9

Multi-layer Fabrics

TREBLE CLOTHS

In treble cloths there are three series of warp and weft threads which form three distinct fabrics, one above the other. Except for the ties, when a face pick is inserted all the centre and back ends are left down; when a centre pick is inserted all the face ends are raised, and all the back ends are left down; while when a back pick is inserted, all the face and centre ends are raised. The face ends and picks interweave with each other to form the face fabric, the centre ends and picks to form the centre fabric, and the back ends and picks to form the back fabric. By interweaving the centre ends or picks with the face and back picks or ends, the three fabrics are joined together, and the resulting cloth is equal in thickness and weight to the three single fabrics. Greater weight combined with equal fineness of appearance can thus be obtained in this than in the double system of construction. The weight of double woollen structures is frequently increased by excessively shrinking the cloth in the milling process, the chief disadvantages of which are that its elasticity, air permeability and clarity of effect are liable to suffer. This does not occur when increased weight is obtained by making the cloth three-fold, hence the treble principle can be advantageously employed in preference to the double system in adding weight to cloths which require little shrinking in the finishing processes.

Systematic construction of treble cloths

The method of constructing a treble cloth is illustrated stage by stage in *Figure 9.1* where, it will be noted, the weave in each of the three fabrics is not only the same but it is also started on the same footing. This creates the most favourable conditions for tying and should be used whenever identical weaves are required in all the layers.

A 2-and-2 twill is used in each fabric and this is represented at A, B and C which correspond to the face, centre and back cloths respectively and differ from one another only in the type of mark which is employed in each case.

Once the weave of each fabric layer is determined the construction can be commenced in the following order:

(1) Mark out around the margin of the design repeat the order of arrangement of the three series of threads. In the case of the example given at D the order for both the warp and the weft is 1 face (f), 1 centre (c) and 1 back (b). The minimum size of repeat for a 4-shaft weave construction in treble cloth is 12 X 12 but to show a sateen order of stitching the above example has been worked out over an area of 24 X 24.

(2) Insert the face weave on face ends and picks (solid marks), the centre weave on centre ends and picks (shaded marks) and the back weave on back ends and picks (diagonal marks). The different marks are used to simplify checking the design for correct placement of the weaves. This stage is shown at E in *Figure 9.1* and it may be noted that, as before, all marks indicate warp up unless otherwise stated.

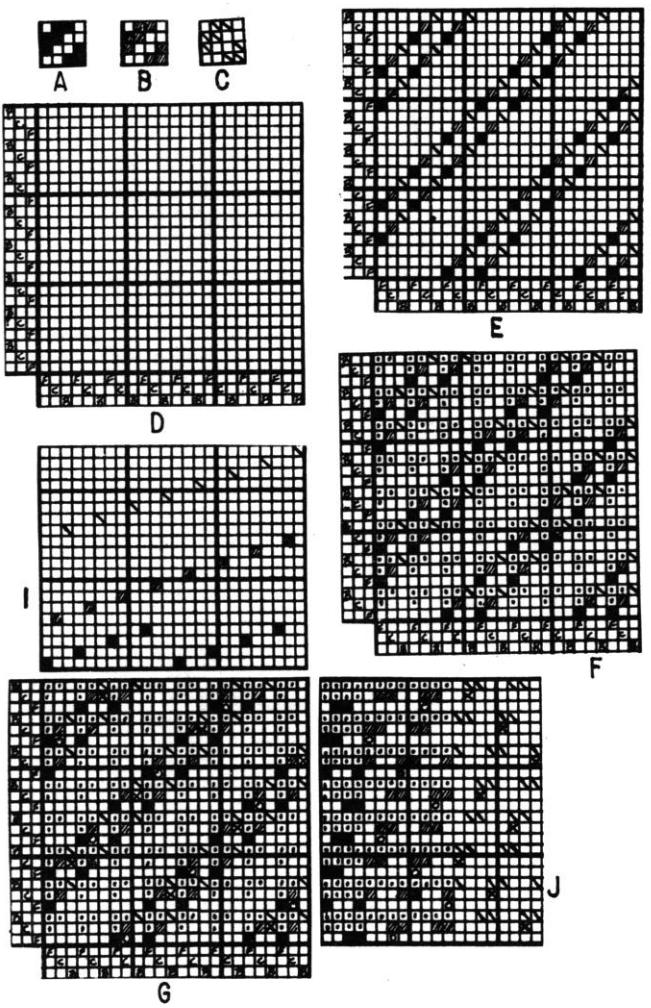

Figure 9.1

(3) Insert the separating lifts. In the treble cloths this is achieved in practice by lifting all the face ends on all the centre and back picks, and by lifting all the centre ends on all the back picks which is denoted by the dots in F. It must be borne in mind, of course, that the necessary corollary to this is

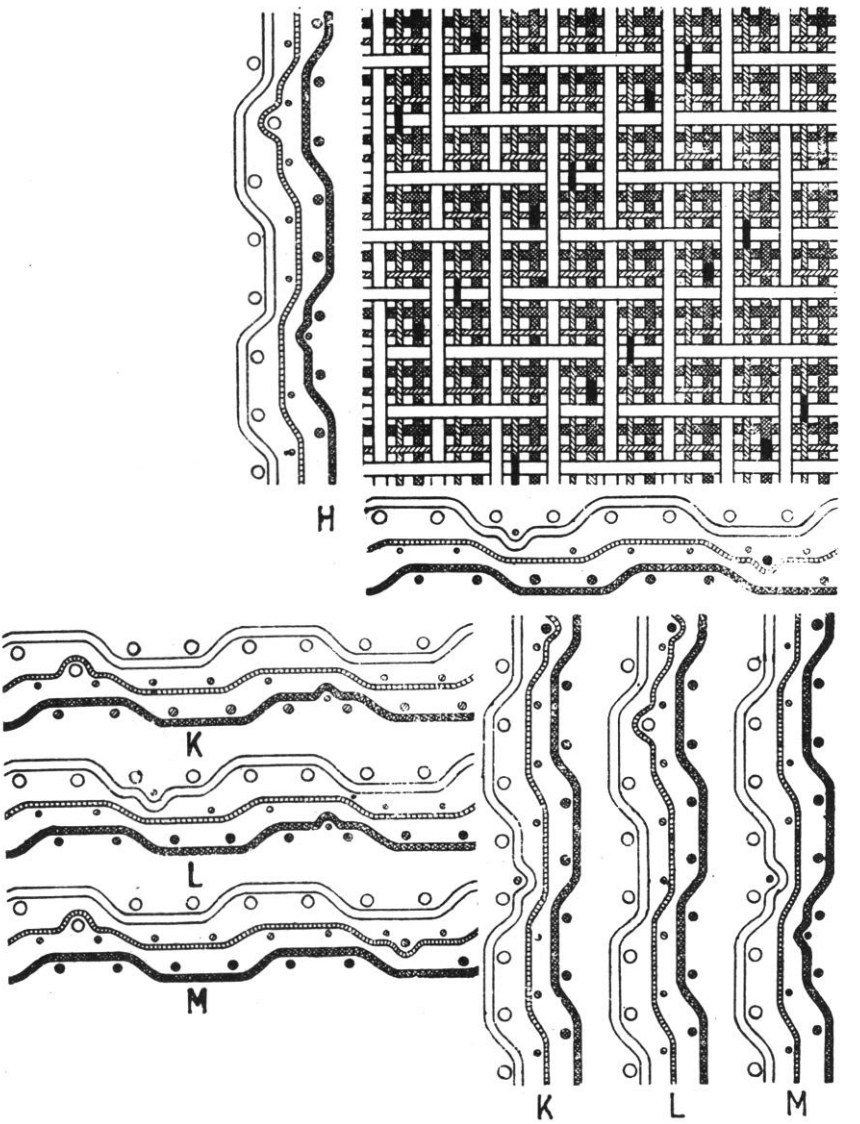

Figure 9.2

that on the face picks all the centre and back ends must be down, and on the centre picks all the back ends must also be down, but as the ends will automatically remain down unless marked, this latter situation is obtained by default.

(4) Introduce stitching marks. The treble cloths are usually self-stitched and the rules stated in connection with the tying of double cloths are equally applicable here. To reiterate the most important points: The stitching should be as regular as possible to prevent uneven tension; the ties should be adequately concealed on the face and on the back by corresponding face and back thread floats; the face and the back ends can only be used for stitching purposes when absent from the visible surfaces of their respective cloths. In the example given at G in *Figure 9.1* and in the interlacing diagram H in *Figure 9.2* a method of stitching is shown in which the three layers are united by raising the centre ends on the face picks at certain selected positions in an 8-shaft sateen order, and by similarly raising the back ends on the centre picks. The former lifts are indicated by the circles and the latter by the crosses in the design G whilst in the diagram H the stitch points are emphasised by the solid lines.

The fully worked-out design G represents a complete treble cloth structure with a suitable draft provided at I and a lifting plan, in which all marks indicate lifts, at J. The sections given below and at the side of the interlacing diagram H in *Figure 9.2* indicate respectively the interweaving of the first face, centre and back picks and ends of the structure given at G and H. The sections show clearly that the two visible sides of the compound cloth are undisturbed by the ties due to their correct placement.

Methods of stitching

In the example given in *Figure 9.1* only one method of stitching has been shown in which the centre ends were lifted on the face picks and the back ends on the centre picks. It will be appreciated, however, that in a treble construction other possibilities exist, which may, in certain conditions, be more suitable than the common method indicated above. Thus, in the designs K, L and M in *Figure 9.3* the remaining three methods of tying, utilising the centre cloth yarns, are shown. All the three designs are identical with the construction G in *Figure 9.1*, apart from the method of stitching. In the design K the stitching is effected by dropping the face ends on the centre picks, indicated by the circles, and the centre ends on the back picks, represented by the crosses. In each instance, therefore, the tying consists of the cancellation of certain selected separating lifts. Construction L is stitched by raising the centre ends on the face picks (circles), and lowering them on the back picks (crosses). Finally, at M the tying is achieved by dropping the face ends (circles), and lifting the back ends (crosses) on the centre picks. The ties can be seen clearly in the sectional views in *Figure 9.2*, lettered to correspond, which show the first three picks and ends of each of the above three structures.

Although the first method, indicated at G in *Figure 9.1*, is the one most commonly employed, any of the other three may be preferable when the positions of convenient binding points in the face and back weaves are unsuitably placed in respect of the manipulations of threads required in the original system; or, if the relative thickness or quality of the yarns is such that the other methods result in a lesser degree of disturbance to the visible surfaces of the cloth. As the centre cloth never appears on the surface the position of the ties

in that layer is of no particular importance in itself; however, efforts should be made to adhere, if possible, to the normal rules of stitching even in respect of the centre layer because any undue disturbance of its regularity is liable to result in a degree of distortion in the face or the back layer.

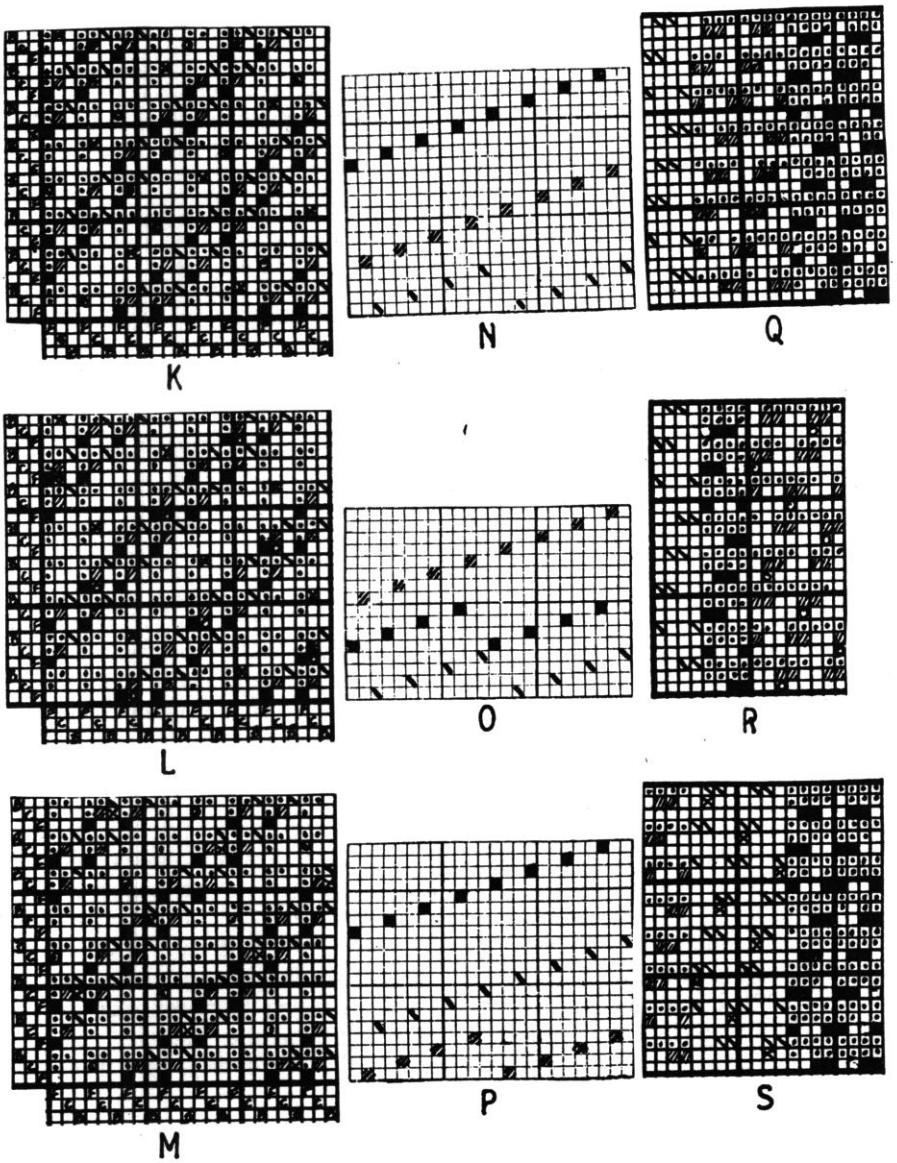

Figure 9.3

Apart from the four methods of stitching illustrated in the foregoing in which the threads of the centre cloth are involved it is also possible to tie a treble cloth together by either dropping the face ends on back picks, or, lifting

the back ends on face picks, as in an ordinary double cloth. This form of stitching, in which the centre cloth merely acts as a wadding layer, is considered further on.

Beaming and drafting of treble cloths

From the point of view of the ease of warp yarn preparation and the ease of access to the weaving machine a single beam is more convenient than a double-beam or treble-beam mounting. When the materials and the weaves in each one of the three layers of a treble cloth are similar single-beam operation is possible. Some materials, notably the woollen yarns, are sufficiently accommodating to permit single-beam weaving even when there is a degree of dissimilarity between the yarn thickness and the weave in the various cloth layers. With other materials, in which such dissimilarities are encountered, it is necessary, however, to use two beams where two layers are similarly constructed and one is different, or three beams where all three structures are quite unlike one another. This is the case particularly when the warp take-up in each layer varies so that separate and independent regulation of each warp pay-off becomes necessary.

I in *Figure 9.1* and N, O and P in *Figure 9.3* illustrate four drafting arrangements commonly used in treble-cloth weaving. The main criteria are the regularity and the simplicity to facilitate the drawing-in of ends both during the entering and also following the breaks in weaving. As shown in the examples given it is usual to separate the healds into sets to correspond with each fabric layer but there is no specific reason why the treble cloths should not be woven in straight drafts if desired. It is sometimes claimed that the checking of the pattern chains is easier if the healds are separated into sets but as this is not a common occurrence it should not override the primary requirement of the regularity of end distribution. Whether the face, centre and back cloth sets are placed in the front, middle or back of the weaving machine is frequently a matter of choice. However, if the geometry of shed formation in a weaving machine is such that the front healds cause the least strain in the yarn then, undoubtedly, the weakest yarns, or, the most crowded and the most frequently interlacing sets of healds should be placed at the front.

In the lifting plans Q, R and S in *Figure 9.3* all the marks indicate healds up, the symbols used to denote a drop of an end for stitching in the corresponding designs having been deliberately omitted.

Construction of treble cloths with dissimilar weaves in the different fabric layers

The examples given in the preceding sections show that when the same weave is used in every fabric layer, and the threads are arranged in equal proportions, favourable conditions for tying are obtained by commencing the weave always in the same relative position. The weft and warp floats on the upper surface of the centre and back fabrics respectively are then directly below the warp and weft floats on the under-surfaces of the face and centre fabrics, hence there is no obstacle to the interweaving of the threads of one fabric with those of

another. When different weaves are employed, however, such favourable disposition may not exist directly and a degree of experimentation may be necessary before the best relative starting position for each weave is determined. The construction of a fully worked-out design should not be commenced, therefore, before each of the constituent weaves is arranged separately in such a relationship with one another that the desirable coincidence of the warp and weft floats is obtained. In practice, when new constructions are attempted, the solution often lies in marking the weaves lightly on transparent design paper, superimposing one upon another and shifting them in turn until the greatest possible degree of coincidence between the warp-on-warp, and the weft-on-weft float is achieved. This, in fact, is most easily done in pairs because the two relevant relationships from the point of view of stitching are: (a) The position of the face weave in respect of the centre weave and (b) the position of the centre weave in respect of the back weave. As the face layer is normally joined to the back layer only through the intermediate agency of the centre layer the coincidental relationship between the floats of the face and the back cloth is of little significance. The two basic relationships are more difficult to establish without the aid of the transparent paper but they are clear enough in the designs A, B and C in *Figure 9.4* when studied in the relevant pairs. Thus, the face weave A which is a warp-faced satinette is placed in correct relationship with the 2-and-2 twill centre weave B; then, having determined the starting position of the centre weave, the back weave C which is also a warp-faced satinette is juggled with until the best relationship between it and the centre layer is established. The construction of a fully worked-out design can then be commenced. It must be realised, of course, that should it be entirely impossible to produce the required relationships between the pairs of weaves the weave of the centre layer, which is never visible, could be modified.

The fully worked-out design to correspond with the individual weaves A, B and C is shown at D and in the interlacing diagram E. The stitching is achieved by lifting the back ends on centre picks (circles) and the centre ends on face picks (crosses), and both sets of ties are distributed in a satinette order. The warp and weft sections below and at the side of the diagram E show that the tie placement in no way disturbs the appearance of the visible surfaces of the face and the back layers. The concealment of the back warp stitching lifts in the centre layer is, however, not perfect, as in some positions there is only one adjacent float instead of two at the stitch points. Although such an arrangement is slightly less than perfect it is quite acceptable in view of the fact that the aesthetic appearance of the centre cloth is of no importance—it is only its functionality that must remain unimpaired.

The diagrams F to K in *Figure 9.4* show the construction of a treble cloth in which the threads are arranged in the order of 1 face, 1 centre, 1 face, 1 back. A 4-and-4 twill is used for the face layer, and a 2-and-2 twill for the centre and back layers, the method of tying being the same as in the preceding example with the ties arranged in a twilled order. F is the face weave and is shown paired together with the centre weave G in an extended form to account for the disparity in their respective thread ratios. At H the same centre weave as at G is shown in the normal form paired together with the back weave I. It will be appreciated that as the thread ratios of the centre and back weaves are identical

no need for an extension of either of them exists. The fully worked-out construction is given at J in which the circles indicate the stitching lifts of the back ends on centre picks, and the crosses, the stitching lifts of centre ends on face

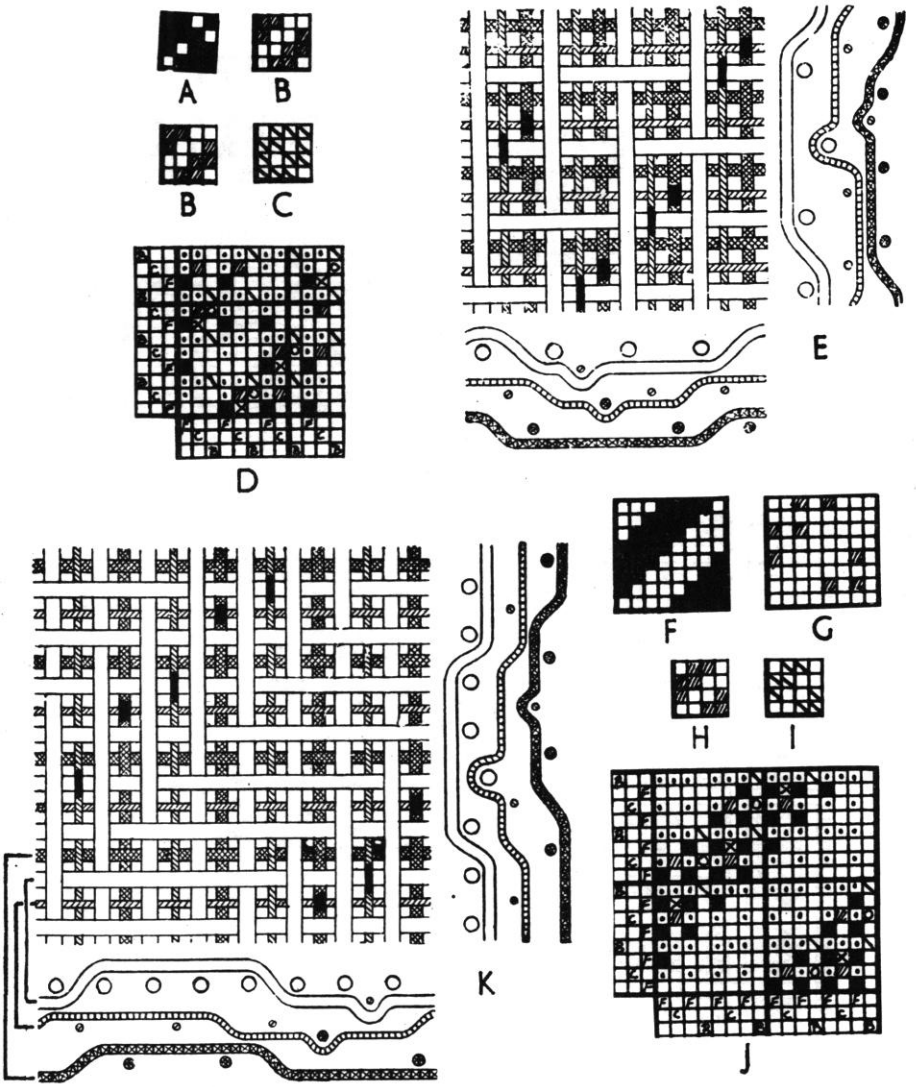

Figure 9.4

picks. In the interlacing diagram K the positions of the ties are clearly indicated by the solid black spaces. The warp section below the interlacing diagram shows the interweaving of the second, third and fourth picks of the structure, whilst in the weft section to the side of K the interweaving of the second, third and fourth ends is depicted.

In *Figure 9.5* the diagrams illustrate the construction of a treble cloth in which there are 2 face and 2 back threads to 1 centre thread, the arrangement being 1 face, 1 back, 1 centre, 1 face, 1 back, as indicated at O. Five-thread satin and sateen weaves are used for the three fabrics, the face layer being a warp satin and the centre and back layers the weft sateen. This in effect means that

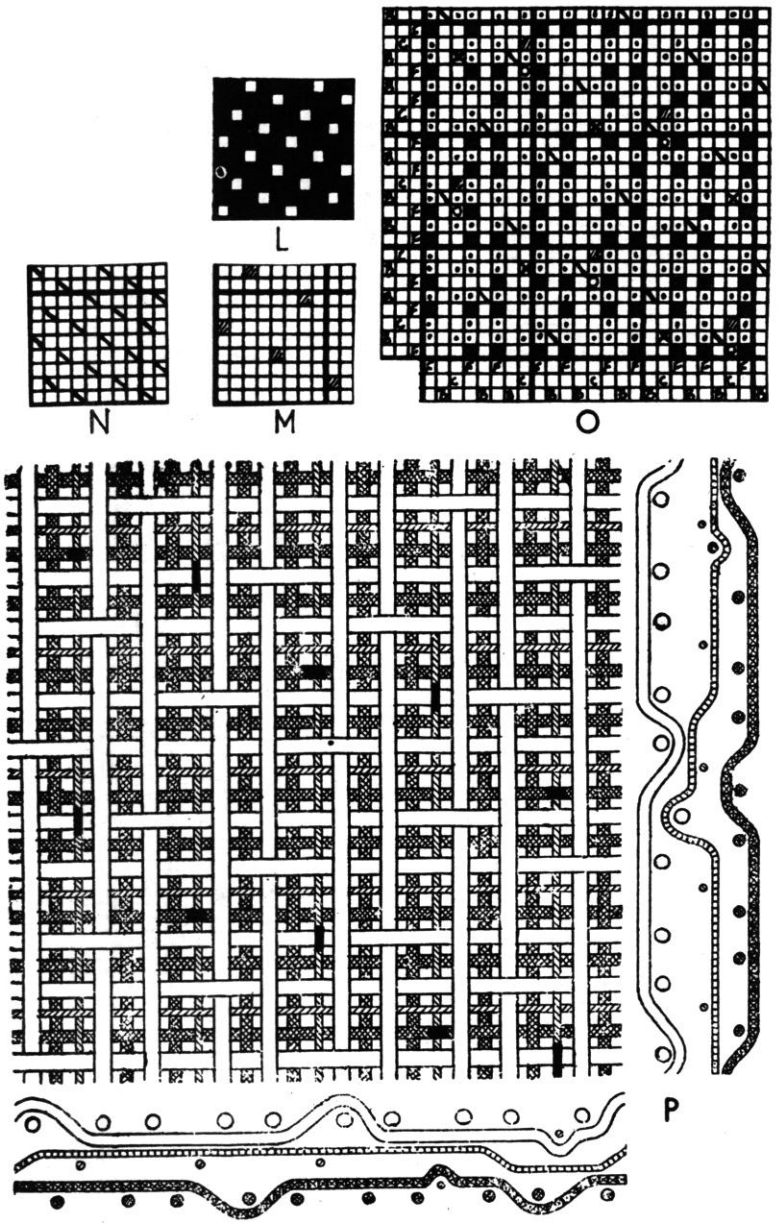

Figure 9.5

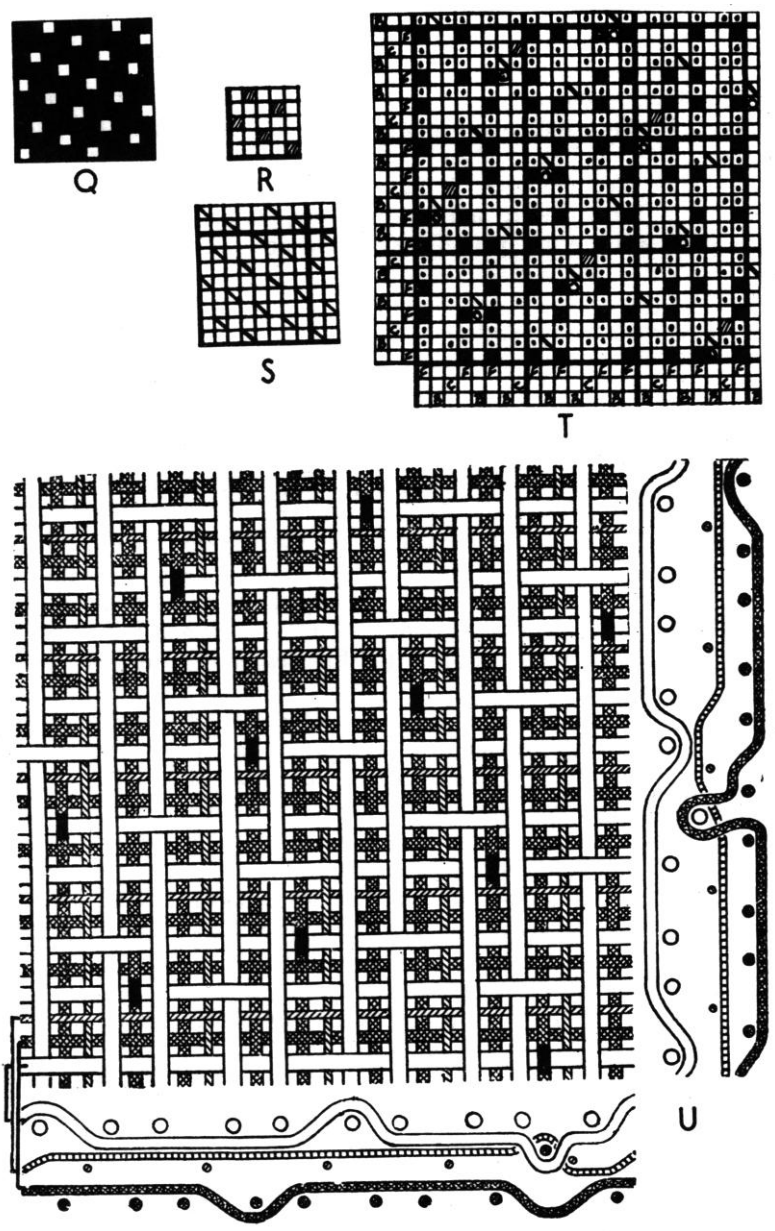

Figure 9.6

the fabric is reversible as the visible surfaces of both the face and the back cloth are composed of warp floats. The tying is effected by lifting the centre warp threads on face picks, as shown by the circles at O, and by dropping the centre ends on the back picks as indicated by the crosses. This method is the most suitable one for stitching reversible warp face constructions and is particularly

applicable to structures in which the centre warp is not much thicker than the face and back yarns, whereas the centre weft is much coarser. Following the previously established practice the three constituent weaves L, M, and N are arranged side by side, with the centre weave extended to compensate for its lower ratio, for the purpose of locating the correct stitch points. It will be noted from the interlacing diagram P and the accompanying cross-sectional views that the ties in the face and back cloths are adequately covered by two adjacent corresponding floats of warp and are, therefore, perfectly placed. Furthermore, the continuity of the centre yarn floats also remains undisturbed.

Use of the centre layer as wadding

The design T in *Figure 9.6* and the corresponding diagrams show a method of uniting the three fabrics which is different from any of the foregoing. In this case the centre threads do not interweave with either the face or the back threads, but are used purely in forming a wadding cloth, the tying being effected by raising the back ends over the face picks in 10-thread sateen order. The system can be advantageously used when the centre yarns are of lower quality and much thicker than the face and back yarns. In arranging the positions of the weaves and ties it is only necessary to consider the face and back fabrics, as in the self-stitched double cloths. Q shows the face weave and S the back weave. The centre weave is given at R, and the full design at T, in which the circles indicate the positions of the ties.

An examination of the interlacing diagram U in *Figure 9.6* will show that the centre ends and centre picks interweave only with each other. The interweaving of the picks 1, 2, and 3 is shown below the flat view, and it will be noted that the first face pick passes under the ninth back and between the fourth and fifth centre ends. In the section alongside the flat view, which shows the interweaving of the ends 1, 2, and 3, it will be seen that the first back end passes over the fifth face pick between the second and third centre picks. The tying may also be similarly effected by the lowering of the face ends on back picks.

MULTI-PLY BELTING STRUCTURES

Solid woven multi-ply beltings are today produced mainly for conveyor work. At one time they were also made extensively for power transmission but with the introduction of the V-belt drives the flat belting is now used for driving only in exceptional circumstances. Where it is retained it is usually in the form of a narrow belt and is, therefore, woven by the narrow fabric techniques similar to those used for the construction of safety belts for the aircraft and motor-car industries.

Conveyor belts are produced in widths of 0·4 m to 1·5 m and in thicknesses varying from 3 mm to 10 mm. The thinner belts are of a two-ply construction the number of plies increasing progressively with the increase in the belt thickness so that to produce the thickest belts six-ply or seven-ply structures are required. Almost any type of material can be conveyed and the goods handled range from rock and coal to grain, dusts, foodstuffs and bagged or packaged

articles. To suit the wide variation in the materials different finishes are applied although the p.v.c. coated belts are by far the most common on account of their toughness, non-flammability and easy cleaning qualities. If required the belts can be run at very high speeds reaching for some materials 210 m/min, or they can be operated at 6 to 10 m/min for such operations as sorting or picking. They represent a very economic method of carrying a large volume of material over short distances and flat belts about 1 m wide can convey as much as 200 to 250 t/h. When suitably troughed a similar belt would convey double the above tonnage at a modest power requirement of 25 h.p. when running on plain bearings or 18 h.p. when mounted on roller or ball bearings. Apart from being able to carry materials along a horizontal plane the belts can operate over considerable gradients which for some goods can be as steep as 25°. For very acute inclines the conveyor can be modified into an elevator belt by having buckets bolted on to its surface.

It will be clear from the foregoing that to produce a worthwhile article for the purpose the architecture of the construction must be very carefully thought out. The difficulty exists in the fact that there is a clash of requirements for a conveyor belt—on the one hand, it should be rigid enough to carry considerable weight of materials without undue sagging between supports, on the other, it should be sufficiently flexible to permit easy bending when running over pulleys or when troughed. The stresses suffered by a belt upon bending are due to the forces of expansion and contraction between the outer and inner faces of a belt and are defined by the diagram and the general formula given in *Figure 9.7.*

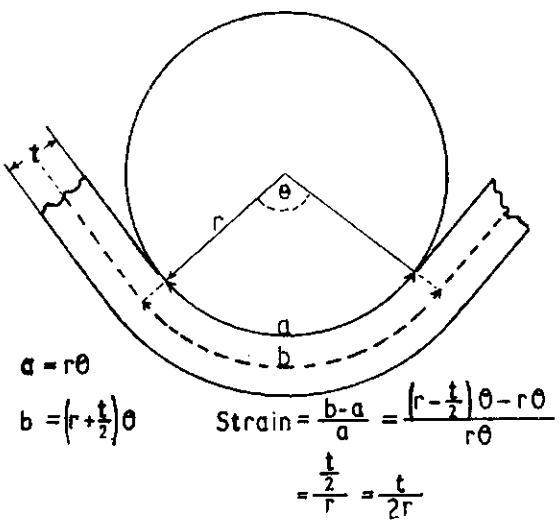

Figure 9.7

From the illustration it becomes apparent that the best solution of the divergent and opposite requirements may be achieved by a compromise, constructing the central layers, which suffer no length deformation, more rigidly than the outer layers. The construction of a belt must also be such that it will not permit undue stretching under load.

Early constructions did not conform to the ideas of a planned engineering approach which were not developed until later and the belts frequently consisted of a multi-ply (3 to 6) plain weave stitched right through the plies in a manner shown by the weft section A in *Figure 9.8.* As all the layers were constructed in the same weave and with the same density of yarn spacing the outer plies suffered very considerable deformation stresses upon bending. Failure of a belt of this type occurred prematurely unless very large diameter pulleys were used. With the improved knowledge of the behaviour of belts under loads and with better understanding of the role of the construction in achieving superior belt performance many other designs were tried from which certain basic types were developed.

In one type of belting which is made in three-ply or four-ply structures the outer faces consist of twill weaves, such as 2-and-1 or 2-and-2. This permits denser setting of the warp thus allowing greater number of yarns to sustain the load and inhibit stretching because the load is distributed over a greater number of units and also on account of a lower inherent crimp in the warp yarns. The looser structure of the twill also allows greater freedom of flexing than is possible with a tight plain weave interlacing. The neutral central axis of the belt which, as stated before, does not undergo the same strain as the outer layers is

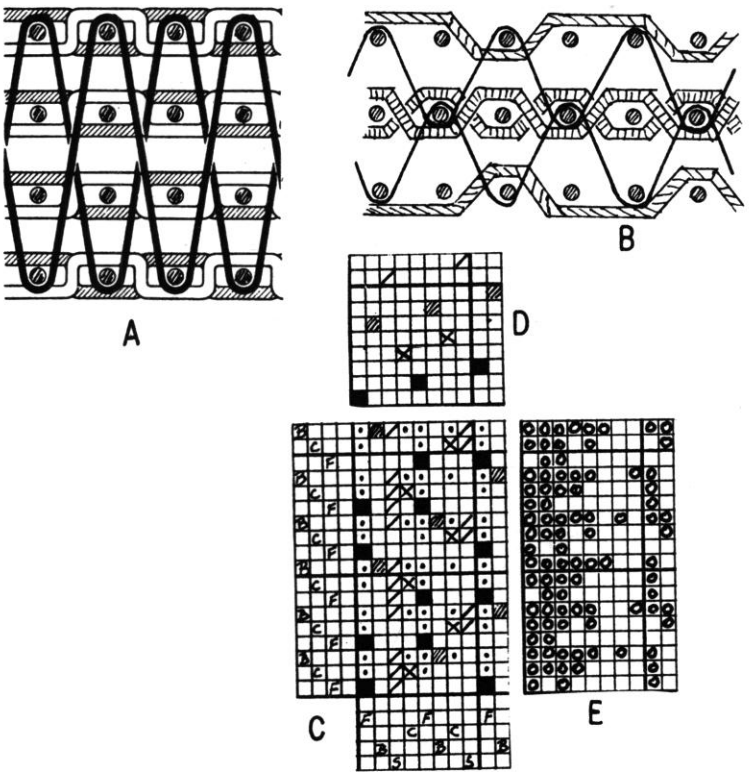

Figure 9.8

made more rigid by using in it a plain weave structure. This, apart from improving the load-bearing characteristics of the belt, also improves the fastener holding properties–another important aspect in an endless belt operation.

A three-ply structure of the type described is illustrated in the form of a weft section at B in *Figure 9.8*, and as a fully worked-out design at C. In the section only one warp end of the 3-thread twill is shown in the face and back layers to preserve the clarity of the structure. The stitching yarns, indicated in solid lines, produce a hinge action by which a freedom to expand or contract in the outer layers is not restrained but their binding is sufficiently effective to prevent any layer to creep in respect of another which is undesirable as it promotes the tendency to ply separation. In the design C the weave of each layer is indicated by the distinctive marks, the separating lifts by the dots, and the operation of the stitchers by the diagonal marks. The ends and picks are designated by the letters F, C, B, and S at the margins of the design which stand respectively for face, centre, back, and stitcher. The draft for the structure is shown at D and the lifting plan at E in *Figure 9.8*.

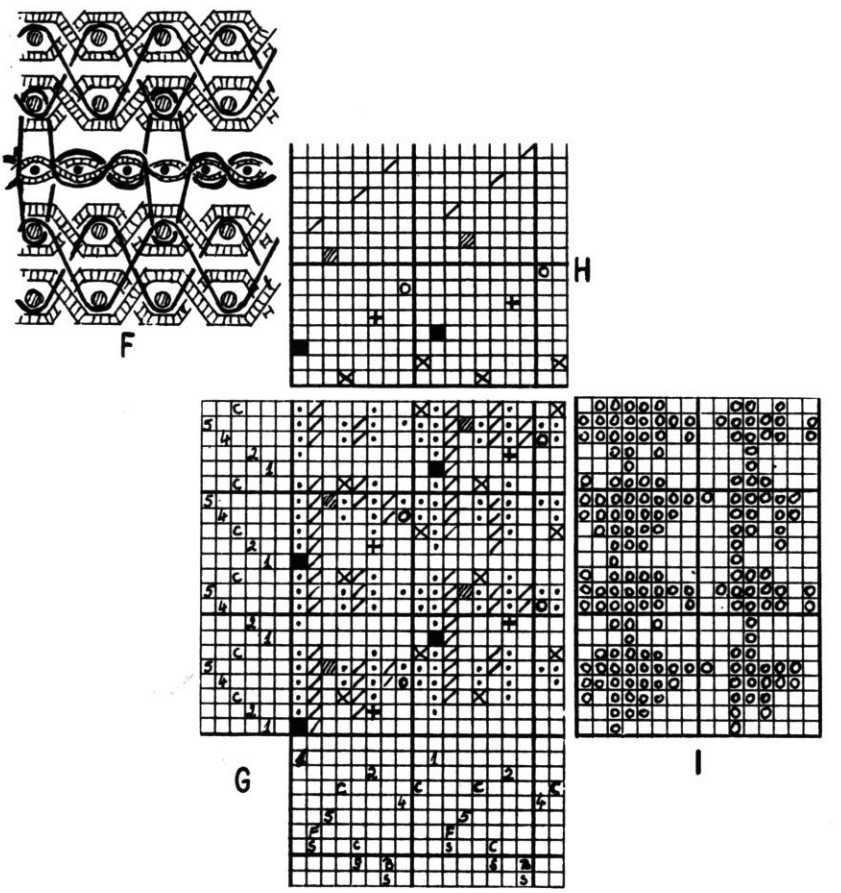

Figure 9.9

A different construction consisting of five layers is shown in the weft section at F in *Figure 9.9.* In this fabric the rigidity and inhibition of stretch is provided by the fine, densely set plain weave layer along the neutral axis of the belt. The other four layers each consist of a coarse plain weave construction which can flex reasonably easily due to an ingenious system of stitching. The binding yarns (marked in solid black) operate on a two-tier base radiating from the centre outwards. The binding is so arranged that the belt retains complete cohesion even when the extreme outer layers (1 and 5) are completely worn. The fully worked-out design for this structure is given at G in which the distinct marks indicate warp lifts in each ply and the dots and diagonal marks refer again to the separating lifts and the stitching weave respectively. The ends and picks which form the different plies are designated in the margins by 1 (the top layer), 2, C (the centre layer), 4 and 5 (the bottom layer) and the stitching ends are marked FS, CS and BS for face, centre, and back stitcher respectively. A suitable draft for this structure is provided at H and the lifting plan at I.

Cloths of the belting type are woven in heavy weaving machines using positive tappet shedding with either conventional shuttle or single rigid rapier forms of weft insertion. The yarns may be all cotton but at present the most common materials are heavy multifilament polyamide yarns combined with cotton during doubling or used as composite core spun yarns. Apart from adding to the bulk the presence of cotton is desirable to improve adhesion to the various coating agents and to act as insulation to guard the polyamide fibres against damage due to heat. The counts of the yarns vary considerably ranging from 95 tex to about 1000/3 tex or in some cases even heavier.