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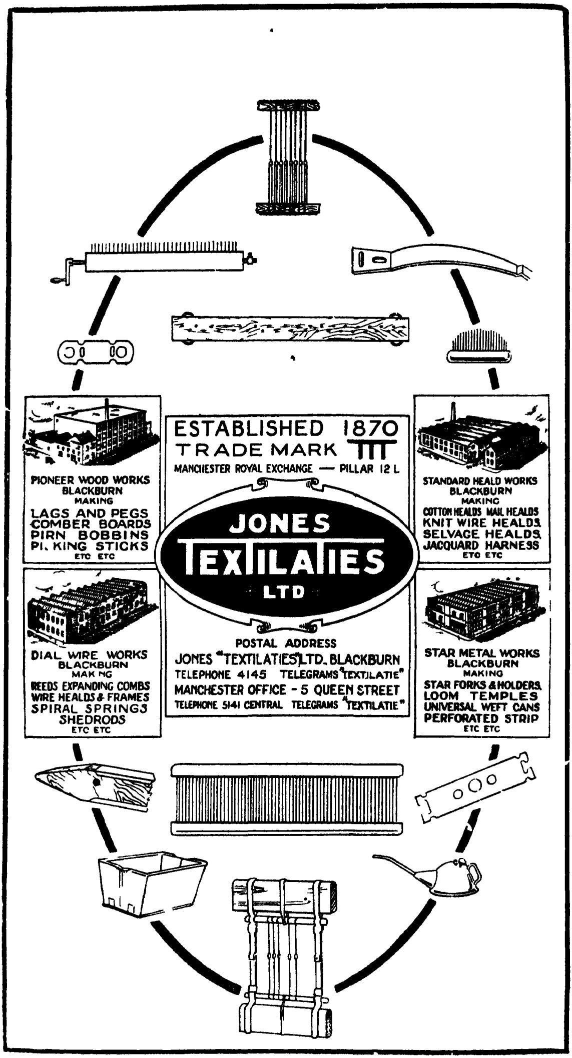
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WEAVING

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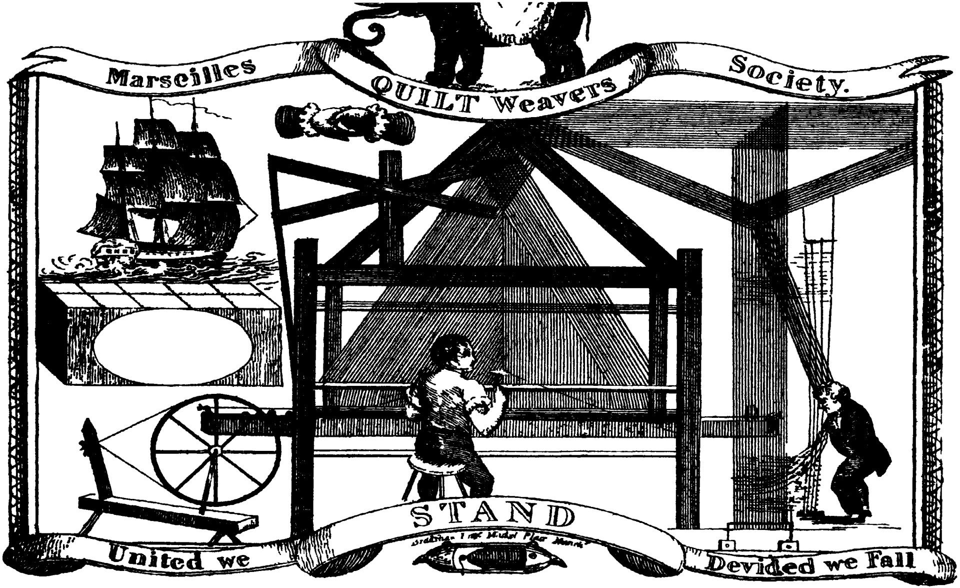

Frontispiece

MEMBERSHIP CARD OF THE MARSEILLES QUILT WEAVERS' SOCIETY ABOUT A.D. 1825

PITMAN'S COMMON COMMODITIES
AND INDUSTRIES

WEAVING

BY

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PREFACE

THE object of the present work is to offer a brief account of the processes of weaving which, while avoiding intricate details, will enable the reader to understand the operations and machinery involved in the conversion of yarn into woven fabrics. Such an account, it is hoped, will be found useful by the weaving student as an introduction to his more detailed studies, by merchants and others who have dealings in woven fabrics, and by the handicraft weaver. The inclusion of short chapters on the history of weaving and the characteristics and production of the various yarns which form the raw materials of the weaver will also be found serviceable by such readers.

My thanks are due to Mr. J. Hampson and Mr. J. H. Jakens for drawings; to my daughter, Miss E. M. Crankshaw, M.A., for assistance with the chapter on the history of weaving; and to the machinery makers who have so generously assisted with the illustrations.

W. P. CRANKSHAW.

May, 1924.

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CHAPTER I

THE HISTORY OF WEAVING

THERE is little need to demonstrate the antiquity of the art of weaving, since it is admitted that food and clothing are the two prime necessities of man His earliest clothing was probably of a ready-made character, such as the skins of animals Of the clothing of palaeolithic or old stone man there is no trace, but, when the remains of neolithic or new stone man are examined, there are reasons for thinking that he had some knowledge of the formation of fabrics by the interlacing of suitable materials.

The most definite evidence that we have of the antiquity of weaving is the paragraph in Genesis, which describes how Pharaoh clothed Joseph in "vestures of fine linen." It is evident from these words that the art had reached a high stage of development. Indeed, mummy coverings recently discovered show that the term "fine linen" was no exaggeration, for, among the large number of mummy coverings which have been examined, specimens of a fineness surprising even for these days were found. The work of the ancient Egyptians was not, however, limited to linen, for they also manufactured woollens and produced figured as well as plain fabrics in both materials.

The Chinese also acquired considerable skill in weaving, their records extending back to about 3,000 B.C. They manufactured silk goods, and the richness of these both as regards material and ornamentation has been recognized from remote ages. They made "precious figured garments resembling in colour the flowers of the field and rivalling in fineness the work of spiders." Even to-day it is difficult to excel the work of the old Chinese weavers.

Just as Egypt was the home of the linen, and China of the silk, industry, so India may be regarded as the home of the cotton manufacture. For ages it has been famous for cotton textiles of unrivalled delicacy, and much of India's best work is still done on hand looms of rude construction.

It is also interesting to note in passing that the manufacture of textiles was carried on by the ancient Peruvians, and pieces of cloth have been discovered of a coarse quality somewhat resembling sail cloth and made of vegetable fibres.

Although the Greeks and Romans have left no clear records of their method of weaving, there is little doubt that their looms differed only slightly in detail from those of the ancient Egyptians. They had advanced so far as to be acquainted with the use of healds, and Plato mentions the difference in the amount of twist in the warp and weft yarns. The results of their knowledge were shown in the magnificent garments which were worn by their priests and by the Roman Emperors. It may here be said that the earliest silk textures produced in the Levant were woven from threads obtained by unweaving loosely woven silk fabrics imported from China, the secret of silk spinning not having yet left the Far East.

On the downfall of the Western Roman Empire the skill of the Roman workmen was preserved at Constantinople, the capital of the Eastern Empire. What remained of it in Western Europe was to be found in the few monasteries and convents that contrived to survive the invasions of the barbarians. But, after these Northern invaders had scattered the weavers of Europe, Southern invaders, the Saracens, gave a fresh impetus to weaving in Spain where cottons were woven, and in Sicily. Much of the Sicilian work was executed in silk, of which the Saracens had a considerable knowledge, and the latter evidently gave to Sicilian textiles that Oriental splendour for which they are renowned. When the Holy Wars began, the Crusaders' first place of call was generally Sicily; hence the fame of the Sicilian goods spread over Western Europe.

As Sicilian excellence in weaving declined the manufacture passed to Northern Italy, where it was taken up by the City States, especially Genoa, Venice and Lucca, which last was one of the first towns to manufacture velvet. The velvets of Florence, however, were the most famous and the most beautiful, being lavishly ornamented with gold. Later, her chief rival was Venice, which at one period dictated the fashions to Western Europe.

It was left to the colder Northern Europe to develop the manufacture of fabrics from wool, and in this England and Flanders played the chief parts. The Romans are said to have established a woollen factory at Winchester, but it is quite probable that the British already possessed a knowledge of the art, as the short wools most suitable for the manufacture were grown in the neighbourhood, and shortly after the occupation British cloths were held in high esteem in Rome, both for colour and texture. The Phoenicians who traded with Cornwall for tin also took back with them British woven cloths. It is also recorded that the mother of Alfred the Great was skilled in spinning and taught her daughters the art.

England however was chiefly a wool growing country, and the importance of that industry can be gauged by the number of statutes regulating the export of wool and by the fact that the Lord Chancellor sits on the "Woolsack." It is also interesting to note that when Richard the Lionhearted was imprisoned by the Duke of Austria on his return from the Crusades in 1192, his ransom was paid in English wool.

The principal market for English wool was Flanders, which in the Middle Ages became the chief wool manufacturing country and derived enormous riches from it. When William I conquered England in 1066 he was accompanied by a number of Flemish weavers; and a number of others who were wrecked on the coast during his reign settled in the country and carried on their trade. Later English Kings, notably Edward III, observing the wealth which the Netherlands derived from English wool, made great efforts to establish the manufacturing industry in this country. By the offer of privileges and protection a number of Flemish weavers were induced to bring over their families and teach the arts of spinning, weaving and dyeing. But the industry did not become securely established until a second and much larger influx of skilled weavers came over from the low countries to escape the persecution of the Spaniards in the sixteenth century.

England also benefited greatly in the seventeenth century by the persecution of the French Huguenots, many of whom escaped to this country and set up the manufacture of silk in Spitalfields and Macclesfield.

But cotton is king of the textiles. As already mentioned, India was the home of this branch of the industry in the Eastern hemisphere, and fine muslins were among the most valuable of its exports to this country up to the end of the eighteenth century. Even in ancient times, however, the cotton plant was indigenous in Egypt and the Levant, although no use appears to have been made of the fibre for textile purposes, probably because there was an ample supply of flax and wool to meet these requirements. Eventually a knowledge of its manufacture spread over Arabia and the Levant and was carried by the Moors into Spain, from whence it found its way by France and Flanders into England.

The earliest reference to the manufacture of cotton in England is contained in documents of the latter part of the thirteenth century, which mention the production of coarse cotton threads for candle wicks, a name which is to this day applied to the very coarsest cotton yarn. In sixteenth century writings the name "Cottons" is of frequent occurrence, but it is extremely unlikely that these were cotton goods in the present-day sense of the word. The probability is that they were light fabrics woven from wool and flax in imitation of the cotton fustians of Spain and Flanders. This confusion of terms probably arose from the fact that Englishmen could not conceive of anything so closely resembling wool which had not been taken from the back of an animal, and the writer of Mandeville's travels, when referring to the cotton plant, describes a small woolly lamb growing on a tree.

The earliest references to actual cotton goods occur in the first half of the seventeenth century, when Lancashire is mentioned as making "fustians of a kind of bombast or down, being a fruit of the earth." This trade was evidently becoming important, for it was specially mentioned that the woven fabrics were "not seldom sent to foreign parts." As time passed, the cotton industry began so to rival the woollen industry that, in the eighteenth century, people had to be forced by law to patronize wool materials.

The difficulty in manufacturing cotton fabrics at this time was due to the fact that cotton yarn could not be spun of sufficient strength to weave as warp, and flax or linen yarn had to be used for this purpose until the invention of the throstle frame by Arkwright in 1767 enabled a sufficiently strong thread to be spun from cotton. Before that time, cotton was used only for weft.

Until the middle of the eighteenth century textile manufacturing was carried on as a domestic industry, that is, the raw material was spun into threads and woven into cloth in the homes of the workers, who often carried on the work along with some other occupation, such as farming. Towards the end of the century, however, the application of steam as a motive power and the invention of machinery for spinning and weaving caused the work to be concentrated in factories. This change from the domestic to the factory system was carried out at a time when England was at war with Napoleon, and it was largely owing to the Continental demand for English cotton and woollen goods that Napoleon was unable to make his blockade of England effective. It was also owing to the invention of the fly shuttle by Kay; of spinning machinery by Hargreaves, Arkwright and Crompton; and the power loom by Cartwright, that the English textile industry was enabled to take the leading position in textile manufacturing, which it still holds.

CHAPTER II

THE WEAVER'S MATERIALS

TEXTILE fabrics may be defined as fabrics which are made from threads of fibrous materials. Threads may be defined as filaments of indefinite length and sufficiently strong to withstand the strain and friction of weaving. Fibres may be defined as filaments which are either too short or too delicate to be directly converted into fabrics other than those of the felt type.

The conversion of fibres into threads is the function of spinning, which usually comprises the operations of—

1. Cleaning, or the extraction of impurities.
2. Straightening and reducing masses of fibres to parallel order and forming them into thick strands called slivers.
3. Reducing the slivers to rovings of the requisite degree of fineness.
4. Twisting, to bind the fibres of the reduced strand firmly together in the form of a thread or yarn.

Since yarn is the raw material of the weaver, it will be advisable briefly to review the process of spinning in order that the features and properties of the various kinds may be understood.

In cotton spinning, the processes of bale breaking, opening and scutching roughly comb and beat the hard masses of fibres taken from the bales to remove heavy impurities, such as sand and seeds, and finally deliver the material in the form of a thick sheet or lap. Laps are then passed to the carding engine, which extracts light impurities such as leaf, broken seed and neps or bunches of entangled fibres, and at the same time partly straightens out the fibres by combing them with fine wire-covered surfaces, and delivers them in the form of a thick soft strand or sliver. A number of slivers, usually six or eight, are then combined together at the draw frame and passed through four pairs of closely set rollers, each succeeding pair revolving at an increased speed and drawing fibres out of the mass presented to it slightly faster than the preceeding pair delivers them. In this manner the thickness of the issuing sliver is reduced approximately to that of one of the original slivers, which means that, for every inch of the compound sliver fed to rollers, six inches, or eight, of the resultant sliver will be delivered; or, as it is usually expressed, there will be "a draft of six or eight." Issuing slivers are similarly combined and the process repeated up to three times, the final sliver being uniform in thickness and the component fibres straight and parallel. Drawn slivers are then passed through a series—two to four in number—of machines called "speed" or "fly frames" which gradually reduce them to thin, soft rovings. These are wound upon bobbins and passed to the spinning machines.

The first successful spinning machine was the "Flyer" or "Throstle" frame of Sir Richard Arkwright, in which the roving, having been reduced to the required degree of fineness by drawing rollers, was twisted into a strong compact thread and wound upon a bobbin by means of a spindle and flyer. Unsuitability for fine yarns and low production have, however, caused this machine to become practically obsolete in the cotton trade, and its place has been taken by the "Mule" and the "Ring Frame." In mule spinning, roving is delivered by drawing rollers to spindles, which are mounted in a carriage and revolved to insert twist as the carriage slowly recedes to a point some five feet or more from the rollers. The motion of the latter is thereupon stopped and the spindles more rapidly revolved, until the suspended thread has been twisted to the requisite degree. The carriage is then moved towards the rollers and the completed thread coiled upon the spindle in the form of a cop, which, upon completion, can be drawn off and either transferred to the weaver's shuttle or placed upon another spindle for rewinding. Mule yarns are soft, full and comparatively even, and are suitable for either warp or weft. The finest yarns can be spun only by this machine. In ring spinning, a spool or bobbin is mounted on a spindle inside a metal ring with smooth flanged edges upon which a piece of bent wire, called a traveller, can be clipped to guide the thread to the bobbin. As the latter revolves with the spindle, twist is imparted to the thread and the traveller pulled round the ring at a slightly lower speed, with the result that the bobbin is enabled to draw the thread upon its surface. Thus the processes of drawing, twisting and winding proceed simultaneously, and the production by each spindle exceeds that of the mule which performs these essential operations intermittently. Ring yarn is stronger and more compactly spun than mule yarn, and is therefore more suitable for warp yarn than for weft.

For superior qualities and the finest yarns, the process of combing is introduced between carding and drawing, with the object of extracting fibres below a certain standard of length and any impurities which may have escaped the carding process. The resultant yarn is smoother, more lustrous and compact than carded or uncombed yarn.

Waste and the shortest of cottons are chiefly spun by the condenser system, in which the sheet of fibres delivered by the carding engine, instead of being formed into a single sliver, is divided into a number of thin strands which are wound upon a bobbin and taken direct to the mule. The latter has only one pair of rollers, which support and deliver the rovings at a slightly lower rate than that at which the carriage and spindles move outwards. In this manner the rovings are slightly stretched and further reduced in thickness and formed into threads of a soft, fibrous and woolly character, such as are mainly suitable for weft.

In flax spinning the fibres are first " scutched " or beaten to remove particles of adhering woody matter; next " hackled " or drawn through combs of graduated fineness to separate them and extract the shortest fibres or " tow." The fibres are then " spread " to form a thick sheet and passed through a pair of rollers, from which they are carried by " gills " or bars of pins to a second pair of rollers of superior speed. These draw out and reduce the thickness of the sheet. A number of the slivers delivered by the gill boxes are then combined together for redrawing, and the resultant uniform sliver is afterwards reduced in thickness by the drawing rollers of roving frames. In the spinning frame, which is of the flyer type, the roving is passed through a trough of hot water to soften the fibres and render them more amenable to the drawing and twisting operations. This " wet " spinning system is used for the finer yarns and superior qualities, and produces what are called " line " yarns, which are compactly spun and therefore strong, smooth, and lustrous. " Tow " yarns are spun from the tow or short fibres extracted during the hackling process and may be either " wet " or " dry " spun. In the latter case they are carded and spun in the dry state to produce a soft, spongy and fibrous thread.

Jute is first " batched " or made into a stack and sprayed with oil and water, then " softened " by passage through a large number of pairs of fluted rollers; then carded by the carding engine and drawn by "gills" or pin bars and rollers; the resultant slivers are reduced to rovings and finally spun by a flyer spinning machine.

The first operation in wool spinning is " scouring " or " washing " to remove grease and foreign matter. " Willowing " or light opening by a spiked cylinder then follows to remove dust, after which a blend or mixing is made and oiled to facilitate subsequent treatment. This varies considerably according to the style of the ultimate yarn, which may be either (*a*) woollen or (*b*) worsted. Woollen yarns are soft, spongy, elastic and oozy or fibrous, and the fabrics produced from them have a dull surface, in which the thread structure is more or less obliterated by the milling process through which woollens are usually passed. Worsted yarns are more compactly spun and have a clear surface; hence they produce stronger and more lustrous fabrics. Roughly, it may be said that in woollen spinning fibres are carded and condensed and mule spun, while worsted spinning comprises carding, combing, drawing, and ring or flyer spinning. Also woollen is generally spun from the shorter wools and worsted from the longer ones, but there are many combinations of the two systems.

The silk fibre already possesses one of the essential qualities of yarn, namely, adequate length; hence silk spinning or, as it is more correctly termed, " throwing " mainly consists of placing together a sufficient number of fibres to produce a thread of the desired strength and thickness. Reeling is the first operation. A number of cocoons are here placed in a bowl of hot water, and the fibres therefrom gathered together into a single thread, which is wound upon a reel. During the process, fibres from additional cocoons are taken up, either to take the place of those which have run out, or to compensate for the gradually decreasing thickness of the individual fibres. Reeling is performed in the silk-producing districts and the material reaches the spinner or thrower in the form of large hanks. These are first tested and sorted into their various sizes or thicknesses, after which they are wound upon bobbins and "cleared" of faulty places. Following this, threads from a number of bobbins, according to the fineness of the thread required, are wound together. For "organzine," or warp yarn, the combined thread is twisted to give the required strength, but, in the case of "tram" or weft, the thread may be either only slightly twisted or not twisted at all, in the latter case it being termed "no throw."

The above system produces[1] "thrown" or "net" silk. "Spun" or "schappe" silk is produced from damaged cocoons and from waste which has been made in throwing and weaving operations. These are reduced to short fibres and spun somewhat after the manner of cotton.

The threads produced by the ordinary operations of spinning as above described are termed "singles" or "single yarns," and are distinguished by the fact that, when untwisted, they are resolved into their constituent fibres. For certain purposes such as abnormally strong cloths, sewings, lace, knittings and soft, full handling cloths, single yarns may be deficient in strength, smoothness, or bulk. In such cases the operation of doubling is employed in which a number of singles are placed together and twisted. The process is also used to produce fancy threads or "twists" in which threads of different colours, materials, or

[1] The earliest meaning of "to throw" is "to twist," from the Anglo-Saxon *thrawan*.

thicknesses are doubled together at uniform or varying rates of delivery.

Yarn Counting or Numbering. It will be evident that the sizes of spun threads must be capable of more exact definition than is possible by the use of the merely relative terms "fine" and "coarse," or "thick" and "thin." This is the function of the terms "count," "number," "size" and "grist," which are used in different branches of the textile industry. These terms may be defined as "a number which indicates the relationship between the length and weight of yarn." Such relationship may be expressed either (*a*) in terms of length units per weight unit, or (*b*) in terms of weight units per length unit. Thus the count of cotton yarn indicates the number of hanks of 840 yards each contained in 1 lb. of yarn, i.e. 20's cotton yarn has 20 hanks, or 20 × 840 = 16,800 yards in 1 lb. The grist of jute yarn indicates the weight in lbs. of a spyndle of 14,400 yds., i.e. a spyndle of 8lbs. yarn weighs 8lbs., and therefore has 14,400 ÷ 8 = 1,800 yds. per lb. The units of length and weight vary considerably in different districts and branches of the industry as shown by the following tables, which give the more important systems of yarn numbering—

(*a*) Fixed Weight Systems

System.	*Length Unit.*	*Weight Unit.*
English cotton . . .	Hank of 840 yds.	1 lb.
Worsted	560 ,,	1 lb.
Yorkshire woollen	Skein of 1,536 ,,	6 lbs.
Wet spun linen .	Lea of 300 ,,	1 lb.
Spun silk . .	Hank of 840 ,,	1 lb.

(*b*) Fixed Length Systems

Jute and dry spun linen .	Spyndle of 14,400 yds.	1 lb.
Net silk, English system .	Hank of 1,000 ,,	1 dram
Net silk, Continental system	,, 520 ,,	1 denier (533⅓ deniers = 1 oz. avoir.)

CHAPTER III

THE PREPARATION OF YARN FOR WEAVING

BECAUSE either of its form or of its condition, the yarn produced by the spinning machines must, with one exception, undergo certain preparatory processes before it is ready for weaving. The nature and extent of these processes vary according to the nature of the material, the style of the yarn, the style and ultimate use of the cloth to be woven, the form in which the yarn is spun and sold by the spinner, and the size and organization of the weaving establishment.

Thus the processes are different for cotton and silk, for single twist and folded yarns, for grey and coloured goods, for cloths which have to undergo processes subsequent to weaving and those which are used in the loom state. Some yarns, notably ring spun yarns, are usually sold in a more advanced state of preparation than others, and the processes are often influenced by the number of looms to be supplied, and the productive capacity of certain machines in the equipment which it is desired to keep fully employed.

The general objects of these processes are—

1. (*a*) To gather together in sufficient number and length the threads to form the warp for the desired cloth.

(*b*) To prepare such threads to withstand the strain and friction of weaving, and

(*c*) To coil the threads evenly and in their proper order upon a beam or flanged roller which can be placed in the loom.

2. To convert weft yarn into a form convenient for the shuttle. The exceptional case of yarn which does

not require preparation for weaving is mule and ring weft, the former of which can be formed into cops, and the latter wound upon tubes of convenient size for the shuttle. The usual forms in which cotton yarns are supplied are shown in Fig. 1.

The various systems of warp preparation may be illustrated by those in general use in the cotton trade, which are set out below in diagrammatic form beginning in each case with the yarn as it leaves the spinning machine. Thus mule or ring yarn for grey goods is first wound upon spools and therefrom passed through one of the three systems outlined at (*a*), (*b*) and (*c*). For coloured goods five systems, (*d*) to (*h*), are shown.

FOR GREY GOODS

Mule Cop or Ring Bobbin.

Twist Winding.

(*a*)	(*b*)	(*c*)
Beam Warping. Slasher Sizing.	Mill Warping. Ball Sizing. Beaming.	Section Warping. Ball Sizing. Beaming.

FOR COLOURED GOODS

Mule Cop or Ring Bobbin.

Twist Winding.		Reeling. Hank Bleaching or Dyeing and Sizing. Hank Winding.		
(*d*)	(*e*)	(*f*)	(*g*)	(*h*)
Mill Warping, Dyeing and Sizing in the chain. Yorkshire Dressing.	Chaining or Balling. Dyeing and Sizing in the chain. Beam Warping. Scotch Dressing.	Section Warping. Rebeaming.	Mill Warping. Beaming.	Beam Warping. Scotch Dressing.

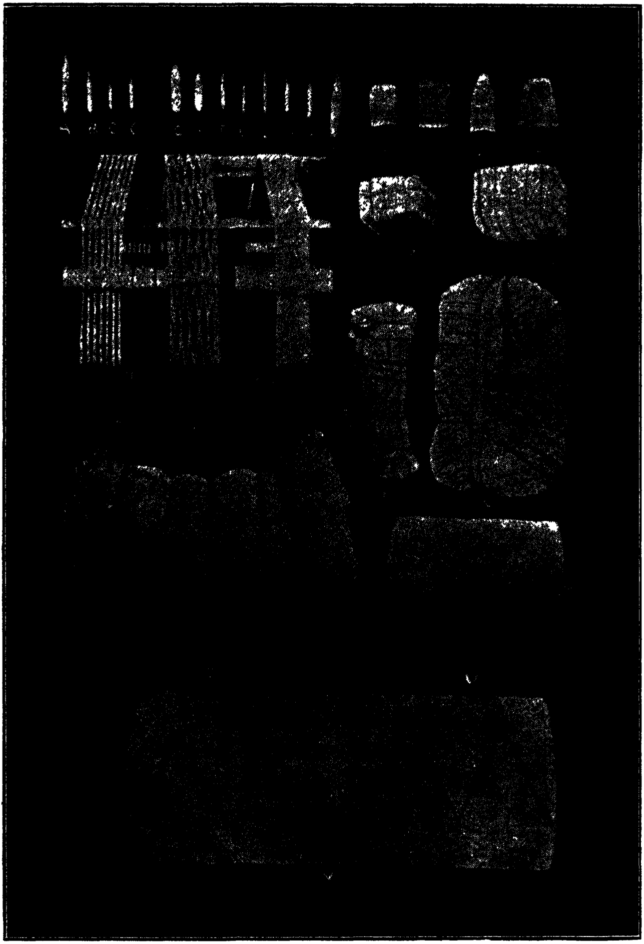

FIG. 1

A. Mule twist cop
B. Mule cop, bastard size
CC. Mule weft or pin cops
D. Ring twist bobbin
E. Ring twist tube
F. Ring weft pirn
GG. Weft pirn tubes
HHH. Weft pirn bobbins
I. Warping bobbin
J. Warping cheese
K. Bottle bobbin
L. Cone
M. Seven lea hank
N. Grant or diamond-reeled hank
O. Cross-reeled hank
PQ. Press bundles
R. Long bundle
S. Ball warp
Chain warp
U. Cross-balled warp
V. Back beam

FORMS IN WHICH COTTON YARNS ARE MADE UP

For grey, i.e. unbleached and undyed goods, system (*a*) is by far the most used on account of its greater economy, which depends upon the fact that a continuous length of yarn sufficient to fill a considerable number of loom beams can be prepared in one operation. Systems (*b*) and (*c*) are chiefly used in small mills and for specialities, being convenient for small orders but otherwise expensive because they prepare only sufficient length to fill one loom beam.

The coloured branch of the cotton trade comprises the manufacture of striped and checked fabrics from bleached and dyed yarns. Smaller orders and a greater diversity of yarns have to be dealt with ; hence there is a greater diversity in the systems of preparation. System (*d*) is largely used in certain districts, and is considered to be economical for one warp to a pattern when there are not more than three or four colours or kinds of yarn. In other districts, system (*f*) is preferred because of its adaptability to all kinds of work and for the expedition with which an order can be completed, there being as a rule a shorter interval between the time of ordering and receiving bundles than warps. System (*g*) generally requires skilled male labour and is therefore more expensive than (*f*), for which female labour is employed. Systems (*e*) and (*h*) are most advantageous for long lengths of cloth of the same pattern.

With slight modifications, systems (*a*) and (*b*) are used for linen, jute and worsted yarns ; (*f*) and (*g*) for silk, but without the sizing, while certain classes of woollen yarns are section warped direct from the mule cop and beamed upon the loom beam without sizing.

In every case, the process last mentioned is followed by drawing-in or entering or passing the warp threads through the heald eyes and reed, which must be done with new healds, or by twisting, tieing-in or otherwise connecting the threads of a new warp to those of a similar exhausted warp.

If drawing-in and twisting be omitted, it will be found that warp preparation comprises four main operations, namely, winding, warping, sizing and beaming, and these may now be briefly examined in detail.

In **winding**, the yarn is, as far as possible, cleared of faulty places and impurities and transferred to large bobbins or spools, or wound in the form of cheeses or cones upon tubes, each of which is capable of holding continuous lengths ranging from several ounces of the finest to as many pounds of the coarsest yarns. In the vertical spindle winder, Fig. 2, which is used for grey cotton yarn, the bobbins to be filled are carried by revolving spindles, and the threads from cops or ring bobbins passed over a drag board and through a fine slit in a guide plate to the bobbins. As the latter revolve, the plate is caused to rise and fall slowly and guide the threads up and down in close spirals between the flanges of the bobbins. In cheese winding a tube is placed upon a spindle and the thread given a quick horizontal traverse so that a package with self supporting ends may be built up. Cones are produced in a similar manner but the tube in that case has one end greater in diameter than the other. Fig. 3 shows a cone winder. The drum winder, Fig. 4, is used for hanks which are supported on rices or cages. The bobbin barrels rest upon horizontal drums and the friction between the two surfaces enables the threads to be drawn from the hanks, the traverse of course being from flange to flange. For silk winding, however, the spindle, which is passed through the bobbin, is provided with bosses; these grip the flanges and rest upon revolving discs, so that the objectionable

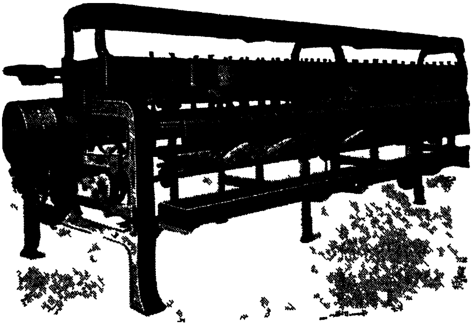

FIG 2

WARP WINDING MACHINE

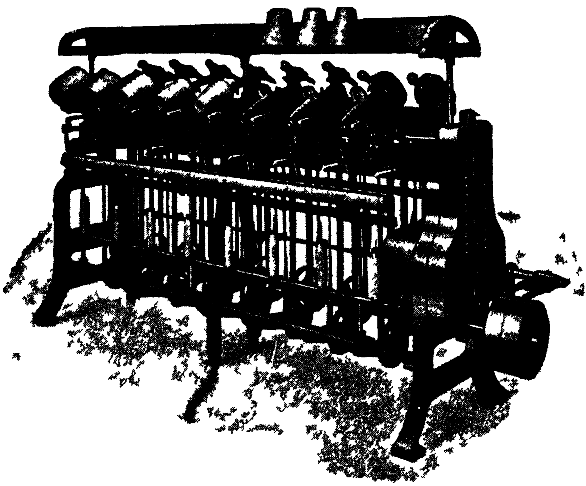

FIG 3

CONE WINDER

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friction between the thread and the drum may be avoided.

In **warping**, the bobbins or spools prepared by the winder are placed in a creel and the threads—

(*a*) Coiled in layers upon a large vertical reel or mill (see Fig. 5), and afterwards withdrawn in the form of

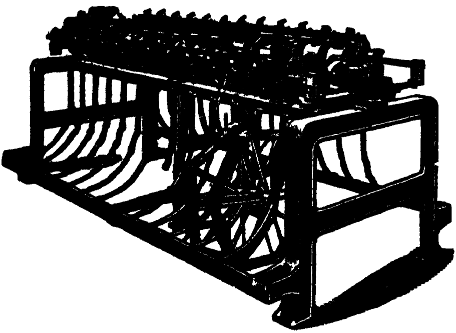


FIG. 4

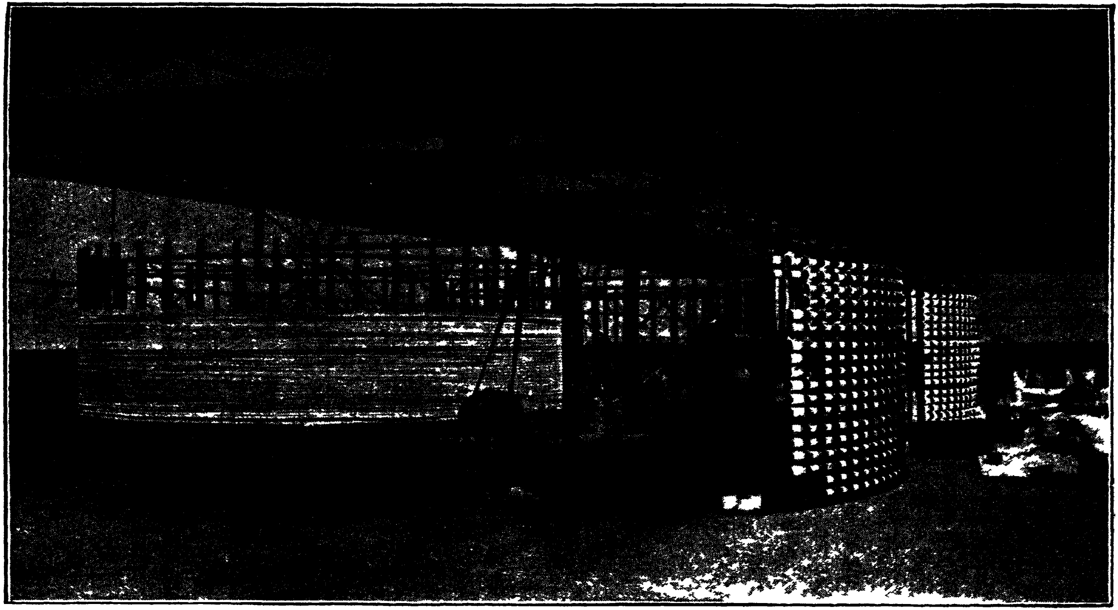
DRUM WINDER

a rope and made into a ball, as shown in Fig. 1, whence the name "mill" or "ball warping," or

(*b*) Withdrawn in the form of a loose rope and linked into a chain as in Fig. 6, or wound upon a spool as shown at U, in Fig. 1.

(*c*) Wound in the form of a broad sheet upon a large flanged roller which is known as a "back beam," the process being known as beam warping. See Figs. 1 and 7.

(*d*) Wound in the form of narrow tapes, side by side, upon a large horizontal reel from which the combined sheet is rewound upon the loom beam. This is the standard method for silk and wool yarns. See Fig. 8; or



FIG

(*e*) Wound in the form of narrow sheets upon circular blocks which can afterwards be placed side by side to enable the completed warp to be rewound upon the loom beam. This method is known as "Section Warping," and along with method (*d*) has the advantage of placing the threads upon the loom beam in the exact order which they occupy in the creel. See Fig. 9.

In methods (*a*) (*d*) and (*e*) there is no limit to the number of threads which can be brought together, but the length is sufficient only for one loom beam. In methods (*b*) and (*c*) the number of threads in the rope or on the beam is limited by the bobbin capacity of the creel, which is usually about 500; hence the threads from a number of balls or beams must be combined to form a warp, but the length of the combined threads may be sufficient to fill a number of loom beams.

The chief object of **sizing** is to increase the strength and smoothness of warp threads and thereby enable them to withstand the strain and friction to which they are subjected during weaving. The process is essential for single twist yarns of a fibrous character, and generally for all yarns when the cloth to be woven has a considerable number of weft threads to the inch. It is therefore invariably required for cotton, linen and worsted, but is seldom required for silk and strong folded yarns, and is sometimes omitted for jute and woollen. The process consists of coating or impregnating the thread with a mixture of adhesive and lubricating substances which will bind the fibres more firmly together, particularly those only partly incorporated during spinning. This, together with the nature of the substances used, gives the necessary weaving strength and smoothness. Advantage can also be taken of the process to load the threads with substances which will increase their weight and bulk and thereby improve the appearance and handle of the cloth; this is especially the case with certain classes of cotton goods which are sold and used in the loom state. The ingredients used for sizing purposes include—

(*a*) "Adhesives," which comprise various kinds of flour, starches, gums and glue. These serve to strengthen

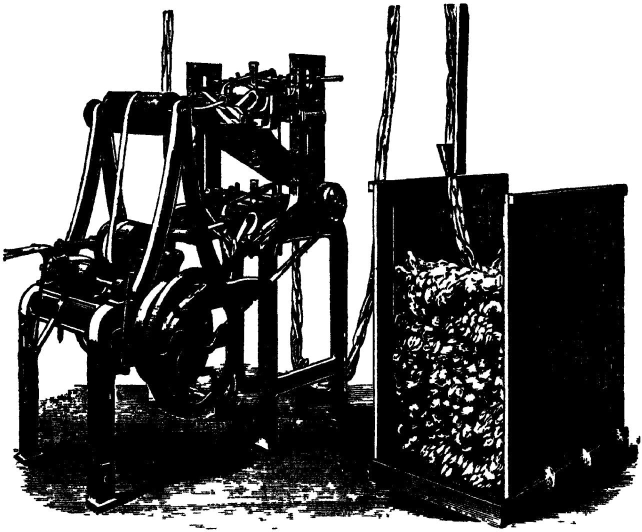


Fig. 6

CHAIN WARPER

the yarn and fix other substances firmly upon the threads;

(*b*) "Softeners," which lubricate the thread and neutralize the harshness imparted by the adhesives. They include tallow and other fats, oil, wax, glycerine and soap;

(*c*) "Weighting" substances, of which china clay is the most important for grey yarns and sulphate of magnesia (Epsom Salts) and sulphate of soda (Glauber's Salts) for coloured yarns ;

(*d*) " Deliquescents," or substances to keep the sized yarn moist and pliable and also to enable the adhesives to keep a firm hold upon other substances of a powdery

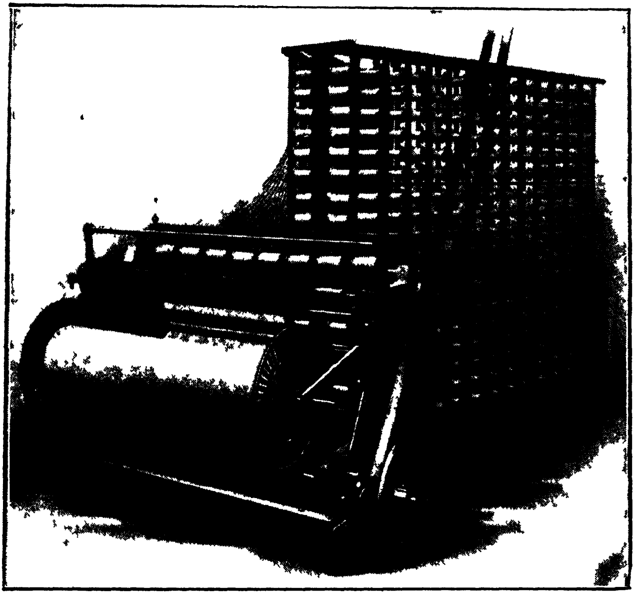


FIG. 7

BEAM WARPER

nature. Magnesium chloride is almost exclusively used for this purpose ;

(*e*) " Antiseptics," or substances to destroy or prevent the growth of mildew, for which purpose zinc chloride is chiefly used.

The composition of size mixings, even for a single class of material, is much too varied to be dealt with in a work of this description. It may, however, be said that for a " pure " size, or one which will impart the requisite weaving properties to the yarn, suitable proportions of adhesives and softeners give all that is required, and this is the general rule for cloth which has to be bleached, dyed or otherwise finished. But, for " medium " and " heavy " sizing, which increase

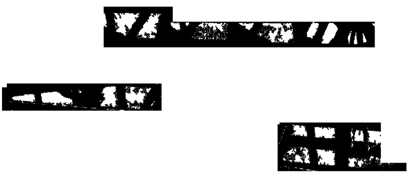


FIG 8

HORIZONTAL WARPER

the weight of the yarn by 20 per cent to 200 per cent, suitable proportions of each of the other three classes of ingredients also must be added.

In the hand loom days, the warp was beamed in the soft state and size was applied by means of a flat brush which was lightly passed over the sheet of threads stretched between the healds and warp beam. A hot iron was then held close to the threads and air fanned upon them until they were dry, after which a brushing of tallow completed the operation. This method which was known as dressing, produced an ideal thread for weaving purposes, the fibres being well incorporated and bound together, and the maximum strength and smoothness imparted; but obviously the output of the loom was greatly interfered with. Ball sizing was then adopted. In this method the rope of threads

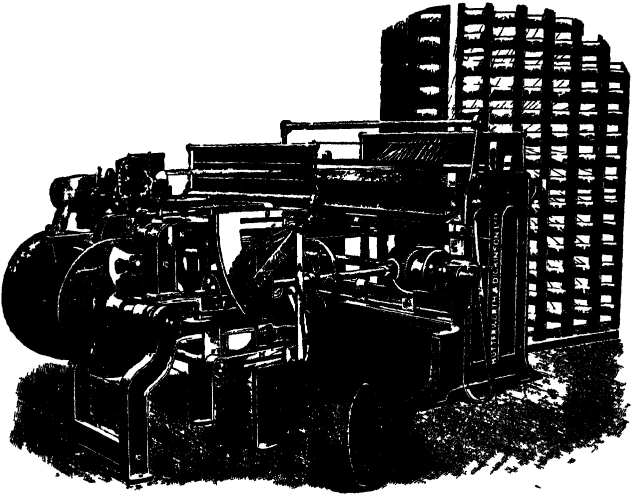


FIG 9

SECTION WARPER

produced by the ball warper was saturated by passage through a solution of hot size and a pair of squeezing rollers; dried by steam cylinders, and beamed when required by a separate machine. The method is still in use and, although comparatively expensive because of the amount of handling required, has the advantages of permitting the operation to be repeated when extra strength or very heavy sizing is required, and also of leaving an interval between drying and beaming during

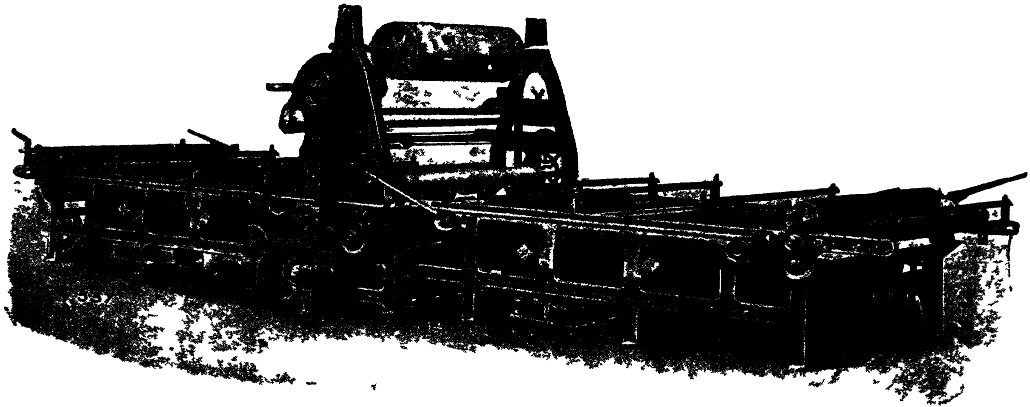


Fig 10
DRESSER SIZING MACHINE

which the threads can regain their elasticity and suppleness.

Ball sizing is, however, unsuitable for the finest yarns, and improvement in this respect was obtained by the invention of the dressing frame, Fig. 10, and its adjunct, the beam warper, Fig. 7. In this method the threads to form a warp are divided over a number of back beams, the whole containing sufficient yarn to fill a number of loom beams. Half of the beams are placed at either end of the frame and the threads therefrom combined into a single broad sheet, which is impregnated with size by passage between a pair of rollers, of which the lower one is partly immersed in size. The threads are then gently brushed by revolving brushes and dried by hot air, after which the sheets from the two ends of the frame are combined and run on the loom beam at the centre. During the process the threads are kept separate by rods and reeds, and the result is a very close imitation of hand dressing.

Dressing is the standard method of sizing linen yarns, but is too expensive for cottons, save those of the very finest counts. For the ordinary run of cotton yarns the slasher sizing machine, Fig. 11, is almost universally employed. This may be described as a development of the dressing frame, from which it differs mainly in the method of drying adopted. The whole of the back beams are placed at the rear of the machine and the several sheets superimposed to form a single sheet, which is immersed in boiling size, passed between one or two pairs of squeezing rollers to complete the saturation of the threads and press out any superfluity of size, and then round the surface of two large revolving steam cylinders, which rapidly dry the yarn. On leaving the cylinders the threads are practically glued

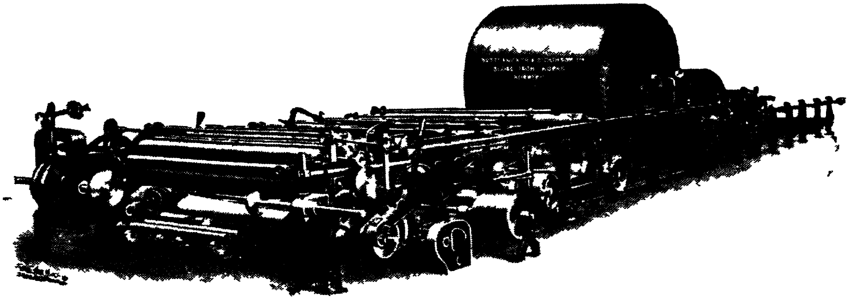


Fig. 11

SLASHER SIZING MACHINE

together, and have to be somewhat roughly separated into the original sheets by a series of dividing rods and further opened by a reed which also contracts the sheet to the required width for the loom beam, upon which it is then wound. The saturation, drying and beaming of the warp are thus carried out in a single operation and at a high rate of speed, and this, together with the fact that a continuous length of yarn many thousands of yards long can be treated almost without stoppage, reduces the cost to a minimum. The application of the size in a boiling condition also enables weighting ingredients to be easily applied. Whilst the result is greatly inferior to that obtained by dressing, the yarn being comparatively harsh, brittle and fibrous, it is nevertheless sufficiently good for the ordinary requirements of cotton goods. When a better quality of sizing is required the yarn is passed through a hot air chamber instead of round steam cylinders; this does not impair the strength and elasticity of the threads to the same extent, but a longer time is required for drying. The hot air type of machine is invariably used for wool yarns.

The usual type of sizing or starching machine for jute yarns is similar to the dressing frame (Fig. 10), with the exception that small cylinders are provided for drying and the threads are drawn direct from spools in creels at the ends of the frame, this being possible because of the small number of threads required for jute warps.

Hank sizing is practically confined to coloured and bleached yarns, which are, as a rule, only lightly sized. In the common form of hank sizer, shown at Fig. 12, the hanks are hung upon revolving rollers so that their lower ends may enter the size. When they have become sufficiently saturated, the hanks are placed

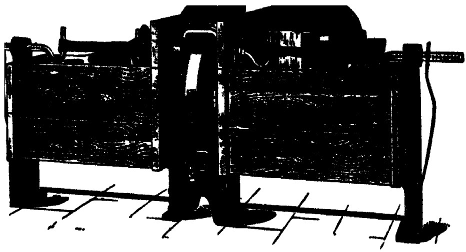


FIG. 12

DOUBLE HANK SIZING MACHINE

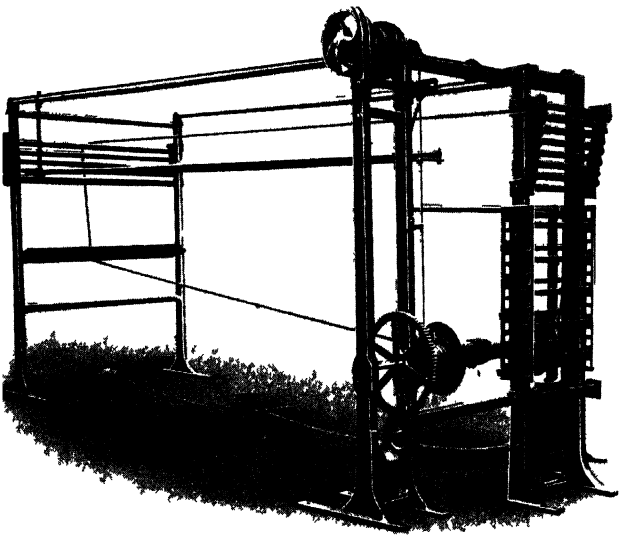


FIG 13

YORKSHIRE DRESSING FRAME

upon hooks and twisted to remove the excess size and afterwards hung in a stove to dry.

The beaming of ball and chain warps is a comparatively simple operation. It consists of passing the rope of threads between tensioning rollers and opening it out to a sheet of the required width by the aid of a

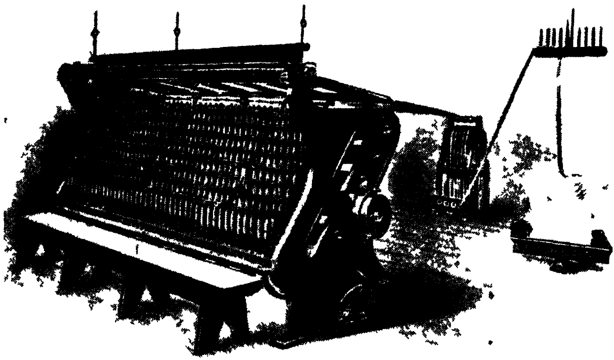


FIG 14

WARP PIRNING MACHINE

coarse reed or raddle, each split of which receives one or more of the half-beers, or groups of threads, formed by the warper. The threads are then made fast to the loom beam, which is revolved to draw the sheet upon its surface. At the end of the warp an " end and end lease " or crossing of the threads, also formed by the warper, enables the drawer-in or twister to select them in their proper order. Fig. 13 shows the Yorkshire dressing frame which is used for the beaming of coloured stripe warps. Separate balls of each colour are provided, and the threads, after passage through a tensioning ladder, are arranged in the required order in a reed and wound upon the loom beam.

The Preparation of Weft Yarn. As was previously stated, some mule and ring wefts are ready for the

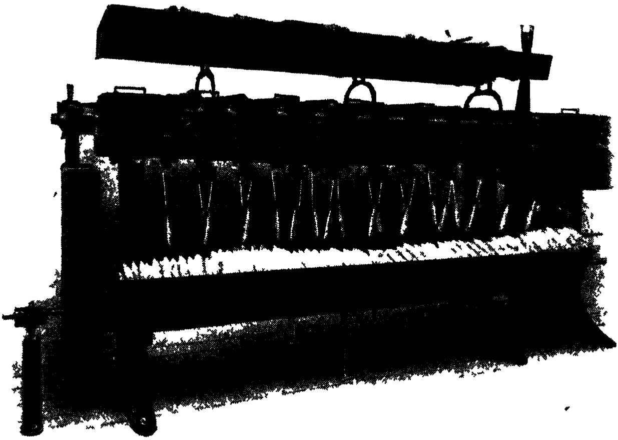


FIG 15

PIRN OR WEFT WINDER

shuttle as they are taken from the spinning spindles. But, in other cases, some preparation is required either to bring it to the desired condition, or to convert it into a form which is suitable for the shuttle. Thus weft yarn may require to be bleached or dyed, or occasionally to be sized; or it may have been spun into cops of a size too large for the shuttle; or upon bobbins or tubes of unsuitable shape.

Bleaching, dyeing and sizing are usually done in the hank form, but for the warp pirning machine shown at Fig. 14, the processes are done in the chain form. Cop bleaching and dyeing are also done to a considerable extent, in which case reeling into hanks and subsequent pirn winding are not required, but the saving thus affected is largely discounted by the increased amount of waste made in weaving.

When rewinding is necessary it is usually performed by a pirn winder, of which there are a number of types. These transfer the yarn to paper tubes or wooden pirns of suitable size for the shuttle and in a manner which will permit of easy withdrawal during weaving. Modern machines, such as the one shown at Fig. 15, also wind the thread more compactly than is possible during spinning and thereby enable a greater quantity to be placed in the shuttle. For this reason rewinding is now done even with mule wefts. The very coarsest yarns are generally rewound into solid cops of correct size for the shuttle, which is thus enabled to carry the maximum supply of weft.

CHAPTER IV

THE PRINCIPLES OF FABRIC STRUCTURE AND THE ELEMENTARY WEAVES

THREADS may be converted into fabrics (*a*) by looping, (*b*) by twisting and (*c*) by interlacing, and upon this are founded the three branches of the textile industry, viz., the hosiery, the lace, and the cloth branches.

A fabric can also be made by the process of felting, in which sheets of fibres, usually wool, are placed upon one another and subjected to pressure and friction whilst in a hot solution of soap. This causes the fibres of the different layers to mat together, or interlock with each other, in such a manner as to produce a dense fibrous mass of moderate strength and durability, such as may be used for carpets, table covers, and similar purposes. Felt may therefore be termed a fibre structure, and for this reason it cannot be classed with the true textile fabrics, which are essentially thread structures.

Loop structures comprise knitted goods or hosiery. In their simplest form, these are made from a single thread which is formed into a succession of rows of loops, the loops of one row being passed through those of the preceding row, as shown in Fig. 16, and forming a close elastic structure, which can be shaped to any desired fashion and unravelled into the original single thread if cut at any point.

Twisted structures comprise a variety of complicated and widely differing structures which are known as " Lace " and " Net." The simplest type may be said to consist of a series of threads which are twisted round one another in groups, the groups being united and

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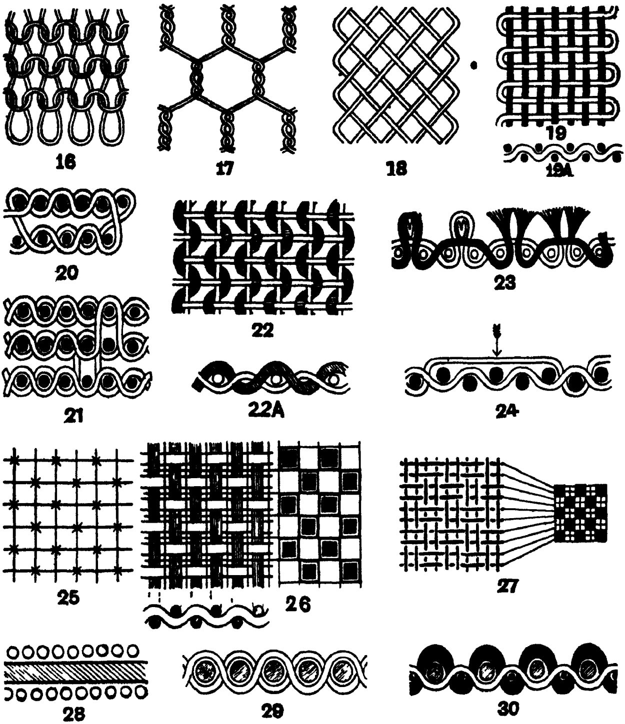
pattern developed by the method of twisting adopted. Fig. 17 shows a simple style of net. The fabrics in this group may also be described as warp structures,



FIGS. 16–30

FABRIC STRUCTURE

since the threads are prepared in the form of a warp. They are characterized by extreme openness and lightness, and are stronger than any other fabrics of equal weight and material, Interlaced structures are produced by interlacing threads, and comprise two distinct types, namely, plaited structures, and woven structures. The first type is essentially a warp structure, and is produced by the diagonal interlacing of a series of warp threads as shown in Fig. 18, in which it will be observed that the direction of the threads is reversed as they reach the edges. The principle is, however, applicable only in the production of narrow wares, such as tapes, bands and ribbons.

The second and more important group of interlaced structures consists essentially of two distinct series of threads which are interlaced with one another at right angles. The lengthwise series of the threads is termed the " warp " or " chain," and the transverse or cross-wise series the " weft," or " woof " or " shoot," respectively. This method of interlacing is shown at Figs. 19 and 19A.

Woven fabrics are comparatively easy to produce and ornament, and there is practically no limit to their width, weight and bulk.

The Classification of Woven Fabrics. Various classifications of woven fabrics have been suggested, but they may, for our present purposes, be divided into three groups, namely—

1. Ordinary woven fabrics, in which warp and weft threads interlace as above described. These may be sub-divided into—

   (*a*) Single-make fabrics, which contain only one series of warp threads, and one series of weft threads ; and

   (*b*) Double or compound fabrics, which contain two or more series of threads in either or both directions. See Fig. 20, which shows two separate cloths, joined together at the edges to form a tube, and Fig. 21 which shows three cloths joined together uniformly to produce a strong fabric.

2. Cross-woven fabrics in which warp threads are caused to twist or cross, either partly or wholly, round one another, and interlace with the weft, first on one side and then on the other of adjacent threads as shown by Figs. 22 and 22A. This group includes the fabrics known as " gauze " and " leno."

3. Pile or plush fabrics. In this group, threads are caused to project from a ground or foundation fabric and thereby form a pile or brush-like surface. Such pile may be formed by warp threads as in velvets, carpets and Turkish towelling ; or by the weft, as in velveteen and corduroy. Fig. 23 shows the structure of warp pile and Fig. 24 the structure of weft pile, the latter representing the cloth as it leaves the loom and before the pile threads are cut to form the pile at the points indicated by the arrow.

Weaves. A weave may be defined as a scheme of interlacing.

The repeat of a weave is the number of threads required for the complete scheme of interlacing.

A design is the plan or representation of a weave.

With one or two minor exceptions, all weaves are repeated a number of times in the width and length of a piece of cloth, such repetition being necessary by reason of the limited number of threads which can be separately controlled. It will, therefore, be obvious that designs must be arranged in such a manner that perfect patterns will result when they are so repeated.

There are three methods of representing weaves, namely—

1. By the plan and section, as shown by Figs. 19 and 19A. Whilst this method is simple and easily

understood and is useful in the analysis of complicated structures, it is too cumbersome for ordinary purposes.

2. By drawing horizontal and vertical lines across one another to represent weft and warp threads respectively, and marking the intersections thereof at the points where one of the two sets of threads appears on the surface. The marks may represent either warp threads or weft threads on the surface, but not both in the same design. See Fig. 25, which represents the interlacement of six warp threads with the same number of weft threads; the crosses indicating the points at which warp threads are above the weft, and the unmarked places those at which weft threads cover the warp. This method is convenient for weaves of small repeat.

3. By using "squared," "point," or "design" paper and taking horizontal *spaces* to represent weft threads, and vertical *spaces* to represent warp threads. Marks are placed within the spaces to indicate the point at which one of the two sets of threads is uppermost. In the cotton trade it is usual to mark warp risers, i.e. to indicate by marks the points at which warp threads cover the weft. The blanks then indicate the points where weft threads cover the warp. See Figs. 26 and 27. (In the woollen and worsted industry the contrary method is usually adopted, i.e. marks represent weft threads and blanks warp threads on the surface.) The advantage of this method is that designs of large repeat can be easily and quickly prepared on paper of convenient size.

The Elementary or Fundamental Weaves. There are three elementary or fundamental weaves, namely—

1 The plain, calico, or tabby weave,
2. The twill weave, and
3. The satin or sateen weave.

These are called elementary or fundamental weaves because they are the simplest weaves of a distinctive character, and they form the basis upon which other weaves are constructed.

The **plain** weave is the simplest and most used of all weaves. It consists of interlacing warp and weft threads alternately under and over one another as shown in the plan and section, Figs. 19 and 19A, and the point paper design, Fig. 26. This weave has the maximum amount of interlacing, and when the warp and weft threads are equal in number and thickness—in which case the resultant cloth is said to be a true plain cloth—each set of threads bends equally during weaving. Each thread thus lies in the hollows of the opposite set and is thereby enabled to offer resistance to forces which may tend to displace it. The result is a closely woven fabric of greater firmness and strength than that produced by any other ordinary weave. This accounts for the extensive use of the plain weave for the lightest as well as the heaviest of fabrics.

Owing to the frequency of the interlacing, plain woven fabrics usually have level surfaces, and are free from pattern markings. But these conditions can be considerably modified in several ways. Thus, by using extra hard twisted yarns we obtain the well-known crêpe cloth in which the abnormal amount of twist causes the cloth to shrink to an extraordinary degree and develop a crinkly surface. An uneven surface is also produced if the warp threads are woven too slack; if they are arranged in groups of tight and slack threads "crimp stripes" are produced, while a fine ribbed effect is produced when alternate threads are woven very tight and intermediate threads very slack. If a considerable alteration be made in the proportioning of the warp and weft threads, well defined cords or ribs are developed. In poplins a very large number of fine warp threads are used along with a small number of very coarse weft threads. The fine warp bends round and completely covers the weft threads, which, by reason of their thickness, lie straight and form pronounced ribs across the width of the cloth. By reversing these conditions and using coarse warp and fine weft threads, ribs with a weft face are developed along the length of the cloth as seen in moreen skirting fabrics. In the true "repp" fabric, fine and coarse threads are arranged alternately in both warp and weft. The fine warp threads are held very tight, and all are lifted above the fine weft threads. The coarse warp is held moderately slack and its threads are all lifted when the coarse weft is inserted. In this manner transverse cords of a more pronounced character than the poplin cords are produced. Figs. 28 and 29 show sections of a poplin, and Fig. 30 a section of a repp.

The Twill Weave. In any departure from the plain weave, the threads of one set must be "floated" or passed over consecutive threads of the other set. Three important results follow this change in the order of interlacing, namely—

1. The firmness and strength of the cloth is reduced, because the threads do not support one another when they float, as they do when they interlace.

2. A heavier and bulkier fabric can be woven because the spaces left by the omitted intersections can be filled by increasing either the number or the thickness of the threads, and

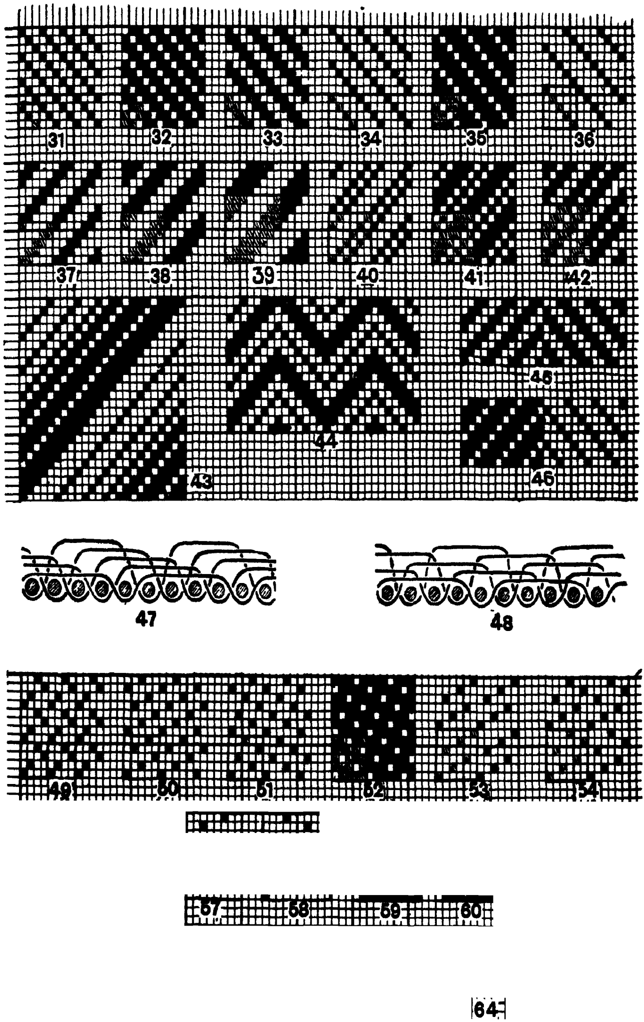
3. Pattern can be developed by varying the length of the float, i.e. the number of threads passed over, according to the outline of the figure required.

The twill weave is the simplest figured weave, and the figure or pattern produced by it consists of diagonal lines, which are developed by arranging floats to advance thread by thread in a diagonal direction. Such direction may be either from right to left upward, in which case the twill is described as a " twill to the left " ; or from left to right upward, in which case it is said to " run " or " twill to the right." In cotton fabrics twills usually run to the left, but in woollens, worsteds and silks, they are usually in the contrary direction. The surface float may consist either of warp or of weft threads, or there may be floats of both sets of threads. In the first case, the effect is one-sided, because one set of threads predominates on the surface. In the second case, it is either one-sided or reversible, according as the floats are unequal or equal.

In simple or regular twills the diagonal lines are of a plain and uniform character, because the floats are caused to " step " or advance one " end," or warp thread, for each " pick " or weft thread, in the desired direction. Also there are as many ends as picks in the repeat.

In designing a regular twill weave the repeat and length of float or floats are first settled. The length of float depends chiefly upon the fineness of the cloth to be woven and the style of twill required. Thus a float of four threads in a cloth with 40 threads to the inch is the same length as a float of eight threads in a cloth with 80 ends to the inch, but obviously, the shorter the float the firmer the fabric. When these points have been decided, the interlacing of the first thread of weft with the required number of warp threads is marked out on point paper and the float stepped off one end each successive pick in the desired direction.

Designs 31 and 32 show the 3-thread twill with weft and warp faces respectively. In the cotton trade these are known as the Jean and Jeanette twill, and are used



FIGS. 31–65

TWILL AND SATIN WEAVES

when a light firmly woven twilled cloth is required. Design 33 is the well known Harvard, sheeting, shalloon or serge twill which is largely used on account of the combination of strength and fullness given to the cloth. Design 35 is the Florentine twill, used for cotton drill suitings and design 36 the Beatrice twill, used for lining fabrics.

Designs 37 to 42 show how the twill lines may be varied to suit the size of float and firmness of cloth desired; 43 is a "shaded" twill, 44 a "wave" or "zig-zag" twill in which the lines are reversed about a central thread; 45 and 46 are "herring-bone" twills which form pronounced stripes owing to the reversal of the face of the twill along with its direction.

The Satin or Sateen Weave. The terms "satin" and "sateen" are generally used to describe particular styles of fabrics woven from silk and cotton respectively. But in the present case the terms must be understood to relate to weaves which produce cloth having a smooth, lustrous and patternless surface.

To secure these features either the minimum number of warp threads, i.e. one to the repeat, or the maximum number, i.e. all except one to the repeat, are lifted for each pick of weft, and the intersections are arranged in such a manner that they are covered by the floats of adjacent threads. This will clearly be seen on comparing the twill and satin sections, Figs. 47 and 48. The resulting one-sided effect is further emphasized by making the surface threads much greater in number and finer in counts than the opposite set. In silk fabrics the difference between the number and fineness of the warp and weft thread is usually so great that the interlacings and under set of threads are completely obscured, and the surface corresponds with that described above. But in other fabrics the difference is not so marked, and faint twill lines are developed which may, however, be neutralized by the direction of the spinning twist of the surface threads.

The rules for the construction of satin or sateen weaves are as follows—

1. For each pick of weft either lift or leave down only one warp thread in the repeat according as a weft or a warp surface is required.

2. Distribute the intersections evenly and in such a manner that no two consecutive warp threads interlace with consecutive weft threads, i.e. leave an interval between the warp threads lifted for consecutive picks.

To obtain a suitable interval between the intersections, divide the number of threads in the repeat into two unequal parts such that (*a*) neither divides evenly into the other nor into the repeat, and (*b*) both cannot be evenly divided by a third number. Thus for a 10-end satin weave, neither 1 nor 9, and neither 2 nor 8 can be used because of (*a*) and neither 4 nor 6 can be used because of (*b*). But either 3 or 7 can be used.

Designs 57 and 58 show the resulting weaves with weft faces and 59 and 60 with warp faces. It will be observed that the arrangement of the intersections is the same in each case, save that they incline in opposite directions. This is because 7 and 3 are complementary numbers of 10, i.e. together make up 10. When numbers which are not complementary can be used, as in odd thread repeats, more than one arrangement is possible as shown by the 11-end satins, designs 61 to 64, the interval nearest to half of the repeat being generally the best.

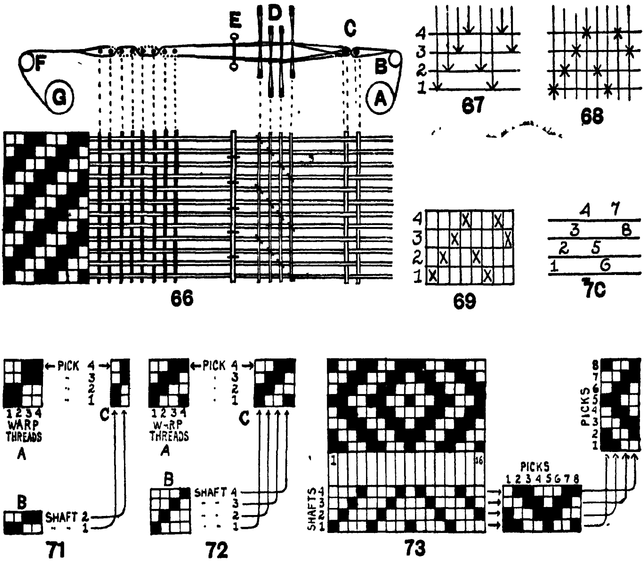
When no interval which fulfils the required conditions can be found for the required repeat, the intersections must be arranged either in an irregular order, or so that two come together. The weave is then said to be an "imperfect" satin, of which there are two examples, namely, the 4-end, design 49, called a satinette, and the 6-end satins, designs 53 and 54.

For cotton and linen fabrics the 5-end satins, designs 50 and 51, and the 8-end satin, designs 55 and 56, are chiefly used both for plain satins and as ground weaves for figured designs. Satin weaves of larger repeat are only used when the fineness of the cloth exceeds that of ordinary cottons and linens. The sixteen thread weave, design 65, is frequently used in the silk trade, in which fabrics with several hundreds of threads to the inch are not uncommon.

The Preparation of Working Plans for Weaving. During weaving it is necessary to form "sheds" or divisions in the warp threads, through which a shuttle containing the weft can be passed. The upper line of this division must contain all warp threads which require to be above the weft, and the lower line all threads which require to be below it. For this purpose the warp threads are passed through the eyes of healds or loops of twine, which in the case of weaves of small repeat are attached to thin wooden staves or shafts, so that by a single movement of one or more of the shafts the requisite opening can be formed. This will be understood by reference to Fig. 66, which shows how the warp is mounted in the loom; *a* being the warp beam, *b* the back bearer, *c* the lease rods, *d* the healds, *e* the reed, *f* the breast roller and *g* the cloth roller.

Before weaving can be begun, it is therefore necessary to determine (*a*) the number of shafts of healds required to produce the desired weave, (*b*) the order in which the warp threads must be drawn through the eyes of the several shafts, and (*c*) the order in which the shafts must be raised and depressed to produce the desired pattern.

As regards (*a*) there must be as many shafts of healds as the weave contains warp threads which interlace differently from one another. For example, in the 4-thread mat weave, design *A*, Fig. 71, the warp threads



FIGS. 66–73

HEALD DRAFTS AND LIFTING PLANS

interlace in two ways, hence two shafts are required for that weave; but in the 4-thread twill, design *A*, Fig. 72, no two threads work alike; therefore it requires four shafts.

(*b*) All warp threads which work alike can be controlled by the same shaft. Thus, threads 1 and 2 of the mat weave can be drawn upon the same shaft, and threads 3 and 4 upon another shaft, as shown at *B* But a separate shaft will be required for each thread of the twill weave, because no two threads require to work alike.

(*c*) A heald shaft must work, i.e. must rise and fall, in the order which the design shows its warp threads to require. The mat weave, for instance, requires the first and second warp threads to be above the weft for the first and second picks. Therefore the first shaft must be lifted for the first and second picks. The third and fourth warp threads require to be above the weft for the third and fourth picks ; hence the second shaft must be lifted for those picks.

" Heald drafts," " entering draughts," or " drawing in plans " may be represented by taking vertical lines or spaces to represent warp threads, and horizontal lines or spaces to represent heald shafts. The particular shaft upon which a thread is to be drawn is shown (*a*) by terminating the vertical lines (Fig 67), (*b*) by a cross at the intersection of the two lines (Fig. 68), or (*c*) by marking the space which is common to the particular thread and shaft (Fig. 69). Or the positions of the warp threads may be indicated by figures placed upon the horizontal lines as in Fig. 70.

The plan which indicates the order of lifting the shaft is termed the " lifting plan " or " pegging plan." It is obtained by grouping together the various thread workings of the design, or the interlacing of one thread from each shaft in the heald draft. The lifting plans for the mat and twill weaves above dealt with are shown at *C*, Figs. 71 and 72, and it will be observed that vertical spaces therein represent heald shafts and horizontal spaces, picks, or weft threads.

It will be evident that the proper connection between a heald shaft in the drawing-in plan and the corresponding shaft in the lifting plan must be preserved ;

otherwise the desired design will not be produced. To avoid confusion in this respect, the horizontal spaces which represent shafts in the draft may be continued, and the picks represented by vertical spaces drawn across them as shown in Fig. 73. In this manner the working of each shaft is directly connected with the warp thread, or threads to be controlled by it.

CHAPTER V

THE PRINCIPLES OF WEAVING AND THE DEVELOPMENT OF THE HAND LOOM

WEAVING has been defined as " a process which unites a series of parallel strands, or warps, by a crossing strand, or weft, which may interlace, wrap, or twine as it moves back and forth across the warp strands to form an expanded surface."

Such an interlacing may be performed in several ways. Thus, in one form of plaiting a few strands may be placed in parallel order on any flat surface and interlaced by crossing strands ; also the fabric can be expanded by the addition of other strands to any one of its four sides. But, in darning and loom weaving, the first or parallel strands, by reason of their flexibility, require the assistance of a frame of some kind to retain them in their proper positions while the interlacing is carried on ; hence the fabric can be expanded in the direction of its length only.

The fundamental principle of weaving, however, is that of dividing the warp threads into two lines, the upper line containing all those which require to be above a weft thread, and the lower line those which require to be beneath it. The weft is then passed by a single stroke through the " shed " or opening thus formed and afterwards beaten up or closed in to the preceding weft thread. When it is understood that the division of the warp threads also can be accomplished by a single movement, the fundamental difference between weaving and other methods of interlacing threads will be appreciated.

The essential operations of weaving therefore comprise—

1. "Shedding," or the formation of "sheds" or openings in the warp ;

2. "Picking," or passing the weft through the sheds ; and

3. "Beating-up," or closing-in the weft ; and the frame or machine in which these operations are carried out is called a "loom."

A brief outline of the development of the loom will be sufficient for our purposes, the reader who is interested in this subject being referred to the excellent handbooks by Ling Roth[1] and Kissell[2] .

The most primitive loom appears to have consisted of a rude frame carrying a bar from which the warp threads were at first freely suspended and later kept taut by means of weights. Next the warp threads were passed round a pair of bars, which enabled the length of the cloth to be doubled, and the length was further increased when the warp was stretched horizontally, as the bars could then be placed farther apart than was possible in the vertical loom. Eventually the limitation of the length of the cloth was removed by the substitution of revolving rollers to carry the warp and cloth in place of the fixed bars ; an arrangement which also enabled the loom to be brought within a more convenient compass.

At a very early period lease rods were introduced to spread out the warp threads and keep them in their proper order. With the threads so arranged it was then possible either to darn the weft into the warp, thread by thread after the manner of the earliest

[1] *Ancient Egyptian and Greek Looms*, Halifax, 1913 ; *Studies in Primitive Looms*, Halifax, 1918.

[2] *Yarn and Cloth Making*, New York, 1918.

weavers, or divide the warp into sheds for true weaving. In the next step the lease rods were transferred to their correct position, namely, close to the warp, and the front rod duplicated to serve as a shedding stick whereby the front shed was permanently maintained within easy reach of the weaver; but it was still necessary to pick up the threads for the counter shed as in darning. From this arrangement it would appear to be a natural step to pass a series of leashes or loops of twine, called healds or heddles, round the threads beneath the shedding stick and make them fast to a second rod or shaft placed above the warp so that by raising this shaft the threads of the counter shed could be instantly lifted for the next pick of weft. This will easily be understood by reference to Fig. 74. In the vertical loom the heald shaft would of course be placed in front of the warp and drawn forward to produce the counter shed.

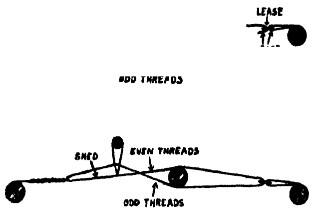


FIG 74
PRINCIPLES OF SHEDDING

The shedding arrangement was next practically perfected by linking a second series of leashes through those of the upper shaft and securing them to a shaft below the warp, the threads of the latter being passed through the clasps. By using a similar pair of shafts for the even-numbered threads and connecting the top shafts by cords suspended from a roller, or from the ends of levers, it became possible to work the shafts and form the sheds either directly by the toes or, through the medium of treadles, by the feet, and thus remove the necessity of using the hands for the purposes of shedding. In the modern heald a knot is tied near the end of the upper leash to form an eye for the warp thread, which is thereby freed from the grip of the leashes and enabled to move forward easily when the cloth is wound upon the roller.

We may now turn to the operation of picking. In the earliest form of weaving, both warp and weft probably consisted of short strands or filaments the length of which determined the length and breadth of the cloth to be woven. The weft would then be either darned into the warp, or drawn through a shed by means of a hooked or notched stick after the method in use to-day for horse-hair weaving and mat making. Of course the cloth would have raw edges, although in some cases the ends of the threads were turned into the shed to form semi-perfect selvages. But when the weft was prepared in the form of a continuous thread it was handed through the shed, probably at first in the form of a ball and later coiled upon spools which in some cases had rounded and in others notched ends. Next, a carrier was provided for the straight ended spool, first in the form of a cylindrical case which was handed through the shed and, later, in the form of a shuttle or boat-shaped carrier, which could be thrown through the shed by one hand and caught by the other.

Primitive weavers appear to have had two methods of beating-up the weft, namely, a flat sword-like stick and a short heavy comb. With the former a single stroke pressed the weft into position, but a number of strokes of the latter were required to produce the same result. The sword shape, however, was generally used. In some cases it was straight and long enough to reach across the full width of the cloth ; it was then often used also as a shed stick and turned on edge to facilitate the insertion of the weft. In other cases it was curved and notched at the end in order that it might also serve as a weft carrier.

At a later stage a warp spacer was used to spread the warp to the desired width. This first consisted of a notched bar placed near the warp beam. Next, the bar was provided with pegs or teeth between which the warp threads were placed in groups. This form, known as a " wraithe " or " raddle," developed into what is now called a " reed," in which thin flat strips of cane or metal are secured between pairs of ribs at the top and bottom, and spaced by wrapping bands to form " dents " or " splits " through which the warp threads can be drawn. Eventually this reed was placed in front of the shedding apparatus and used to beat up the weft, first by moving it to and fro with the hands, and, later, by swinging it about an overhead centre from which it was suspended by cords.

This brings us to the modern hand loom, which chiefly differs from the more advanced primitive loom above described in the method of carrying the reed and supporting the shuttle in its passage through the shed. These purposes are served by the " sley," or " batten," which is a heavy beam of wood faced with a thin, hard " race board " and bevelled to form, in conjunction with the reed, a trough in which the shuttle runs upon the lower line of warp threads which rest lightly upon the race board. At the back of the race board a groove is cut in the sley to receive the lower rib of the reed and the upper rib enters a similar groove in the hand top which is threaded upon, or otherwise secured to, the sley arms or swords. This enables an even blow of the requlsite strength to be easily given to the weft. For coarse work the cloth is usually passed over a breast beam to the cloth roller, placed lower in the framing in order that the line of the warp may remain unchanged during weaving, and rigidly held by a ratchet wheel and catch. The warp beam is either similarly held, or braked by weighted ropes to give the requisite amount of "pace" or tension to the warp. Weaving then proceeds without alteration in the parts until the space between the cloth and reed is too small for the swing of the sley, whereupon the beams are released, cloth wound upon the cloth roller, and warp drawn off the warp beam.

The shuttle was, however, still thrown by one hand and caught by the other, or, in very wide looms, by a weaver at each end of the sley. This method continued until 1733 when John Kay of Bury lengthened the sley and formed a box at each end into which the shuttle could run after leaving the warp. Across the top of each box he fixed a spindle to carry a sliding driver or "picker," and connected both pickers by cords to a short stick which he carried in his hand. He was thus enabled to stand or sit at the middle of the loom and jerk the shuttle to and fro with one hand and leave the other free to move the sley for beating-up.

Kay's invention is known as the "fly shuttle," and was the first and perhaps the most important in the chain of inventions which ultimately revolutionized the textile industry. Besides quadrupling the output of the loom and dispensing with the necessity for a second weaver on broad looms, it had other effects of a far-reaching character; for it at once destroyed the equilibrium which had hitherto existed between the production and consumption of yarn, up to that time laboriously spun one thread at a time, and created a demand which eventually led to the improvements in spinning machinery by Hargreaves, Arkwright and Crompton. These improvements resulted in a superabundance of yarn that caused attention to be again turned to the question of an automatic loom capable of keeping pace with the supply, and it was then found that Kay's invention overcame the difficulty which for a century had stood in the way of the power loom. For there is little doubt that either de Gennes in 1678, or Vaucanson in 1745, would have produced a successful

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FIG. 75

OLD HANDLOOM AND BOBBIN WINDER

loom of this kind had either adopted the principle of throwing or jerking the shuttle instead of trying to pass it through the shed by means of levers.

It is a somewhat remarkable fact that the next important improvement in the loom should be made by Robert Kay, a son of John Kay, who in 1760 invented the drop box, which enabled the weaver to

FIG 75*a*

MODERN HANDLOOM

control a number of shuttles on the fly principle. This was accomplished by providing, at one or both ends of the sley, a series of sliding shelves or boxes which could be raised or lowered to bring any desired box level with the race board to deliver or receive its shuttle.

So far we have considered only two shafts of healds. But, when more than that number are required, the principle of having a separate treadle for each shaft is inexpedient owing to the difficulty of selecting and

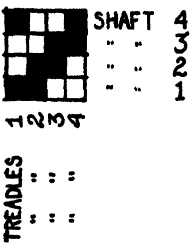


FIG. 76

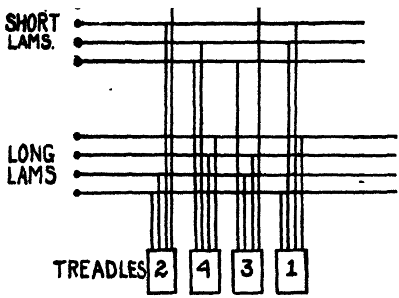


FIG. 77

HAND LOOM TIE-UP

depressing the proper treadles for successive picks of weft. This difficulty is overcome by a system of cording or tying-up in which the depression of a single treadle produces the desired shed. In this case two sets of levers called long and short "lams" or "marches" are fulcrumed on the side framing immediately above and at right angles to the treadles, as shown in Fig. 75*a*. Each short lam is directly connected to one of the bottom heald shafts and each long lam to a jack which is fulcrumed on the top cross rail and has a connection to a top heald shaft; hence the depression of a short lam causes the corresponding healds and warp threads to be lowered, while the depression of a long lam causes them to be lifted. Therefore, if, for any given shed, cords from the short lams connected to heald shafts which require to be lowered, and cords from long lams connected to shafts which require to be raised, be tied to the same treadle, the depression of that treadle will bring about the desired result. It will be evident that there must be as many treadles as there are different sheds in the pattern to be woven, and it is usual to arrange them so that it will not be necessary to cross the feet for successive sheds. Thus, suppose the pattern to contain six different sheds, i.e. sheds with different shafts of healds lifted and depressed, the treadles would be arranged in the order 1, 3, 5, 6, 4, 2, or 5, 3, 1, 2, 4, 6. Then, suppose the sheds to follow one another consecutively, number 1 treadle would be depressed by the left foot for the first pick; number 2 treadle by the right foot for the second pick, and so on.

Fig. 76 shows the "tie-up" or "cording plan" for the four shaft Harvard twill, and Fig. 77 the connections of the treadles and lams, from which it will be understood that cords are tied to the corresponding long lams where there are marks in the tie-up and to short lams where there are blanks.

The hand loom is still used as a commercial machine for the finest silks and linens, which are unable to withstand the severe strain, friction and high speed of the power loom; for the most expensive and elaborately ornamented fabrics such as are used for ceremonial purposes, in which the cost of weaving forms a comparatively small proportion of the total cost and in which the increased output of the power loom is counterbalanced by the greater risk of faultily woven cloth; and for pattern weaving, owing to the facility with which changes can be made.

CHAPTER VI

THE POWER LOOM. ITS DEVELOPMENT

IT was shown in the last chapter that in hand loom weaving the healds, shuttle, sley and beams are separately controlled by the feet and hands of the weaver. In power loom weaving, however, these and all other parts of the loom are controlled so as to work automatically and in unison on the application of manual or other power at a single point.

The problem of automatic weaving was first solved in ribbon and smallware weaving. Originally, these fabrics were woven in narrow looms one at a time, but there is evidence that as early as the sixteenth century a loom had been invented which was capable of weaving a number of such fabrics at a time. This was known in England as the "Dutch Engine" and the "Swivel Loom," and is frequently mentioned in history because of the troubles which its introduction caused among the workpeople and the frequent prohibitions of its use. By gradual stages this loom was improved, until finally two types, each completely automatic, were evolved. In the "Bar" loom, which was a foreign invention, the application of manual power to a vibrating bar in front of the loom set in motion the requisite parts and operations, while similar results were obtained in the second case by the application of any kind of power to a revolving pulley and shaft. The latter type of loom is interesting because it was invented by John Kay of Bury and Joseph Stell of Keighley some twelve years after the former had patented the fly shuttle, and also because the principal motions were controlled by cranks and tappets practically as they are controlled in the most modern power loom. But, whereas the problem of picking the shuttle in the ribbon loom was comparatively simple by reason of the narrowness of the fabric, which made it possible to control the separate shuttles used for the several ribbons by means of a rack and pinion or by pegs in a sliding bar, it was a much more difficult matter to pass a shuttle through the warp of a wide cloth such as calico.

The first notable attempts to produce an automatic loom for wide cloth were made by de Gennes, a French naval officer, in 1678, and by Vaucanson, the French scientist, in 1745, and reference has already been made to their failure with the picking problem. Both attempted to accomplish this by using levers to carry the shuttle through the shed. Vaucanson applied the friction roller taking-up motion now in common use, and also modified the shedding arrangement known as the "draw loom," in such a manner that it required improvement only in a few of its minor details to enable Jacquard to produce the machine which is now known by his name.

The next attempt was made by Robert and Thomas Barber of Nottingham, who, in 1774, constructed a loom upon principles so correct that only a few slight improvements upon it would have achieved the desired object. Their picking motion was identical in principle, and almost in arrangement, with the cone overpick now universally applied to high speed power looms. Altogether it is suprising to find that the inventors did not persevere with the loom and that no use appears to have been made of it.

We next come to the year 1785 when the Rev. Dr. Edmund Cartwright took out his first patent for a power loom. It is recorded that his attention was first directed to the subject during a conversation with some Manchester gentlemen at Matlock in 1784. Arkwright's inventions were being discussed, and the question was raised what would be the result of the superabundance of yarn which would undoubtedly follow the expiration of his patents. Cartwright suggested that, since machinery had been invented to spin yarn, other machinery should be invented to weave it, a proposition which the Manchester gentlemen declared to be impracticable.

Some time afterward Dr. Cartwright recalled the conversation, and, although he possessed no practical knowledge of weaving and had not even seen a weaver at work, he engaged workmen to carry out certain ideas which he had formed about the process. The result was the loom described in his patent of 1785, in which the warp was placed vertically, the reed fell, as he afterwards said, " with the weight of at least half a hundred-weight," the shuttles were thrown by springs " strong enough to throw a Congreve rocket," and the efforts of two powerful men were required to work it. Still it would work, and, having proved the practicability of the idea, he " condescended to see how other people wove " and was astonished to find how easy their methods were compared with his own. He thereupon set to work upon a second loom, which was completed and patented in 1787. In this loom he reverted to the horizontal type and, although he failed to accomplish all he had projected, he laid securely the foundations upon which the power loom was ultimately perfected. A persual of this specification quickly reveals the cause of his failure—he attempted too much. He sought to dispense with the operations of warping, sizing and beaming by providing a creel of bobbins from which the warp threads could be drawn and sized, or dressed, during their passage to the healds; and the loom included positive take-up and let-off motions, parts to stop it in the event of the weft failing or of a warp thread breaking, and also self-acting temples; all of which were beyond the mechanical skill of his time and were not perfected until many years later.

After losing £30,000 in a spinning and weaving mill at Doncaster and having a number of his looms destroyed in the burning by the mob of the mill of Messrs. Grimshaw of Manchester, Cartwright received a grant of £10,000 from the Government as compensation for his losses and inventions. Besides his work on the power loom he invented a very successful wool-combing machine, from which, however, he derived very little benefit owing to infringements of his patent, and also machines for making bread, bricks and ropes. Clearly Dr. Cartwright is worthy of a high place in our list of inventors.

By confining their attention to minor and essential details, subsequent inventors—among whom William Horrocks and Thomas Johnson, both of Stockport, stand out prominently—made steady, if slow, progress in the development of the power loom, until, in 1822, Richard Roberts practically completed it by settling what is virtually its present form and action. Thereafter it chiefly remained to take advantage of the advances in engineering skill and practice to add improvements in its details and adaptations to bring the loom to its present state of perfection.

CHAPTER VII

THE PLAIN LOOM—PRIMARY MOTIONS

THE loom for weaving plain and other simple weave fabrics requiring up to six or eight shafts of healds is commonly known as the plain loom. Its parts may be classified as follows—

(*a*) Primary motions, i.e. shedding, picking and beating up.

(*b*) Secondary motions, i.e. tensioning the warp and taking up the cloth, and

(*c*) Supplementary motions, such as preventing damage to the warp and cloth, stopping the loom on the failure of the weft and keeping the cloth distended to the width of the warp threads.

The loom is usually driven by a belt which passes round driving pulleys on the crank shaft, *A*, Fig. 78. The latter has two cranks or bends, *B*, which, through connecting arms, *C*, cause the sley, *F*, to vibrate about a centre, *E*, and a ratchet, *Z*, on one of the sley swords, or supporting uprights, *D*, gives intermittent motion through a train of wheels to the taking-up roller, 5. Between the driving pulleys and the framing a spur wheel is keyed upon the crank shaft to drive, through another spur wheel of twice the size, a lower or second motion shaft, *I*, at half the rate of speed. This second motion shaft carries a picking tappet, *P*, near either end and also in the case of the plain weave the shedding tappets at the middle. As the cranks and sley recede from their forward position, the shedding tappets, *J*, begin to open the shed, which by the time the cranks reach their lowest or bottom centre becomes fully opened. Thereupon one of the picking tappets causes the shuttle to be driven through the shed to the

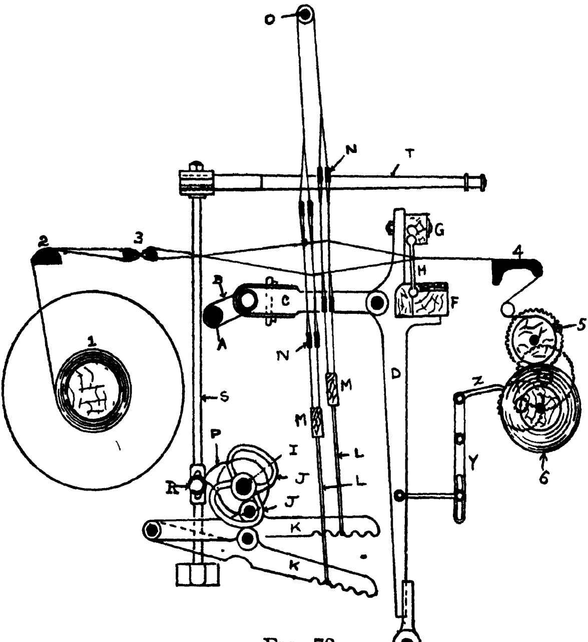


FIG. 78

SECTION THROUGH PLAIN POWER LOOM

	Crank shaft	J.	Shedding Tappets	T.	Picking stick
	Crank	K.	Treadles	Y.	Taking-up lever
	Connecting rod	L.	Lam rods	Z.	Taking-up catch
	Sley sword	M.	Lams	1.	Warp beam
	Rocking shaft	N.	Heald shafts	2.	Back bearer
	Sley	O.	Top roller	3.	Lease rods
G.	Sley cap	P.	Picking tappet	4.	Breast beam
H.	Reed	R.	Picking cone	5.	Taking-up roller
I.	Tappet shaft	S.	Picking shaft	6.	Cloth roller

opposite box, which it reaches as the cranks approach the top centre. At this point the action of the shedding tappets ceases and the shed closes. The sley then advances to beat up the weft, and the cycle of operations begins again.

A more detailed examination of the plain loom can now be made.

Shedding is usually controlled by rotary tappets or cams which, operating through treadles and levers, move the healds and the warp threads as required. These tappets are, according to circumstances, placed either inside or outside the loom framing. For the smaller weaves and when the latter do not require to be frequently changed, inside tappets are generally preferred, as they take up less room and act more directly upon the heald shafts ; hence they consume less power and enable the loom to be run at higher speeds. For two-pick weaves, i.e. weaves which repeat themselves at every two picks, these tappets are keyed upon the bottom shaft, but for weaves of larger repeat they are either carried by a sleeve which is slipped on the bottom shaft, or fixed upon a countershaft, and in either case suitably driven from the bottom shaft. Outside tappets are preferred when it is necessary to make frequent changes of the pattern for which they are more conveniently situated. Fig. 81 shows the arrangement known as the Bradford Twill Tappet, in which as many leaves or projections as there are shafts of healds are cast in a single piece upon a boss and freely revolved upon an extension of the bottom shaft by suitable gearing from the top shaft. As will be observed, the treadles are connected by rods to jacks or levers fixed near the ends of cross rods that are supported by ladder-shaped brackets, and the heald shafts are suspended from the quadrants or curved arms carried by the cross rods. A change in the weave requires, of course, a fresh set of tappets, which are, however, easily placed in position. In an improved form of tappet,

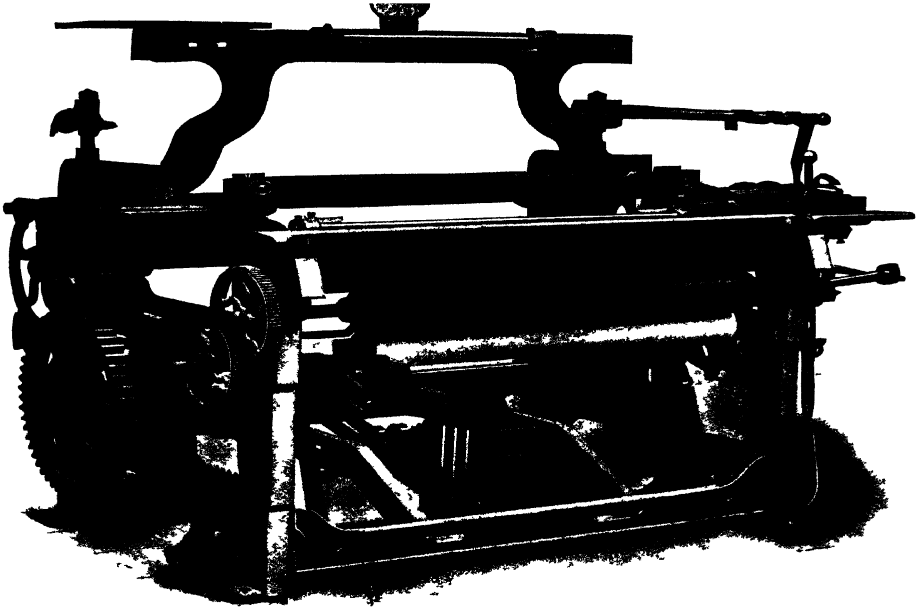


Fig 79.—PLAIN LOOM—FRONT VIEW.

interchangeable pieces are bolted upon a series of discs, which are fastened together and similarly placed and driven. This facilitates change of pattern and avoids the necessity for fresh tappets at each change.

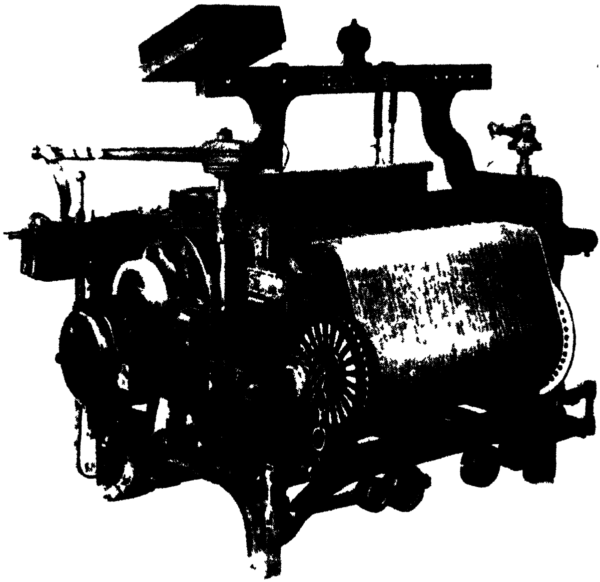


FIG. 80

PLAIN LOOM, WITH MOTOR FOR ELECTRIC DRIVING —BACK VIEW

It will be observed that the action of the foregoing tappets is to move the treadles and healds in one direction only; that is, the inside tappets only depress and the outside tappets only raise healds and warp threads. Supplementary parts connected to the opposite shafts

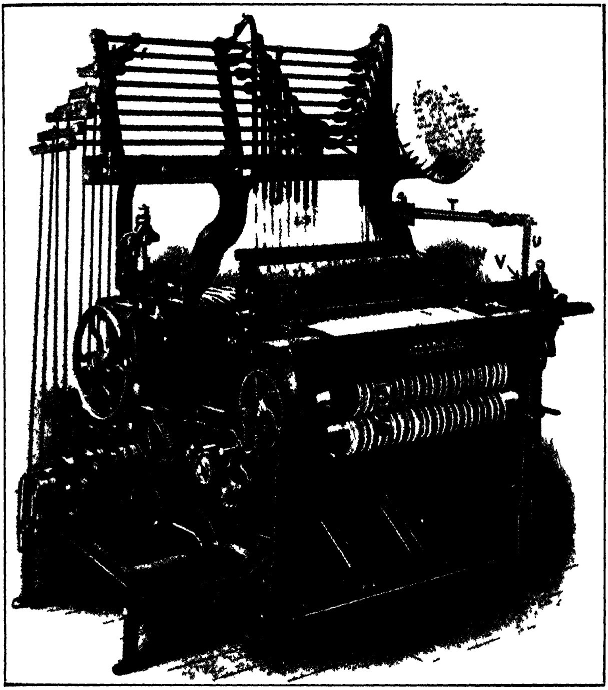


Fig 81

BRADFORD TWILL OR CROSS-ROD LOOM

of the healds are therefore required to bring them back to their original positions. For this reason these tappets are described as " negative " tappets. " Positive " tappets, however, both elevate and depress the treadles, and each of the latter is connected to a top and a bottom shaft of healds, so that the movements

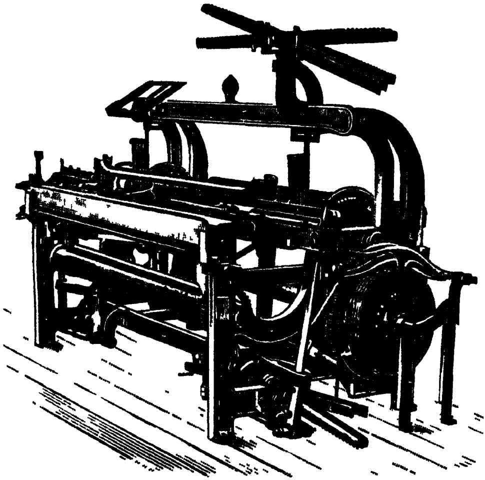


FIG. 82

FUSTIAN LOOM, WITH WOODCROFT TAPPET

of the warp threads are completely controlled. This type of tappets is preferred for strong heavy fabrics, which require the warp threads to be more heavily tensioned during weaving. (Tappets are also classed as " open " and " closed " shedding. In the former, a heald once moved is retained in the new position until its warp threads require to return, no matter how many picks of weft may intervene ; but in " closed " shedding a heald shaft and its warp threads are brought to their original positions after every pick.)

The box plate and Woodcroft tappets belong to the positive class and are extensively used; each is fixed outside the framing as shown in Fig. 82, and consists of a series of circular plates, one for each treadle and shaft of healds, with continuous beadings cast upon their faces to act upon anti-friction rollers carried by the treadles. In box plate tappets fresh plates are required for a fresh pattern, but in the Woodcroft tappet the plates are composed of interchangeable segments, which can be bolted together and rearranged according to the weave required.

It will be obvious that the negative shedding tappets must move the healds the full depth of the shed, but, since the positive tappet can move them in both directions, a shed of given size can be produced by raising those threads which require to be above the weft half the depth of the shed and depressing the remainder to a similar extent. That is, the warp threads move to and from a central line; hence this kind of shed is called a "centre" or "split" shed. It is formed in less time and with less power than top and bottom shedding and places less strain upon the yarn. On the other hand, the whole of the threads are moved for every shed, which is not desirable in high speed looms.

Tappets give the easiest kind of movement to the warp threads, because they can generally be constructed to accelerate the motion toward the centre of the lift and from that point gradually to decrease it until it merges into a full pause. This is known as an eccentric motion, and avoids the jerking of the healds and warp threads which tends to develop in high speed looms.

The manner in which the operation of shedding is performed materially affects the quantity and quality of the cloth produced. The shed should not be deeper than is necessary for the free passage of the shuttle, otherwise excessive warp breakages will result ; if the shed be not deep enough threads will be caught and broken by the shuttle, which will also require more power to drive it through, whilst if the shed is not even in its depth the shuttle may pass under or over threads which should be in the opposite lines.

Plain cloths of medium fineness are usually woven with two warp threads in each dent of the reed. This tends to cause the threads to run together in pairs and form more or less distinct gaps or " reed marks " in the cloth. To neutralize this tendency, the back rest, or roller over which the warp threads pass from the beam to the healds, is raised above the level of the front or breast beam, and the healds set to deflect the warp out of the straight line between these two points. This causes the top line of the warp threads to be slacker than the bottom line when the shed is opened and throws the greater part of the strain upon the bottom line. The slack threads thereupon spread themselves into spaces between the tight threads, and, by setting the pick a little late and slightly opening the shed before the weft is beaten up, the slack threads are retained in the positions which they have taken up. The warp threads thus become evenly spaced and form what is called a " well covered cloth " in contradistinction to " bare " or " reedy " cloth.

Picking. Frequent reference has been made to the difficulties which the early inventors met with in this motion, and it still remains the most difficult problem of the power loom. This will easily be understood when it is realized that a body of constantly changing weight has to be suddenly shot across a surface which is moving not only at right angles to the direction of the shuttle but also towards a lower plane, and while the weft thread is exerting a varying pull at one end. Positive picking has been mentioned in connection with the ribbon loom, and the same principle has also been applied to looms for beltings and hose-pipes, in which the shuttle is drawn across either by a rack and pinions or by levers which enter slots in the under side of the shuttle.

Ordinary looms are provided with "negative" picking motions, which are divided into "over" and "under"

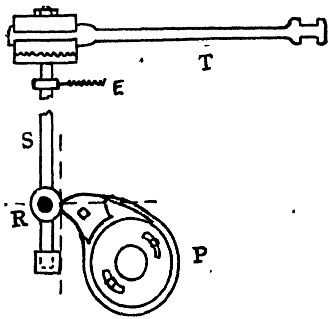


FIG. 83
CONE PICKING MOTION

picks according as the shuttle is moved from a point above or below the box.

The "cone" pick belongs to the first named class. It contains the following parts, which are duplicated at each side of the loom and set to act alternately—

An upright shaft *S* (Figs. 78 and 83), which is supported so that it may turn freely in a footstep and an upper bearing on the loom side; a cone or conical anti-friction roller *R*, carried by a stud near the foot of *S*; a picking stick or arm *T*, secured to the top of *S* by a pair of adjustable rings and a cap; a picker *V* (Fig. 81) which is free to slide along a spindle fixed over the centre of the shuttle box; a leather strap or picking band *U*, which connects the picker with the forward end of *T*; a picking tappet, *P*, which comprises a boss, keyed on the second motion shaft, to which is bolted a shell with edges bevelled to correspond with the taper of the cone, *R*, and grooved to receive a nose which is bolted to the shell and similarly bevelled; and a spiral spring which is hooked to the framing and to a strap bolted to shaft, *S*, to keep the cone in contact with the tappet and secure the return of the picker and arm after the shuttle has been moved. In narrow looms, however, the straps on opposite shafts are usually connected by a long spring which passes below the warp.

The action is as follows: Shaft *S* is set to place the cone in contact with the shell, and, since the latter is concentric with the shaft to which it is secured, the cone remains stationary until the nose engages with it. Thereupon the shaft and arm are moved through an arc at a gradually increasing speed until the nose point has passed and the shuttle, through the medium of the strap and picker, gains a sufficient amount of momentum to carry it across the sley. This gradual development of the momentum constitutes the chief value of the cone pick, because it gives a comparatively smooth and steady motion to the shuttle.

For slow looms the tappet *P* is usually set to move the picker when the crank is at, or a little past, the bottom centre; for fast looms it is set a little earlier. Slight adjustments of the timing are provided for by the discs which carry the picking sticks, and also by the slots in the shell. For larger adjustments the driving wheels are taken out of gear and set one or more teeth forward or backward as required. The strength of the pick is adjusted by moving the tappet nearer to, or farther away from, the cone.

The action of the picking tappets ceases before the picker has travelled the full length of the spindle, and the further movement due to the momentum acquired by the picking stick is finally arrested by leather washers, threaded upon the spindle to form a buffer which prevents damage to the picker and spindle stud. The shuttle is checked and prevented from rebounding on entering the box by means of "swells" and "check straps." A swell is a piece of wood or metal which is hinged in the box back at the one end and pressed forward by a flat spring at the other, so that a bulge on the tapered face projects into the box to grip the entering shuttle. A check strap consists of a narrow piece of strapping, which is carried by staples in front of the sley and threaded on the spindle behind the bow leather at the box end. Between the staples at the centre of the sley a short piece of strapping is riveted upon the long piece and drawn first against the one staple and then against the other by the movement of the shuttle against the picker to check the further movement of the latter.

While the cone pick may be regarded as the most satisfactory of all picks from an economical point of view, its application is practically limited to narrow and fast running looms, weaving light and medium weight fabrics, because it is difficult to obtain from the slow-moving second motion shaft the power requisite to throw a heavier shuttle against the greater resistance of the warp threads. The cone pick is also unsuitable for bleached and coloured goods on account of the risk of oil splashes from the spindle and accumulations of dirt from the boxes, and for drop box looms because of the interference of the picker with the movement of the boxes. It is also difficult to adapt to "pick and pick" looms, i.e. looms which require to pick a number of times in succession from the same side. For one or other of these reasons "under" picks are used, and of these there is a considerable number.

Perhaps the simplest of all picks, either under or over, is the "side lever" pick which is used in looms

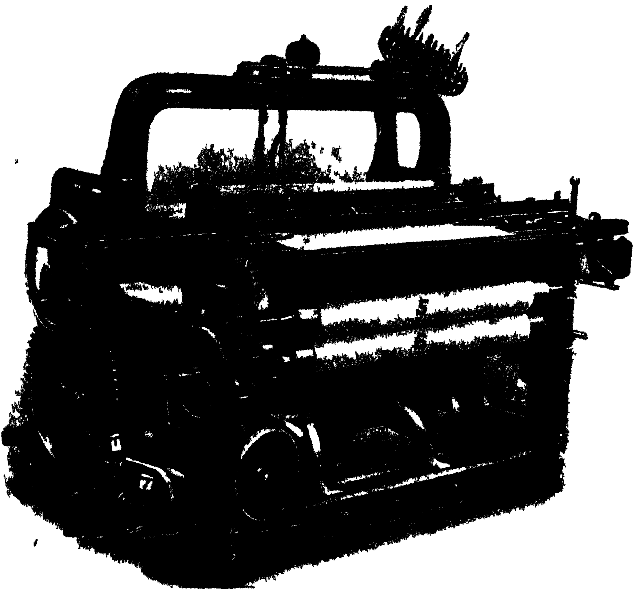


FIG 84

UNDER-PICK LOOM

weaving both light and heavy fabrics when freedom from oil stains is important. This is shown on the loom at Fig. 84, and consists of a short arm keyed at the end of the second motion shaft to carry an adjustable stud and bowl. Within the path of the bowl a plate with a pointed face is bolted to a horizontal lever, 7, fulcrumed at one end on the loom framing and resting at the other end upon the arm of a picking shoe which is pivoted on a stud and carries an upright picking stick, *T*. The picking stick passes through the slot of a metal plate that forms the bottom of the shuttle box and also through a leather picker which rests upon the plate, and is prevented from rising by a wooden rib on the box back. As the second motion shaft revolves, the bowl strikes the plate and depresses the lever, whereupon the stick and the picker are suddenly jerked forward and the shuttle driven across the sley, after which the stick is drawn back by the pull of a spring on the underside of the shoe. The motion is clean and simple in construction and action, but requires the parts to be carefully adjusted, or frequent breakages of the sticks and levers will occur.

When a very strong pick is required in a slow running loom, the top or crank shaft is utilized as the source of the picking power, and there are many motions of this type which chiefly differ in the method of securing the alternate action of parts at the opposite sides of the loom. The usual arrangement consists of strikers or projecting pieces on the fly or balance wheels, which are caused to engage at alternate revolutions of the crank shaft with a finger on an inclined shaft connected by a strap with the picking stick as shown in Fig. 82. In some cases the striker is moved so as to miss the finger for alternate strokes, in others the finger is moved out of the path of the striker. It is inevitable from the abruptness of the striker's action and the difficulties of correctly shaping the striker and finger and maintaining such shape that the pick should be of a harsh character.

Beating-up. As has already been indicated, the functions of the sley or going-part of the loom are the carrying of the shuttle in its movement from box to box and the beating up of the weft. For the first of these it is withdrawn from the cloth and either moved slowly or kept stationary whilst the shuttle is passing; for the second a quick forward movement is desirable, that is, the motion must be reciprocating, and should be eccentric or variable in speed.

The earliest power looms, having been modelled on the hand loom, had the sley swung from the top, an arrangement which required the loom framing to be carried sufficiently high for the purpose, and power looms constructed on this principle are still to be met with. But it was soon realized that the sley could be more easily controlled and the framing simplified by inverting this arrangement and moving it about a centre near the foot of the loom. Cams, springs and compressed air were first applied for moving the sley, arrangements which, although they produced the desired kind of movement, did not ensure a uniform stroke of the reed and correct timing with the other motions. The problem was finally solved by the application of the crank and connecting rod, which not only gave the desired kind of movement to the sley, but also placed it under positive control.

In narrow looms the swords or arms which carry the sley are bolted to a rocking shaft *E* (see Fig. 78), which extends from side to side and is supported in bearings at the foot of the loom. In wide looms each sword is carried by a separate short shaft. Immediately behind the lower part of the sley ears are cast on the sley swords to receive pins for securing the ends of connecting arms *C*, which are joined at the opposite ends by straps, gibs and cotters to cranks *B* bent on the driving shaft *A*. The revolution of the latter shaft thus causes the sley to swing on the rocking shaft, alternately away from the cloth to allow the shuttle to pass, and towards it for the beating up of the weft. So far as the movement alone is concerned, the use of cams would appear to be preferable to cranks and for that reason are used in abnormally wide looms. Cranks, however, besides giving more complete control over the movement of the sley also provide a sufficient amount of eccentricity for all ordinary looms and fabrics.

The eccentric motion imparted by cranks arises from the conversion of their circular motion into the nearly straight line motion of the sley connecting pins. It can be varied within reasonable limits to suit the speed and width of the loom and depends upon the relative lengths of the cranks and crank arms and the relative positions of the cranks and the connecting pins.

For light and quick running looms a comparatively small amount of eccentricity is required, but a larger amount is necessary in the case of wide and heavy looms. The former, therefore, have relatively short cranks and long arms, and the latter long cranks and short arms. An increase in the length of the cranks, however, gives a greater sweep to the sley and increases the yarn friction; hence looms which require an abnormal amount of eccentricity often have long ears cast on the swords, in order that the arms may be shortened without requiring cranks to be lengthened to a degree that would take the race board below the lower line of the warp and possibly bring the swords into contact with the crank shaft.

In weaving carpets, hose-pipes, belting and other abnormally heavy fabrics it is necessary to give a double beat of the sley and reed for every pick of weft. The usual method of accomplishing this consists of using an arm fixed upon a stud at one end, hinged at the centre and connected to the sword at the other end. The crank is connected by an arm to the hinged joint, which is caused to rise and fall as the crank revolves. The reed is in contact with the cloth when the two parts of the hinged arm are in the same straight line, and, as the joint is carried both above and below this straight line once for each complete revolution of the crank, the reed is brought into contact with the cloth twice for each pick.

CHAPTER VIII

THE PLAIN LOOM—SECONDARY MOTIONS

THE secondary motions comprise warp tensioning or letting off and taking up. **Letting off** is effected by motions which are either (*a*) negative or (*b*) positive. Negative motions frictionally retard the rotation of the yarn beams and thereby tension the warp, which has to be pulled off the beam, against the resistance thus set up by the combined action of the shedding and taking-up motions. Whilst motions of this type are simple in construction and easily adapted to circumstances, they subject the yarn to undue strain, require frequent adjustment as the warp weaves down, and involve the lifting of weights when it is necessary to turn the beam backwards. Positive motions, on the other hand, give off the yarn by positively rotating the beam and, theoretically, after a preliminary adjustment require no further attention until the warp is finished.

In the ordinary type of negative let-off motion, which is invariably applied to looms for light and medium weight fabrics of every description, the beam is supported in brackets and has at one or both ends a rope or chain coiled several times round it. One end of the rope or chain is fastened to a fixed hook and the other to a lever which is fulcrumed at one end and weighted at the other ; but in Fig. 80 a series of compound levers is used to reduce the size of weight required. The amount of drag or friction thus set up is varied to suit the yarn or cloth to be woven, and it depends upon the size and position of the weights and the number of times which the rope is coiled around the beam as well as upon the nature and size of the friction surface, but in any case the weights must gradually be moved towards the fulcrum as the diameter of the yarn on the beam decreases, in order that the diminishing leverage of the yarn beam may be compensated for, since it is this leverage which has to overcome the drag or friction upon the beam.

One advantage of the foregoing type of letting off motion is that the weights are free to rise as the shed opens and thereby relieve the yarn of undue strain. Also by falling as the shed closes the weights are enabled to take back the amount of yarn not drawn forward by the take-up motion. Yarn strain can also be equalized by the use of a vibrating back rest which moves towards the healds as the shed opens and returns as it closes. Such rests, however, are not suitable for open shedding or for heavily wefted cloths, which require the yarn to be held firmly at the moment of the beat up.

As previously mentioned, positive let-off motions positively rotate the yarn beam. Theoretically this is more correct in principle than frictional retardation, because it would appear to ensure the delivery of the exact amount of yarn required for the cloth drawn forward by the take-up motion, and thereby give a more even fabric and the maximum length of cloth from a given length of warp; it would also facilitate the production of certain styles of pile fabrics and others of abnormal weight. But, excepting for the last mentioned fabrics, the principle has not proved wholly satisfactory, chiefly because the warp is rigidly held at all times and the shed has to be formed by stretching the yarn, which results in undue breakages. Positive motions are therefore applied only to automatic looms and to looms for weaving abnormally strong and heavy cloth and special pile fabrics. In the true positive let-off the yarn beam is rotated so as to give off a definite amount for each pick of weft. But most so called positive let-off motions are really semi-positive in their

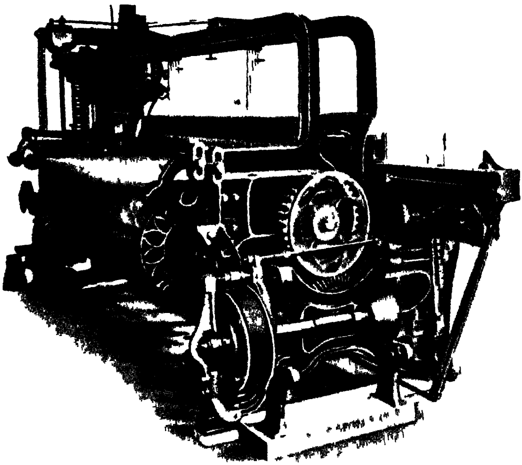


FIG. 84*a*

HEAVY WOOLLEN LOOM WITH SEMI-POSITIVE LET-OFF

action, for, although the yarn beam is positively geared, its rotation and the delivery of the warp are controlled by a sensitive back bearer which responds to the variations in the yarn tension consequent upon the action of the shedding and taking-up motions. (See Fig. 84*a*.)

Take-up motions serve to draw the cloth forward as it is produced. They are either (*a*) negative, or (*b*) positive. In the former, the cloth roller is moved negatively by springs or weights at the moment when the reed is pressing upon the cloth, while in the latter a taking-up roller is positively moved by a train of wheels which give a definite movement for every pick of weft inserted.

Negative motions are used when the weft is liable to vary in thickness, when an abnormally large number of picks to the inch have to be inserted, and for silk and other fabrics of a like character which are liable to be damaged by the rough surface of a taking-up roller.

In the common style of negative take-up motion applied to the fustian loom, Fig. 82, the cloth passes directly from the breast beam to the cloth roller. The latter has a wheel at one end which is driven by a worm on a short cross shaft that has a ratchet wheel at the other end and is driven by a catch on a loosely fulcrumed arm from which is suspended a weighted stalk. As the sley moves backwards the stalk is pushed upwards and held suspended by the ratchet catch as it reverses. If the pull thus set up on the ratchet wheel and cloth roller exceeds that exerted by the warp beam weights, the roller is moved and the cloth drawn upon its surface, any movement being retained by a dead catch. But, if the pull on the yarn exceeds the pull on the cloth, picks continue to be inserted without movement of the roller until the pressure of the reed causes the cloth to become momentarily slack, whereupon it is drawn forward. As the cloth roller fills, the weights upon the stalk must be gradually increased to compensate for the greater weight to be moved. As in all negative motions the closeness, or number to the inch, of the picks is chiefly regulated by the weighting of the yarn beam.

In positive take-up motions, a taking-up roller which has a roughened surface of emery, sand, perforated zinc, wire teeth or fine pins draws the cloth forward and delivers it to the cloth roller. The first or take-up roller is positively driven either intermittently by the action of a catch which is attached to, or actuated by.

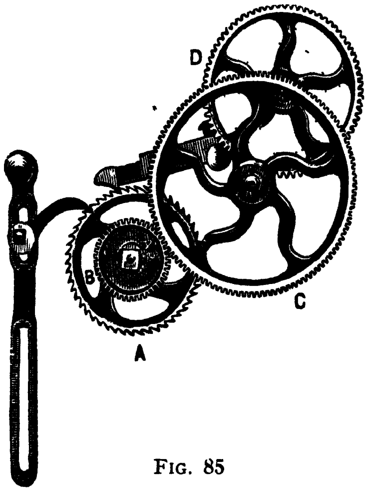


FIG. 85

POSITIVE TAKE-UP MOTION

one of the sley swords, as shown in Fig. 78, or continuously by connection with the crank or tappet shaft.

Practically all ordinary looms are fitted with motions of the intermittent type. The motion usually applied to cotton looms (see Figs. 84 and 85) consists of a train of five wheels, the first being a ratchet or rack wheel *A*. At the other end of the ratchet stud is a change pinion *B*, which gears with a stud or carrier wheel *C* compounded with a stud pinion that drives the beam wheel *D* at the end of the taking-up roller. A holding back or dead catch also engages with the ratchet wheel to retain any movement of the same. The following "gears" or trains of wheels are in common use on cotton looms—

Ratchet Wheel.	*Stud Wheel.*	*Stud Pinion.*	*Beam Wheel.*	*Circumference of Beam.*	*Dividend per ¼ in.*
50	120	15	75	15 ins.	507
60	120	15	75	,,	609
50	145	14	90	,,	794
50	100	12	75	,,	528
60	100	12	75	,,	634

(1). To find the change pinion for a given number of picks to the ¼ in.

$$\frac{\text{Ratchet Wheel} \times \text{Stud Wheel} \times \text{Beam Wheel}}{\text{Circ. of Beam in } \frac{1}{4} \text{ ins.} \times \text{Stud Pinion} \times \text{Picks per } \frac{1}{4} \text{ in.}} = \text{Change Pinion}$$

(2). To find the number of picks to the ¼ in. obtained by a given change pinion

$$\frac{\text{Ratchet Wheel} \times \text{Stud Wheel} \times \text{Beam Wheel}}{\text{Circ. of Beam in } \frac{1}{4} \text{ in.} \times \text{Stud Pinion} \times \text{Change Pinion}} = \text{Picks per } \frac{1}{4} \text{ in.}$$

Calculations are shortened by using a "dividend" or "constant number," which may be defined as a number equal to the product of the number of teeth in the change pinion and the resultant number of picks to the ¼in. or other unit space, hence

(3). Dividend ÷ Change Pinion = Picks to the ¼ in.

(4). Dividend ÷ Picks to the ¼ in. = Change Pinion.

The Dividend is found by

(5). $$\frac{\text{Ratchet} \times \text{Stud} \times \text{Beam Wheel}}{\text{Circ. of Beam in } \frac{1}{4} \text{ in.} \times \text{Stud Pinion}} = \text{Dividend.}$$

When the cloth is released from the tension of the loom it usually contracts in length, and by bringing the picks closer together increases the number per inch. It has, therefore, been agreed that, for the purpose of wage calculations, since the cloth is measured out of the loom, an addition of $1\frac{1}{2}$ per cent shall be made to

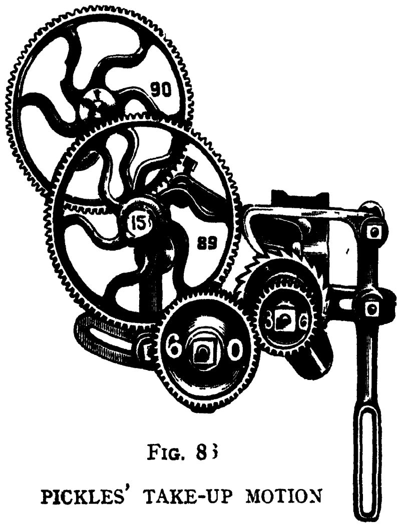


FIG. 83

PICKLES' TAKE-UP MOTION

the "Mathematical Dividend" obtained by formula 5, to give the "Practical Dividend," e.g. 500 mathematical dividend plus $1\frac{1}{2}$ per cent = $507\frac{1}{2}$ practical dividend (507 being generally used).

Gears with smaller dividends are suitable only for low picked cloths, because of their limited range and the difficulty of obtaining an exact number of picks ; thus if a 35 pick cloth is required with the 507 gear, 507 ÷ 35 gives 14·48 change pinion, for which either a 14's or a 15's must be used. In the former case the result would be 36·21 picks in the cloth and in the latter 33·8 picks; that is, the cloth would have 1¼ picks either too much or too little. But with the 794 dividend a pinion of 22·8 teeth or, say, 23, would be necessary, which would give 34·52 picks, or only half a pick short. The larger pinion also gives easier working.

The difficulty illustrated by the above examples is avoided by the use of "seven wheel gears" (see Figs. 81 and 86), which are usually arranged on the "pick to each tooth" principle; that is, each tooth in one of the wheels in the train has a definite pick value, such as one pick to each tooth, half a pick to each tooth, and so on. Thus, in the former case a 35's pinion would give exactly 35 picks. A further advantage of this type of motion is the elimination of calculations, with the consequent risk of error and wrongly picked cloth; also the picks are directly proportionate to the number of teeth, i.e. a larger pinion gives more picks and a smaller pinion fewer picks, whereas in the five wheel motion the picks and teeth are in inverse proportion. The best known motion of this type is Pickles' which is being increasingly applied to cotton looms. It consists of a ratchet wheel of 24 teeth on the same stud as a standard wheel of 36, 27, 18 or 9 teeth which drives the change pinion. The latter is on the same stud as a swing pinion of 24 teeth driving a carrier of 89 teeth, with which is compounded a carrier pinion of 15 teeth and the latter drives the beam wheel of 90 teeth. The beam is 15·05 in. circumference. Each tooth in the change pinion is equal to one pick to the inch when the standard wheel has 36 teeth; 1⅓ picks when the standard has 27 teeth; two picks when the standard has 18 teeth and four picks when the standard has 9 teeth.

CHAPTER IX

THE PLAIN LOOM—SUPPLEMENTARY MOTIONS

The Weft Fork Motion. The function of the weft fork motion is to stop the loom in the event of the breakage or failure of the weft. Fig. 87 illustrates the arrangement, which comprises an upright grate *A*, a three pronged fork *B*, which is fulcrumed on pin *C*, a fork holder *D*. secured at the end of lever *E*, which is fulcrumed at *F*, hammer *G* and lever *H*, which are joined together at *J* and fulcrumed on a stud at *K* and a tappet *L* on the bottom shaft. The grate has three openings and is fixed slightly behind the front of the reed at the entrance to the shuttle box at the driving side of the loom, at which point a groove is cut across the shuttle race to receive the grate and permit the passage of the fork prongs as the sley moves to and fro. The prongs are bent downwards nearly at right angles to the body of the fork and close to the bottom of the groove. The fork is slightly heavier on the straight or hooked end, so that, when no obstruction is offered to the passage of the prongs through the grate the hook continues to rest on the hammer head, with the result that, when the latter is moved forward by the action of the tappets and the lever, the fork holder and holder lever are also drawn forward. The last named lever is placed immediately behind and in contact with the starting handle *M*, so that, when this action takes place, the handle is thrust out of its notch and the driving belt moved to the loose pulley. But the weft when unbroken crosses the path of the prongs and prevents them from passing through the grate as the latter advances, whereupon the hook end of the fork is lifted clear of the hammer head at the time when the latter moves forward so that the position of the fork holder remains undisturbed and the loom continues to run. It will be evident from this description that the various parts must be carefully timed and set ; otherwise, the motion may either fail in its object and allow the loom to continue in motion when the weft is absent or cause it to stop when the weft is present.

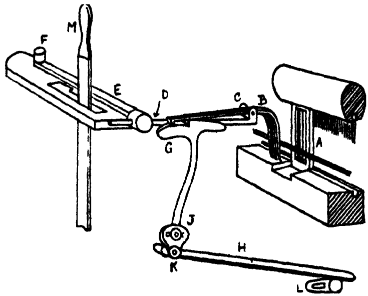


FIG. 87
WEFT FORK MOTION

Owing to the position of the parts and the fact that the hammer is actuated from the tappet shaft, the motion operates only for alternate picks, and for this reason two or three picks of weft may be omitted before the loom is brought to a standstill. To avoid the formation of a crack or thin place in the cloth by the omission of these picks, the dead catch of the taking-up motion is lifted clear of the ratchet wheel by means of a vertical lever which is compounded with the catch and fulcrumed at the joint, and rests in contact at its upper end with the front of the fork holder lever.

A weft fork motion of the above described type may be used on drop-box looms which are fitted with changing boxes at one side only ; but, when the changing boxes are applied at both sides and arranged to pick at will from either, such a motion is practically useless. For, if two or more shuttles were driven from the same side in succession, the fork might be actuated by the weft of the first shuttle; in which case the loom would continue to run even though the remaining shuttles were empty. The arrangement also fails in wide looms when very soft weft is used, owing to its liability to "break and catch." In these cases, a centre weft fork is used, which is placed in a groove at the middle of the sley and is arranged to feel for every pick of weft and to stop the loom immediately a failure occurs. Besides the very careful setting required in this case, the fork is likely to loop the weft on the under side, especially if it is very thin; hence many looms of the type indicated are run without weft fork and depend upon the watchfulness of the weaver for stopping the loom.

Warp Stop Motions. Warp stop motions are intended to stop a loom whenever a warp thread breaks. Although a distinct improvement is thereby effected in the quality of the cloth produced, such motions are seldom applied to ordinary looms because of their complexity and the increased strain and friction which they impose upon the warp; they are also generally unsatisfactory for fine yarns and heavy sized goods. But the motions are indispensable when automatic weft supply mechanism is applied to looms, as the number of the latter under the control of each weaver is too great to permit of each one's receiving that amount of attention which will enable it to be stopped immediately a thread breakage occurs.

Some warp stop motions are arranged to act in conjunction with the healds, but the majority are arranged to operate independently and usually consist of a series of thin steel droppers, which are supported by the warp threads so as to be clear of some negatively driven moving part so long as they remain unbroken. But, when a warp thread breaks, its dropper falls into the path of the moving part and stops it ; whereupon other parts bring the loom to rest. Some droppers are shaped like hairpins and are merely dropped upon the warp threads ; but these can easily be tampered with and are therefore used only to a limited extent. In most cases the warp threads must be drawn through the droppers, an arrangement which overcomes this disadvantage.

Warp Protectors. Warp protectors are designed to stop the loom automatically, if from any cause the shuttle fails to reach the box at the proper time.

In looms for heavy goods the reed is fixed in the sley and cap, and, if the shuttle should fail to clear the shed, it would be forced through the warp at the next forward stroke of the reed, unless means were provided to arrest the further movement of the sley. In looms for light goods, the reed is supported in such a manner that its lower rib can swing backwards to prevent damage, if the shuttle obstructs its forward movement. This arrangement is known as the loose or fly reed and enables the loom to be run at the highest possible speed.

In all looms which employ negative picking the shuttle box is fitted with a swell as already described. The bulge of the swell projects into the box and the shuttle must force it back before it can enter. In fast reed looms the swell serves the double purpose of bringing the shuttle to rest and actuating the warp protector or stop rod.

Fig. 88 illustrates the stop rod arrangement. This consists of a rod *A* extending across the loom and supported in bearings either on the under side of the sley or upon the sley swords. It carries two vertical fingers

B, which press upon the back of the swells *C*, and two flat blades *D* which are welded to its ends. In front of and directly in the path of each blade is a buffer or frog *E* provided with a shoulder which is struck by a blade whenever the shuttle is absent from the box. The frogs are carried by the loom framing, and their forward ends press against rubber cushions or against strong flat springs which absorb the force of

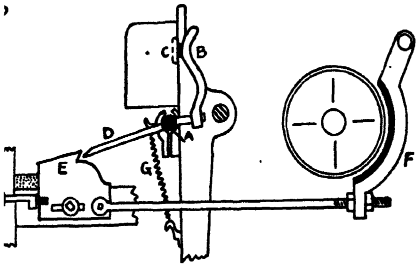


FIG. 88

WARP PROTECTOR

the impact, whilst in some looms the frog is connected to a brake *F* which is drawn against the fly wheel whenever the frog is pushed forward by the blade.

Blades and frogs are shaped to dove-tail with each other to prevent slipping, and the blades are kept in a striking position either by a flat spring which presses against the vertical finger or by a spiral spring *G* hooked into a blade and the framing. An arm is projected from one of the frogs to push the starting handle out of its notch and stop the loom whenever the blades and frogs engage. So long as the shuttle reaches the boxes the loom will continue to run, for, as the shuttle enters the box, it pushes back the swell and finger and causes the rod to lift the blades clear of the frogs ; but, if a shuttle does not enter the box, the blades and frogs engage and the loom is stopped.

The Loose Reed. The momentum of the parts of a high speed loom is such that considerable breakages would result if the stop rod principle were applied. The loose reed arrangement, therefore, is invariably applied to such looms, and the effect of the shuttle's being trapped in the shed is merely to cause the reed to yield

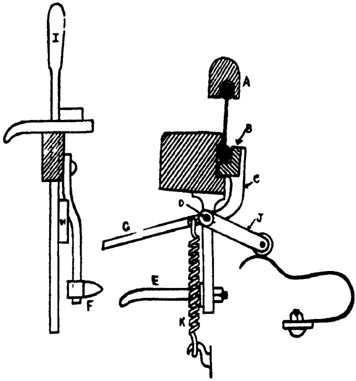


FIG. 89

LOOSE REED

to an extent that prevents the warp from being damaged although the loom may continue to run.

The upper rib of the reed is slipped from one end into a groove in the sley cap *A*, Fig. 89, and its lower rib is pressed inwards by an angle bar *B*, carried by a number of arms *C*, supported on rod *D*, which occupies the same position as the stop rod of a fast reed loom. An additional arm on the rod is provided with an adjusting screw to press against the sley sword and regulate the pressure upon the reed. The rod also carries two curved arms *E* that engage with the upper or lower faces of wedge-shaped heaters or frogs *F*, which are rigidly held by brackets bolted to the fram ing. *D* also carries an arm *G* immediately opposite a buffer *H* on the starting handle *I*. Outside the loom framing rod *D* carries an arm *J* which is provided with an anti-friction roller to run on a bow spring and hold the reed steady whilst the shuttle is crossing ; a spiral spring *K* serves when *J* and the bow spring are apart.

So long as the shuttle is running properly, the curved arms pass to the under side of the frogs and hold the reed firmly for the beat-up. But, if the shuttle is trapped, the reed and bar are thrust backwards and the rod *D* rotated, and thereupon the curved arms engage with the upper sides of the frogs and assist the pressure of the shuttle to overcome the pull of the springs at the moment when the arm *G* engages with the buffer to push the starting handle out of its notch. In this manner the loom is brought to a standstill without the violent concussion which takes place when the stop rod is used.

Several arrangements have recently been introduced to combine the advantages of fast and loose reeds and enable heavy cloth to be woven at higher speeds than formerly, in addition to avoiding the shock and damage which follow the action of the stop rod in the ordinary fast reed loom. In Livesey's "fast loose" reed, or reed release motion the reed can swivel about its upper rib in a groove in the sley cap in the usual manner, and is normally held in the fast position by a clamping bar, which is controlled by springs and locked by a key bar that is connected by a finger to the shuttle box swells. When the shuttle fails to enter the box the key bar is engaged by a dagger and moved sideways. This action releases the clamping bar and allows the springs to thrust it outwards and set the lower rib of the reed free. The latter, being retained in position by parts on the front of the sley, is held more rigidly than is the case in either fast or loose reed looms; hence the full weight of the sley can be thrown into the beat-up and heavy cloth woven with every pick of the weft perfectly straight. Stop rods, curved arms, and heaters are dispensed with, and the reed, being actuated by springs instead of by the shuttle when the latter is trapped, is saved from damage.

The Brake. Brakes are usually applied to high speed looms to destroy the momentum of the moving parts whenever the driving belt is moved to the loose pulley. The usual form, Fig. 90, applied to loose reed looms, consists of a lever having a short curved arm covered with leather to act upon the rim of the fly or balance wheel, and a long straight arm which extends to the front of the loom where it is notched to carry a weight and supported by a rod to hold the leather-covered arm clear of the fly wheel when the loom is running. The upper end of the rod is attached to a short lever which is fulcrumed at the opposite end and has its curved underside resting upon a bracket on the starting handle. When the loom is running the bracket lifts the short lever, and the rod thereupon takes the leather-covered arm clear of the wheel. But, if the starting handle is pushed out of its notch by the action of the weft fork or by other means, the rod is allowed to fall and the weight then causes the leather-covered arm to come into contact with the fly wheel and arrest its motion. In fast reed looms the brake is placed behind the fly wheel and connected with one of the frogs *E*, Fig. 88, so that it may be brought into action whenever the frog is moved by the action of the stop rod.

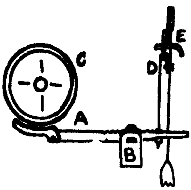


FIG. 90.—BRAKE

Unless the brake is carefully set and maintained in good condition, it may put considerable strain upon the moving parts and interfere with the work. It may also cause faulty places to develop in the cloth.

Temples. With a few exceptions, such as coarse linen, jute and sized cotton weft and fabrics of the poplin type, all cloths tend to shrink in width during the process of weaving, owing to the contraction of the weft and its interlacement with the warp. The amount of such shrinkage varies with the nature of the material, the weave, and the relative number, thickness and tension of the warp and weft threads. Temples are therefore used to counteract such tendency and to keep the cloth distended to the width of the warp in the reed, in order that the outside warp threads may be relieved of undue friction and breakage and the reed wires saved from being bent or broken.

Hand loom temples consist of a pair of flat wooden bars or stretchers hinged at the centre and fitted with spikes at the end to grip the cloth. They require to be moved at frequent intervals as the cloth is produced, and are therefore unsuitable for power loom weaving, although they are occasionally used for highly picked fustian fabrics.

Out of the large variety of self-acting temples applied to power looms to suit the variety of cloth produced, four distinct types are in general use, namely, bar temples; side roller temples; ring, segment, or swiss temples; and star temples.

Bar temples are used for light and medium plain fabrics. They consist of a semi-circular trough, *C*, Fig. 91, extending across the cloth and hollowed at the ends to form bearings for a revolving bar or roller, which is secured by caps bolted to the trough. With the exception of the ends and a few inches at the middle the roller is fluted along its length and spirally grooved to form teeth, which incline in opposite directions from the centre. The frontage of the trough is fixed as close to the cloth fell as possible without touching the reed by two upright springs, which are bolted to the front rail of the loom and capable of yielding in the event of the shuttle's being trapped. The cloth is taken round the under-side of the roller, and the grip of the latter is increased by raising the front edge of the trough so

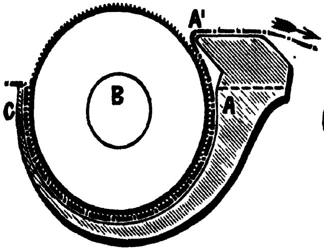


FIG. 91

BAR TEMPLE

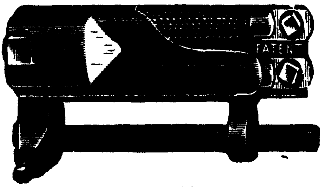


FIG. 92

TWO-ROLLER TEMPLE

that the cloth is prevented from shrinking at the latter point. This temple improves the cover of the cloth, enables the maximum width to be woven, avoids temple marks at the sides, and helps the shuttle to throw a loose reed back in the event of a trap. On the other hand, it cannot grip strong cloth with sufficient power to prevent contraction, and the first inch or two of the newly woven cloth is hidden from the sight of the weaver.

Side roller temples consist of short toothed or spiked rollers, which are capable of free rotation in boxes placed at the sides of the cloth, and the latter is bent over the teeth by a cap. Single roller temples are used for light and medium fabrics, and when there is not much space between the reed and the breast beam.

They usually consist of steel teeth inserted in a conical boxwood tube, which revolves on a stud, the teeth being set closer at the outer or selvedge end than at the inner end. Two-roller temples (see Figs. 92 and 93) are used for stronger fabrics, especially in the coloured trade. Each box contains two rollers, which may be either conical or cylindrical, and either parallel or converging. The box is provided with holes on the underside to allow size and dust to fall through, and the cap

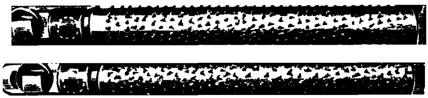


FIG 93

TWO-ROLLER TEMPLE

is ribbed at the middle to ensure the cloth's engaging with the rollers. Three-roller temples are used for the strongest fabrics, the third roller being fitted in the cap, or occasionally there are two rollers in the cap and one in the box. This gives greater holding power and reduces the friction between the cap and the cloth, which is liable to glaze or polish the latter to an objectionable degree in dark colours.

Ring or segment temples, Fig. 94. This type usually consists of a series of ten or twelve brass rings, each with a single row of steel teeth and capable of freely turning upon eccentric bossed washers that are skew-drilled and flanged to separate the rings. The washers are threaded, with the full part of the eccentric uppermost, on a stud which is bolted to a holder, and the latter is usually pressed forward by a strong spring. The effect of the skew-drilling of the washers is to incline the rings and cause the cloth to be drawn outwards at the same time that the eccentrics draw the teeth away as the rings are pulled round by it. The cloth is deflected by a cap as in the roller temple. The chief objection to this type is the liability of the teeth to pick up loose threads of warp and weft, which prevent the

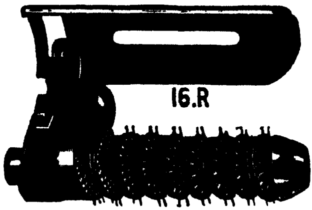


FIG. 94
RING OR SEGMENT TEMPLE

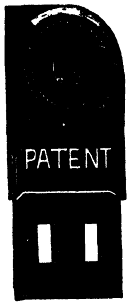


FIG. 95
STAR TEMPLE

rings from rotating as the cloth is drawn forward and result in the latter's being torn. The same result is also liable to occur if the rings become choked by size and dust.

The star temple, Fig. 95, consists of a large toothed ring supported horizontally and capable of rotation upon a central pin. The ring is surrounded by a shield plate, which is grooved to cause the cloth to embrace a portion of the ring's circumference and to hold it firmly on the teeth. It is placed under the cloth with the outer circumference in a line with the dents of the reed which contain the outside threads, and as near to the cloth fell as possible. It is fairly good for medium fabrics, but is liable to tear the cloth when the weft is either weak or very elastic. It is also used for fustian fabrics, because the pull is exerted wholly at the selvedges and the teeth do not engage with the floating weft threads.

The fixings for side temples must provide means for lateral adjustment, and this is usually accomplished by set-screwing them to bars which stretch from side to side beneath the cloth. Such bars may be round, flat, or angle-shaped. Round bars allow the temples to be placed low and near the reed, because they are secured to the bar from the front; the temples, however, have a tendency to work round the bar. Flat and angle bars avoid the latter difficulty and hold the temples more firmly, but angle bars must have the set screws on the under-side; hence the temples cannot be placed so close to the reed owing to the risk of the screw's touching the sley. Arrangements are also provided either in the temple holders or in the bar fixings to hold the temples forward and to permit them to move back if they should strike the shuttle. Spiral springs, short flat springs, and long flat vertical springs are chiefly used for this purpose.

CHAPTER X

AUTOMATIC WEFT SUPPLY

THE application of the positive take-up, weft fork and warp protector motions so reduced the necessity for close attention that eventually one weaver was enabled to supervise a number of looms. With ordinary plain fabrics the cotton weaver attends to as many as four or six looms, and his duties mainly consist of replenishing the shuttle with weft and piecing broken warp threads, each of which involves a stoppage of the loom. When a moderately good quality of yarn is used warp breakages are comparatively few in number; hence it may be said that the output of the loom depends chiefly upon the frequency of the stoppages consequent upon the exhaustion of the weft, a frequency which of course depends upon the carrying capacity of the shuttle. But this capacity is limited by considerations of size and weight, and, when these limits have been reached, the number of stoppages due to weft exhaustion still remains considerable.

It is therefore natural to find that from an early period in the history of the power loom attempts have been made to obviate such stoppages and thereby increase either the productivity of the loom or the number of looms to a weaver. These attempts have been made along three distinct lines, namely (1) the provision of a continuous supply of weft; (2) the automatic removal of an exhausted shuttle and the substitution of a loaded one; and (3) the automatic ejection of a spent spool or cop holder from the shuttle and the substitution of a full one.

The Seaton loom was constructed to accomplish the first named object by providing a supply of weft upon large bottle-shaped bobbins, which were placed at the sides of the loom and capable of lasting several hours. The thread was drawn through the shed first from one side and then from the other by a carrier provided with jaws or nippers at the end, the threads being cut off at the selvedges and left to form raw edges. Later a double length of weft was cut off and inserted from each end alternately in such a manner that a fairly satisfactory selvedge was formed. Parts were also added to enable a number of different wefts to be fed to the carrier for the production of check fabrics.

Since the first automatic shuttle changer was patented in the year 1840, many attempts have been made to supply a satisfactory arrangement of this type. Shuttles have been changed in a variety of ways in an ordinary shuttle box; inserted in one box and removed from the other; and drop and circular boxes have been used for the purpose. Also the changes have been made with and without alteration in the speed of the loom and the loom has been stopped for the change and afterwards automatically re-started. Although a number of looms of this type are actually in use, shuttle changing is not regarded as a satisfactory solution of the problem, chiefly owing to the shock and vibration which usually accompanies a change; the difficulty of re-starting the loom after a change has been made; the risk of damaging the shuttle during the change, and of securing the necessary number of shuttles exactly alike in weight and fitting.

Cop or shuttle changing arrangements date from the year 1857, and, although less numerous than shuttle changers, they have proved more satisfactory, for it is obviously easier to change the contents of a shuttle than it is to change the shuttle itself. The Northrop cop-changing mechanism, invented in the United States, has been found so successful that it has been applied to upwards of 500,000 looms weaving all classes and widths of goods.

On considering the problem the inventor had to solve, it will be evident that he had to provide not only mechanism which would change the cop at the proper time and only act when the shuttle was in the proper position, but also a self-threading shuttle and parts for severing any portion of the weft thread left suspended outside the cloth. Furthermore, in order that full advantage might be taken of the relief thereby obtained it became necessary to provide efficient motions for stopping the loom in the event of a warp thread's breaking, and for automatically controlling the let-off and tensioning of the warp. All these, besides other minor improvements, have been successfully accomplished, and the Northrop loom of to-day may be regarded as automatic in every sense of the word. The Northrop weaver attends to six (instead of two) broad looms and up to twenty (instead of four or six) narrow ones, and, in mills where they have been installed, it has been found necessary to make considerable re-organizations in the staffing and equipment.

Compared with other countries the Northrop system has made only moderate progress in the British textile industry, chiefly owing to the high cost of the equipment and the fact that an ample supply of efficient labour for the ordinary loom, which can be run at a higher speed, has hitherto been available.

The controlling agent of the Northrop mechanism is the weft fork, which is made to operate parts that eject a spent bobbin or cop-holder from the shuttle and insert a full one between successive beats of the

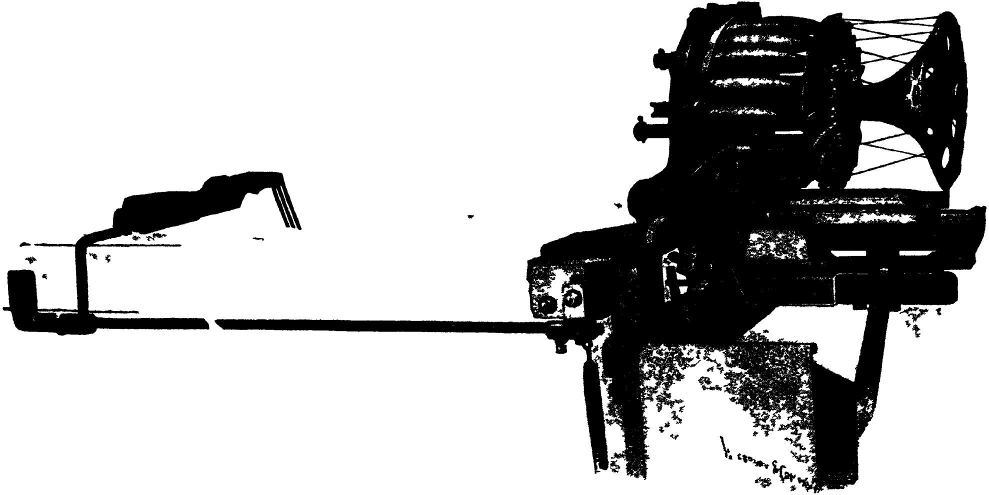


Fig 96

NORTHROP BATTERY WITH CHANGING MECHANISM AND WEFT FORK sley without involving any change in the speed of the loom. The shuttle is of the usual shape, with an open bottom, and provided at the rear end with a metal slide and spring jaws, which are grooved to receive corresponding ribs on the head of the bobbin or cop

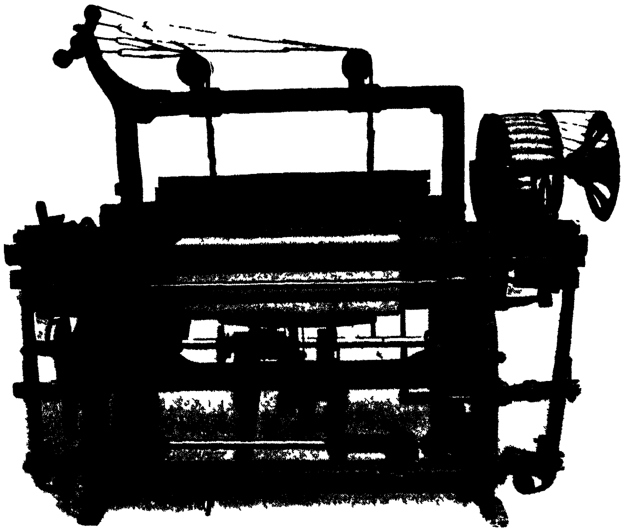
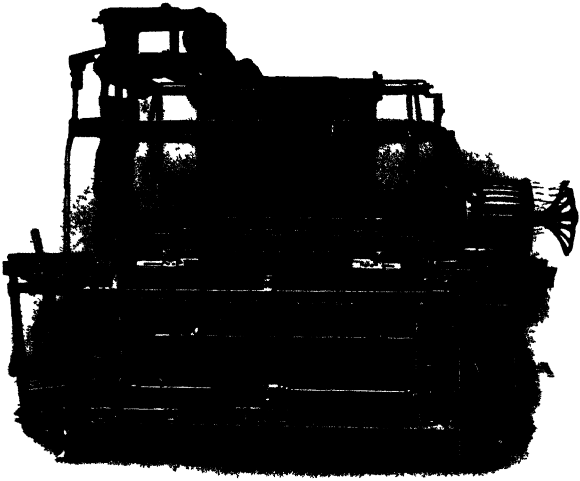
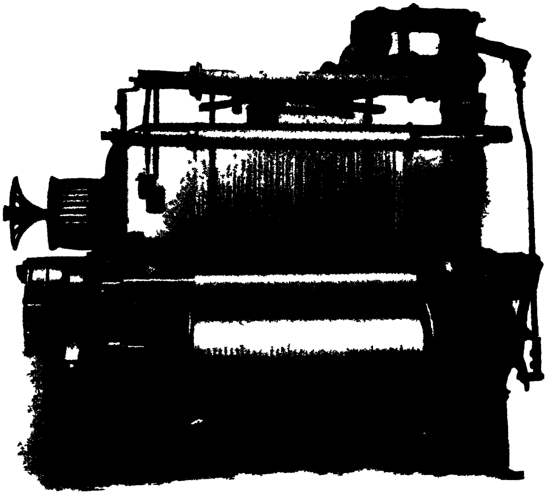


FIG. 97

NORTHROP LOOM WITH LACEY TOP MOTION

skewer. As seen in Fig. 96, full bobbins or skewers to the number of 25 are carried in the circular hopper, which can be filled at convenient intervals, and the threads made fast to the hopper stud. It rotates to bring each in turn directly over the shuttle box when the sley is at the back centre. When the weft fails, either from exhaustion or breakage, and the shuttle





FIGS 98 AND 99

NORTHROP LOOM WITH DOBBY—FRONT AND BACK VIEWS reaches the box, the weft fork at the opposite side causes a transferrer to press the lowest bobbin or cop upon the top of the spent bobbin or skewer and force the latter through the bottom of the shuttle, from whence it drops through the box into a receptacle. The transferrer, however, can act only when the shuttle is in the proper position for receiving the full bobbin. If it should rebound or fail to reach home, it is sent across again by the picker, and the repeated action of the weft fork then causes the loom to be stopped. But, when the change has been properly effected and the shuttle is driven across, the weft thread falls into a slit leading to the shuttle eye, which it enters on the return stroke; whereupon weaving continues in the ordinary manner. Should the thread fail to enter the eye, the weft fork again operates to stop the loom. The length of weft suspended between the battery stud and the cloth selvedge is severed by cutters attached to the temple. It will be noticed that the mechanism operates only after the weft has been absent in front of the fork, for which reason "missed picks" are unavoidable. When these are objectionable, however, a "feeler motion" can be applied, which will cause the change to be made just before the weft has become completely exhausted.

Originally made for light cotton fabrics, the Northrop loom has been developed to weave almost any cloth that can be made from one weft, including cotton sheetings and shirtings, woollen and worsted cloths, silk and artificial silk, linen and jute, canvas and duck cloth, and dobby and jacquard cloths. The principle has also recently been applied to multiple shuttle looms for check and other fabrics requiring a variety of wefts.

Fig. 96 shows the battery and changing mechanism together with the connections to the weft fork; Fig. 97, the Northrop loom with the Lacey top motion for weaving plain, twill and satin cloths up to six shafts. The heald shafts are controlled by inside tappets and are connected at the top to straps which pass round pulleys carried by compounded levers. By a simple adjustment the motion can be changed to work two, three, four, five, or six shafts. Figs. 98 and 99 show front and back views respectively of a dobby loom weaving cloth from three warp beams.

CHAPTER XI

FANCY WEAVING

THE fabrics produced by the mechanism already described are usually classed as "plain," and consist of simple weaves such as the ordinary run of plains, twills and satins, either self-coloured or striped in the warp and requiring only one shuttle. The more ornamental fabrics are classed as "fancies," and according to the style may require mechanism for controlling a greater number of thread workings, a number of shuttles, or for the production of special effects.

Dobby Machines. Dobby machines are invariably used to control shaft harnesses when the pattern requires more shafts than can be governed by tappets. In the cotton trade, dobby machines are used up to 20 shafts of healds, but in other branches they are sometimes used up to 40 shafts. They vary considerably in construction and action according to the style of loom and cloth to be woven.

The simplest type of dobby is that known as the "single lift" dobby, which is used for slow looms and heavy fabrics. Fig. 100 shows one arrangement of a card dobby which is identical in principle with the jacquard machine. Each shaft of healds is suspended from a stout wire hook, *A*, Fig. 109, which has a long upward turn at the bottom terminating in a slight bend to rest upon a supporting grid *B*, and a slight downward turn at the top. The hooks are arranged in one or more rows, so that their upper bends are normally above a flat bar or "griffe," *C*, which is caused to rise before and fall after every flight of the shuttle.

Round each hook is bent a wire *D*, called a " needle," which is passed through a needle board *E* at the front, and provided with a spiral spring *F* at the opposite end to keep it pressed forward through the board and also keep the hook normally over the griffe. In front of the needle board is a four-sided cylinder bored with

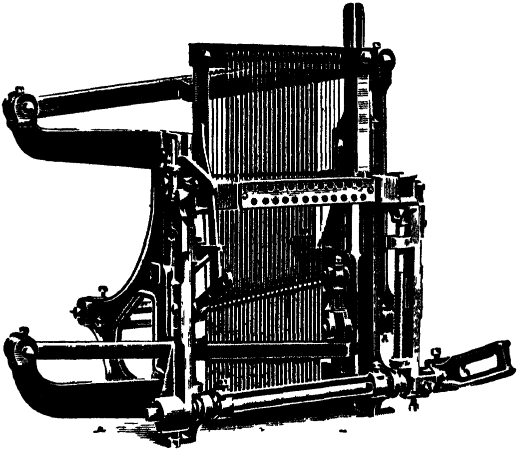


FIG. 100

SINGLE LIFT DOBBY

holes to correspond with the number and pitch of the needles and hooks, and capable of sliding or swinging alternately against and away from the needle board. Over the cylinder is passed a chain of stout paper cards perforated according to the pattern to be woven. When the cylinder is pressed against the board, needles pass through holes in the card into the cylinder and leave their hooks undisturbed, but where there are blanks in the card the corresponding needles and hooks are pressed backwards, so that when the griffe rises immediately afterwards the former hooks with their shafts are lifted and the remainder left down. As the griffe rises, the cylinder moves outwards and is turned a quarter of a revolution by a catch to bring a fresh card opposite to the needles for the next pick. The machine is operated from a crank on the driving shaft of the loom and a connecting rod and levers which, in Fig. 100, cause the grid upon which the hooks rest to fall as the griffe rises and thereby lower the hooks and shafts left down. This gives what is called a " split shed " which is preferable for certain classes of fabrics. The machine is called a " single lift " because there is only one series of lifting agents, i.e. hooks and griffe, which must be returned to their original positions after every pick in order that a fresh selection may be made. The necessity for this greatly limits the speed at which the dobby, and therefore the loom, can be worked.

To overcome the speed limitation of the single lift dobby the griffe and hooks are duplicated, so that each shaft can be lifted by either of two hooks and two griffes. In this manner the selection of hooks to be lifted for the following shed can be made whilst the shuttle is passing through the previously selected shed, and immediately the latter begins to close the new one begins to open. In this manner time and power are economized because the weight of the falling parts acts as a counterpoise to the rising parts. Yarn strain is also reduced because a longer time is available for opening a shed, and warp threads which have to lift for successive sheds need not return to their lower positions until required by the pattern. There is also less vibration and less risk of breakages and faulty cloth because the speed of the moving parts is reduced by one half.

The most popular of the double lift dobby machines is the " Keighley " dobby invented by Messrs. G. Hattersley and Sons, of that town, and illustrated by Fig. 101 In this machine a heald shaft is suspended from a jack, or elbow lever, with a curved upward bend, fulcrumed at the elbow upon a shaft, and connected at the end of the upward arm to the middle of a vertical bar or

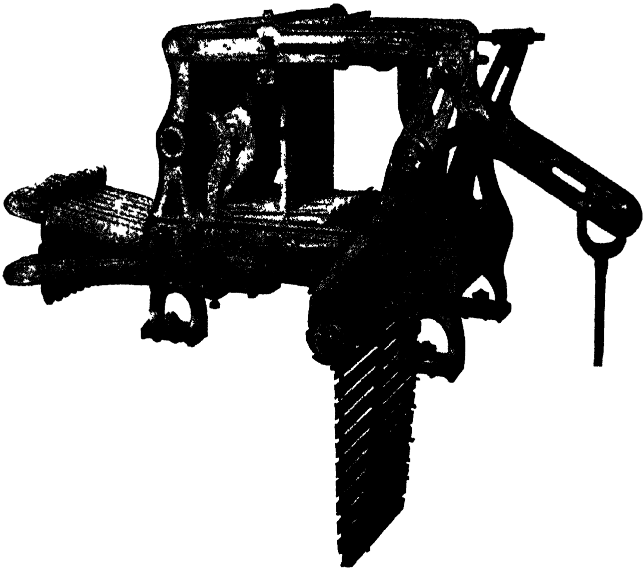


FIG. 101

KEIGHLEY DOUBLE LIFT DOBBY

baulk lever. The ends of the latter bar are connected to horizontal hooks, of which the top one rests upon a spindle supported by the end of a heavy-ended lever, while the bottom hook rests upon the upward turn of an otherwise similar lever. The heavy ends of these levers rest upon an eight-sided barrel, and keep the hooks normally above flat draw bars which are secured to the top and bottom of a rocking bar that is oscillated about its centre by means of a connecting rod and crank

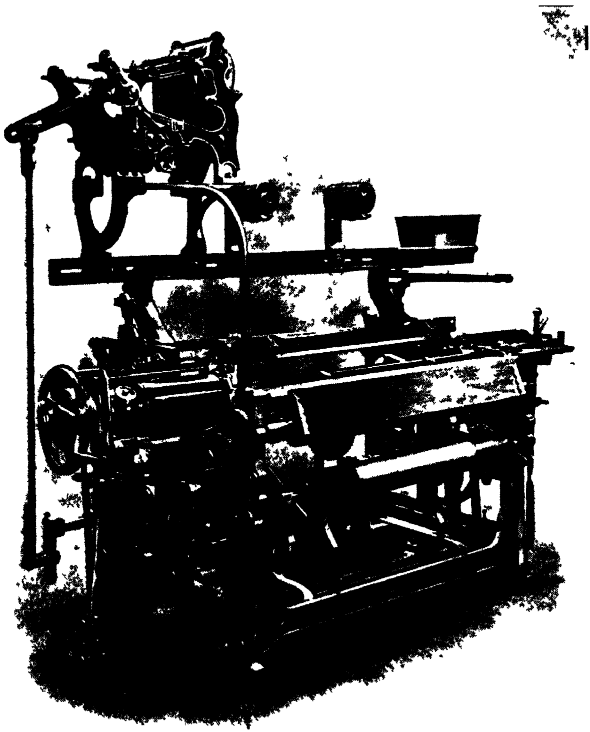


Fig. 102

CIRCULAR BOX LOOM WITH IMPROVED KEIGHLEY DOBBY

on the bottom shaft of the loom. A chain of wooden lags, bored with holes to the pitch of the heavy-ended levers, is passed over the barrel and, where a peg is inserted, the heavy end of the corresponding lever is raised and the opposite end lowered so that a hook may drop into the path of the draw bar. Thereupon the end of the baulk lever is drawn forward and the heald shaft lifted. But, when one draw bar is at its extreme outward position, the other is at its inward position receiving the opposite set of hooks to be drawn and ready to move forward as the other returns. If a heald shaft having been lifted by the action of, say, the top hook and top draw bar for one pick requires to be lifted for the following pick, the lower end of the baulk lever will begin to move forward as the upper end begins to return, and thus, with the exception of a very slight downward movement due to the necessity for moving the bars slightly farther to allow the hooks being lifted clear, the middle of the bar and therefore the position of the jacks and healds remains unchanged. In this manner the principle of open shedding is obtained. Fig. 102 shows the latest type of Keighley dobby, in which the draw bars are moved in inclined slots to overcome the tendency of the hooks to be thrust off the bars as they near the extremity of their stroke.

In the heavy woollen trade the Dobcross dobby, Fig. 103, made by Messrs. Hutchinson, Hollingworth & Co., is largely used. This is made with a capacity up to 40 jacks and heald shafts and, besides controlling the shedding, also controls the taking-up, picking and shuttle boxes, which is a very decided advantage in fancy weaving, since all are kept in their correct relationship in any re-adjustment which may be required. The novel feature of this machine is the use of toothed discs and cylinders for moving the heald shafts. The top shafts of the healds are connected by cords to the vertical arms and the bottom shafts to the horizontal arms of L-shaped levers fulcrumed at the elbows. The vertical arms are joined by connectors with thin toothed discs which are supported so that they can turn freely upon vibrator levers. These vibrators are fulcrumed at one end and rest upon a cylinder over which a chain of spindles carrying metal collars and bowls is passed. A bowl has the effect of raising a vibrator lever and

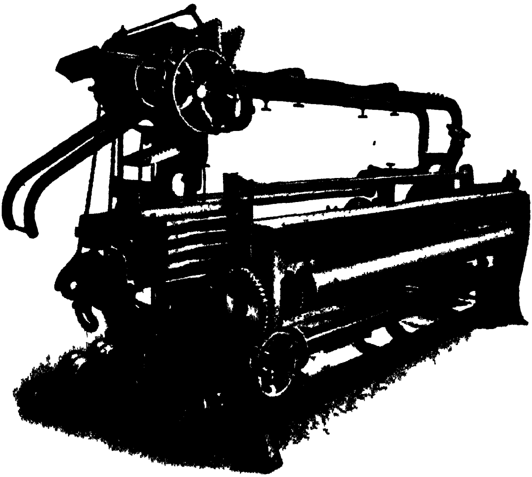


FIG 103

DOBCROSS LOOM

disc so that the latter may gear with a cylinder which is toothed half way round its circumference, while a collar allows the disc to drop into the path of a similar cylinder underneath. In this manner the vertical arm is either pulled forward to raise its healds or thrust backwards to raise the horizontal arm and pull the healds down. Provision is also made for keeping the position of a heald shaft unchanged until required by the pattern. Thus the shedding is " open " as well as " positive."

A number of fabrics such as towels, shawls and handkerchiefs have borders of different weaves at the ends. These are known as cross borders and dobbies for weaving them are provided with arrangements which facilitate the changes of pattern. Thus the single lift card dobby may have a cylinder and cards containing two or more rows of holes each capable of producing a different weave. When the pattern has to be changed the needles are moved opposite to the desired row by means of a handle which raises or lowers the needle board. In the Keighley dobby the same result is obtained by the provision of extra cylinders and chains of lags which can be automatically moved into and out of action at the proper time. This is shown on the terry towel loom, Fig. 104, which automatically changes the weave and the shuttles for the headings, and also makes the fringes at the ends of the towel.

Shuttle Box Motions. When the cloth to be woven requires a variety of wefts mechanism must be provided for controlling the requisite number of shuttles. In the early days of the hand loom these shuttles were placed on the cloth in front of the weaver, who selected them in the required order for throwing through the shed and afterwards returned them upon the cloth. This method continued in use until the year 1760, when Robert Kay, the son of the inventor of the fly shuttle, arranged a series of shelves which could be raised and lowered to bring any desired shuttle under the action of the picker by means of a lever fixed behind the sley.

On the introduction of the power loom many attempts were made to enable multiple weft cloths to be woven. Among other inventors, Dr. Cartwright placed shuttles in the compartments of a flat tray which was pulled and pushed to bring the proper shuttle under the action of the picker. Other inventors followed, but it was not until the year 1843 that Luke Smith provided a satisfactory arrangement in the form of a circular box, and two years later Squire Diggle was successful with a drop box motion.

In the circular box motion, shown on the loom in Fig. 102, the boxes are arranged in the form of a cylinder, usually for six, but sometimes up to twelve, shuttles and usually at one side of the loom only. The cylinder is supported at the end of the sley by a hoop and a shaft upon which is also fixed a disc from which project as many pins as there are boxes. The disc and boxes may be turned in either direction by two catches which rest above the pins. Each catch is at the end of an upright rod connected with a horizontal lever that is fulcrumed at the centre and provided with a similar hooked rod at the opposite end. This latter hook passes through a slot in a lever which is raised once every two picks by means of a cam and bowl. The slot is long enough to allow the lever to be lifted without moving the catch, in which case no change is made in the position of the boxes; but the catch may be thrust upon the full part of the lever by means of an arm governed from a cylinder and chain of perforated steel cards. When the catch is lifted the opposite end of the bottom lever is pulled down and the disc catch caused to turn the disc and cylinder. High speeds can be attained with this motion because there is very little rebound in the boxes and the rotary motion gives a steady movement. Also a greater number of shuttles can be controlled without decreasing the speed of the loom. The arrangement is, however, suitable only for light and medium weight fabrics, because it is necessary to use a loose reed. In the ordinary arrangement of the motion the movement is limited to one box, but additional parts can be added whereby any box can be brought into action

In Diggle's drop box motion the boxes are fixed at the top of a rod which is supported at the end of a lever from which a connecting rod passes to an upper lever fulcrumed at one end and provided at the middle with a bowl that rests upon a barrel over which a chain of links is passed and moved intermittently. The links are of different heights according to the movement to be given to the levers and boxes, a high link lifting the boxes and a low one allowing them to fall. This motion is still used for slow-running looms and heavy goods as it is simple in construction and certain in action. In other cases, however, the length and weight of the chain is cumbersome for long patterns ; it is not advisable to skip more than one box, and high speeds are impossible owing to the rebound which follows the falling of the boxes.

Probably the most successful of modern drop boxes are those constructed upon Whitesmith's principle in which the movement is positively controlled by eccentrics, an arrangement which places no limit upon the speed of the loom and enables the shuttles to be brought to the race board in any desired order. As shown in Fig. 104, the box rod is supported at the end of a lever which is connected at the opposite end with a strap that encloses two or more compound eccentrics, one inside the other. Each eccentric is capable of independent movement and of determining the position of the boxes according to the extent of its throw. For four boxes two eccentrics are used, the inner one having a throw equal to the lift of one box and the outer one a throw equal to the lift of two boxes. The eccentrics are

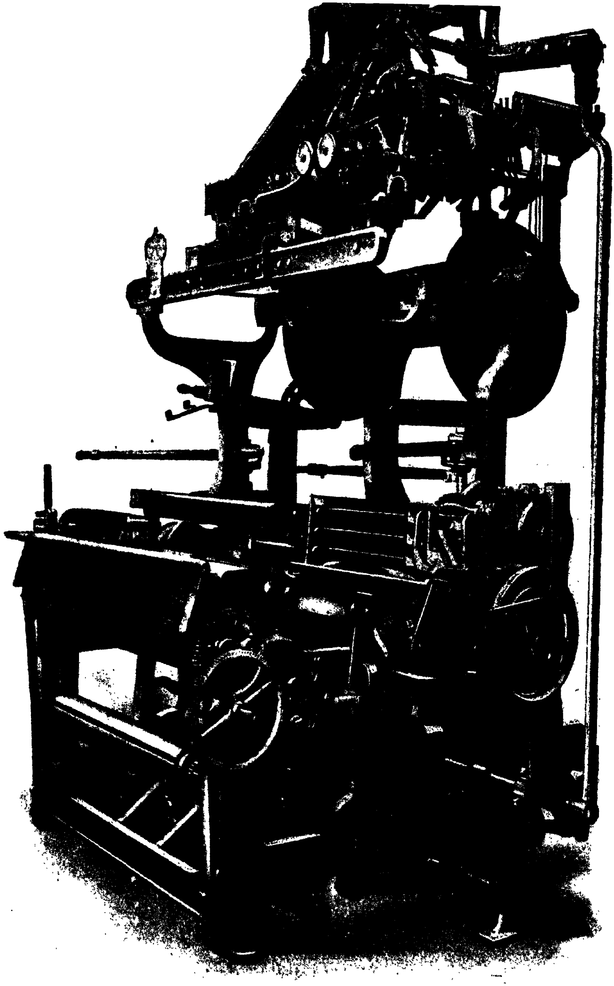


Fig. 104

TERRY TOWEL LOOM WITH CROSS BORDER DOBBY AND ECCENTRIC SHUTTLE MOTION actuated by clutches and controlled by needles and a chain of steel cards, or, as in Fig. 104, by connections from the dobby. In the older motions of this type similar cards did not always bring the same box into the operative position owing to the fact that the eccentrics were rotated in one direction only. This objection has been overcome by providing a separate needle for each box, which greatly facilitates the building of the chain and enables the weaver to bring any desired box into position.

Lappets, Swivels, Smallwares and Warp Pile. Out of the many mechanisms used for the production of special effects the above named may be briefly described.

Lappet and swivel mechanisms are used to produce effects which resemble those obtained by embroidery. In lappet weaving a series of " extra " warp threads from one or more small rollers, called whip rolls, are passed between the healds of the ordinary, or ground, warp threads, under the sley and through the eyes of needles fixed in the tops of thin flat bars or frames. These frames—up to four in number—are supported in a slot between the race board and the reed in such a manner that they can be raised to bring the eyes and whip threads to the top line of the shed. After the shuttle has passed the frames are dropped and moved sideways whilst the sley advances to beat up the weft, following which the needles are again pushed through the warp and the whip threads secured above the weft in the new position. The illustration, Fig. 105, shows the Scotch lappet motion in which the lateral movement of the frames, and therefore the outline of the pattern, is controlled by a groove cut in the face of a flat disc carried at the end of the sley. In the Lancashire lappet motion the pattern is determined by indentations cut in the edge of a hollow cylinder.

Chains of pegged lags are also used for the same purpose.

In swivel weaving a series of small shuttles are used to produce embroidery effects from extra weft. These shuttles are carried in a rack in front of the sley cap in such a manner that the whole can be lowered to the level of the race board and the shuttles passed through sheds formed in gaps in the rack. The latter is then

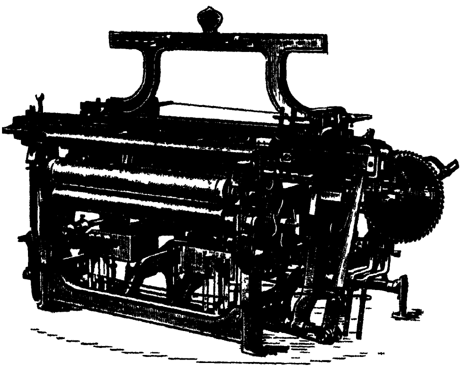


FIG 105

LOOM WITH SCOTCH LAPPET MOTION

raised whilst an ordinary or ground shuttle is passed through an ordinary shed. The closeness of the figures so produced is limited by the size of the shuttles and the gaps of the racks. The arrangement will be understood by reference to Fig. 106.

As already mentioned, in smallware and ribbon weaving a number of tapes or ribbons are woven simultaneously. The warps for the several fabrics are spaced in the loom and a separate shuttle is provided for each so that perfect selvedges may be formed. The shuttles are moved from side to side through sheds

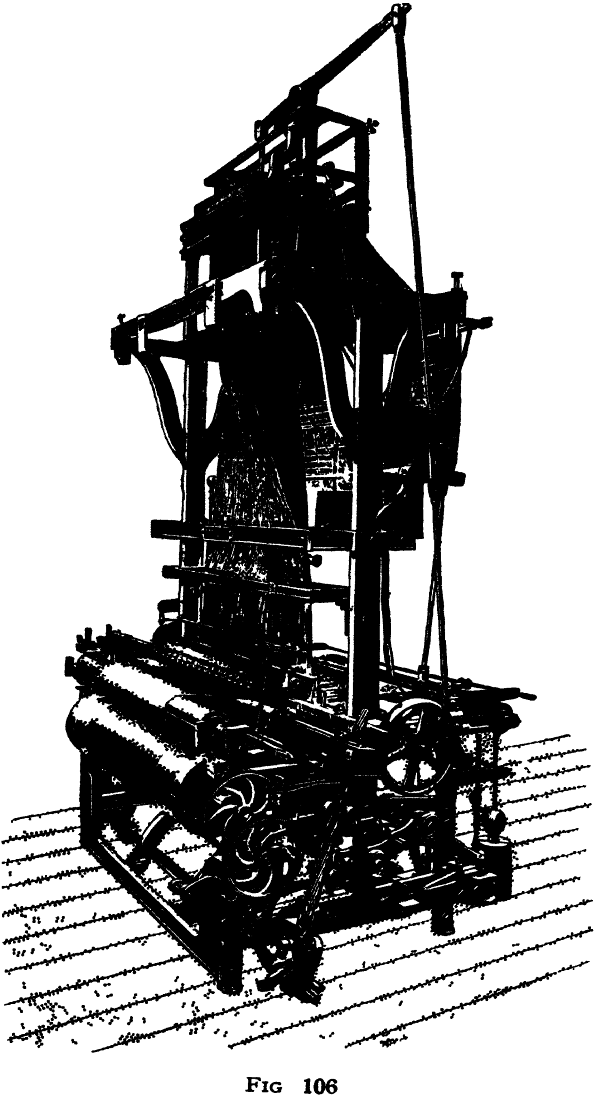


Fig 106
SWIVEL LOOM

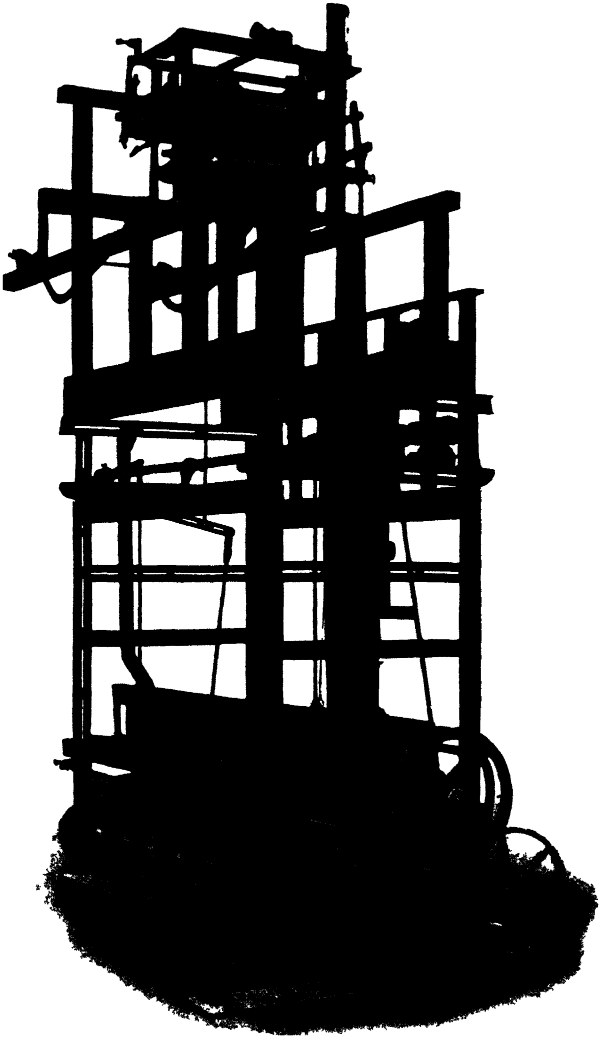


Fig. 107

JACQUARD RIBBON LOOM

formed in their respective warps, by the rack and pinion arrangement employed in the swivel loom described above, or driven through on the fly shuttle principle, by upright pegs fixed in a sliding bar. Fig. 107 shows a jacquard ribbon loom in which each ribbon may use

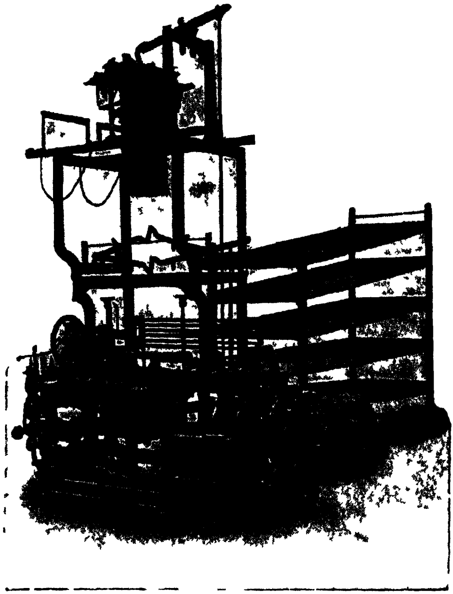


FIG 108

BRUSSELS CARPET LOOM

up to six shuttles, the latter being mounted in tiers and brought into operative position by the raising or lowering of the sley or batten.

In the ordinary warp pile fabrics such as velvets, plushes and certain kinds of carpets, notably Brussels and tapestry, it is necessary to insert, at intervals, wires in sheds formed with the pile thread in the top line and after a number have been so woven into the cloth, to withdraw them. Between each wire a number of picks of weft are inserted and the interlacing is of such a kind that the pressure of the reed forces the wires upon the surface of the cloth. In the power loom, the wires are automatically inserted and withdrawn and the pile thread may either be left in loops or cut by a knife at the end of the wire. The wire motion is shown on the Brussels and Wilton carpet loom (Fig. 108), in which the pile threads are drawn from bobbins in the creels or frames shown behind the loom, each frame usually containing a different colour.

CHAPTER XII

JACQUARD WEAVING

WHEN the number of thread workings in the design to be woven is beyond the capacity of a shaft harness a thread or twine harness is used. This consists of a series of long twines each provided with a " mail " or metal eye (see Fig. 109) to receive a warp thread and a " lingoe " or wire weight to keep it steady and also to return it to its original position after it has been lifted. The twines are passed through the holes of a " cumber " or " comber " board, which regulates their closeness and keeps them in their proper order.

The Chinese are credited with the invention of this arrangement and are said to have records of its use for more than two thousand years. In its original form, which is still used in China, an assistant, located upon a platform above the warp, forms the sheds by drawing up the cords which have been previously selected and bunched together. In this form the arrangement appears to have been introduced into Europe and the method of selecting and drawing the cords was gradually improved until it finally resulted in the jacquard machine, which is now invariably used for figure weaving.

About the year 1603 a Frenchman named Simblott connected the harness cords to a series of tail cords which were passed over pulleys in a box and continued horizontally to a hook in the wall of the room. At a convenient point outside the loom a series of vertical cords, called " the simple," were secured to the tail cords and also to a bar fastened to the floor. The assistant or " draw boy " was thus enabled to work at the side of the loom. Before commencing to weave the simple cords to be drawn for successive sheds were selected and bunched together by thin leashes which were looped round one or more thick cords parallel with the simple. By grasping the leashes in succession, the draw boy was thus enabled to separate and draw the required simple cords. The frontispiece shows the "draw loom" as introduced into this country in the seventeenth century.

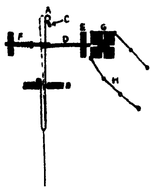


FIG. 109
SECTION THROUGH JACQUARD AND HARNESS

When the harness was extensive a number of draw boys were required, and it is therefore not surprising to find that many attempts were made, either to facilitate the work of the draw boy, or to dispense with his aid.

English inventors attained a fair amount of success in the first named direction, but the French proceeded on the latter lines, and finally developed the jacquard machine which immediately displaced all other methods of controlling harnesses for figure weaving.

The first step in the development of the jacquard was made in 1725 by Bouchon who tied a hooked wire to the end of each simple cord and passed it through the loop of a horizontal wire or needle which was projected slightly through a needle board. A band of paper, perforated with holes according to the pattern, was passed over a round, grooved or perforated cylinder and pressed against the needles. Thereupon needles which were opposite holes in the paper passed through the same and, together with their hooks, remained undisturbed. But blanks in the paper pressed back needles and brought their hooks beneath the pins of a sliding comb which was depressed by a foot treadle to draw down the hooks and simples. Three years later Falcon arranged the needles and hooks in rows in order that space might be economized and a larger number more conveniently controlled. He also used a corresponding number of bars fixed in a frame for drawing the hooks and a square cylinder over which was passed a chain of cards instead of a continuous band of paper. In 1746 the famous inventor Vaucanson swept away the tail cords and simple and dispensed with the services of the draw boy by placing the hooks upright above the loom and suspending the harness cords directly from them. He arranged the hooks in two rows, used the continuous band of paper and round cylinder of Bouchon, and made the cylinder move against and away from the needles and turn to bring a fresh row of holes in the paper into operative position. The bars or "griffe" for lifting the hooks were raised by a lever under the control of a treadle beneath the loom. Little use appears to have been made of the machine, apparently owing to the tendency of the hooks to turn round and become inoperative, and the difficulty of securing the correct action of the cylinder.

In 1790 Joseph Marie Jacquard, a silk weaver of Lyons, completed a machine for controlling a harness, which, however, bore no resemblance whatever to that which we now know by his name. About 1804 he was called to Paris to repair a model of Vaucanson's machine and appears to have set about improving its details. He altered the shape of the hooks and the method of lifting the griffe; he also substituted Falcon's chain of cards and square prism, which he perforated on each face, and improved its manner of working.

Eventually he produced a machine which "would work" and which has remained unaltered in its essential details to the present day, although most of its parts have been modified.

The original jacquard machine was "single lift" in its action and satisfied the requirements of the ordinary hand loom in use. But as the latter became displaced by the power loom, there arose a necessity for higher working speeds and for modifications to suit special looms and fabrics, with the result that there is to-day quite a number of distinct types of jacquards. Thus we have "single lift," "double lift," "split shed," "open shed," "cross border," "twilling," "leno," and "carpet" jacquards.

The size of jacquards is of course varied according to the repeat of the design to be woven, the following standards being in general use in this country—

100's	containing	26	rows of	4	or	104	hooks	in all.
200's	,,	26	,,	8	,,	208	,,	,,
400's	,,	51	,,	8	,,	408	,,	,,
500's	,,	51	,,	10	,,	510	,,	,,
600's	,,	51	,,	12	,,	612	,,	,,

Until recently designs of larger repeat were provided for by placing two or more jacquards together, but instead of this, "fine pitch" or "fine index" machines are now being used. In these machines the hooks and needles are made of finer wire and placed closer together, with the result that a greater number can be contained in a single framing; this simplifies the harness and reduces the weight and cost of cards. The closer pitch of these jacquards involves more accurate setting and working than is necessary in the older pitch. In the Verdol jacquard, which has the finest pitch of all, a special attachment is used to operate the needles and hooks instead of the ordinary type of cylinder and the pattern is determined by a band of perforated paper which is only one-fifth the weight of the cards for the same size of design.

A brief description of the various types may now be given. Fig. 109 shows the essential parts of the jacquard and harness and Fig. 110 the arrangement of hooks and needles in a 400's single lift machine, which is also shown complete at Fig. 111.

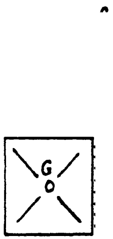


FIG. 110

SECTION THROUGH SINGLE LIFT JACQUARD

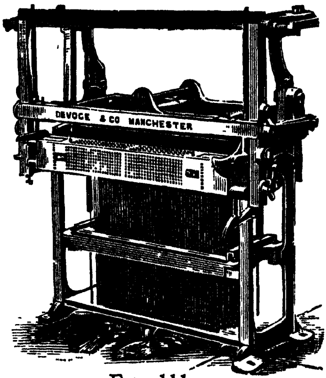


FIG. 111

SINGLE LIFT JACQUARD—SWING MOTION

The action is identical with that of the single lift dobby, Fig. 100, the harness cords and warp threads being lifted by the hooks and griffe and selected by the needles, cards and cylinder, and the whole operated from the crankshaft of the loom. The maximum speed at which this type can be run is about 120 lifts or " picks " per minute, hence it is only suitable for wide and other slow running looms.

Two distinct types of double lift jacquards are in use, namely, the double lift single cylinder and the double lift double cylinder machines The arrangement of hooks and needles in the first named is shown at Fig. 112, from which it will be seen that each harness cord is attached to a pair of adjacent hooks which can be lifted by separate griffes that work oppositely to each other, on the principle already described. Each pair of hooks, however, is under the control of the same needle and cylinder, which must therefore work at the full loom speed although the griffes move at only half that speed. In the double lift double cylinder arrangement shown at Fig. 113, both lifting and selecting parts are duplicated and the machine really consists of two complete jacquards one within the other. In this manner a speed of 180 picks per minute can be attained against 160 with the single cylinder machine. The double cylinder arrangement however involves the use of two chains of cards, one for odd numbered and the other for even numbered picks of weft. As these chains are

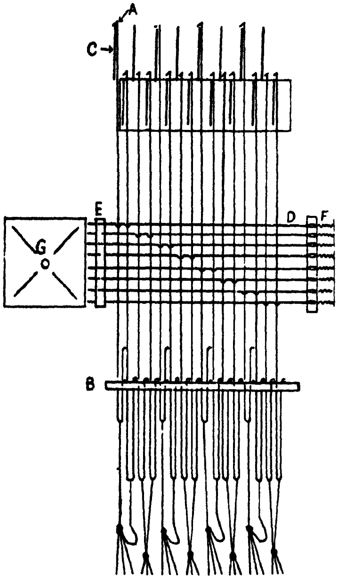


FIG. 112

SECTION THROUGH DOUBLE LIFT SINGLE CYLINDER JACQUARD liable to get out of their proper sequence and spoil the pattern, the single cylinder machine with its single chain is often preferred notwithstanding its lower working speed.

The principle of the split shed jacquard will be understood by reference to the single lift split shed dobby (Fig. 100).

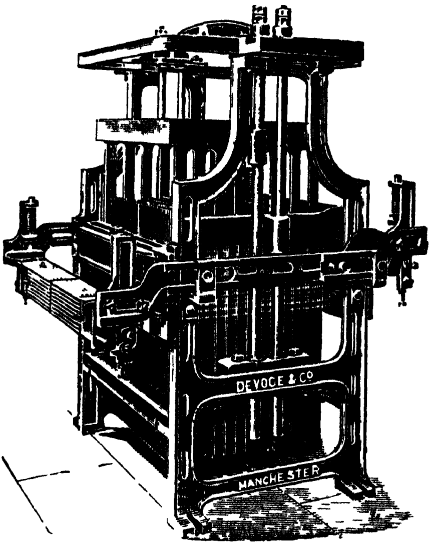


FIG 113

DOUBLE LIFT DOUBLE CYLINDLR JACQUARD WITH SLIDE CYLINDER MOTION

Many attempts have been made to apply the principle of open shedding to the jacquard but so far a satisfactory arrangement has not been obtained. In most cases a supplementary stationary griffe is provided to receive and retain the hooks, which are specially constructed, as long as their warp threads require to be above the weft. But whilst it is easy enough to place the hooks upon the stationary griffe it is difficult to push them off when they require to fall again.

In cross border jacquards the hooks of an ordinary single lift machine are also under the control of a supplementary cylinder and set of needles, or a double lift double cylinder machine is converted to work as a single lift, and in both cases one cylinder and set of cards is worked for the border design and the other for the centre, the change being made either by the weaver, or automatically by the action of special hooks in the jacquard itself.

Twilling jacquards are largely used in linen damask weaving and are arranged to form the satin or twill binding of the ground and figure. This greatly reduces the work of preparing the design. Formerly the combination of shaft and twine harnesses known as "pressure harness" was used in weaving these fabrics.

Leno jacquards are used in weaving the cross woven fabrics known as "leno brocades" and differ from the ordinary jacquard in having a supplementary griffe which gives a reduced lift to the "slackener" or "easier" mails at the time when the cross shed is being formed.

Carpet jacquards vary according to the structure of the fabric. The Brussels carpet jacquard often has knotted cords in place of hooks and a hole board in place of a griffe. The holes of the board have small slots out of which the cords are thrust when the needles are pressed back by the action of the card. Cords left in the slots are then lifted by their knots when the board rises. In the Kidderminster carpet jacquard one cylinder and set of needles control the hooks of two distinct machines which are placed side by side in the same framing. One set of hooks is normally "on" or over its griffe and the other set turned in the contrary direction and normally "off" or away from its griffe. The effect of a hole in the card is thus to lift an "on" hook and a blank to lift an "off" hook. The griffes lift alternately and the same card is pressed against the needles for two successive picks. The use of this machine, which is sometimes called a "twin" jacquard greatly simplifies designing when two sets of warp threads require to work oppositely to one another.

Attention may now be turned to the harness. The cords are attached to the hooks in various ways according to the style of the design to be woven. The order of attachment is known as the " tie-up " and this may be " solid " or " single,"; " lay-over " " vandyke " or " centred, ; " " bordered," or any combination of these. The " solid " tie up can only be used for narrow fabrics, such as ribbons, because there must be as many hooks as there are warp threads, each of which may however be worked differently from the rest. The " lay-over " tie is used when the design is to be exactly repeated a number of times across the width of the cloth and each hook controls one thread out of each repeat. The " vandyke " tie-up is used when the design is symmetrical or can be turned over about a centre line ; with the exception of the first and last, each hook then controls two threads in each repeat and the effect is thus to produce a design of twice the size as the same number of hooks would produce with a lift-over tie. In bordered ties a portion of the hooks are set off to govern the border threads and the remainder the centre threads of the cloth.

To increase the size of pattern obtained by a given size of jacquard adjoining threads of fine silk and linen fabrics are often controlled by the same hook and thereby worked as one in forming the figure, which is correspondingly increased in size. The threads are then split up by a supplementary harness and worked singly in the ground of the design. In " bannister," or " double-scale " weaving, this is accomplished by forming long loops in the harness twines between the cumber board and mails and inserting a thin shaft through a long row of loops. The shafts are then lifted, according to the desired ground weave, by special hooks in the jacquard which is thus left to concern itself only with the lifting for the figure.

In pressure harness weaving a number of warp threads are drawn through the eyes of a " decked " mail and then singly through the heald eyes of a front shaft mounting containing as many shafts as are required by the ground weave to be used. The healds have eyes deep enough to allow of a shed being formed in them by the lifting of the mail harness. For each pick of weft one of the shafts is lifted to bind the ground warp threads left down by the mail harness. Also one shaft is pulled down to a lower level to bind those threads lifted by the mails to form figure. The remaining shafts are left in a midway position and do not affect the action of the mail harness. On account of the strain put upon the warp by the combined action of the healds and mails the shed and shuttle have to be very small. This is a very old method of figure weaving and was used in weaving the rich damask fabrics for which the eastern weavers of old were famous. Besides increasing the size of the pattern the arrangement simplifies designing. Although the outline of curved figures woven in this manner is somewhat lacking in precision, this is hardly noticeable in the fine fabrics for which it is used. Twilling jacquards are now used in the linen damask trade to produce the same effect.

In another kind of compound harness weaving, shown in the frontispiece, certain of the warp threads, which work in a simple order, are controlled by a shaft harness and treadles, or in the power loom by tappets. The remainder of the threads are governed by the jacquard harness and are lifted to stitch through the cloth produced by the action of shaft mounting and form figures of a " quilted " or embossed character.

Fig. 114 shows the piano card cutting machine which is used to transfer the design from the point paper to the cards. The headstock is provided with keys which are worked by the fingers to lock punches, and all are then depressed by the right foot and treadle

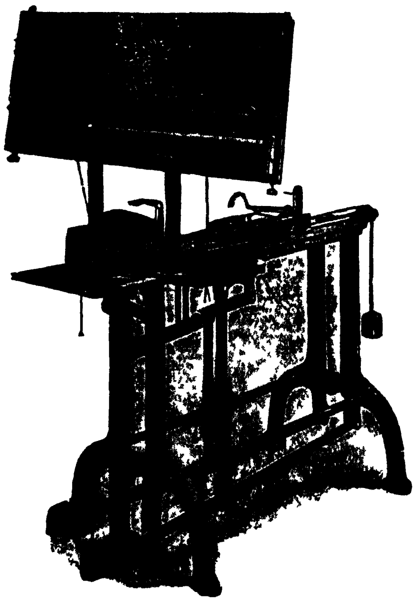


Fig 114

PIANO CARD CUTTING MACHINE

to force the punches so locked through the card. The point paper is ruled off by thick lines into divisions which correspond with the number of hooks in one row of the jacquard to be used, namely, eight for a 200's or 400's machine, twelve for a 600's, and so on, and the design is read off bar by bar and cut row by row in the cards.

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See p. 137 for illustration of Piano Machine
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„ 133 „ „ „ Double-lift „

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