitting on the other, a single-needle rack will produce a 45 degree inclination on the knitted loop side, irrespective of which needle bed was racked (Fig. 18.7). The open legs of the tuck loops resist the effect of racking so the tension only inclines the knitted loop side of the course. Half- or full-cardigan sequences (Figures 18.5 and 18.6), which consist of courses of knitted loops on one bed and tuck loops on the other, are thus an ideal base for racked structures.
4 With half-cardigan, racking can occur only after every alternate course of the two-course repeat – it cannot occur after the 1×1 rib knitting course. The racked effect will show only on one side of the fabric – the all knitted loop side – at every second row. In-between the racked loop courses, the 1×1 rib courses will appear as minute upright loops on the effect side.
5 In the full-cardigan sequence, every course has tucks on one bed and knitted loops on the other, so that racking can occur after every course. The racked loops will appear on one side of the fabric at the first rack and on the other side at the next, always on the side remote from the tuck loops of that course.

Racked loops can be produced at every row of knitted loops on each side of the fabric because the tuck loops are hidden inside the structure.

6 In a full-cardigan sequence, if racking occurs to the left at the first course and to the right at the second course, all loops will be racked in the same direction on both sides of the fabric. This is because racking knitted loops to the right produces the same direction of inclined loops as racking the tuck stitches to the left. If the colour of the yarn is changed at fixed intervals of courses and the fabric is cut in rectangular pieces at right angles to the inclined selvedges, diagonal rather than horizontal stripes will be produced relative to the selvedge.

7 If in a full-cardigan sequence racking occurs in the same direction at two successive courses and is followed by two racks in the opposite direction at successive courses, alternate courses on each side of the fabric will show loops inclined in opposite directions.

8 A *Vandyke* or *zigzag selvedge edge* will be produced if the principles explained in 6 and 7 are combined. *Example*: 16 courses might be knitted with a rack to the right after every odd course and a rack to the left after every even course. This is then followed by a course without a rack so that the racking sequence recommences out of phase producing inclined loops in the opposite direction for a further 16 courses before the next no-rack course completes the repeat of the design. On each side of the fabric, courses will incline in one direction for 8 face rows before the inclination is reversed. Every 16 face rows there will be one row of small insignificant upright loops that alternates on one side and then on the other.

9 Racked loops are produced only if a needle in one bed racks past a needle in the other bed. If a needle racks past an empty trick (because the needle in the other bed has been removed or is out of action) there will be no inclined loop in that wale.

10 A pattern repeat of racked and straight wales can be produced across one side of a full-cardigan fabric. It is knitted with a needle-out sequence with racking to the right after every second course and to the left after the next two-course sequence. With this arrangement, a needle racked to the right and later to the left past a tuck loop on a needle in the other bed, will produce a wale of inclined loops whereas a needle racked to the right and left past an empty needle trick will produce a wale of upright loops. The sequence can be interrupted by making two successive racks in the same direction before continuing the previous sequence. The needle that was racked past the tuck will now be racking past an empty trick, so its wale changes from inclined to upright loops, whereas the needle previously racked past an empty needle is now racking past a tuck loop, so the loops in its wale are no longer upright but inclined. The changeover in either direction can be achieved whenever required.

11 The racked effect is more prominent if the wales are spaced further apart by *half-gauging*, i.e. removing every alternate needle from each bed before arranging the needle set-out.

18.14.2 Knop structures

Knop fabrics are relief structures in rib where successive tuck stitches on all the needles or certain needles of one bed produce a three-dimensional effect. Some-

times the all-knit courses are produced in a different colour and sometimes racking occurs after the knop sequence so that the next knop is off-set.

18.14.3 The cable stitch

Cable stitch is a traditional hand-knitted stitch pattern incorporated into fishermen's sweaters in the islands of Jersey, Guernsey and particularly Aran, where it is one of a range of stitch patterns (Fig. 18.8) that includes *ladder*, *blackberry stitch* and *honeycomb* [2]. Traditionally, the yarn is partly-scoured wool in its ecru (undyed and unbleached) colour. The cable stitch is a three-dimensional design of cords of face loop wales, centred in a panel of reverse loop stitches bordered on either side by rib wales of face stitches. Each cord is usually three wales wide; these move as a unit when they are crossed (twisted) over another cord. The direction of twist of the cords is always the same relative to the surface of the design.

Cables are normally either two-cord or three-cord. In machine knitting, the cords are knitted on one needle bed and the background panel on the other. The cable loops are longer to reduce the tension where cords twist. At this point, the loops of

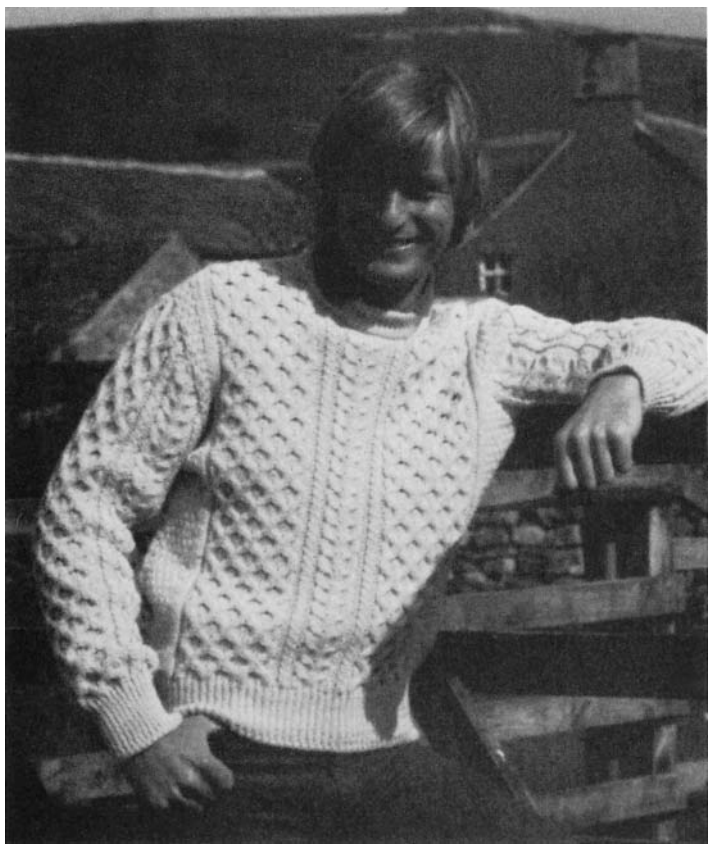


Fig. 18.8 Aran crew-neck pullover knitted by T W Kempton on a 5-gauge JDR flat machine from 2/6's worsted count woollen spun yarn [British Wool Marketing Board/Marks and Spencer].

one cord are transferred over to the other bed so that the two cords can be racked past each other before they are transferred back to recommence knitting. Cable stitches are knitted on some automatic flat rib and purl machines, as well as on a few double-cylinder machines with the facility for shogging the top cylinder. Generally, double-cylinder machines knit only mock cable effects using purl stitch designs.

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