1

Elements of Woven Design

CLASSIFICATION OF WOVEN FABRICS

Woven fabrics are composed of longitudinal or warp threads and transverse or weft threads, interlaced with one another according to the class of structure and form of design that are desired. The terms *chain* or *twist* are applied to the warp, and the warp threads are known individually as *ends*, while the terms *picks* and *filling* are applied to the weft threads. In the following the term threads is used in referring to warp and weft collectively, but in order to distinguish clearly one series from the other the warp threads are mostly described as 'ends', and the weft threads as 'picks'.

Woven structures may be conveniently divided into two principal categories, as follows:

(1) Simple structures, in which the ends and the picks intersect one another at right angles and in the cloth are respectively parallel with each other. In these constructions there is only one series of ends and one series of picks and all the constituent threads are equally responsible for both the aspect of utility or performance in a fabric and the aspect of aesthetic appeal.

(2) Compound structures, in which there may be more than one series of ends or picks some of which may be responsible for the 'body' of the fabric, such as ground yarns, whilst some may be employed entirely for ornamental purposes such as 'figuring', or 'face' yarns. In these cloths some threads may be found not to be in parallel formation one to another in either plane, and indeed, there are many pile surface constructions in which some threads may project out at right angles to the general plane of the fabric.

This book deals primarily with design in simple structures where *construction*, i.e. yarn interlacing, is frequently synonymous with *design* or the surface effect formed; in compound fabrics, however, the term 'construction' must be clearly separated from *ornamentation*, or *design* which may depend entirely on colour distribution and may, therefore, be independent of the construction itself.

BASIC OPERATIONS IN WOVEN CLOTH PRODUCTION

Cloth weaving is nowadays accomplished on sophisticated, high speed, precision machinery which in itself represents a field of intensive study for mechanical engineers. From the point of view of the designer the complicated operations of a weaving machine can be broken down into simple functions related to the process of cloth formation with particular reference to those functions which have the greatest influence upon the structure and the appearance of fabrics.

Figure 1.1 illustrates the lay-out of a weaving loom in the form of a simple, schematic diagram. The sheet of warp yarn, consisting of the required number of ends wound into a considerable length, is carried upon the

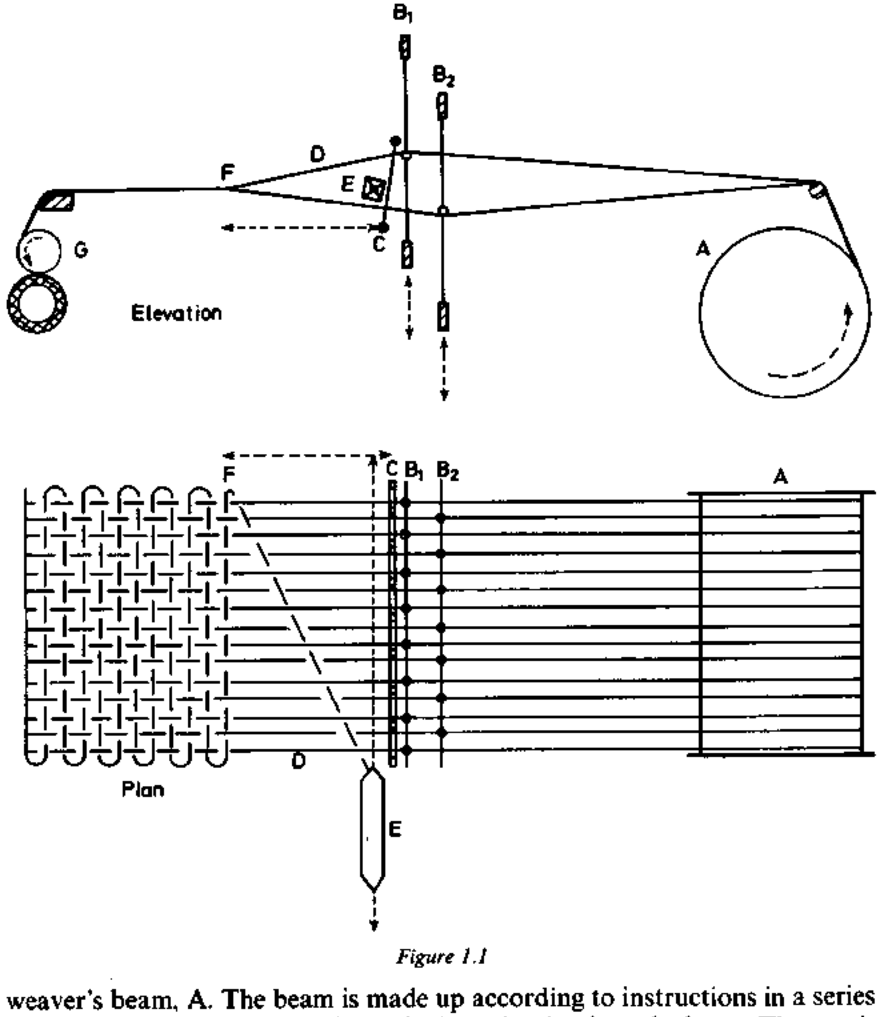

Figure 1.1

weaver's beam, A. The beam is made up according to instructions in a series of preparatory operations prior to its introduction into the loom. The specification for making the beam, in addition to stipulating the type of yarn, the number of ends, and the length of the warp, may also include a pattern if it is desired to produce a cloth with coloured stripes. The warp ends from the beam are then drawn through the healds, B_1 and B_2, threaded through the splits of the reed C and at the point D they become interlaced with the weft supplied by the shuttle E. The cloth is formed at the *fell* of the cloth, marked F, and is wound upon the cloth roller situated at the front of the loom.

The weaving process itself consists of three basic operations which form a continuous cycle whether in the simplest hand-loom, or in the most complex automatic machine. These primary motions can be described as follows:

(1) Shedding—the separation of the warp threads into upper and lower layers forming a *shed*, or a tunnel, through which the weft is passed.
(2) Picking—the insertion of the weft through the shed.
(3) Beating-up—the carrying forward of the last inserted pick of weft to the cloth already woven.

The picking and the beating-up operations are fixed no matter what type of fabric is being produced, but the shedding motion is variable and can be described as the heart of weaving as it is here that the nature of the interlacing, or the weave, is decided, and in order to be able to construct the desired effects the textile designer must have a very thorough knowledge and understanding of this primary operation.

In addition to the three principal operations, several ancillary motions are required for control purposes, and of these some are merely mechanical devices connected with the safety and the continuity of weaving operations, but some are of considerable interest to the designer as their influence can alter the cloth appearance to no lesser degree than the shedding. These are:

(1) Warp pay-off—This determines the rate at which the warp is fed forward and the tension of the warp yarn. The tension is largely responsible for the configuration of warp ends in the cloth and two fabrics of identical design but woven with varying degrees of tension may appear different and may possess different characteristics.
(2) The cloth take-up—this determines the speed of cloth withdrawal and, therefore, the density of spacing of the weft picks in the cloth.
(3) The weft colour selector—this device is only built into machines on which it is intended to weave fabrics with transverse, or 'cross-over', stripes consisting of different colours or kinds of weft. Modern machines may contain devices capable of introducing into the cloth up to eight different weft threads.

The shedding, during which the warp threads are manipulated to produce a given interlacing, is achieved by threading each end through an eye of a heald wire, and raising or lowering this wire dependent on whether it is required to lift the end above the weft, or to keep it below the weft during picking. In tappet and dobby shedding systems heald wires are not operated singly, but are attached to heald frames, or heald shafts, and each wire on a given shaft conforms to the movement of that shaft, rising or falling together with it (*Figure 1.2*). The tappet, or cam, system is used to control the shedding where, due to simplicity of interlacing, only few heald shafts, or healds, are required. Dobby shedding systems offer the designer a considerably greater scope for producing figured effects and are often capable of controlling up to 24 healds. In addition the dobby selection device offers the ease of pattern change, whereas the tappet assembly is quite rigid. Also, tappet shedding imposes a limit as to the length of the design whilst no such limits exist in the dobby system. For these reasons the tappet principle of shedding is employed mainly for high speed production of standard cloths where changes of structure are infrequent, and where its simplicity offers some advantages.

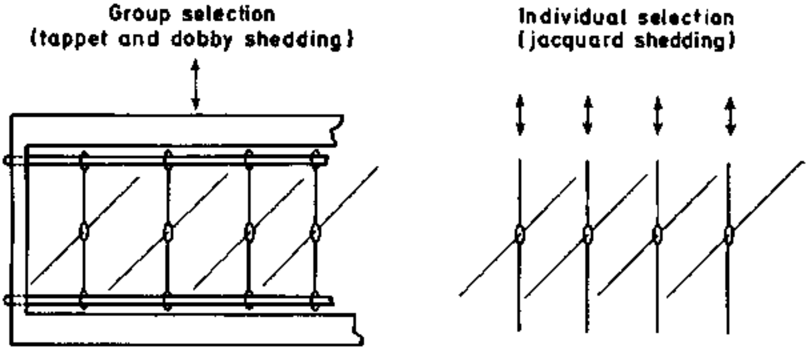

Figure 1.2

The dobby is used in the production of simple, figured fabrics, but ornate figured styles require a jacquard system of shedding in which heald wires can be manipulated individually be means of cords and not collectively through the agency of the heald frames (*Figure 1.2*).

METHODS OF FABRIC REPRESENTATION

The unit of woven fabric is the point of intersection of a warp end and a weft pick, the interlacing being of two possible kinds as shown in *Figure 1.3*. In either case the interlacing is achieved by the manipulation of the ends, these being raised to obtain the interlacing (a), or lowered to produce the interlacing (b). A number of these interlacings combined together in both

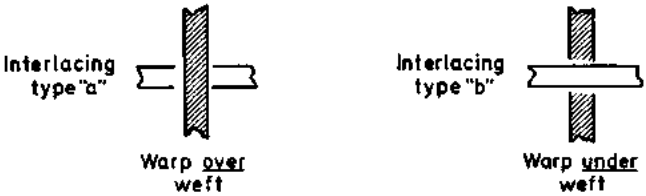

Figure 1.3

directions produces a unit of design, or one repeat of the weave. The simplest weave which can constitute a cloth requires two ends and two picks as a repeat of design, is known as the plain weave, and can be pictured as at A (*Figure 1.4*). In this diagram it will be seen that on pick 1 the first end is raised to produce the interlacing (a), whilst the second end is lowered to give the interlacing (b).

As the diagram represents a complete unit of design it must be understood that successive neighbouring units will be identical with the first as shown at B, *Figure 1.4*. In this diagram four repeats of the construction are shown but normally one unit is quite sufficient to depict the entire interlacing pattern of a cloth and, therefore, looking at the order of interlacing as shown at A, it will be taken that on pick one every odd end in the warp will be raised and every even one lowered, whilst on pick two the reverse takes place. Interlacing diagrams as shown in *Figure 1.4* are not normally employed in designing woven fabrics as they are too laborious to prepare especially when large designs are considered. They are occasionally used to depict cloths in which threads are displaced from the straight path, but in most cases design paper (point paper, squared paper) is employed, and offers an easy way of representing the interlacings in a quick and simple manner. The standard textile design

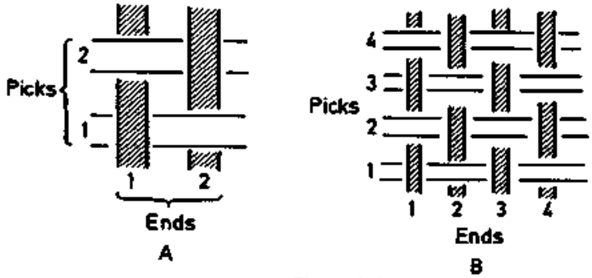

Figure 1.4

paper is ruled in groups of 8 × 8, these being separated by thicker bar lines as shown at A, in *Figure 1.5*.

Each vertical space is taken to represent a warp end and each horizontal space a weft pick, each square, therefore, indicates an intersection point of an end and a pick. At B in *Figure 1.5* square 'x' indicates the point of crossing of the second end with the second pick, whilst square 'y' is the point at which

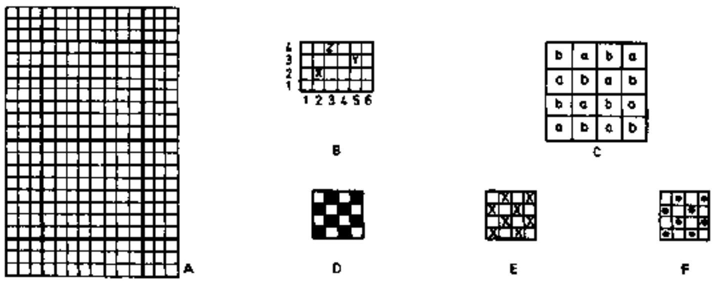

Figure 1.5

the fifth end crosses the third pick, and square 'z' shows where the third end intersects the fourth pick. Developing the idea of the two different types of interlacing, the diagram shown at B in *Figure 1.4* could be represented on design paper as at C, in *Figure 1.5*, which shows quite clearly the alternate occurrence of interlacings 'a' and 'b' in both directions. Even this method, though quicker than an interlacing diagram, suffers from the lack of definition so the normal convention, which satisfies the conditions of clarity and rapid execution, is to use *marks* to denote the interlacing 'a' (warp over weft), and *blanks* to denote the interlacing 'b' (warp under weft) as shown at D, E and F in *Figure 1.5*. As can be observed, any kind of mark is satisfactory and it will be seen later that several types of marks may be used in one design simultaneously to indicate that, perhaps, some ends differently marked vary in their thickness, colour, or function from the others. Certain designs may be more easily followed when the convention is reversed and in such cases it is easy to adopt the opposite procedure, i.e. use marks to denote 'warp under weft' and blanks to indicate 'warp over weft', but since this is contrary to the normally accepted convention it is advisable to indicate clearly that the reversal of the convention has taken place. Whichever system of marking is used it must be remembered that the point paper is not merely a general representation of the design but is a specific plan of the order of the interlacing of threads, and that each square is the point of intersection of a warp end and a weft pick. To interlace, the threads must cross one another and, therefore, in each full repeat of the weave every vertical space and every horizontal space must have at least one mark and at least one blank otherwise the threads do not interlace but merely form loose floats which do not become woven into the cloth. One such unacceptable design is illustrated at A, in *Figure 1.6*, where ends 1 and 5 are clearly not interlacing with the weft but simply lying on top of it, and pick three lies below all the warp ends without any interweaving.

Although the design on point paper conveys clearly the plan of interlacings in the repeat of a weave it cannot be used to indicate also the configuration of the threads in the cloth and in cases in which this is important the design may be supplemented by the fabric sections. In fact, many compound structures cannot be properly understood without the use of sectional diagrams. The use of such diagrams and their relationship with the design paper is shown in *Figure 1.6*. Design B represents an area of plain weave, whilst C shows a section of the cloth cut through the warp at pick one, and

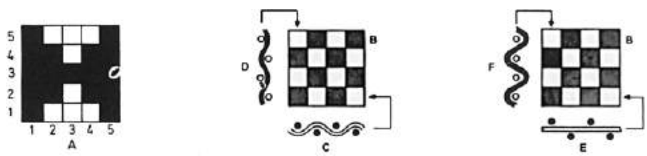

Figure 1.6

D, a section through the weft at end one in a fabric in which both the ends and the picks are equally displaced. The sections E and F are cut respectively at the same points with regard to the design as C and D, but although identical weave is used in each instance, different thread configuration is obtained, with the weft in this case lying quite straight and causing the warp to bend markedly. Of course, the different arrangement does not occur either spontaneously or at random but is dependent upon well defined conditions which are fully explained in the following chapters.

In the foregoing examples only the standard 8 × 8 design paper has been illustrated but in some cases, especially in connection with large figured designs, other orders of ruling are used and these are illustrated in *Figure 11.15*, and the reasons for their use are explained in Chapter 11.

WEAVE REPEAT UNIT

Any weave repeats on a definite number of ends and picks (or of vertical and horizontal spaces): generally only one repeat need be indicated on design paper. The number of ends and picks in a repeat may be equal, or unequal, but in every case the complete repeat must be in rectangular form on account of the threads interlacing at right angles. For instance, a weave cannot take the form shown at A in *Figure 1.7*; if, as shown in the example, any part of the complete repeat extends over 10 ends and 10 picks, every other portion must extend over 10 ends and 10 picks.

It is necessary for the marks and blanks to join correctly at the sides, and at the top and bottom of a design, in order that when the pattern is repeated in the loom from side to side and from end to end of the cloth an unbroken

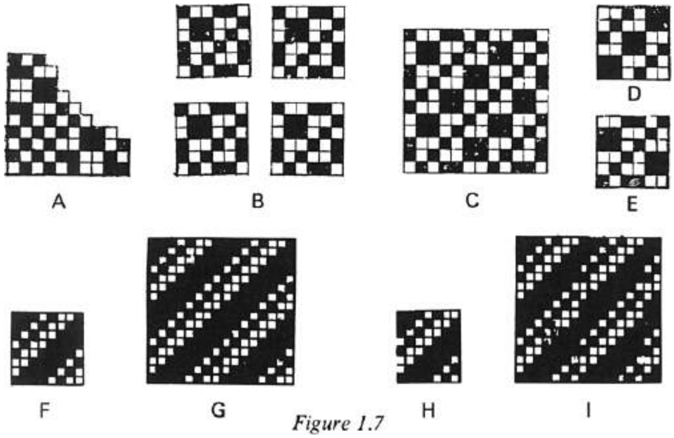

Figure 1.7

weave will result. The joining of the repeats of a weave is illustrated at B and C in *Figure 1.7*, in which B shows four complete repeats of a weave on 6 ends and 6 picks detached from each other. In each repeat the last end and pick respectively join correctly with the first end and pick, so that when the repeats are put together, as shown at C, a continuous and unbroken weave is formed. A warp 100 cm wide, with 30 ends per cm, will contain $100 \times 30 = 3000$ ends, which will give $3000 \div 6 = 500$ repeats of the weave B across the width of the cloth.

D and E in *Figure 1.7* show that a weave may appear different on account of being commenced in a different position, if only one repeat is shown, but such an alteration does not cause any change in the woven cloth, as either D or E will produce exactly the same effect as C.

Commencing a weave at a different position, as stated above, does not in any way affect the appearance of the cloth but whatever the starting point a full repeat must be invariably given. An incomplete repeat, if used as the basis for a design, results immediately in a faulty construction and this is clearly illustrated at H and I in *Figure 1.7*. F and G represent respectively the correct, full repeat and the effect of combining of several repeats to form a faultless cloth. H shows an incomplete repeat of the same weave and whilst the fault is not very obvious in the single unit it becomes immediately apparent when several of these faulty units are joined together as at I.

CONSTRUCTION OF DRAFTS AND LIFTING PLANS

A draft indicates the number of healds used to produce a given design and the order in which the warp ends are threaded through the mail eyes of the healds. (Note—the terms shafts, leaves, staves, cambs and heddles are synonymous with the term healds.)

Lifting plan (weaving or pegging plan) defines the selection of healds to be raised or lowered on each successive insertion of the pick of weft.

The weave or design depends entirely, as far as the interlacing of threads is concerned, upon the order of drafting in the healds combined with the order of lifting or lowering of the healds. Skill in drafting is particularly useful in designing for the tappet and the dobby shedding systems as these limit the number of different orders of interlacing to eight healds and to twenty-four healds respectively and in order to increase the width of the repeat beyond the eight or the twenty-four ends, the designer must depend upon skilful use of drafting. The length of the design is normally limited to eight picks in tappet shedding while this limitation does not exist in dobby shedding where, theoretically, designs of any length can be produced.

Methods of indicating drafts and lifting plans

Various methods of indicating drafts may be employed, as for instance—(*a*) By ruling lines, as shown in *Figure 1.8* at A, B, and C, in which the horizontal lines represent the healds, and the vertical lines the warp threads, while the marks placed where the lines intersect indicate the healds upon which

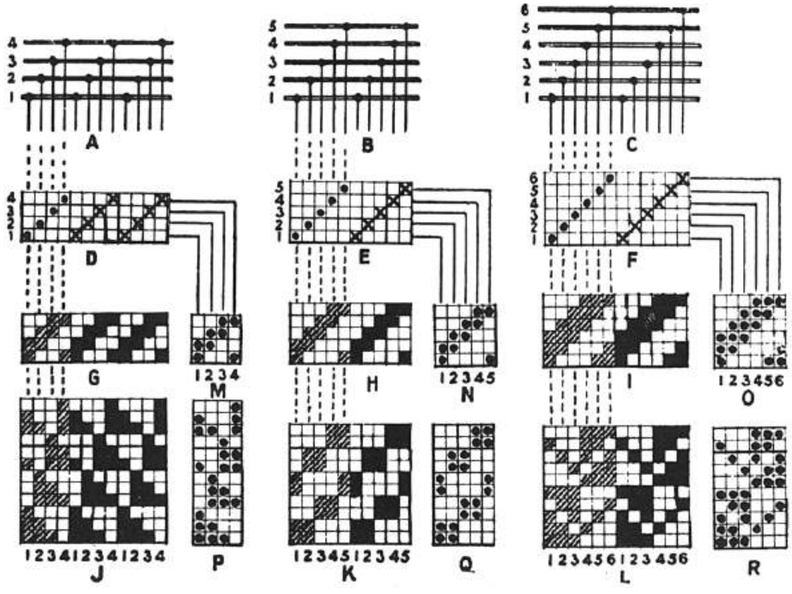

Figure 1.8

the respective threads are drawn. (*b*) By the use of design paper, as shown at D, E, and F in *Figure 1.8*, in which the horizontal spaces are taken to represent the healds, and the vertical spaces the warp threads. Marks are inserted upon the small squares to indicate the healds upon which the respective threads are drawn. This method is usually the most convenient. (*c*) By numbering, as shown by the numbers below the designs given at J, K, and L in *Figure 1.8*, which refer to the number of the healds (the front heald is number one). In this case the threads are successively drawn on the healds in the order indicated by the numbers.

The principle in drafting a pattern is that *ends which work in different orders require separate healds* and it should be obvious that as the heald is an entity all ends drawn through the eyes of a given heald must work alike. The converse of the above rule is not entirely applicable, and although it may be said that all ends which work alike *may* be placed on the same heald, it will be found later that occasionally it is more convenient to draw ends operating in identical fashion through different healds. Nevertheless, in order that the issue is not confused all examples shown in *Figure 1.8* employ the simple method of: separate healds for ends working differently, same healds for ends working alike. All the examples in *Figure 1.8* show the use of the most common and the simplest system of drafting known as *straight* drafting upon four, five, and six healds. In the straight draft, using a weave repeating upon four ends, successive ends of the repeat are drawn upon successive healds until the end of the repeat is reached whereupon the end number five which is the first end of the second repeat and, therefore, identical in its working with the first end of the first repeat, is drawn upon the first heald, and so on until the sequence is completed again (A and D in *Figure 1.8*). In this system of drafting the number of ends in the design repeat cannot exceed the number of healds employed, but it may be a factor of the number of healds. Thus, any weave, repeating upon two ends, or upon four ends, as shown at G and J in *Figure 1.8*, is suitable for the draft A; any weave on five ends such as H and K is suitable for the draft B, while weaves repeating on two, or three, or on six ends, as shown at I and L, can be woven on the draft C. For the purpose of illustration, in each example more than one repeat of the design and the draft are given (different marks are shown in the first repeat), but in practice it is necessary to show only one repeat. The draft is repeated in the healds across the full width of the warp (with the exception in some cases of the selvages), and if there are 2400 threads in the warp the draft A will be repeated 600 times, the draft B 480 times, and the draft C 400 times. It will be noted from the various examples given in *Figure 1.8* that the number of picks in a repeat is of no consequence as far as the draft is concerned, but will have to be considered carefully in connection with the lifting plan.

The examples M, N, O, P, Q, and R in *Figure 1.8* are the respective lifting plans for the designs alongside which they are placed; they indicate the order in which the healds are raised and depressed in forming the design. M, N, and O form designs suitable for tappet shedding on account of the low number of picks per repeat and in this instance the lifting plan is indicative of the shape and arrangement of shedding tappets or cams. Where a dobby is used, as it must be in cases of P, Q, and R due to the length of the repeat, the lifting plan indicates the order of pegging, or cutting the control lattice of the selection mechanism. The numbered vertical spaces of the lifting plans correspond with the numbers at the side of the drafts; the vertical space numbered 1 in the lifting plans indicates how the first heald is operated; that numbered 2, the second heald; that numbered 3, the third heald; and so on. The plans further show which healds are raised and depressed on succeeding picks; thus, M indicates that on the first pick the healds 1 and 4 of the draft D are raised, and the healds 2 and 3 depressed; on the second pick, the healds 1 and 2 are raised, and the healds 3 and 4 depressed; on the third pick numbers 2 and 3 are raised, and 1 and 4 depressed; and on the fourth pick numbers 3 and 4 are raised, and 1 and 2 depressed. In the same manner P indicates that on the first pick the healds 1, 2, and 3 are raised; on the second pick, the healds 1 and 2; on the third pick, the heald 1 and so on.

In each example given in *Figure 1.8* the lifting plan is exactly the same as the corresponding design, a feature which only occurs in straight drafts. The threads of a warp may be drawn straight from right to left instead of from left to right (this is not commonly done), which, unless allowed for in the lifting plan, will cause the direction of the design to be reversed.

Relations between design, draft, and lifting plan

The three factors upon which the construction of any woven fabric depends —the design, the draft, and the lifting plan—are very closely dependent on one another as already indicated. A thorough knowledge of this interdependence is very valuable to a designer upon whose skill severe mechanical limitations of the weaving loom may be imposed. In many cases it is only his intimate acquaintance with the drafting systems and the possibilities of manipulating the lifting orders which enables him to introduce variety into apparently rigid mechanical systems of operation. In normal practice the designer's brief is to produce a range of designs for looms with a known pattern scope. This usually also involves the draft and the lifting plan construction. A similar procedure is adopted when the designer is asked to reproduce a specific design from a sample. The weave in the sample is analysed and a suitable draft and lifting plan devised. Occasionally a more difficult task is encountered which is to construct designs and the corresponding drafts to suit a given lifting plan. This may occur in tappet shedding where the lifting order is fixed by the cam shape and all else must be subordinated to it, but an extension of the pattern range is desired. Yet another different exigency arises when the designer, engaged in the production of experimental pattern ranges, works with a dobby loom and wishes to design a series of patterns and the corresponding lifting plans to suit the existing draft in a warp that is in the loom. The following examples show the various procedures adopted in the different circumstances and emphasise the close interdependence of the three factors.

Construction of drafts and lifting plans from given designs

The construction of the draft and lifting plan for a given design is illustrated in stages in *Figure 1.9*. Following the rule stated earlier: The threads in a design, which are raised and depressed simultaneously—that is, are indicated the same in the design—may be drawn on the same heald; the threads that are different from each other must be drawn on different healds. As many healds are, therefore, required as there are threads working differently from each other in the repeat of a design; thus a 4-thread twill requires four healds, a 5-thread twill five healds, etc. In practice it is sometimes found advantageous to use more healds than the least possible number.

In constructing the draft for design A in *Figure 1.9* the first end is indicated on the first heald, then all the ends in the design, which work the same as the first end, are also indicated on the first heald, as shown at B. The working of the first heald is copied from the design A on to the first vertical space of the lifting plan, as shown at C. The second end in the design A works differently from the first end, and is, therefore, indicated on the second heald, and all the ends, which work like the second end, are indicated on the same heald, as shown at D; while the working of the second heald is copied from the design on to the second vertical space of the lifting plan, as indicated at E. The third end in the design A works differently from either the first or the second, and is, therefore, indicated on the third heald, and also all the corresponding ends, as shown at F; then the working of the third heald is indicated on the third vertical space of the lifting plan, as shown at G.

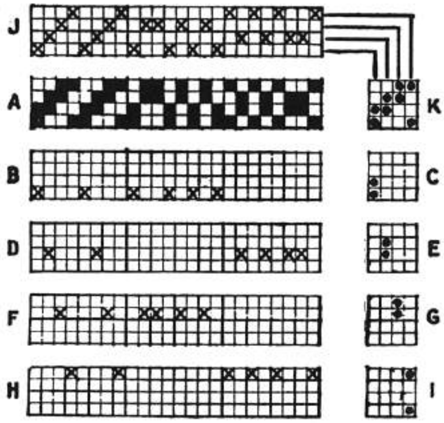

Figure 1.9

In the same manner the fourth end of the design, which works differently from either the first, second, or third, is indicated on the fourth heald, and also all the corresponding ends, as shown at H (this completes all the ends in the repeat), while the order of working is indicated on the fourth vertical space of the lifting plan, as shown at I. B, D, F, and H are shown combined at J, and C, E, G, and I at K, which thus respectively show the complete draft and lifting plan for the design A.

The foregoing system of constructing a draft and lifting plan fully illustrates the principles involved, but the usual method of procedure is that represented in stages at A to O in *Figure 1.10*, in which A shows the design. The draft is made first, the ends of the design being taken in succession, and commencing with the first end it is indicated on the first heald, as shown at B. (It does not follow, however, that the first end of a design should in all cases be indicated on the first heald, this being shown at G in *Figure 4.12*.) The second end is different from the first, hence it is indicated on the second heald, as shown at C in *Figure 1.10*; the third end is like the first, and is, therefore, indicated on the same heald as the first end, as shown at D; the fourth end is like the second, and is indicated on the same heald as the second end, as shown at E; the fifth end is like the first and third ends, and is indicated on the same heald, as shown at F; the sixth end is different from any of the preceding and is, therefore, indicated on the next heald (the third), as shown at G; the seventh end is different again, hence it is indicated on the fourth heald, as shown at H; the eighth end is like the sixth, and is indicated on the same heald, as shown at I; the ninth end is like the seventh, and is, therefore, indicated on the fourth heald, as shown at J; while the tenth end is like the sixth and eighth, and is indicated on the third heald, as shown at K.

In constructing the lifting plan, the healds are taken in succession from front to back, and the order of working of the corresponding ends is copied from the design on to successive vertical spaces from left to right. Thus, the working of the ends, drawn on the first heald, is indicated on the first vertical space of the lifting plan, as shown at L in *Figure 1.10*; of the ends, drawn on the second heald, on the second vertical space, as shown at M; while in the same manner the working of the third heald is indicated on the third vertical space, as shown at N, and of the fourth heald on the fourth vertical space, as represented at O. The lifting plan is complete on as many vertical spaces as there are healds in the draft, and on as many horizontal spaces as there are picks in the design. The threads are conveniently followed if the draft is placed directly above or below, and the lifting-plan alongside the design.

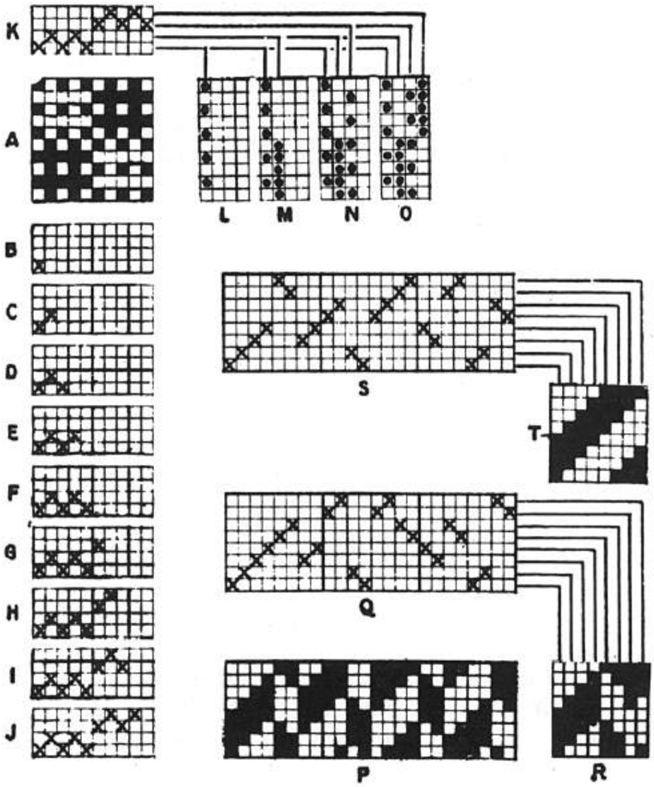

Figure 1.10

In drafting the ends of a design from the first to the last in successive order, it is not always advisable to indicate those which are different from each other in the same order on the healds as they are found in the design. A draft should be arranged in an order which can be easily followed and remembered by the drawer-in and weaver, and to accomplish this, in many cases, it is necessary for the order of drafting to correspond with the basis upon which the design is constructed. For example, P in *Figure 1.10* shows a design in which the threads are reversed in sections of four and two; if the threads which work differently from each other are indicated on the healds successively in the order in which they are found in the design, the draft will be as shown at Q, which is too irregular to be readily remembered. By indicating the draft to correspond with the arrangement of the design, as shown at S, however, the order of drawing in is simply four to right and two to left, with a break of four healds at each change. In the latter method the lifting plan also is more regular, as will be seen by comparing the plans R and T, which respectively correspond with the drafts Q and S. Certain designs can be drafted in different ways, but a change in the order of drafting necessitates a corresponding change in the lifting plan.

The healds for designs in which different weaves and different yarns are combined, may usually be divided into two or more distinct sections, which are put together to form the complete set of healds. The different sections should be placed in such positions relative to each other as will most contribute to successful weaving. There is no fixed rule that can be practised, but, generally, the healds should be placed nearest the front, which (*a*) carry the weakest yarn, (*b*) carry the threads which are subjected to the most strain (are most frequently interlaced), and (*c*) are the most crowded with the threads.

Construction of drafts from given designs and lifting plans

This process is illustrated in stages in *Figure 1.11*, in which K shows the design, and L the lifting plan. The first vertical space of L indicates that the first heald is raised on the picks 1 and 2, therefore all the threads of the design K, which are raised on the picks 1 and 2, are drawn on the first heald, as shown at M. The second vertical space of L shows that the second heald

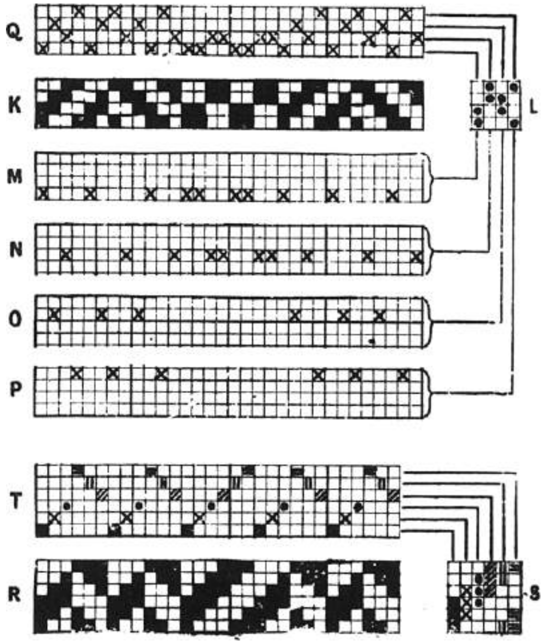

Figure 1.11

is raised on the picks 3 and 4, therefore all the threads in the design K that lift on the corresponding picks are drawn on the second heald, as shown at N. In the same manner, all the threads which are raised on the picks 2 and 3 to correspond with the third vertical space of L, are drawn on the third heald, as shown at O, and those that are raised on the picks 1 and 4, to correspond with the fourth vertical space of L, are drawn on the fourth heald, as indicated at P. Q shows the marks of M, N, O, and P combined, and thus indicates the draft, which will produce the design K if the lifting plan L is employed. The design K in *Figure 1.11* is similar to the design G in *Figure 1.12*, but the lifting plan L is different from the plan B, therefore in one case the draft Q is required in producing the design, and in the other case the draft A.

In further illustration, a design is given at R in *Figure 1.11* and a lifting plan at S, for which the draft indicated at T is required; the different marks will enable the successive stages in the construction of the draft to be followed.

Construction of designs from given drafts and lifting plans

The method of constructing the design from a given draft and lifting plan is illustrated in stages in *Figure 1.12*, in which A shows the draft and B the lifting plan. The vertical spaces in B, in the order of 1, 2, 3, and 4 respectively, indicate how the healds 1, 2, 3, and 4 are operated, and the marks of B indicate healds raised. Thus, the first vertical space of B shows that the first heald is raised on the picks 1 and 2, therefore all the threads that are drawn on the first heald will be correspondingly raised, as shown at C in *Figure 1.12*.

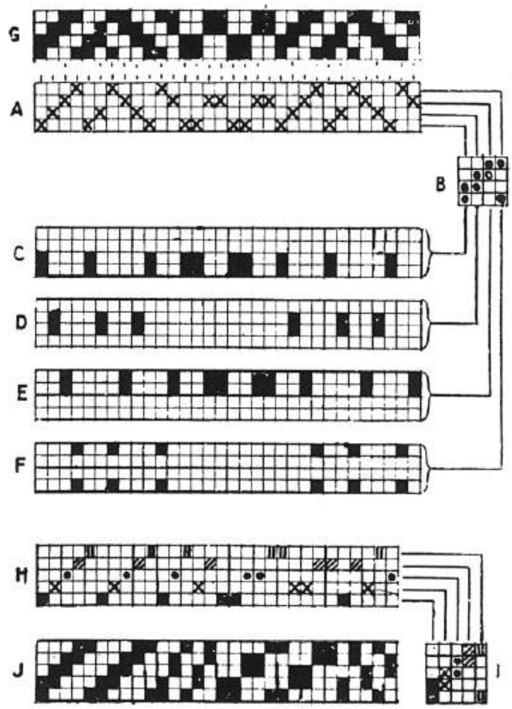

Figure 1.12

The second vertical space of B shows that the second heald is raised on the picks 2 and 3, all the threads drawn upon the second heald being, therefore, lifted, as shown at D. In the same manner the third heald is raised on the picks 3 and 4, and lifts the threads drawn upon it, as shown at E, while the fourth heald is raised on the picks 1 and 4, and produces the lifts indicated at F. The marks given in C, D, E, and F are shown combined at G, which thus indicates the design produced by the draft A and the lifting plan B.

As a further illustration a 5-heald draft is given at H, and the lifting plan at I, which produce the design shown at J; the ends upon each heald, and the corresponding order of working are represented by a different mark in order that the building up of the design J may be conveniently followed.

Systems of drafting

In addition to the straight drafts and the various mixed drafts which were illustrated in the preceding sections there exist several other well defined orders of drafting, such as: skip, point, sateen, herring-bone, reversed,

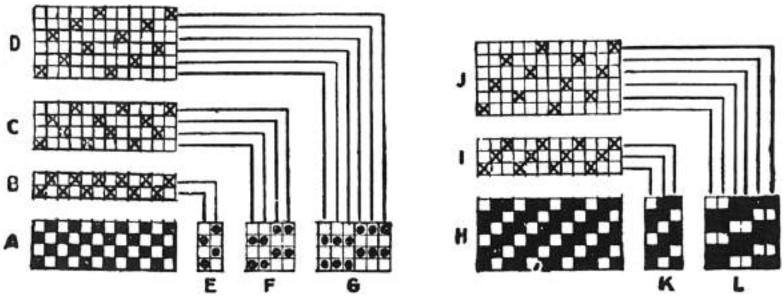

Figure 1.13

transposed, curved, combined, etc. Of these, the first three mentioned are most important and the remainder, though occurring reasonably often are usually formed as a natural outcome of following the design or the lifting plan for which they are arranged similar to the various mixed drafts shown above.

Skip drafts: this system is particularly useful in weaving very densely set fabrics where normally a small number of healds is required. In order that the mails will not be too crowded on the shafts and to reduce friction and rubbing between the ends it is customary to use more healds than the minimum necessary for the weave. For example, the plain weave indicated at A in *Figure 1.13*, may be drawn on two healds, as shown at B, if the cloth is coarse; or on four healds, as shown at C, if the cloth is of medium fineness; or on six healds, as indicated at D, if the cloth is very fine. Assuming in each case that there are 10 mails per cm on each shaft, draft B will give 20 ends per cm; draft C, 40 ends per cm; and draft D, 60 ends per cm. In tappet shedding, with the draft C the first and second healds are joined together, and the third and fourth together; and with the draft D the first, second, and third together, and the fourth, fifth, and sixth together. The operation of two plain tappets then lifts the odd threads on one pick, and the even threads on the next pick. In dobby shedding, the lifting plans for the drafts B, C, and D are as shown at E, F, and G respectively.

The design given at H in *Figure 1.13*, may be drawn on three healds as shown at I, or on six healds, as shown at J. In the latter case the healds 1 and 2 are coupled together, and 3 and 4, and 5 and 6, if the usual three tappets are employed; but in dobby shedding the lifting plans for the respective drafts are as shown at K and L.

Sateen drafts: the purpose of sateen draft is similar to skip draft in that each is used to reduce friction between adjacent warp ends and to alleviate the overcrowding of the mails. In sateen drafts, however, this result is not achieved by duplication of the healds but by staggering the end placing. The principle is illustrated in *Figure 1.14* in reference to a sateen draft on five healds, and it will be found useful to compare these examples with those shown in connection with the straight draft on five healds given in *Figure 1.8*.

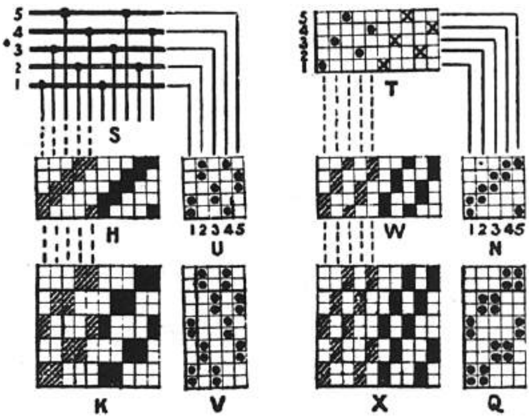

Figure 1.14

The examples which are alike in the two figures are lettered the same. As shown at S and T in *Figure 1.14*, the threads in the order of 1, 2, 3, 4, 5, are drawn on the healds in the order of 1, 3, 5, 2, 4, therefore the threads are not lifted in the same order as the healds are raised. Thus, in order to produce the design H, the lifting plan U is required, and to produce the design K, the lifting plan V. In the same manner the lifting plan N produces the design W, and the lifting plan Q, the design X. Further, the plan N indicates that on the first pick the healds 1 and 5 are raised, which lift the first and third ends in each repeat of the design W; on the second pick the healds 1 and 2 are raised, and lift the first and fourth ends; on the third pick the healds 2 and 3 lift the fourth and second ends, and so on; the design W thus resulting from the combination of the draft T and the lifting plan N. A draft is complete on the same number of ends, and a lifting plan on the same number of picks, as the design.

Point drafts: point drafts are used for weaves which are symmetrical about the centre, and they are frequently employed to produce waved or diamond effects. The main advantage of this system is that it allows the production of quite large effects economically which if attempted on the straight drafts would require almost twice the number of healds. Examples B and E in *Figure 1.15* show the method used to construct these drafts and it will be seen that to achieve a well defined point in the design the ends are drawn in straight order starting with heald 1 and finishing with the last heald in the number employed, whereupon the order of drawing-in of the consecutive ends is reversed. The first and the last healds carry only one end each, whilst all the healds in the middle carry two ends each per repeat of the draft. As a result, using this system of drafting the number of ends per repeat of the design is: 2 × (No. of healds) less 2. This is illustrated at A, where the waved design constructed on five healds repeats upon eight ends,

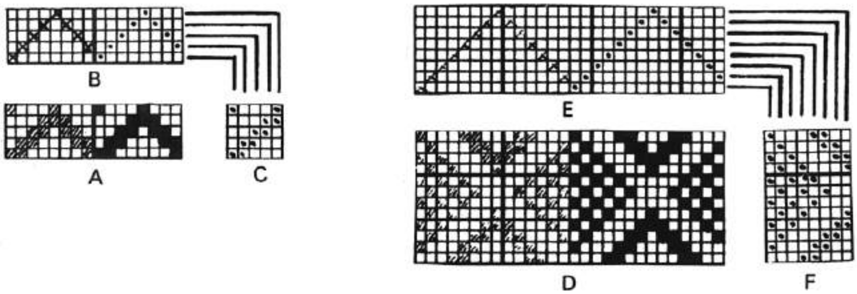

Figure 1.15

and at D, where the diamond effect using eight healds repeats upon fourteen ends. Further extension of design size is possible with special adaptations of the point draft and several examples of this are given in chapters devoted to waved twills and diamonds (*Figures 3.7* and *4.5*).

HEALD CALCULATIONS

There are two principal types of healds in use: the knitted healds in which the mails are fixed according to a definite pitch or density, and the slider wire healds in which the mails are free to move in either direction. In each group several sub-types could be enumerated, but their existence does not in any way prejudice the main argument. The knitted healds are cheaper but their useful life is shorter and they suffer from the rigidity of pitch, also, they have to be manufactured for a specific sett and a specific draft. As a result, they are nowadays only employed in certain special fields and the slider wire healds have become generally accepted in all branches of weaving where their adaptability and long lasting qualities are capable of offsetting the higher initial cost.

Whatever the type of healds used in constructing tappet and dobby designs, the draft should be considered carefully in order to avoid needlessly complicating the healds. A good design, however, should not be sacrificed in order to simplify the arrangement of the healds. An ideal draft, so far as regards the healds, is obtained when (*a*) an equal number of ends is drawn on each heald, and (*b*) the mails on each heald are evenly distributed across the width. The first point is illustrated by the examples given in *Figure 1.16*, in which two rather similar designs are given at A and C, each of which repeats on 42 ends, while the respective drafts are indicated at B and D. The design is constructed in such a manner that in the repeat the same number of ends—vis., 7—are drawn on each heald, as indicated in the draft B, hence all the healds are alike. Assuming that there are 42 ends per cm in the reed, each heald will have (42 ends ÷ 6 healds) = 7 mails per cm, and if the healds are 80 cm wide, each will contain (80 × 7) = 560 mails. In the design C, however, the conditions are different, as will be seen from an examination of the draft D, in which in the repeat of 42 ends, 8 ends are indicated on each of the healds 1, 3, 4, and 6, as compared with 5 ends on healds 2 and 5. Assuming, again, that there are 42 ends per cm in the reed, each of the healds 1, 3, 4, and 6 will require $(42 \times \frac{8}{42}) = 8$ mails per cm, while each of the healds 2 and 5 will require $(42 \times \frac{5}{42}) = 5$ mails per cm. If the healds are 80 cm wide, each of the shafts 1, 3, 4, and 6 will contain $(80 \times 8) = 640$ mails, and healds 2 and 5 $(80 \times 5) = 400$ mails.

In reference to the second point, while the distribution of the ends on each heald, in the drafts B and D in *Figure 1.16*, is not perfectly uniform, it is near enough to allow each heald to be knitted at a uniform rate. This last condition is, of course, not valid in slider wire healds where the mails assume automatically the correct position in respect of the reed, once the warp ends are tightened in the loom.

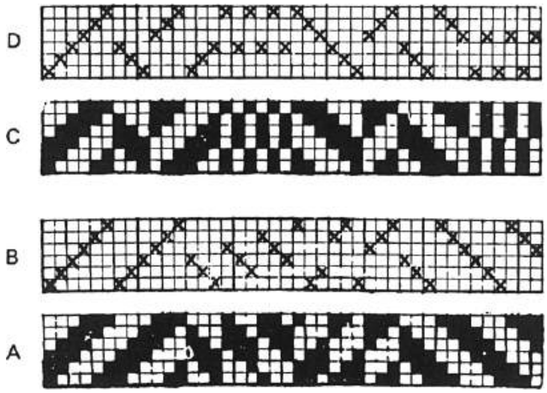

Figure 1.16

At one time efforts were frequently made to adapt healds knitted for high sett fabrics to serve also lower sett fabrics if drafts were similar. The adaptation was achieved by casting-out in the healds, i.e. leaving empty certain mail eyes at regular intervals. This procedure has been largely discontinued as it makes drawing-in of ends very laborious, mitigates against the introduction of automatic in-drawing machinery, and increases labour costs beyond the point at which a saving through the re-use of an existing set of healds could be achieved. However, the techniques of casting out in the healds are similar in principle to the casting out in jacquards, which process is described in detail in Chapter 11.

DENTING

Warp ends during weaving are spaced out across the width of the warp sheet according to a desired density by the wires of the reed. The most frequent order of denting (drawing ends through a space—dent or split—between two wires in the reed) is one, two, three, or four ends per dent regularly across the width. There are some types of fabric, however, which require an irregular order of denting to emphasise certain design features and in such cases the order of arrangement of the ends in the reed becomes an essential part of the design and must be indicated carefully and in the correct relationship in respect of the weave and the draft. Circumstances which necessitate the use of the special denting orders are explained and illustrated, as they arise, in the subsequent chapters. At this point only the basic considerations involved are discussed and the various methods of indicating the denting are illustrated.

A in *Figure 1.17* shows a weave in which adjacent ends work alike, if these pairs of ends were drawn through the same split of the reed they would tend to roll over one another, in this way losing the clarity of the design. To

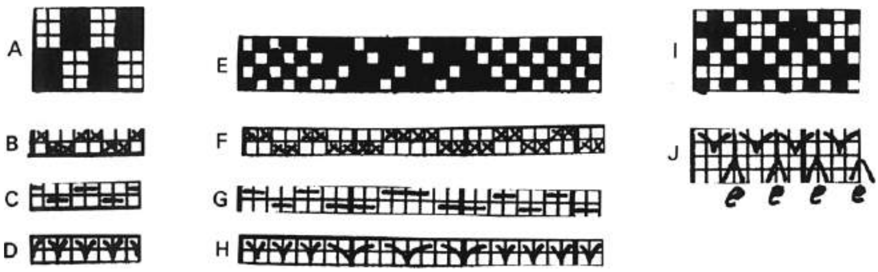

Figure 1.17

prevent this, the ends which work alike are drawn through different dents, and the reed wire which separates them ensures that no rolling takes place. B, C, and D show the different methods used to indicate the order of denting suitable for this weave. At E a crammed stripe design is illustrated in which the ends forming one weave stripe are less densely spaced (two per dent), than the ends forming a different weave stripe (four per dent). F, G, and H indicate how this order of denting could be marked. At I a different construction is shown and, here, the intention is to produce fine, dense lines with the ends crammed closely together separated by lines of open fabric. This is achieved by drawing three adjacent ends through the same split and leaving an empty dent in between each filled dent. J illustrates a convenient method of indicating this order with 'e' showing where a dent is left empty.

2

Construction of Elementary Weaves

PLAIN WEAVE

In plain weave the threads interlace in alternate order, and if the warp and weft threads are balanced—that is, are similar in thickness and number per unit space, the two series of threads bend about equally. This is illustrated at C in *Figure 2.1*, which shows how the first pick of A interlaces, and at D, which represents the interlacing of the last end of A. In this class of plain cloth each thread gives the maximum amount of support to the adjacent threads, and in proportion to the quantity of material employed, the texture is stronger and firmer than any other ordinary cloth. The weave is used for structures which range from very heavy and coarse canvas and blankets made of thick yarns to the lightest and finest cambrics and muslins made in extremely fine yarns. In the trade such terms as tabby, calico, alpaca, and taffeta are applied to plain cloth.

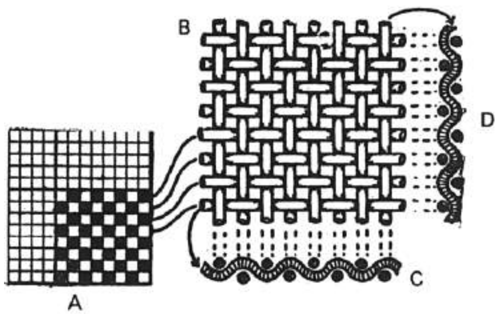

Figure 2.1

Plain weave produces the simplest form of interlacing, but it us used to a greater extent than any other weave, and diverse methods of ornamenting and of varying the structure are employed, as for example: Threads which are different in colour, material, thickness, or twist are combined; the number of threads per split of the reed, or of picks in a given space, is varied in succeeding portions of a cloth; the ends are brought from two or more warp beams which are differently tensioned, or are passed in sections over bars by which they are alternately slackened and tightened; while by means of a specially shaped reed which rises and falls the threads are caused to form zig-zag lines in the cloth. Two or more of the foregoing methods may be employed in the same cloth, and after weaving further variety may be produced by the processes of dyeing, printing, and finishing. A number of different kinds of plain cloth are illustrated in *Figure 2.3.* A represents a fine cotton muslin cloth; B shows a coarse jute hessian; in C threads of different colours are combined in check form; in D the threads in both warp and weft vary in colour and in thickness; E illustrates the use of fancy slub yarns; in F the pattern is formed by combining different orders of denting; G shows a seersucker stripe produced by using two warp beams which are differently tensioned; while H represents an all-over crepon effect that is due to the use of hard-twisted (crepon) weft which, when the cloth is scoured, shrinks irregularly.

Rib and cord effects produced in plain weave

Plain weave structures in which considerable difference exists between the warp and the weft threads as regards thickness and number per unit space result in rib and cord effects. (The term cord is frequently applied to ribs which run the length of the cloth in order to distinguish them from those that run horizontally.) In cloths where the number of ends per unit space largely

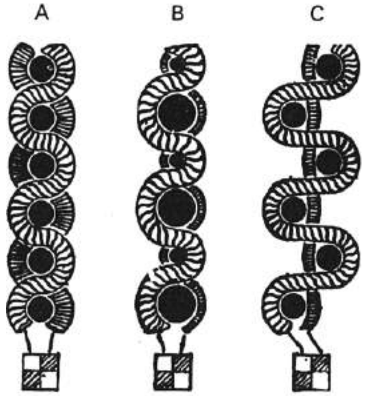

Figure 2.2

exceeds the number of picks, the latter tend to lie straight in the cloth with the former bending round them, and a warp rib structure results. If the opposite conditions prevail, the ends tend to lie straight with the picks bending round them, a weft rib structure being formed. In each case the prominence of the rib is accentuated if the straight threads are thicker than those which bend. These various constructional differences cannot be shown adequately by the design paper representation and their portrayal is best effected by the sectional diagrams as shown in *Figure 2.2.* At A one rib is shown in which all the warp threads are similar in thickness as also are the weft threads and the rib is formed due to greater number of ends than picks per unit space. In this type of fabric rib lines which are uniform in size appear on both sides of the cloth. A different form of rib structure is produced, however, if a thick and a fine thread alternately are employed in warp and weft, as shown at B. In forming a warp rib the thick ends always pass over

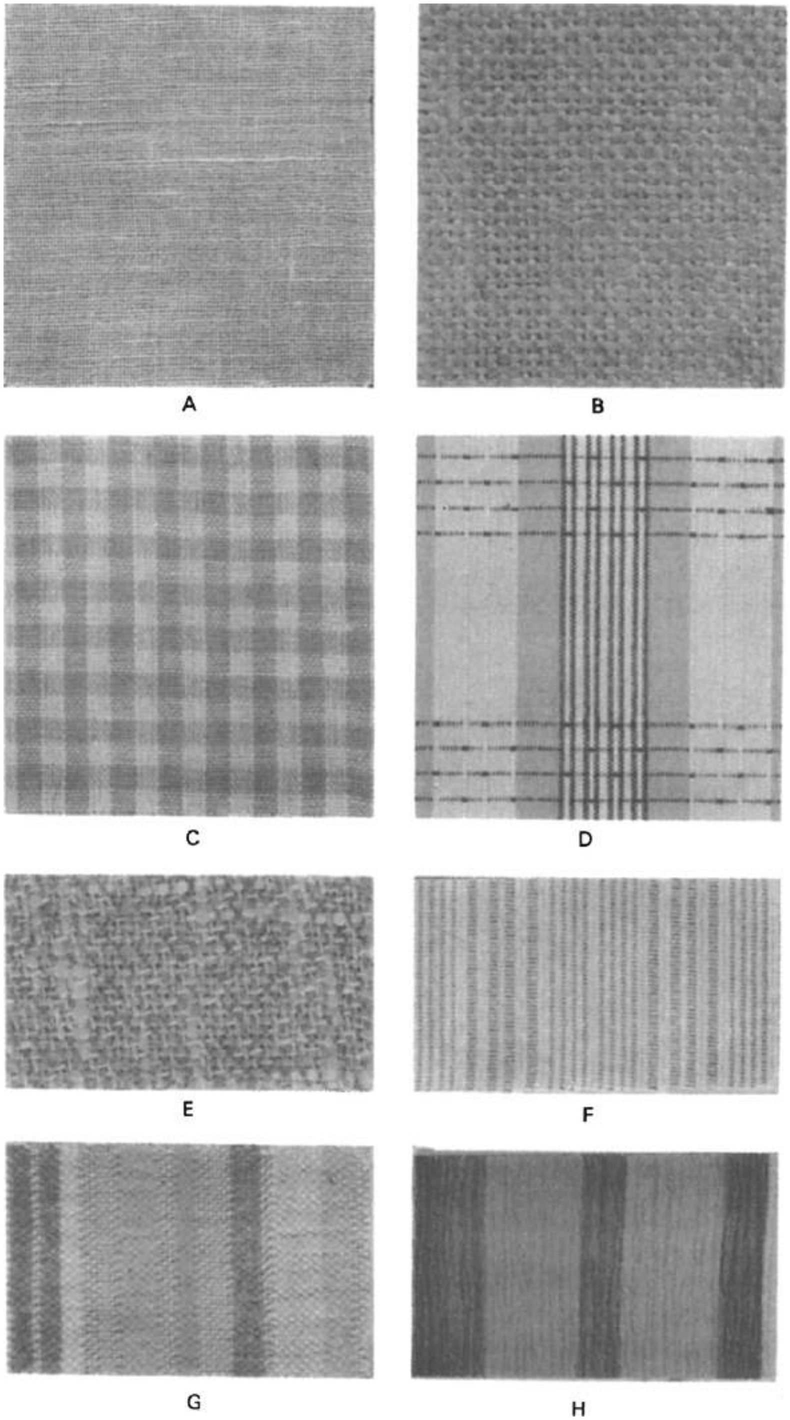

Figure 2.3

the thick picks, and under the fine picks; whereas in forming a weft rib, the thick picks always pass over the thick ends and under the fine ends. In the warp ribs there should be more ends per unit space than picks, and in the weft ribs more picks than ends. In this case, the rib lines, which are separated from each other by fine lines, show prominently on one side of the cloth only.

In another method of producing a warp rib structure in plain weave the odd ends are brought from one warp beam, and the even ends from another beam. One beam is much more heavily tensioned than the other, with the result that the heavily tensioned ends lie almost straight in the cloth and force the picks into two lines. The lightly tensioned ends are therefore compelled to bend round the picks in the manner illustrated at C, so that horizontal ridges and depressions are formed in the cloth. The rib formation is quite prominent if all the ends are equal in thickness, but it is still more pronounced if the lightly tensioned ends are thicker than the others.

SIMPLE OR REGULAR TWILL WEAVES

The twill order of interlacing causes diagonal lines to be formed in the cloth, as shown in the fabric represented in *Figure 2.4*. The weaves are employed for the purpose of ornamentation, and to enable a cloth of greater weight, closer setting, and better draping quality to be formed than can be produced in similar yarns in plain weave. Twilled effects can be made in various ways,

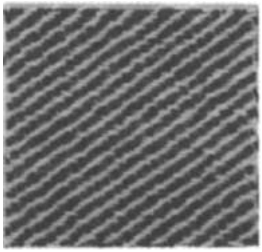

Figure 2.4

but in simple twills the points of intersection move one outward and one upward on succeeding picks. A twill cannot be made upon two threads, but upon any number that exceeds two; a simple twill is complete upon the same number of picks as ends. Twill lines are formed on both sides of the cloth, and the direction of the lines may be either to the right or to the left, but the direction on one side is opposite to that on the other side when the cloth is turned over. Warp and weft floats on one side of the cloth respectively coincide with weft and warp floats on the other side; thus, if warp float predominates on one side weft float will predominate in the same proportion on the other side.

Designation of twills

The order of interlacing of regular twills is the same for every thread in the repeat and, as stated above, the diagonal line is formed by advancing this order in steps of one in either direction. The fact that the interlacing order of all threads in the repeat is identical makes it possible to designate twills by describing the interlacing of the first thread, e.g.: -2 up, 2 down; 2- and -2; 2/2; or, more conveniently $\frac{2\cdot}{\cdot 2}$. This could be taken to indicate that on the first pick the first two ends are up, and the following two down; or, that the first end is raised for the first two picks and lowered for the following two. Either method could be equally well adopted to build up twills and both are shown in *Figure 2.5*, the first at A and B, and the second at C and D. Looking at several repeats of this weave shown side by side as at E it can be observed that it makes no difference to the appearance of the cloth whichever method is adopted in the construction.

The graphical method of designation described above has two further advantages. In regular twills it indicates at a glance the size of repeat, e.g. $\frac{2\cdot}{\cdot 2}$ twill gives a repeat of 4 ends × 4 picks, and $\frac{1\cdot 2\cdot}{\cdot 3 \cdot 2}$ twill indicates a repeat of 8 ends × 8 picks. The rule to establish the size of repeat is to add all interlacings above the line (warp up) to the sum of interlacings below the line

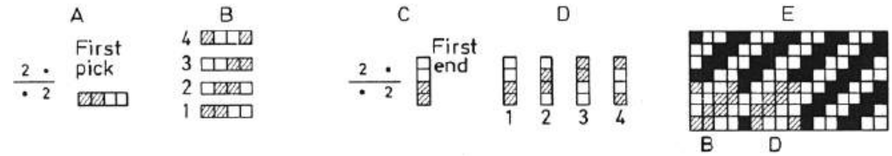

Figure 2.5

(warp down). The second advantage is that using this method it is possible to see immediately whether a twill has equal amounts of warp and weft showing on the face, e.g. $\frac{2\cdot}{\cdot 2}$; or, whether it is predominantly warp-faced, e.g. $\frac{3\cdot}{\cdot 1}$; or weft-faced, e.g. $\frac{1\cdot}{\cdot 3}$. Although it is correct to assume that a warp-faced twill when turned over becomes weft-faced, in practice, twills which are intended to show more warp on the face are constructed with a considerably greater number of ends per cm than picks per cm, and conversely, weft-faced twills are made with greater number of picks per cm than ends per cm. Therefore, even apart from the fact that most clothes are finished on the face side only, a mere reversal of the cloth will not automatically change the character of it as it will invariably appear improperly set on the reverse side.

Systematic construction of regular twills

The smallest number of threads on which it is possible to construct a twill is three and A, B, C and D in *Figure 2.6* illustrate all possible ways in which three-thread, or three-shaft, twills can be formed. Actually, only two interlacings are possible—the weft faced $\frac{1\cdot}{\cdot 2}$ (A and D) and the warp faced $\frac{2\cdot}{\cdot 1}$ (B and C), but as each of them can be used to make a twill running in either direction, four different effects can be produced. The terms *Cashmere*, *Jean*, *Jeanette*, and *Genoa* (q.v.) are applied to certain cloths made in the three-shaft twill weave.

On four threads three orders of interlacing can be made, viz., $\frac{1\cdot}{\cdot 3}$, $\frac{2\cdot}{\cdot 2}$, and $\frac{3\cdot}{\cdot 1}$, and as each of them may be inclined in either direction, six different effects can be formed. These are shown at E, F, G, H, I, and J in *Figure 2.6*. Next to plain weave, the $\frac{2}{2}$ twill is probably used more than any other weave, and is also known by the following trade terms: *serge*, *blanket*, *sheeting*, and *shalloon* (q.v.). The term 'drill' (q.v.) is frequently applied to the $\frac{3}{1}$ twill.

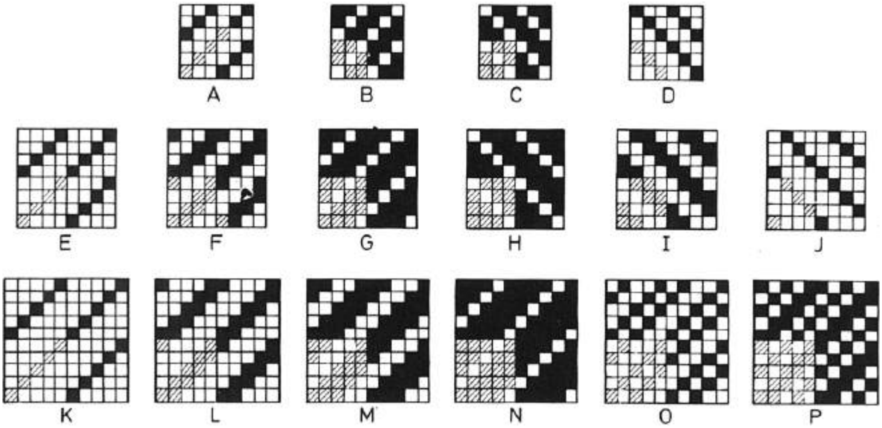

Figure 2.6

On five threads six twill weaves, running to the right, may be woven, as shown at K to P in *Figure 2.6*, while similar effects may be made twilling to the left. K and N are opposite to each other, and also L and M, and O and P; therefore, if one weave of a pair is formed on the face, the other weave will be formed on the reverse side, but twilling in the opposite direction, when the cloth is turned over.

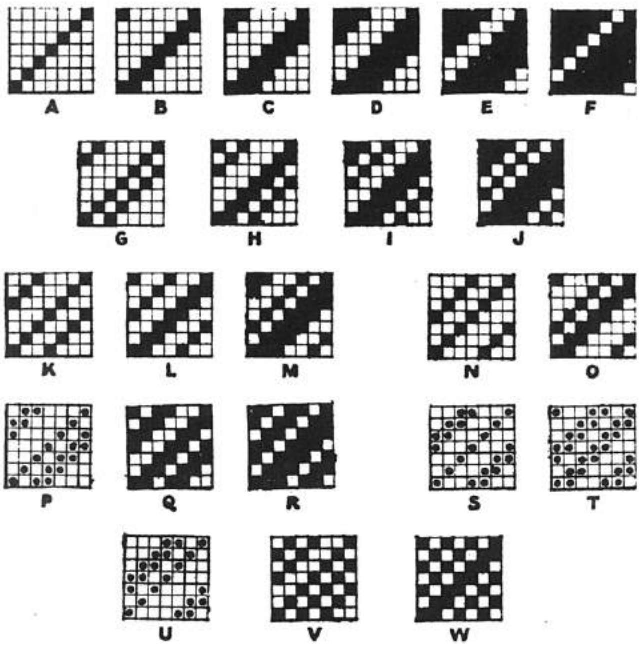

Figure 2.7

A systematic method of constructing simple twills is illustrated in *Figure 2.7*, which shows all the possible effects on seven threads. A single row of marks is inserted in the first weave A, then in each weave B to F a line of marks is successively added alongside. Commencing again with A, a single line of marks, separated by one space from the marks previously inserted, is added to A, B, C, and D, as shown at G, H, I, and J; then the single line is placed two spaces distant, as shown at K, L, and M; and afterwards three spaces apart, as indicated at N and O. A double line of marks is then added to A, B, and C with one space between, as shown respectively at P, Q, and R; then to A and B with two spaces between, as indicated at S and T; and afterwards to A with three spaces between, as shown at U. A commencement is again made with A, and two separate lines of marks are added, as shown at V and W.

The process may be carried still further in constructing twills on a larger number of threads, and by working systematically, as shown in the foregoing, it is possible to ensure that all the possible twills are obtained. It is necessary, however, to examine the weaves carefully, and weed out those that are duplicates of others. In *Figure 2.7*, for the purpose of illustration, duplicate weaves (which are indicated in dots) are included, and it will be found that H and U are alike, and so are O and P, L and S, and Q and T. The elimination of duplicate weaves still leaves 19 different twills and as each one of them could be made with the twill lines running in the opposite direction, a total of 38 effects could be achieved. This illustrates the considerable variety which it is possible to obtain even within a comparatively small size of the repeat. With further increases in the size of the repeat numerous new combinations arise and large twills based on 16, or 20 thread repeats offer almost infinite scope for experimentation. An examination of *Figure 2.7* will show that the various twills differ in the proportion of warp and weft visible on the face, and that they also differ with regard to the number of lines of the warp and the weft float which they contain. Designs A to F contain one warp and one weft float in the repeat and form two lines, whilst designs G to U form four lines, and designs V and W show six lines in the repeat.

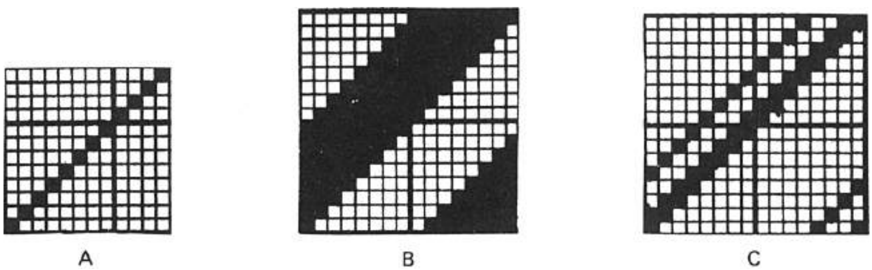

Figure 2.8

From the above examples it will be appreciated that the number of different interlacings which are possible increases with the increase in the size of the repeat. Not all of the constructions produced on a larger base are, however, suitable—many of the arrangements which are possible cannot be used in practice due to excessive length of float which results in a slack, poorly bound construction, unlikely to produce a serviceable fabric. Examples of such unsuitable arrangements are given at A, B, and C in *Figure 2.8*.

Large regular twills

Large twills are frequently also known as the *diagonals*, particularly those which show a prominent line, as in the example represented in *Figure 2.9*. In *Figure 2.10* a method of designing diagonals is illustrated, which can be employed in constructing twills upon any number of threads. It is first necessary to decide upon the number of threads in the repeat, and then to consider the general prominence of the main line or lines of the twill, and whether warp or weft shall be brought chiefly to the surface. If the weft is superior to the warp, the weft float should predominate over the warp float, and vice versa, but if the warp and weft are similar in quality both may be floated equally. Frequently, however, a predominance of weft float is preferred, because as a rule, the weft is rather more lustrous than the warp on account of containing less twist. The next point to consider is the number of intersections in the repeat, which should be sufficient to give the cloth the proper firmness. The twill may then be arranged according to the pattern and structure required; and experiments can conveniently be made by indicating the marks in various ways on the first horizontal space of a number of plans, as shown by the crosses in the examples A, B, and C in *Figure 2.10*. Such arrangements as are considered satisfactory may then be carried out in full by copying the marks one square to the right on succeeding horizontal spaces, as shown at A and C, or one square to the left, as shown at B, according to the direction in which the twill is required to run. The marks are continued from one side to the other, and from the top to the bottom of the plan in such a manner that the twill lines will be unbroken in succeeding repeats; and when the design is completed the same number of marks will have been inserted upon each horizontal and each vertical space.

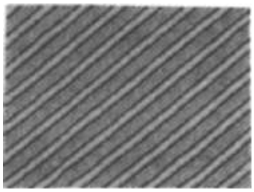

Figure 2.9

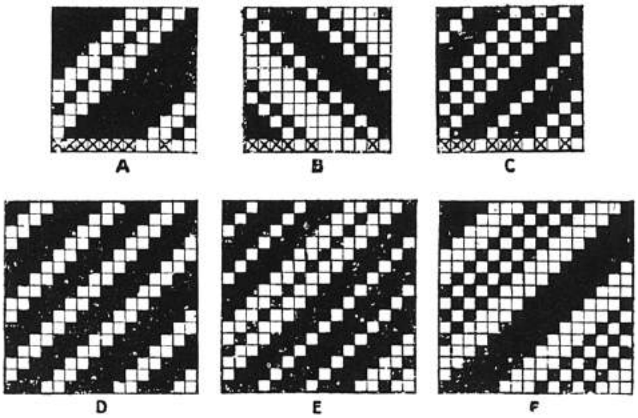

Figure 2.10

A and C in *Figure 2.10* represent warp-faced diagonals, whereas at B an even-sided construction is shown. As regards the number of intersections it may be considered advisable, in constructing a large twill, to obtain about the same degree of firmness as is produced by a smaller twill in the same cloth. Thus, A in *Figure 2.10* contains four intersections in twelve threads, and is, therefore, approximately equal in firmness to 3-and-3 twill, which contains two intersections in six threads. B contains six intersections in twelve threads, and is, therefore, similar in firmness to 2-and-2 twill, which contains two intersections in four threads, while C, in which there are eight intersections in twelve threads, corresponds in firmness to 1-and-2 twill, which has two intersections in three threads.

In constructing a large twill that contains a number of small lines in the repeat, it is necessary to avoid making the lines too much alike. The 16-thread twill, given at D in *Figure 2.10*, is defective in this respect, as it is very little different from a 5-thread twill which can be more economically woven. With a slight alteration, as shown at E, the weave appears distinctly as a 16-thread twill. F in *Figure 2.10*, which corresponds with the fabric represented in *Figure 2.9*, shows distinctly as a large twill, yet it is approximately equal in firmness to 2-and-2 twill.

Using the graphical method of designation the twills in *Figure 2.10* could be indicated as follows: A $\frac{7\cdot1\cdot}{\cdot2\cdot2}$; B $\frac{4\cdot1\cdot1\cdot}{\cdot1\cdot4\cdot1}$; C $\frac{3\cdot3\cdot1\cdot1\cdot}{\cdot1\cdot1\cdot1\cdot1}$; D $\frac{3\cdot4\cdot3\cdot}{\cdot2\cdot2\cdot2}$; E $\frac{3\cdot3\cdot3\cdot1\cdot}{\cdot1\cdot1\cdot2\cdot2}$; and F $\frac{5\cdot1\cdot1\cdot1\cdot}{\cdot3\cdot1\cdot1\cdot3}$.

Relative firmness of twill weaves

Where a weave changes from marks to blanks, and vice versa, the warp and weft threads correspondingly change from one side of the cloth to the other, or 'intersect' each other. Each thread must make at least two intersections in a complete repeat of a weave, one in passing from the face to the back, and another in passing from the back to the face; otherwise the thread will float continuously on one side of the cloth. The intersecting of the threads gives the cloth firmness, and (with certain exceptions) the more frequent the intersections are the firmer the cloth is. If a twill fabric is correctly built *on the square*—that is, with the warp and weft threads equal in thickness and in number per cm—each intersection causes the threads to be separated by about the thickness of a thread. Therefore, other things being equal, the more frequently the intersections occur the further apart should the threads be placed. This is illustrated in *Figure 2.11*, in which three 8-thread twill weaves are given at A, B, and C, while the interlacings of the first pick of the designs are represented at D, E, and F respectively. The dotted vertical lines are placed apart a distance equal to the diameter of a thread, and each intersection is taken to occupy a space equal to a diameter. (This is not strictly accurate, but is near enough for practical purposes.) Weave A repeats on eight threads, and each thread has two intersections, and thus occupies the space of ten diameters, as shown at D; the repeat of B contains eight threads and four intersections, and thus occupies the space of twelve diameters, as represented at E; while in the repeat of C there are eight threads and six intersections, which occupy the space of fourteen diameters, as indicated at F.

It will be readily understood that a cloth which is of suitable firmness when woven in the weave C, will be looser if woven in the weave B, and will be still more lacking in firmness if woven in the weave A. That is, assuming that the warp and weft threads are the same thickness in each case, B will require more threads per unit space than C, and A than B; the relative proportions being (approximately) A:B:C::14:12:10. On the other hand, assuming that the threads per unit space are the same in each case, thicker threads can

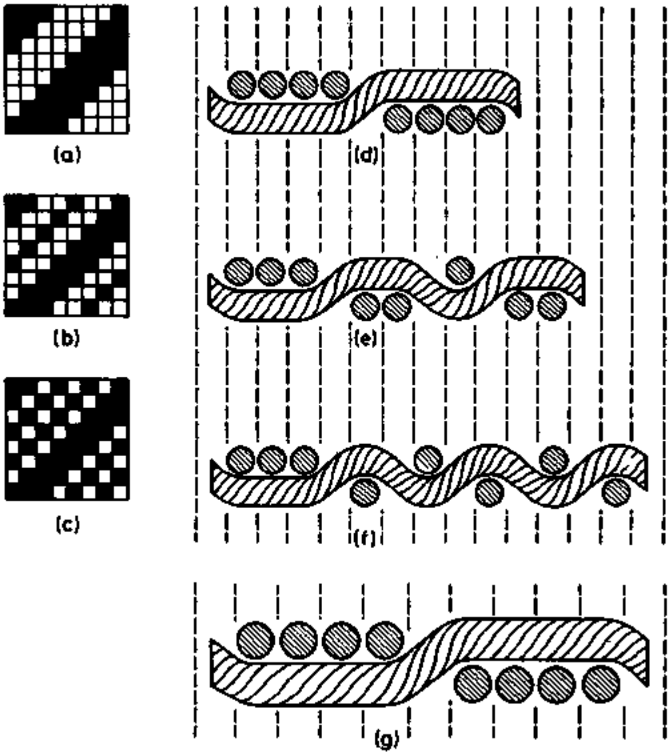

Figure 2.11

be employed for A than for B, and for B than for C. This is illustrated at G, which represents the thickness of the yarn (approximately) that can be employed for the weave A if the threads per unit space are the same as for the weave C. It will be seen that 10 diameters in G occupy the space of 14 diameters in F. A loose weave (such as A), therefore, allows more yarn to be put into a cloth than a firmer weave (such as B), and permits a heavier cloth to be formed. (See Appendix III.)

Influence of the twist of the yarns

The twist, which is put into yarns in order to bind the fibres together, affects the handle, strength, and wearing property of a cloth, and also has a considerable influence upon the appearance of a fabric in which any form of twill line is developed. Generally, just sufficient twist is inserted to enable the threads to withstand the strain of weaving. More turns per inch are required in fine than in thick threads, and for short than for long-fibred materials, while warp yarns are mostly harder twisted than weft yards. The twist, while strengthening the yarn, makes it harder, and reduces its lustre, and to many fabrics the necessary firmness of structure is imparted by the warp, and softness and brightness by the weft. For special purposes yarns are twisted more or less than the normal according to the effect required in the cloth; thus *voile* and *crepon* yarns are very hard twisted, whereas yarns for raised fabrics have less twist.

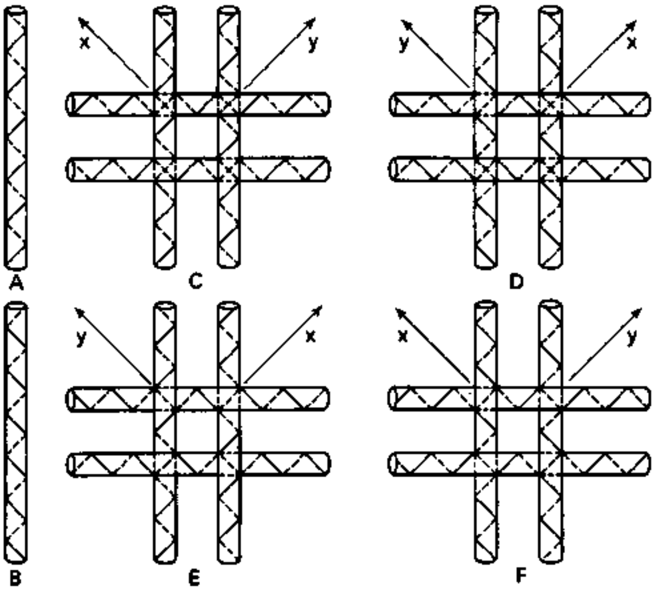

Figure 2.12

If the direction of the twist is to the right looking up the thread, as shown at A in *Figure 2.12*, it is termed 'open-band', or 'Z' twist, and if to the left as represented at B, 'cross-band', or 'S' twist. In cotton yarns A represents warp twist (twist way), and B weft twist (weft way), whereas in worsted yarns warp twist is as shown at B, and weft twist as shown at A. Single woollen yarn is almost invariably twisted, as indicated at B. In folded yarns the twist is mostly inserted in the opposite direction to that of the single threads, because this causes some of the twist to be taken out of the singles, and a softer folded yarn results than if the direction of the twist is the same in both twisting operations; the latter method increases the twist in the singles, and tends to make the folded yarn hard.

C, D, E, and F in *Figure 2.12* illustrate the different ways in which the warp and weft threads may be placed in relation to each other as regards the direction of the twist. In C the warp twist is as shown at A, and the weft twist as at B, the surface direction of the twist being to the right in both threads when the weft is laid at right angles to the warp. D is the exact opposite of C, the surface direction of the twist being to the left. In E both series of threads are twisted 'Z' way, and in F 'S' way. In C and D the direction of the twist, on the under side of the top thread, is opposite to that on the upper side of the lower thread, hence the threads do not readily bed into, but tend to stand off from each other, which assists in showing up the weave and structure of the cloth distinctly. In E and F, on the other hand, the twist on the underside of the top thread is in the same direction as that on the upper side of the lower thread, hence in this case the conditions are favourable for the threads to bed into each other and form a compact cloth in which the weave and thread structure are not distinct.

In twill fabrics the clearness and prominence of the twill lines are accentuated if their direction is opposite to the surface direction of the twist of the yarn. If, however, the lines of a twill are required to show indistinctly, the twill should run the same as the surface direction of the twist of the yarn. If one yarn predominates on the surface the twill should oppose, or run with, the twist of the surface threads according to whether the effect is required to show prominently or otherwise. Thus, in C and D in *Figure 2.12* the arrows X indicate the direction in which the twill should run if the lines are required to show boldly and clearly, and the arrows Y if an indistinct twill effect is desired. In E and F the arrows X show the proper direction for producing a bold twill, and the arrows Y for producing an indistinct twill if the weft yarn predominates on the surface. If, however, the warp forms the face of the cloth in E and F, the arrows Y indicate the proper direction for a bold twill effect, and the arrows X for an indistinct twill. Irrespective of the coincidence, or otherwise, of the direction of the twill with the direction of the twist the weaves appear more distinct in combinations C and D, than in E and F.

If a twill runs both to right and left in a cloth (a herring-bone twill), it shows more clearly in one direction than the other. Also, the difference in the appearance of right and left twist is sufficient to show clearly in a twill fabric in which the weave is continuous, and 'shadow' effects are produced in warp-face weaves by employing both kinds of twist in the warp threads.

SATEEN AND SATIN WEAVES

In pure sateen and satin weaves the surface of the cloth consists almost entirely either of weft or warp float, as in the repeat of a weave each thread of one series passes over all but one thread of the other series.

In addition, the interlacing points are so arranged as to allow the floating threads to slip and to cover the 'binding' point of one thread by the float of another. This results in the production of fabrics with a maximum degree of smoothness and lustre and without any prominent weave features. Very close packing of threads is possible and quite heavy constructions can be achieved with properly set cloths. Fabrics with insufficiently close thread spacing, however, exhibit poor seam strength in made up articles due to seam slippage arising on account of the excessive freedom of the threads.

The terms *sateen*, and *satin* tend to be used somewhat indiscriminately and are frequently confused one with another. Correctly, sateen indicates a weft faced construction, whilst satin is used with reference to a corresponding warp face structure. This difference is reflected in the settings of the respective cloths and sateens are constructed with a greater number of picks per cm than ends per cm, and, conversely, satins have more ends than picks per cm in order to achieve the desired solid surface effect.

Regular sateens and satins

The examples given in *Figure 2.13* will enable the construction of twills and regular sateens and satins to be compared. In twill weaves the distance from a mark on one thread to the corresponding mark on the next thread—termed a step, move, or count—is one, hence in the cloth the intersections support each other, and distinct twill lines are formed. In regular sateen weaves the step, move, or count is more than one, so that the intersections do not support each other, but as the distance moved each time is equal and regular a certain degree of twilling is formed in the cloth. The prominence of the twill line varies according to (a) the order in which the threads interlace; and (b) the direction of the twill line in relation to the direction of the twist of the yarn. In the best regular sateens the points of intersection are equally distributed over the repeat area, and if the twill lines and the twist run in the same direction, a smooth, lustrous, and almost untwilled surface is formed.

In *Figure 2.13*, A shows a 1 up, 4 down twill in which the marks are arranged in the order of 1, 2, 3, 4, and 5; in B the move or count is two to the right, hence the marks are indicated on the spaces in the order of 1, 3, 5, 2, and 4, while in C the count is three to the right, the order of arrangement being 1, 4, 2, 5, and 3. By counting one less than the number of threads in the repeat (in this case four) a reversed twill is produced, as shown at D in *Figure 2.13.*

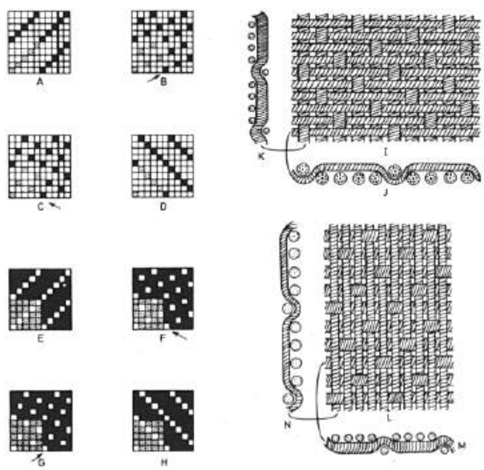

Figure 2.13

A similar procedure can be adopted to produce a corresponding warp faced satin starting with the 4 up, 1 down twill. This is indicated at E, F, G, and H in *Figure 2.13.* I in *Figure 2.13* shows a flat view of the plan B, while J represents the interlacing of the first pick, and K of the first end. If the twist in the yarn is in the direction indicated on the threads in I the twill lines will show indistinctly. The flat view, given at L in *Figure 2.13,* corresponds with the design F, the interlacing of the third pick being represented at M, and of the first end at N. In this case if the threads are twisted in the direction indicated, a rather distinct twill, running to the left will be formed. (In cotton cloths the term *drill* (q.v.) is frequently applied to this structure.)

The arrows under B, C, F, and G in *Figure 2.13* indicate in each case the direction in which twilling lines will tend to appear in sateens and satins if the twist in the yarns and the cloth settings are favourable towards it. In most cases, with the exception of 'drills', any tendency to form distinct twilling lines is avoided, and in subsequent diagrams it is shown that some superficially correct arrangements have to be rejected unless a distinct twill line is desired.

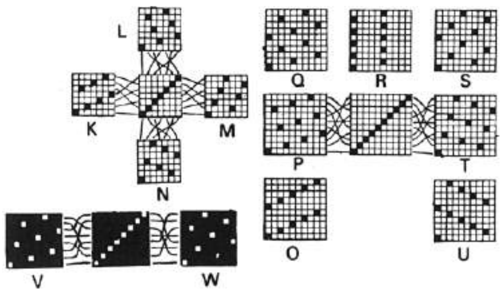

Figure 2.14

All the possible sateens on seven threads are given in *Figure 2.14* at K, L, M, and N, the threads of which are shown connected by lines with the 1-and-6 twill. K is constructed by counting two, L by counting three, M by counting four, and N by counting five, in each case to the right on succeeding picks. It will be seen from an examination of the foregoing weaves, that the move may be either upward or outward; thus, in K the count upwards is four; in L, five; in M, two; and in N three on succeeding ends. N is similar to K, and M to L, but twilling in the opposite direction. It will be noted that all seven thread sateen constructions result in a very obvious alignment of the points of intersection and for this reason the seven thread repeat is not normally employed.

O, P, Q, R, S, T, and U in *Figure 2.14* are constructed on ten threads by counting 2, 3, 4, 5, 6, 7, and 8 respectively, but only P (counting 3) and T (counting 7), which are similar but twilling in opposite directions, are proper weaves. In each of the others no marks are placed on some of the threads, hence 2, 4, 5, 6, and 8 cannot be counted in designing sateens on ten

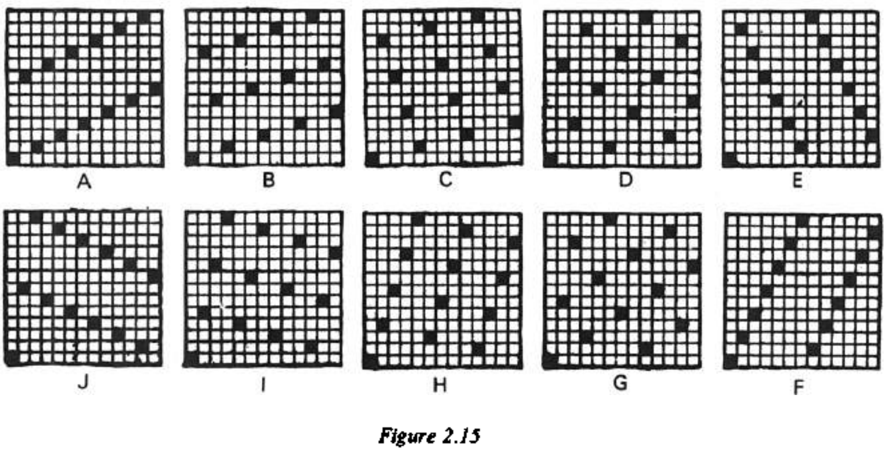

Figure 2.15

threads. From the example the following rule for the construction of regular sateens and satins may be drawn: any number (with the exception of one, and a number that is one less than the number of threads in the repeat) may be counted which has no common factor with the number of threads in the repeat of the wave. Quite similar effects which differ only in the direction of twilling will be produced by using *moves* which are by an equal number higher, or lower than half the number of threads in the repeat. Thus, on eight threads, where only moves of 3 and 5 can be used, the effects, in conformity with the rule established above, are similar and differ only in respect of the direction of twilling. This is shown at V and W in *Figure 2.14* where the two 'moves' suitable for an eight thread satin (or sateen) are clearly represented.

In *Figure 2.15* all the possible sateens on thirteen threads are given at A, B, C, D, E, F, G, H, I, and J, which are produced by counting 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 respectively. Similar sateens result from counting 2 and 11, 3 and 10, 4 and 9, 5 and 8, and 6 and 7, and in *Figure 2.15* the weaves are arranged in pairs one above the other to correspond. A, E, F, and J give poor sateen effects, because of the distinct twill lines that are formed; B, C, H, and I are better, but in each of these the marks form a more prominent line in one direction than in the other; in D and G, however, the distribution of the marks is perfect.

Although most of the examples given above on design paper represented the sateen weaves it must be understood that any rules in respect of *counting*, or *moving* of an interlacing point are equally applicable to the warp satin weaves.

Irregular Sateens and Satins

Regular sateens cannot be constructed on four and six threads, because no number can be counted which has not a common factor with four and six. An attempt to produce an effect similar to sateen on four threads is shown at A in *Figure 2.16*. This is based on the 1 up, 3 down twill with marks arranged in the order of 1, 2, 4 and 3. The term satinette is usually applied to this weave but from the point of view of correct classification of weaves it belongs to a group of structures known as broken twills (q.v.).

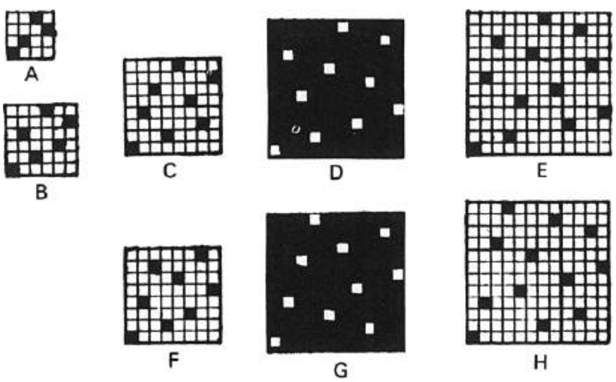

Figure 2.16

In the 6-thread sateen, given at B in *Figure 2.16*, the marks are arranged in the order of 1, 3, 5, 2, 6, and 4. Irregular sateens are entirely free from twill lines, a feature that frequently gives them an advantage over regular sateens, and for this reason sateens are arranged irregularly on eight, ten, twelve, etc., threads. C in *Figure 2.16* shows an irregular sateen on eight threads, in which 3 is counted to the right for four picks; on the fifth pick the count is equal to half the number of threads in the repeat—viz., 4—then on the succeeding picks 3 is counted to the left. A 10-thread irregular satin is given at D, in which the count is 3 for half the number of picks, then 5 is counted, and afterwards the move is in 3s to the left. In the 12-thread irregular sateen given at E the count is 3 and 5 alternately for six picks, then 6, and afterwards 3 and 5 alternately to the left. The weaves F, G, and H respectively correspond with C, D, and E, and are constructed in the same manner except that the count is upward instead of outward.

In sateens and satins it is only possible to introduce different colours effectively in the threads which form the surface. As a transverse stripe is rarely desired the introduction of coloured threads is in practice limited to warp satins. These are particularly suitable for displaying colours in stripe form and, if the warp threads are of good quality and free from irregularities, brilliant effects are produced because the lustrous and unbroken cloth surface enhances the brightness of the colours. Different materials can also be effectively combined in the warp and further variety can be achieved by combining satin with other weaves, particularly the plain and the various twills.