CHAPTER XXXII.

THE LEVERS LACE FRAME, WITH DOUBLE-ACTION JACQUARD APPARATUS.

In the machinery department of the Exhibition, the manufacture of lace, although forming one of the special subjects of this year's (1874) display, is represented by one machine only, which has been contributed and worked by the Nottingham Chamber of Commerce.

The machine is known as a Levers machine, from the name of its inventor, and is provided with a double-action Jacquard apparatus for working the design or figure upon the lace. It is at present employed in weaving guipure, or narrow lace, of which sixty pieces, of about 2½ inches wide each, or a total width of 152 inches, are being woven at once. Of this width it is capable of weaving about one yard per hour, or a total length of sixty yards of narrow lace. The machine can be arranged to weave any desired width of lace, and even shawls may be produced by it. This is effected, not by the alteration of any of its mechanism, but in the production of the figure by the designer. For instance, the sixty pieces that are now being made are simply a repetition of the same figure, and by inserting a thread, called the "lacing thread," at the selvages or divisions of each figure, the whole of the pieces are connected together and form oné piece only. By this means the entire piece when woven can be removed from the machine, and, after being dressed, the lacing threads are cut or drawn out, whereby the narrow pieces become separated, and are packed or wound upon cards, as may be desired. The lacing thread is not, therefore, inserted by any special contrivance, but is introduced by the designer making a special provision for it in the formation of his design, which will be hereafter described.

It will be evident that such a machine is capable of producing all the ordinary varieties of machine-made lace; and, as far as one machine can do, it fairly represents the present state of the lace manufacture of Nottingham.

The total length of the machine is thirty feet, and the height nine feet. It contains 2907 shuttles, or as they are technically called, "bobbins and carriages," and upwards of a hundred warp beams. The speed it is worked at varies from 110 to 120 picks per minute, which means that the shuttles are passed through the machine that number of times in each minute.

From its great size and the multiplicity of its parts, it forms one of the finest examples of mechanical skill ever concentrated in one machine. In it are accumulated the result of the labour of a hundred ingenious men, the history of whose fortunes and misfortunes is of strange interest. Many of them never reaped the benefit of their inventions, but passed their lives in misery and neglect, terminated in some instances by suicide. Others, more fortunate, reaped the full advantage of their skill, and arrived at opulence.

The history of the machine itself, and the various forms and modifications it has undergone before being brought to its present perfection, affords as remarkable an instance of gradual mechanical development as can be found. It does not represent the genius of one or a few men, but rather the experience derived from a thousand different inventions.

Lace has always been admired and used as a most refined and beautiful article of dress. When made by hand it is also by far the most costly of textile fabrics. At the same time, the implements used in its production are of the simplest kind, though in the variety, extent, or richness of design no limit could be fixed that could not be surpassed by their means. Considering, however, the cost of production, it need not be wondered at that men have often been desirous to supplant the tedious process of hand-work by substituting machines for that purpose. The high price which hand-made lace fetched offered an ever-increasing temptation to the ingenious mechanic to attempt its production by other means, and at last it was accomplished. Not that machinery can ever surpass or equal the finest description of hand-made lace, but it can produce very good imitations of it, which have often been substituted for it, and in some cases are superior to it.

There are two descriptions of lace, namely, point and pillow. Point lace is made with the needle, and is a much more ancient art than the making of pillow lace. Point, or needle-made lace is said to have been invented by the Italians at a very early period, and during the 16th and 17th centuries became of very general use in this country, as may be observed in the huge frills, collars, and ruffs worn in the time of Queen Elizabeth, Charles I., and Charles II.

On the other hand, pillow lace is of more recent date, and the history of its invention is known, for Beckmann, with evident satisfaction, says, "I will venture to assert that the knitting of lace is a German invention, first known about the middle of the 16th century; and I shall consider as true, until it be fully contradicted, the account given us, that this art was found out before the year 1561 at St. Annaberg, by Barbara, wife of Christopher Uttmann. This woman died in 1575, in the sixty-first year of her age." The statement does not appear to have ever been disproved, and it is recorded upon her tomb.

Uttmann was a master miner, and his wife, observing that the girls made caps for the miners, taught them to make them on this new plan. She afterwards set up a workshop at Annaberg for the making of lace of different patterns; and it is this description of lace, or pillow lace, with which we are now concerned. There are several varieties of it, such as Brussels, Alençon, Lisle, Honiton, &c., which differ according to the meshes, twistings, thick or thin threads, and other details, but not in the principle of the operation.

The production of pillow lace is effected simply by twisting together a number of threads in the order and combination necessary to produce the desired pattern. To do this, the design is first drawn upon a piece of parchment, and holes are made in the outline of the design for the insertion of pins. Round these pins the threads are twisted, so as to form meshes. Thick and thin threads can be combined, or three or more together. As the lace is made the pins are moved. In the process of knitting the operation is different, in order to form the fabric. Knitting, in its simple form, is effected by using one thread only, upon which a series of loops are made, and they are connected together by intersecting each other, as is well understood in the common process of knitting. Knitting and lacemaking are therefore widely different in their modes of production; but as nearly all the first attempts for the making of lace were tried upon modifications of the stocking-frame, they will be noticed in the description of that machine.

In the production of figured lace it is requisite that the threads should be arranged in such a manner that they can be twisted round each other any number of times, and in any quantity and arrangement. In bobbin net it is also requisite that the threads should be twisted round each other, and follow the arrangement necessary for the production of meshes of uniform size and order. Previous to Mr. Heathcoat's invention, the meshes were produced by loops or knotting, and not by twisting the threads round each other, as in the production of pillow lace or bobbin net. He was the first who arranged the threads one part in a warp and the other part upon bobbins. The bobbins were fixed in carriages, on thin shuttles, which were made to slide in grooves in a comb-bar. The comb-bar being divided for the warp to pass between, the shuttles, as they passed from one side of the comb-bar to the other, necessarily passed through or between the threads of the warp. Now, if the warp threads, being placed in regular order, were kept in that position, and the shuttles also were kept moving backwards and forwards through the warp or between the threads, then no work would be the result. But after passing the shuttle through the warp, as before stated, if a lateral movement were given to the comb-bar, so as to advance it one or more grooves to the right or left of its former position, then on the return of the shuttles through the warp to the other portion of the comb-bar, they would be deposited in different grooves from those they started from. Again, if this motion were repeated in certain order, the threads of the bobbins could not only be made to twist round the warp threads, but they would travel from thread to thread, and the threads of the fabric they had woven would present a diagonal appearance. This motion of the comb-bar is technically called "shogging," and by its means the diagonal arrangement, or "traverse," is given to the threads. By this plan a firmly-made fabric is produced, for if there were no traverse, then on the breakage of any of the threads the work would run or untwist. Mr. Heathcoat having thus solved the problem of forming regular meshes by twisting threads round each other, and then passing from thread to thread and repeating the operation in regular order, accomplished all that was required for the production of bobbin net. The advantages were so great that in all directions a fresh impetus was given for further improvement. Amongst the various inventions thus brought into existence was the invention of the machine known as Levers' machine, the specimen now exhibited being on that principle.

Mr. John Levers was originally a machine maker, or frame smith, of Sutton in Ashfield, but he removed to Nottingham, where he extended his business. The success of Mr. Heathcoat's invention had already given rise to a new one, which, as in many other instances, was simply reversing the process of working the machine. In Heathcoat's machine the bobbin and carriages travelled or traversed, and the warp remained stationary. But it occurred to Mr. John Brown, of New Radford, that by traversing the warp thread, instead of the bobbin thread, a better result might be obtained. This contrivance he patented in 1811. The result was that many of the artisans of Nottingham, seeing the success of Brown's traverse warp, and that he had not been interfered with by Mr. Heathcoat, had an idea that similar efforts might be carried on without incurring the penalties of legal obstruction. With this idea it is supposed that Levers also devoted his mechanical genius and skill to the subject. Mr. Felkin, in his "History of the Hosiery and Lace Manufactures," to which this account is much indebted, gives an interesting account of Levers' invention, from which the following particulars are taken:—

"In carrying out the invention Levers worked in a garret at the top of a building situated in a yard on the northern side of the Derby Road, Nottingham, and so quietly and secretly as not to be seen by any one, even of his own family. The carriage and bobbins, things which presented so much difficulty to Mr. Heathcoat, with some of the inside parts, had been made as thin as was requisite by a relative, Benjamin Thompson, an extraordinarily clever workman in metals. He was never permitted to see the machine in progress, but was the first, except its constructor, to witness its completion. Levers had no son, but two brothers and a nephew, John. All worked afterwards with him, and the nephew always stated that they saw the frame for the first time when it was ready to work. They found it to be eighteen inches in width, waiting for materials, and prepared to start, which it did without difficulty. The entire isolation of the inventor during this period was a remarkable fact. Levers had expended his available means in the lengthened experiments and necessary expenditure incurred during the years 1812-13.

"The house of John Stevenson and Skipworth, carrying on a lace business in Nottingham, was induced to furnish the funds required for producing more machines, upon what terms is now not known. Several were built, one of which was retained by Levers for experimenting upon. The others were worked in a shop, on their owners' premises, in St. James's Street. It is probable that the then exist-ing patent rights on the one hand, and the profits daily realized by Levers and his patrons on the other, were the reasons why no patent was obtained to secure what was new in his method; for it seems to have been the prevailing notion among the mechanicians of the time that a patent must be taken out for all the machine, and not, as might have been, for any parts or combinations only which were really new.

"In 1814 John Farmer, with another hand, worked one of these machines, fifty-four inches wide, each taking five-hour shifts, the machine working twenty hours a day. The production was four pieces of ten racks each weekly. The wages were 5*s*. per rack, *i. e.*, 5*l*. for each workman a week. Some of the bobbins, and all the carriages in the machines, were stamped out by B. Thompson, who employed a very similar process to that described in Mr. Heathcoat's specifications, to get the sides of the bobbins flat and true. Two half circles of very thin brass were placed within each bobbin, fitting exactly the inside; they were put on an arbour, passing through the centres, and were screwed together very tight, and heated until the arbour showed a bluish tint, from which, on gradually cooling, the inside half-circle plates were removed. The bobbins came out perfectly flat, and capable of turning without friction or accident in the carriages. This in Levers' machines, where often thirty carriages and bobbins must work together edgewise within the space of an inch in width, is evidently a matter of the first importance.

"Levers left Stevenson and Co., but for what reason the connexion was broken is not known. In 1817 he worked in a shop in the higher part of St. James's Street, and it was at this time that he altered the arrangement of his frames. They were at first made to work in a horizontal position, but he now made them to work in a vertical one, as at present in use. In 1821 Levers went to France, and set up his machines at Rouen, and there died. Levers is said to have been a friendly, kind-hearted man, and a great politician. He was fond of company, music, and song, and was bandmaster of the local militia. He sometimes worked day and night if a mechanical idea or contrivance struck him, and would then quit all labour for days of enjoyment with chosen boon companions. He was frequently heard to say that the machine he had constructed was only in its infancy, because of the great facilities it afforded for alterations and improvement."

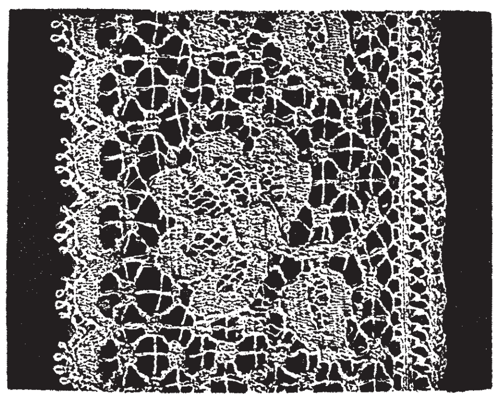
His opinion has certainly been verified, for since the successful application of Jacquard apparatus to it, the power it possesses for the production of figured lace is almost without limit. To adapt the Jacquard machinery to lace machinery proved a long and tedious task, and many years were passed before it was successfully accomplished. The difficulty arose from the circumstance that a widely different requirement was exacted from the Jacquard when applied to the lace machine from that used in the common hand loom, for which it was originally intended. When used in the hand loom, the operation of the cards upon the needles is simply to throw those hooks out of contact with the griffe which are not required to be raised. Thus only those threads of the warp are raised for the passage of the shuttle that are necessary for the formation of the design or pattern. It matters little whether the hooks are raised two or three inches in height, so long as the shed is high enough for the shuttle; in the lace frame this is quite another matter. Not only do the perforations in the cards select the particular threads to be moved, but they also regulate the exact distances they are required to move. These distances are so small, that the most exact working of the parts is absolutely requisite to insure the formation of the pattern.

In the frame shown there are, as before stated, nineteen shuttles working freely in the space of one inch. Now, to produce the figure it is requisite to be able to draw any of the warp threads in such a position that the shuttle, as arranged by the designer, shall pass at the side of any particular thread, and the position must be very correct to accomplish this. Sometimes the thread is drawn only one space, in other cases they are drawn twenty spaces and upwards. These spaces being only 1-19th of an inch from centre to centre, and in some machines only 1-30th of an inch, it follows that to stop exactly at the proper place the mechanical arrangement for that purpose must not only be true, but made upon a principle that will stand the wear and tear of rapid and hard usage. It was also necessary that the Jacquard should be able to work at a speed not only equal to that of the lace frame, but to do its work easily at whatever speed was required. These conditions are admirably supplied in the Jacquard apparatus connected to the lace frame, the principle of which will be hereafter described.

The importance of the Jacquard in conjunction with the lace frame cannot be overrated, and it is questionable whether the modification now shown is not the most valuable and ingenious part of the machine.

Lace-making consists in twisting any desired number of threads round each other in such a manner as to form meshes, or, according to the famous definition given by Dr. Johnson, it is "Anything reticulated or decussated at equal distances, with interstices between the intersections." The threads may be twisted either two, three, or more together, or thick and thin threads may be so combined. For the formation of any desired pattern, or figure, it is requisite that any one, or more, of the threads may be twisted round any one, or more, of the adjoining threads. It is not necessary that the threads should be able to pass completely from

FIG. 1.



side to side of the lace and then be made to twist round the most distant threads, but so long as they can be moved a moderate distance, with perfect freedom, to be twisted together with one or more of the neghbouring threads, that is all that is required, so far, for making ordinary lace.

Before the invention of the bobbin and carriage, by Mr. Heathcoat, a very similar process was, to a slight extent, effected in the common hand loom in the weaving of gauzes and whip nets. In weaving gauzes the adjoining threads of the warp were twisted half round each other, and, by repeating the process backwards and forwards, a gauze mesh, or intersection, was formed. In this case the weft thread held the twisted warp threads in their proper position. But the process was very limited in extent, and it required a great amount of tedious labour even for the production of small designs. One shuttle only was requisite for gauze weaving, the warp threads alone being moved to form the twist.

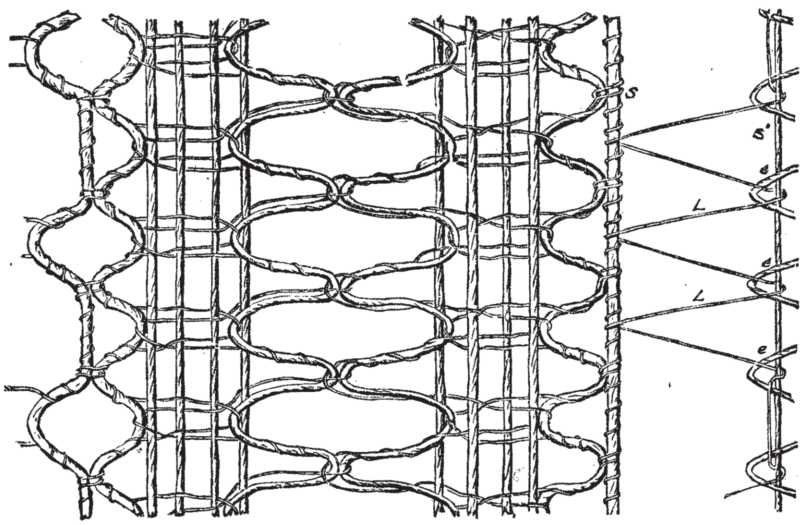
Fig. 1 represents a portion of the guipure or narrow lace made in the Exhibition, and is of the same size as the lace. As before mentioned, sixty of these pieces are made at once, forming a total width of 152 inches. It will be noticed that the figure merely represents a sufficient length to give the whole of the pattern, so that a fair idea of the lace may be formed. In the production of the sixty pieces the pattern is merely repeated sixty times in the arrangement of the frame or loom, all the sixty pieces being governed by one apparatus. They are woven in a vertical position, or, as shown, in the position of the figure. In the production of each of the sixty pieces, forty-eight bobbins and carriages, or shuttles, and 100 beam or warp-threads are required, or a total number of 148 threads for each piece.

Fig. 2 represents a portion of the right hand or plain border of the lace, as it would appear when magnified, and shows about half an inch in length of the actual selvage of the lace, which may be seen by comparing the looped meshes of the two figures. In Fig. 2 the extreme thread of the lace is shown at *s*, and the thread *L*, *L* is the temporary, or lacing thread, which connects the selvage to the opposite selvage of the adjoining piece of lace; in short, the loops *e*, *e*, *e* are the loops which appear at the edge of the curved border of the lace, as may be observed in the left hand selvage in Fig. 1. The lacing thread is connected to a thread placed vertically, *s′*, as shown in the back of the loops in Fig. 2, consequently, the whole of the sixty pieces are held together in this manner. These threads are not removed until the whole width of the lace has been made perfect and dressed; when they are "drawn" or cut, and the pieces of lace become separated. In Fig. 2 the looped or curved selvage appears straight, the loops being in a right line above each other; but in Fig. 1 the same loops are no longer in a right line, but form the curved line as shown. This arises from the circumstance that Fig. 2 shows the border as the lace would appear in the process of weaving, when the necessary tension was operating upon the threads. When the lace is removed from the loom the tension no longer exists and the twisted threads assume the form intended by the designer of the pattern or figure.

If the threads in Fig. 2 be examined, they will appear to consist of three descriptions, viz. 1st, vertical threads, which retain one position only; 2nd, threads which form half-loops or zigzags; and 3rd, threads which are twisted round the others, in order to bind them together. The latter threads are those that have been inserted by the shuttles or bobbins and carriages.

Now, although it would seem that three different kinds of threads composed the design shown in Fig. 2, still there are really but two descriptions, viz., the warp and the weft. The warp threads are shown much thicker in proportion to the weft threads than actually used in the production of the lace, but this has been done in order to represent the manner in which the threads are twisted more dis-

FIG: 2.



tinctly. It will be found that the threads running in a looped or zigzag direction are merely vertical threads that have been drawn from side to side according to the arrangement intended by the designer. This is effected by varying the degree of tension upon the threads, and to accomplish this for the production of complicated designs, or figures, requires consummate skill and labour on the part of the designer. His design must not only show the work to be performed by each of the threads in all their various twistings, but the different degrees of tension must also be shown. When the design is made, it is then transferred to the "drafting" paper, which gives the extent of motion of each of the warp threads laterally. From this draft the Jacquard cards are perforated to correspond. To produce the pattern or design, $1\frac{1}{2}''$ long, shown in Fig. 1, requires 160 Jacquard cards, each 30 inches long by $2\frac{1}{8}$ inches wide. Before these cards could be punched for the production of the small figures or flowers, with the borders annexed, the design and draft have to be completed, and the amount of labour necessary, even for so small a figure, can scarcely be realized. But to give some idea of it, a copy is given in Figs. 3 and 4 of a portion of the actual design and draft that were used for the formation of

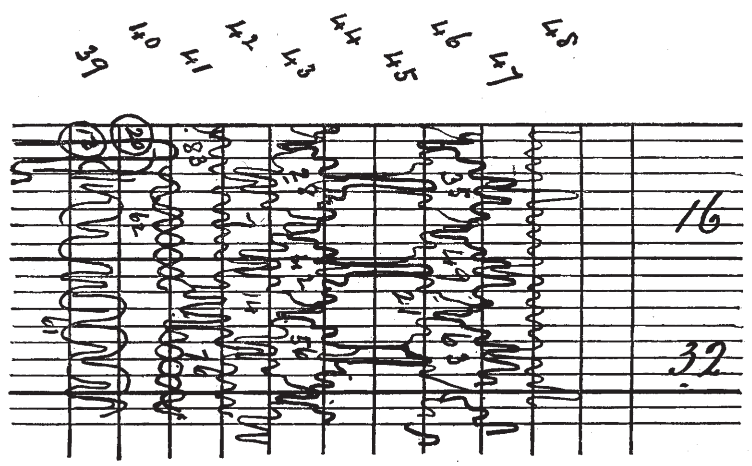


Fig. 3.

the lace shown in Fig. 1. Thus in both the figures, 3 and 4, only 1-50th of the design and draft are represented. In other words the whole of the two figures, 3 and 4, shown, merely represent one quarter of an inch square, of the lace in Fig. 1. Consequently for the production of lace of more extensive and elaborate designs it may be easily understood how great is the amount of skill and labour required.

In Fig. 3, thick and thin lines are shown in a zigzag direction. In the actual design two different colours are used instead, in order to prevent confusion, and to enable the designer to trace the threads more clearly when transferring them to the drafting, Fig. 4, than it would be possible to do if they were drawn in one colour only.

Therefore, to produce figured lace in the loom the movement of each thread must be considered. It is not necessary that the design should be drawn so as to show each twist as distinctly as represented in Fig. 2, for the same effect is produced by the designer in the much more ready manner shown in Fig. 3, which corresponds to Fig. 2. He not only, by this means, shows the warp and bobbin threads, but by the use of numbers and coloured inks he gives every information necessary for transferring the design to the Jacquard cards, and the degree of tension on the threads necessary to produce the desired effect. Thus, the exact distance that each warp thread must be drawn for the proper interception of the shuttles, and the relative degree of tension of the various threads, must all be determined and carefully noted in order to produce the figure.

To assist the designer various contrivances have been introduced from time to time. Messrs. Richardson and Slack, of Nottingham, have recently patented an apparatus in which photography and stencil plates are used. They provide two frames, in which threads or wires can be arranged, so that one frame may represent the warp threads and the other the weft or bobbin threads. These can be regulated by suitable means to any required guage. The outline or design is then placed in front of the photographic apparatus, also the two frames containing the wires. They are adjusted according to the effect or purpose desired, and the draft is then photographed.

The stencil plates are afterwards used to fill in the ground meshes, which may be of one or more descriptions. By this means designs may be enlarged, and the necessary lines to any required guage may be introduced, and the ground and other details may be filled in afterwards.

This system is also adapted to designs for other fabrics.

From the above it will be evident that upon the ability of the designer far more depends than in the designing of other fabrics, and the admirable way in which the machine is contrived to meet the requirements of the designer, alone gives ample proof of the genius of the inventor.

Each of the threads forming the lace, whether weft or warp, has a separate shuttle or warp beam, and the various shuttles and beams have more or less friction applied to them in order to produce more or less tension upon the threads as they are woven. In the shuttles or bobbins and carriages, the friction is caused by a small spring, which not only presses upon the bobbin to cause the friction, but at the same time holds the bobbin in the carriage. These springs are varied, either by using stronger springs or bending them so as to exert greater pressure to several degrees of strength. Fig. 5 represents a bobbin and carriage, also a section of the same, and the letters refer to the same parts in each. The bobbin *B* is composed of two thin disks of brass, $2\frac{1}{8}$ inches diameter, or twice the scale shown in the figure. The weft thread is wound between the disks, and it passes from thence through the eye *t*, at the top of the carriage. The carriage *a a* is made of steel plate, a hole being cut through it of about the size of the bobbin, excepting at the lower part, where a thin flange shown by the dotted line at *c*, is made to

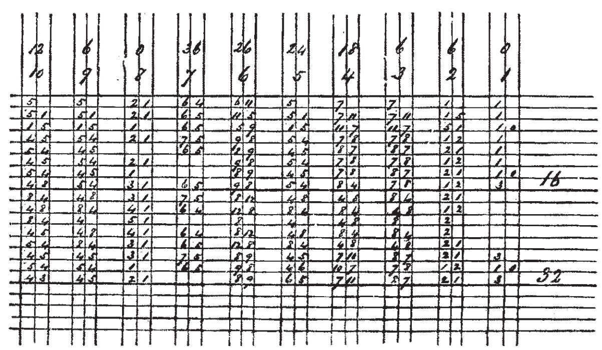


Fig. 4.

fit between the disks of the bobbin, and thus hold it in position. The small spring *s* has a nib, *n*, upon the end of it, the thin portion of which also is inserted between the disks, whilst the broader or upper part presses upon the edges of the bobbin and holds it down upon the flange *c*, as before described. The spring *s* is rivetted into the carriage at *u*, and it will be evident that according to the degree of pressure put upon the bobbin by the spring, so will be the amount of friction and tension upon the thread when unwound. The bobbins will each hold about 120 yards of thread, which is wound upon them when removed from the carriages and placed upon a spindle passing through the hole *d*. The lower portion of the carriage *b* is made much thinner, as will be seen in the section. It is this part of the carriage that slides between the comb plates, as will be hereafter described. The section of the bobbin and carriage is shown much thicker than they are actually made, for in the machine nineteen of the carriages work freely, with room between them for the passage of the warp threads, in the space of one inch, and in some instances as many as thirty to each inch in width of the lace made. In making the lace, as before described, forty-eight bobbins and carriages are used for each of the sixty pieces. This number is not absolutely correct, for although forty-eight spaces for forty-eight shuttles are used, one of the shuttles has been omitted from each of the sixty pieces, these shuttles not being required at the extra width of the space occupied by the lacing thread, as shown at *L, L*, Fig. 2.

The warp threads, of which there are 100 to each of the sixty pieces of lace, are placed upon 100 separate warp beams. The corresponding threads in each of the sixty pieces being used or woven in equal lengths, and requiring the same tension upon them, it fol-

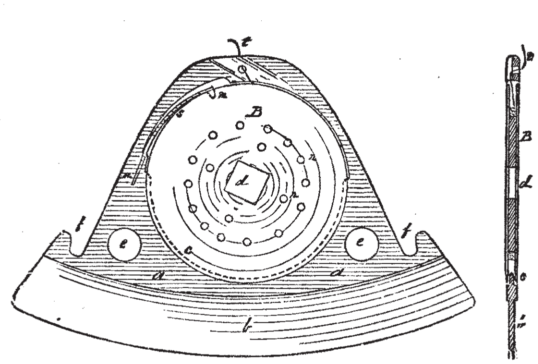


FIG. 5.

lows that one set of beams may contain the threads for the whole sixty pieces as freely as for one piece of lace. Therefore 100 beams are equivalent to having a separate beam for each separate thread in the whole of the sixty pieces.

The friction to cause the tension upon the warp beams is effected in a similar manner to the ordinary loom, viz., by winding a cord round the end of the beam and attaching a spring or weight to it. The tension is regulated by the strength of the spring and the number of turns that the cord is wound round the beam, or the small pulley fixed on the beam for that purpose. This will be better understood by referring to Figs. 10 and 12, in which the warp beams are shown at *w, w*. They have a small pulley fixed on one end, and round this pulley the friction cord is passed as many times as may be necessary. Thus, at *p*, Fig. 12, the cord is shown with one end attached to a stud, or peg, fixed to the frame in which the beams are placed, and after it has been wound round the pulley *o*, once or several times, the other end of the cord is attached to the spiral spring *s*. The warp beams are made of tin, and are about $1\frac{1}{2}$ inches in diameter, with small gudgeons at the ends.

It will be evident that various degrees of tension can be placed upon any of the 147 threads which compose the lace, and it now remains to see the important uses to which this simple matter is applied, and the effect it produces.

Fig. 6 represents five threads hanging from a rod *h*. The thread *a* has but a slight weight or tension applied to it, whilst the threads *b, b, b, b* have a much heavier one. The bobbins *e*, round which the latter threads are wound, are supposed to oscillate in the direction of the dotted lines shown at *o, o'*, the points from which they move being at the level of *d*. If these four threads are made to move, or oscillate altogether, they really represent the motion of the shuttles and weft threads of the lace machine, whilst the thread *a* would represent one of the warp threads. So long as the threads oscillate without any movement of the thread *a*, no effect will be produced, and the threads will remain intact, but if during the oscillation the thread *a* be drawn laterally across the path of the bobbins *e*, then on withdrawing or advancing the thread, it will be found, on continuing the various lateral movements of the thread *a*, that it will become twisted round the threads *b, b* accordingly. In this manner the various threads round which the thread *a* has been twisted, simply correspond to the distance that it has been moved at each oscillation of the threads *b, b*.

There is a comb or fork shown at *c*. The action of this is to beat together the twisted threads in a similar manner to the use of the reed in the common hand loom. But in lace-making the comb must be withdrawn completely clear of the threads after each oscillation, in order to allow of the lateral motion of the warp threads, which the comb would otherwise prevent.

It may now be seen that, owing to the extra tension upon the threads *b, b, b, b*, the thread *a*, after each twisting, is held in the position it was drawn to, for it has not sufficient strain or tension upon it to draw the threads *b, b, b, b* aside. Consequently, the effect produced is similar to the looped threads before alluded to, and shown in Fig. 2.

On the other hand, if the thread *a* had a greater tension upon it than any of th e threads *b, b, b, b,* then the latter threads would be drawn aside in a reverse manner. This will be evident on referring to Fig. 7, where the tension upon the threads is reversed to those shown in Fig. 6. In this instance the threads *b, b, b, b* are, after each oscillation, drawn completely aside, and in this manner the action of drawing the fine, or weft threads, shown in Fig. 2, in the various positions there represented, and particularly so in the case of the lacing thread *L L,* is effected.

FIG: 6

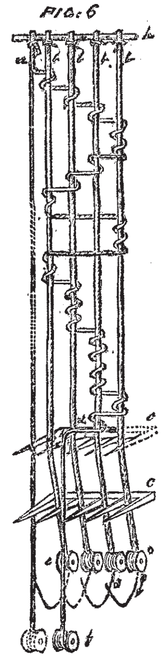
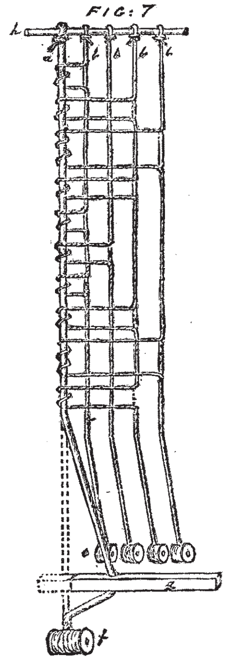


FIG: 7



It may be seen now that the various strains or degrees of tension that the threads are subjected to, perform a most important part in the manufacture of lace. The weft threads themselves have but a simple oscillatory motion, the shuttles simply sliding backwards and forwards from front to back of the machine. The warp threads, on the contrary, are moved to a greater or less extent laterally, and it is in the exactness with which these motions are made, upon which the proper formation of the lace depends.

It is in this portion of the machine that the greatest ingenuity has been shown, for the Jacquard apparatus, together with this peculiar adaptation of it is, perhaps, unsurpassed by any other mechanical invention.

In the production of the lace, as before described, 100 warp or beam threads have been used, and each of these threads must be so arranged that any one, or several of them, may be moved laterally as far as required. They may be required to move only past one of the oscillating or weft threads, or past ten or twenty. The spaces through which they move being in the present machine only 1-19th of an inch for each thread they pass, some idea of the exactness of the motion may therefore be formed. When thirty shuttles or bobbins to the inch are used instead of nineteen, then the difficulty becomes far greater still. The way in which this has been effected gives nothing like uncertainty, but performs the operation with the greatest precision and rapidity.

The processes to be accomplished by the lace machine consist as follows :—

1. In giving the weft or bobbin threads an oscillatory motion.

2. In giving each of the beam or warp threads a lateral motion to any required distance, so that they may be intersected by the shuttles and weft threads at the place desired.

3. In varying the degrees of tension upon the various threads.

4. To beat or comb together the twisted threads as they are formed.

The purpose of each of the above operations having been shown, the method adopted for carrying them into effect will be readily traced in the action of the machine itself, which will now be described.

A general view of the machine is represented in Fig. 8, (see *frontispiece,*) where it will be seen to consist of two separate machines, rather than one only. The larger portion is the lace machine or frame, and the smaller machine is the Jacquard apparatus.

The lace frame consists of a massive iron framework, well fitted together and fixed as firmly as possible, in order to prevent vibration. Both machines are driven by the same shaft *A*, by means of a strap and pulleys at *I*, near to which is also fixed on the same shaft a heavy balance or fly-wheel, to give steadiness to the motion of the machine. Near the top, and at the back of the lace frame, is a revolving shaft *C*, which is driven by a connecting shaft and wheels, fixed at the end of the frame next the driving pulleys. Upon this shaft *C* are placed various cams, and it is consequently named the cam-shaft. Below this shaft there is a vibratory or rocking shaft *D*, which is worked by means of the cranks on the shaft *A* and connecting rod attached to crank levers, as shown at *D*.

The Jacquard machine is connected, and worked by means of the wheels shown at *B*.

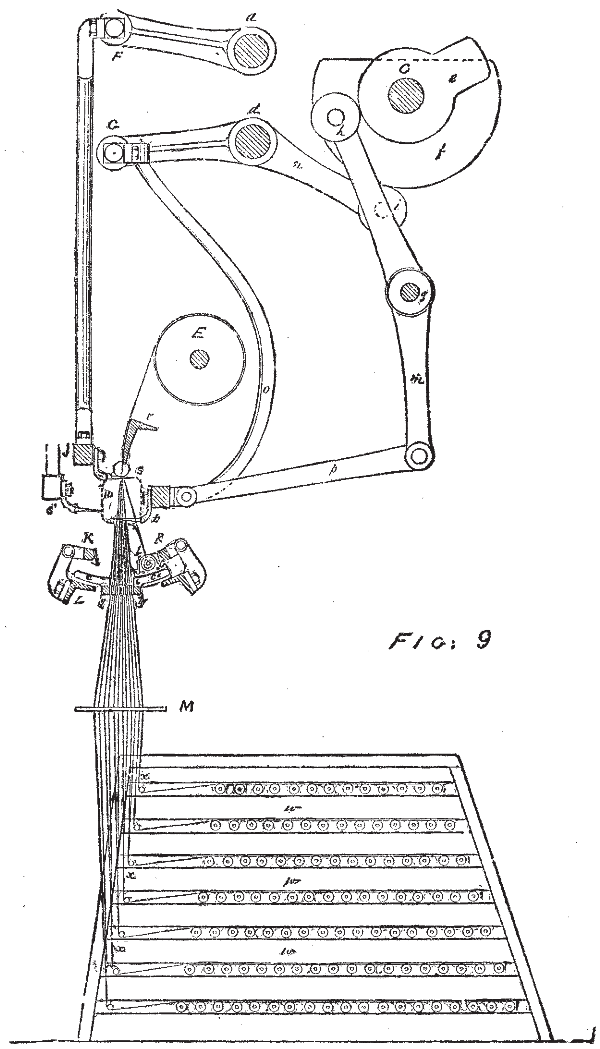


FIG. 9

Fig. 9 is a section of the lace frame, showing the most important parts. The warp beams are shown at *w*, *w*, from which the threads are passed through eyes fixed on the bars *x*, *x*, and from thence they are carried vertically through the perforated plate *M*, and the slide bars *y*, *y*, and are finally attached to the lace-beam *E*, upon which the lace is wound as it is made. At *b* will be seen one of the bobbins and carriages, with the weft thread leading to the point *s*, which is the centre of the arc, or point from which the oscillatory motion of the shuttles or carriages moves. As before described, the carriages slide between the comb or guide plates *c*, *c*, and as they pass from one comb-bar to the opposite one, they necessarily pass through the warp threads *y*, *y*. At *L* will be observed an angle bar. There is also a corresponding bar on the opposite side, and upon them the shuttles which protrude through the comb rest. The bars are called "landing bars," for when the shuttles are pushed through the warp they "land" upon the opposite landing bar, and are then drawn completely through to the other side. In the moving of nearly 3000 shuttles, as in this instance, considerable friction would arise if they were made to slide through the comb without the aid of the landing bar. Attached to each landing bar is a catch bar *k*, *k*. In Fig. 5, representing the carriage, there are two slots *f*, *f*. These slots are for the strip or blade of the catch bar *k*, *k* to fall into, and by that means the whole of the carriages are drawn across. On returning to the opposite side, the catch bar pushes the carriages until they are within reach of the opposite catch, when it drops into the grooves, at the same time the pushing bar is withdrawn. In this manner, by means of the catches and the landing bars, the carriages are moved from side to side of the comb bars.

In the carriages will also be noticed two holes *e*, *e*, Fig. 5. When they are removed from the frame for the purpose of being refilled with thread, a strong wire is inserted in these holes, by which means the lace-maker can remove several hundred carriages at once, which would otherwise take considerably more time to perform.

In the diagrams, Figs. 10 and 11, the carriages may be seen at *b*, *b*, also the comb plates *c*, *c*. The weft threads are shown at *a*, *a*.

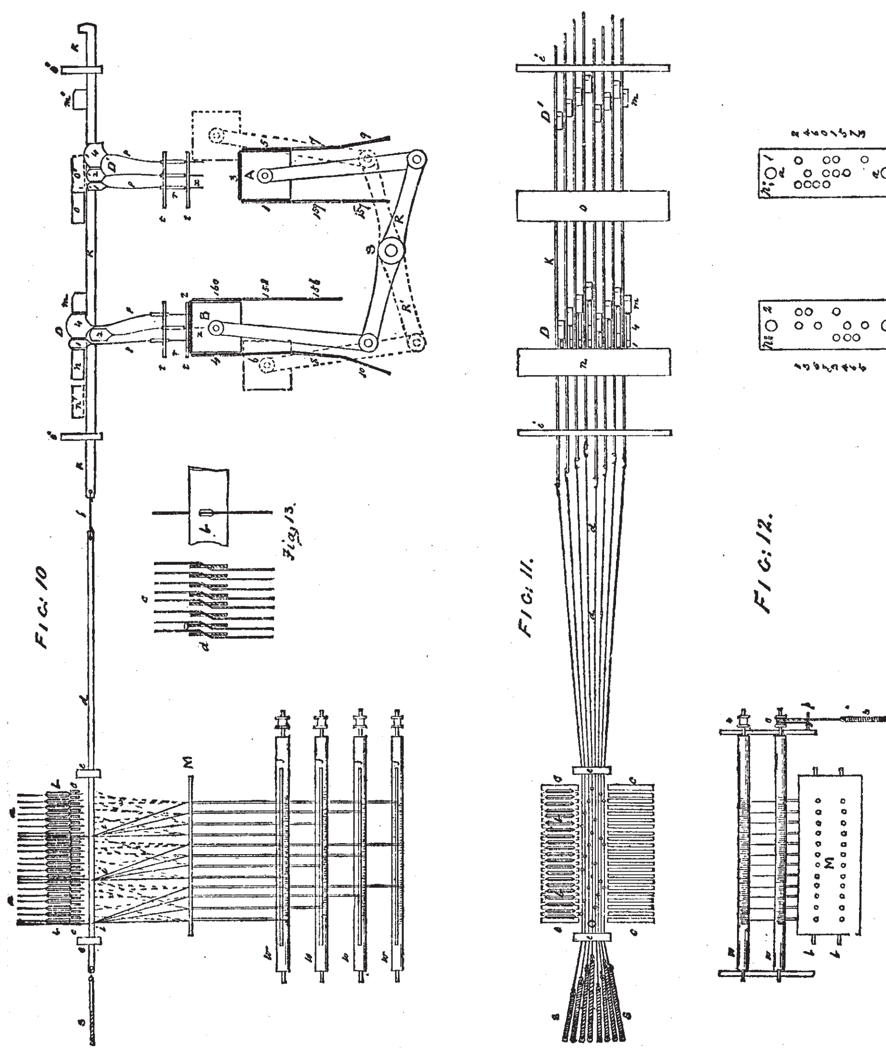
The motion of the carriages from side to side of the comb bars, and the varied pressure put upon different bobbins by the springs, constitute all that is required from them. The oscillating motion is given to the landing and catch bars by means of connexions to the rocking-shaft *D*, Fig. 8.

The arrangement and movements of the warp or beam threads is a very different matter, for each of them can be moved separately. This will be best understood by referring to the diagrams, Figs. 10, 11, and 12, which, instead of showing the whole of 147 threads, as used in the weaving of the lace described, show only 45, which will be quite sufficient to describe the operation of the Jacquard apparatus.

Fig. 10 is a longitudinal section of the machine; Fig. 11, a plan of the same; and Fig. 12 is a sectional plan taken at the level of *M*, Fig. 10.

There are only eight warp beams represented, viz., four tiers in height and two in width, as shown at *w*, *w*, Figs. 10 and 12. The threads are passed under the bars *j* and *b*, and thence through the holes in the plate *M*.

Now it is at this point where a most important and ingenious arrangement occurs, which, when understood, will at once explain the design and draft shown in Figs. 3 and 4. It will be noticed in Fig. 10 that there are 24 threads which pass from the beams through the plate *M*. These threads are not continued upwards in the same order, but are simply divided into three sets or rows of eight each, and they are threaded through the eyes of the slide bars, which lead to the Jacquard apparatus as shown. In Fig. 10 the three sets of eight are seen to converge at *i*, *i*, *i*, where they pass through the eyes of the slide bars. This will be seen on a larger scale in Fig. 13, which represents in section the eight bars with the threads *c* passing through the eyes at *d* and *b*. As there are only eight slide bars and twenty-four threads shown in the diagram, it follows that each bar guides three threads. Consequently, if any of the bars are drawn forward, they draw with them the three threads to an equal distance. For instance, the normal condition of the bars would place the threads in three rows, as shown at *i i i*, Fig. 10, but if the bars be drawn to certain distances, then the threads may be placed in the position as shown in the dotted lines, Fig. 10. Thus, any set of the three threads can be drawn to whatever intermediate space that may be required. In Figs. 11 and 12 the spaces through which the threads, shown by the dotted lines in Fig. 10, have been drawn, can be seen. In Fig. 11, the first eight threads would be in their normal position at *O*, but as the bars have been drawn to various distances, the holes shown upon them show the distances they have been drawn from their normal position, or straight line. This will be more clearly observed by noticing the extent to which the spiral springs *s*, *s* have been drawn, also the various distances at which the opposite ends of the bars protrude at *i* in the same figure. In Fig. 12, the plan of the Jacquard card, marked No. 2, shows that the nearest bar has been moved five spaces, or past five of the shuttles, and the last bar has only been moved one space. It is upon this principle that the 100 slide bars in the machine are used for making the sixty pieces of



lace. In Figs. 10 and 11 only eight bars are used, and they would produce three pieces, or repetitions of the same pattern. But there is this difference in the two cases, that in Fig. 10 the 8 threads are concentrated in one line only, whilst in using the 100 threads in the large machine they have been concentrated in 7 sets or lines. These points or lines of concentration are called "stops," and it is from them that the designer measures the distances that the threads must be moved.

Figs. 3 and 4 may now be understood. In Fig. 3 the numbers 39 to 48 refer to the number of the shuttles, and 16 and 32 are the numbers of the oscillations or cards to be used. It will be remembered that Figs. 3 and 4 only represent 1-50th of the actual design and draft, consequently only 10 of the shuttles are numbered, also 32 out of the 160 cards, in like manner.

As before explained, one of the shuttles was dispensed with, only 47 being used. The one marked 45 in Fig. 3 was the one that was omitted.

The numbers filled in the body of the design refer to the particular beams which supply those threads, and the tension is also marked accordingly. In Fig. 4 the top row of figures represent the "stops" above mentioned, and the second row the consecutive numbers of the warp threads, of which there are 100, but only ten are there shown. The numbers 16 and 32 represent the cards, or 32 out of the 160 required for the pattern as in Fig. 3.

The figures are arranged in two columns. Under each of the consecutive numbers at the top which corresponds to the numbers of the warp threads, and under No. 6, representing the 6th thread of the warp, appear the numbers 6, 11, 11, 5, 5, 9, &c., which refer to the number of spaces that the thread must be moved through, in a similar manner as shown in the case of Fig. 12. In the left hand column the odd numbers of the cards are represented, and the even number on the right. Thus the eight lines, or spaces between them, show the 16 cards, as numbered in the right hand margin. Where no figure occurs in the columns, it is understood that the last number must be repeated. This plan of double columns has the great advantage of showing at a glance the two sides of the cloth, so that the designer can use the threads to the best advantage and effect.

The application of the Jacquard apparatus to the lace machine is quite upon another principle to that applied to hand-loom weaving. In that system of weaving the cards are perforated directly according to the corresponding warp threads that have to be raised, each warp thread having its appointed hook and needle, and a position upon the cord. But in the lace frame, each thread having to be moved to various and certain distances, a very ingenious method has been invented, which accomplishes what is wanted in a most effectual manner. It is done by using a series of wedges of different thickness. These wedges are inserted between a sliding bar and a stud fixed upon each of the slides which move the warp threads. Now if a wedge, representing in thickness the distance through which the slide is required to move, be placed between the bar above mentioned and the stud on the slide, then it will push the slide a corresponding distance. If two wedges are used, then a greater distance can be passed through.

At *D* and *D'*, Fig. 10, three wedges are shown, of three different thicknesses, viz., 1, 2, and 4. If all three wedges be inserted, the bar will be moved equal to 7 spaces. In the figure only two are inserted, viz., the first and third, which represent 5 spaces. In this manner any number of spaces from 1 to 7 can be accomplished by the three wedges shown. If another wedge equal to 8 spaces be added, then any number up to 15 spaces can be drawn. In the lace machine there are five wedges used, viz., of 1, 2, 4, 8, 8, spaces. With these from 1 to 23 spaces can be used.

In Fig. 8, the slide bars *b*, are shown leading from the Jacquard to the lace frame. There are 100 of these bars, and so thin are they that they all work freely in the space of 1¼ inches, besides leaving ample room for the warp threads to pass between them. They are made of fine steel and have guide holes made in them for the threads as shown at *d* and *b*, Fig. 13. One end of each bar is attached to a spring, as shown at *s*, Fig. 11, and the other end is attached to the slides of the Jacquard machine, shown at *c*, Fig. 1, and *k*, Figs. 10 and 11. In Fig. 10 the attachment is shown at *f*. The Jacquard slide bars *k*, in the same figure, are made to move freely in the guides *i*, *i*. At the extreme end of the bar, a nib or projection is left on the bar to form a stop, against which the spring at the other end tends to draw the bar *k* against the guide *i*. On the upper edge of the bars two studs or plates are fixed, *m* and *m'*, Figs. 10 and 11.

There are two bars shown at *n* and *o*, in the above figures, which are made to slide simultaneously in opposite directions to each other; consequently, one of them is always advancing towards the stops on the slides *k*. The dotted lines *n' o'* in Fig. 10, show the extent of their motion. The bar *o* is shown drawn in its normal position, and the wedges *D*, below it can be raised in front of it.

If any of the wedges are raised, then, when the slide moves, it blocks them between the slide *o* and the stud *m'* in a similar way to the position of the wedges 1 and 4 shown at *D*, which are blocked between the bar *n* and the stud *m*. In this case the slide bar *K* is moved five spaces. Whilst the wedges *D* are in work there is ample time for the wedges *D'* to be inserted, for they work upon the same bars, although upon different studs. By this means no time is lost in the movement, and the advantage of the double action is at once self-evident. The cards being divided into two sets, viz., the odd numbers to work on one cylinder and the even numbers on the other, as shown at T^1 and T^2, Fig. 8, and *A* and *B*, Fig. 12, enables them to be used at double the ordinary speed, with all the advantages of steady, uniform, and balanced motion. The Jacquard cylinders are worked in the usual way, and are turned by a catch, except the cylinder *f*, Fig. 8, which is turned by means of the rack and pinion as shown. The wedges are fixed on the ends of thin, flat springs, as shown at *p*, *p*, Fig. 10, and the lower end is made round, so as to pass through the holes in the card where required. Between the spring and the round part there is a strong flat piece *r*, which is made for the purpose of working without turning in the guide plates *t*, *t*.

The cylinders *A* and *B*, Fig. 10, are connected to the rocking shaft *S* by the balance lever *B*, by which means they are alternately raised and lowered, for the purpose of turning and changing the cards, 160 of which are used in the formation of the lace as before stated. Now the cylinders in their upward movements raise the wedges *D* and D^1, unless there are holes in the cards. Where there are holes, of course the round end of the needle passes through the card and the wedges are not raised. At Fig. 12, two cards are shown, the one marked No. 2, is the same as shown raised on the cylinder *B*, and the wedges are inserted as at *D*, Fig. 11. The distances to which the slides can be moved are shown by the figures 1, 3, 5, 7, 2, 4, 6, 5, at the side of the card, which figures indicate the wedges required to be raised by the card. For instance, opposite to 1 there are two holes, but the first space is blank, consequently No. 1 wedge would be raised. Opposite to 5 there are two blank spaces, consequently they would raise No. 1 and No. 4 wedges, as shown at *D*, Fig. 10.

It has now to be observed that the cylinders and wedges altogether move laterally in conjunction with the slide bars *n* and *o*, Fig. 10. If this were not the case the wedges could not be kept in position. The dotted lines show the reverse motion of the cylinders, when following the movement of the slides n' and o'.

In Fig. 8 the slides are shown fixed on the side bars *s, s.* These bars are moved by means of cams fixed on the shaft moved by the wheel *B,* one of the pulleys worked by the cam being shown at the back of the wheel *B.* There are two pairs of these bars, one pair at each side of the Jacquard machine, and the slide bars *w, w,* are fixed upon the top of them, as shown. The spiral springs return the slides to their proper position after each revolution of the cams.

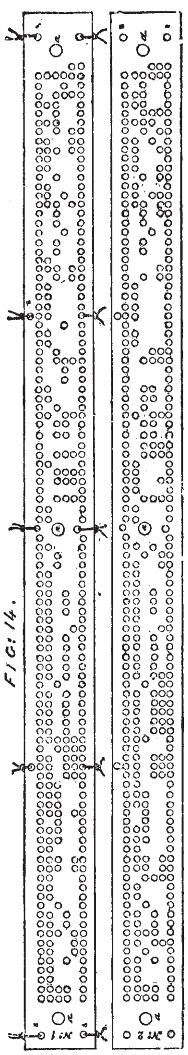


FIG. 14.

Fig. 14 represents two of the cards actually used in the machine, viz., Nos. 1 and 2. They are 30 inches long by $2\frac{1}{8}$ wide. There are 100 rows of holes in each, corresponding to the needles of the Jacquard, besides the needles which work the selvages at the extreme sides of the sixty pieces of lace.

It is in this manner that the Jacquard operates upon the warp threads and effects in the most exact manner all that is desired by the designer.

When the warp threads have been moved according to the arrangement of the cards, the meshes or twisted threads have to be beaten or combed together. This is done by means of two "point bars" placed at opposite sides of the lace, whose operation is similar to that shown at *c, c,* Fig. 6, and in Fig. 9, at *t, t.* The dotted lines *u* shows the path of the points as they descend, for it is only on their ascent that they pass through the lace and thereby comb the threads together. The point bars consist of a row of fine steel points of about fifty or sixty to the inch, and of course they extend the whole width of the lace. They are inserted into the lace and raised, and then removed clear of the lace and lowered by means of a combination of levers and two cams fixed on the cam shaft *C.* These cams operating upon the levers *n* and *m,* and turning upon their fulcrums *d* and *q,* accomplish the motion as above described. In the sketch, only the levers and cams connected with the back point bar is shown; the front bar being moved in a similar manner, it is unnecessary to show it.

Although the most important movements of the machine are those above described, still there are several others that require notice. The lace beam *E*, Fig. 9, is turned by means of the worm and wheel shown at *o*, Fig. 8. The worm is driven by means of a catch, which is moved by a cam and lever in connexion with the shaft *C*. There are three ratchet wheels of different pitch, or distances of the teeth, so that more or less motion can be given to the beam *E* under various circumstances. Temples are also used at each end of the lace beam, as in the common hand loom, for the purpose of keeping the lace stretched. The warp threads *A*, after passing through the perforated board *M*, are not carried up to the slide bars vertically, but are made to lean considerably on one side. This is for the purpose of keeping the thread pressed constantly on one side or edge of the holes in the bars—otherwise, unless the hole was exceedingly fine, there would be too much movement of the thread, and the spaces could not be moved through in an exact manner.

The front catch bar *K*, Fig. 9, is also shown at *J*, Fig. 8. It is provided with handles, so that the weaver can raise it clear from the carriages when he requires to remove them, or to repair any broken threads. The front point bar, in a similar manner, is raised by means of the lever *P*.

The machine is thrown in or out of motion by means of the lever *H*, which is connected to the fork or strap-guide at the pulleys on the driving shaft *A*.

The ends of the warp beams are shown below *D*. At the point *a* is shown the centre of the arc through which the landing bars move; and it is of the greatest importance, in fixing the machine, that the line from end of the frame from these points should be perfectly true.

The large springs *n*, *n* relieve the machine of the weight of the oscillating bars, and give them more freedom and ease in their rapid motion. The rocking shafts *a*, *d*, Fig. 9, are shown also *F*, *G*, Fig. 8, and are for the purpose of raising the point bars, as may be observed in the figures.

Before the application of the Jacquard machine to the lace frame, the organ barrel motion was adopted, but Mr. S. Draper, of Nottingham, having seen a Jacquard machine at work in the Adelaide

Gallery, London, at once attempted to apply it to the lace frame. This was in 1834 and 1835. He took out several patents and the first scarf made on the Jacquard principle is now in the Kensington Museum. In 1841 Mr. H. Deverill obtained a patent for an improved application of the Jacquard to the frame in which two griffe bars and one cylinder were used, and this is said to have been the first successful use of the Jacquard to lace making. A further improvement was made in 1842, by Wm. Catford, who used two cylinders, operating alternately upon one set of levers. In 1858, Mr. G. Pigott made further improvements by using wedges instead of studs of different lengths, and the machine before described is an improved modification of his invention. The object of having two cylinders and griffe bars is to obtain an easy and steady motion, and, in fact, nearly double the speed can be attained than is possible by a single action machine.

By means of Jacquard apparatus, not only can any desired arrangement for guiding the warp threads be made, but the bobbins and carriages can be governed by its means also. Separate pushers can be used to each bobbin; and by combining the "shogging" motion, as used in the bobbin-net machine, various effects can be produced. Even the warp threads have in some cases been dispensed with, and the bobbin threads, only, used for the making of lace.

For the manufacture of wide fabrics, such as curtains, a Jacquard apparatus is fixed on the top of the lace frame in a similar manner to an ordinary Jacquard loom, and the cords are carried down to the warp threads below the carriages and bobbins, but in place of having the slide bars, as before described, each hook of the Jacquard merely draws by means of jacks or guides, the warp thread one space only instead of from one to twenty, or upwards. By this means a very wide pattern can be woven, for a Jacquard, containing 600 needles, may be made to produce a figure several feet wide or several wide pieces or curtains can be made. But by this arrangement the figures have a flat appearance, for they are devoid of the principle of drawing the threads to various distances laterally. It will be evident that numerous modifications can be made in this excellent machine without deviating from the principle of its action.

CHAPTER XXXIII.

THE TRAVERSE BOBBIN-NET MACHINE—THE PRINCIPLE OF ITS ACTION—JOHN HEATHCOAT.

In 1808, Mr. John Heathcoat obtained a patent for a bobbin-net machine, being the first successful attempt to produce by machinery an imitation of pillow lace. The machine was provided with bobbins, placed in the form of a segment of a circle, and the threads from them were concentrated towards the centre of the circle. This arrangement was limited to the production of lace of only a few inches in width.

It occurred, however, to Mr. Heathcoat, shortly after he had satisfied himself of the accomplishment of the task, that, the bobbins should be placed in a straight line, when lace of far greater width could be made. He therefore at once turned his attention to the new plan, and in 1809 he obtained his second patent.

During a period of fifty years previously, numerous attempts had been made to accomplish the making of lace on the stocking frame, as will be hereafter alluded to; but that machine was not adapted to the purpose, and it is to the genius of Mr. Heathcoat that the traverse bobbin-net frame is due. He found out, after carefully watching the process of making lace on the pillow, that the operations required for making bobbin-net, consisted in placing one series of threads in a vertical position, around each of which a second series were twisted, and at the same time to traverse after each twist towards the right hand, whilst another series of threads after each twist traversed to the left. He, therefore, like William Lee, set himself the work of carrying out mechanically the various notions as actually performed in the process of making the lace by hand.

Lace made without this traversing motion would, in case a thread was broken, "run" or become undone. Consequently, the traverse has the effect of binding the parts firmly together, for on the breaking of a thread the "running" would be stopped by the repeated twistings in a diagonal direction.

The machine was completed at Loughborough, hence it was long known as the "Old Loughborough" Bobbin-net machine.

The complexity of the process was proverbial, so much so that Dr. Ure said of it that "bobbin-net surpasses every other branch of industry by the complex ingenuity of its machinery. A bobbin-net frame is as much beyond the most curious chronometer as that is beyond a roasting-jack."

In his work on the "Cotton Manufacture" the Doctor makes use of many pages, including eighteen diagrams, to show the principle only of the machine; but mistakes crept in which were corrected by several additional pages and diagrams, supplied by Messrs. Boden and Morley, lace manufacturers of Derby. The machine is doubtless of an intricate nature, but it is in this respect behind the Levers' frame.

As before stated, the action of the bobbin-net frame consists in arranging a series of threads in a vertical position, and twisting two other series round them, which after each twist has been made traverse to the *right* and *left*. Now this traversing to the right and left may be said to be wrongly expressed and misleading. Let it be said that the bobbins, with the traversing threads, travel or traverse to the right along one side of the cloth, and on reaching the selvage they turn round it and travel back again on the other side of the cloth, at the same time performing the work of twisting as they proceed, then the difficulty of understanding their motion will diminish. They appear to be travelling to the right and left, but really they are *making a continuous circuit*, or traversing first along the face and then along the back of the cloth, and twist round each of the vertical threads as they pass.

This operation will be readily understood by means of the diagram Fig. 15. It is not necessary to follow each motion of the bobbins step by step, by using a number of diagrams and a lengthy explanation, for it is believed that the various motions of the machine will be rendered self-evident when the simple principle upon which they act is represented.

In Fig. 15 the meshes of the net are shown as they appear when in the loom, when the tension on the vertical or warp threads gives them a harsh angular appearance; but when the cloth is taken from the loom they become of a true hexagonal form.

The machine consists of two comb bars *R* and *S* placed facing each other, and the upper surface upon which the bobbins and carriages slide are segmental in form. This form is to cause the threads, when the bobbins travel, to be always at the same distances from the point of intersection with the warp threads, for they move similarly to the oscillation of a pendulum.

Let *A, B, A, B* represent a series of warp threads passing through two guide bars *C, D,* through eyes placed alternately in each bar. By this means the warp threads may be moved laterally, half in one direction and half in another, or in any order that may be desired.

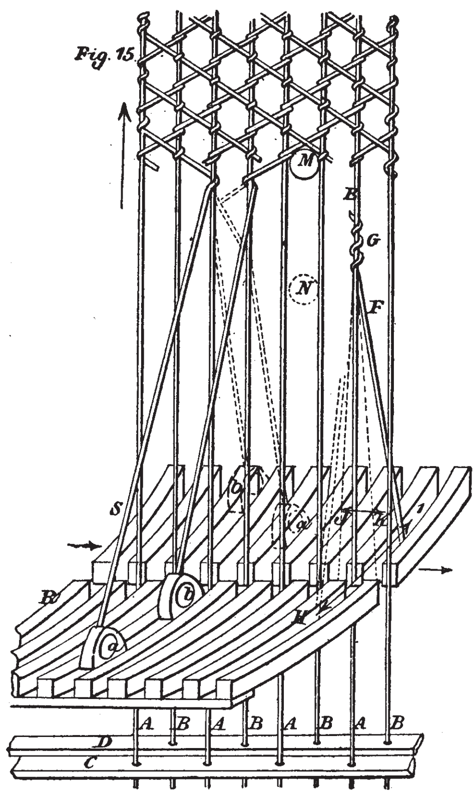
The bobbins and carriages are constructed in the same way as in the Levers Lace Frame, for Levers adopted Mr. Heathcoat's plan of making them. Therefore, let *a* and *b* represent two only of such bobbins and carriages placed in one groove of the comb *R*. These bobbins and carriages can be made to slide across the open space to the opposite comb *S,* as in the Levers machine. In the Levers machine there is only one row or *tier,* but in this machine there are two rows or tiers.

It is at this point where the two machines differ. The two comb bars *R* and *S* are not firmly fixed, but they are capable of being moved longitudinally as indicated by the arrows. Therefore, by this means if the bobbin *b* were pushed across to the opposite comb *S* then that comb could be moved to the *left,* and the bobbin would reach the place shown at *b*. In the meantime if the comb *R* be moved to the *right,* then the bobbin and carriage *a* would arrive at the point *a* on the comb *S,* as shown in both cases in dotted lines. In that position the two bobbins are no longer in the same line or groove but, by the "shogging" motion of the combs, as the longitudinal motion is technically called, they become divided. By this means if two lines of bobbins be placed upon the comb *R,* the whole of them may be made to pass from one comb to the other, and by means of the "shogging" motion being properly arranged, one line of the bobbins may be made to travel in one direction, whilst the other line travels in the opposite direction.

On the other hand, if the comb bars be kept stationary, and the bobbins be made to pass from one bar to the other, as at *H* to *I,* then if the warp thread *E* be drawn, by means of one of the guide bars *C, D,* across the path of the bobbin alternately, as from *J* to *K,* a twist round the warp thread *E* would be effected by the thread *F,* as shown at *G,* and it would continue to do so; but by the alternate action or " shogging " of the combs and the bars *C, D,* the twistings to form the meshes may be carried forward from thread to thread and the formation of the lace be accomplished.

The action of the bobbin-net machine therefore consists simply in the use of two lines of bobbins being made to travel from one comb to the other so as to break joint, as it may be termed, when they pass from one bar to the other. At the same time the guide bars *C D* move the warp threads. Thus the bobbins travel *round*

Fig. 15.



the cloth from edge to edge, as the diagonal threads in the diagram show, first along one side and then back along the other side; and by this traversing motion, threads from the bobbins being intercepted by the warp threads, as indicated in the sketch, the necessary motions are performed for the making of bobbin-net.

The return motion, when the bobbins reach the selvages of the cloth, is made by means of what may be termed a *switch* motion, for after the bobbin has twisted round the end warp thread it is thrown into the other line or tier of bobbins, and pursues its course until it again arrives at the same place.

It may be scarcely necessary to add that when one tier of bobbins has passed from one comb to the other a slight halt in their motion is made, to allow time for shogging the combs and moving the vertical threads before the other tier of bobbins are passed.

Vertical pin bars or combs, for beating or pressing together the meshes, are required, as in the use of the reed in the common loom, and as described in the Levers frame. One pin only is shown in section at *M*, where it has travelled to from *N*, carrying or combing together the mesh.

Since the expiration of Mr. Heathcoat's patent, in 1823, numerous modifications of the machine have been made, and one of the first and most useful may be mentioned as being still in common use.

In some machines spotted net is made, in which an ingenious contrivance is used. The spot is made by traversing the thread a number of times across the space occupied by a single mesh; and during the time this is being worked all the other twisting motions are suspended. But the thread so passing to form a spot would draw the warp threads together unless a special contrivance were used, for the strain, as indicated in Fig. 7, would be too great for the vertical or warp threads to withstand. This effect, however, is counteracted, for before the bobbin is allowed to pass, a flat wire (one to each spotting bobbin) is made to press against the bobbin thread sufficient to slacken off a small quantity; by so doing no strain is put on the thread, as would be the case if the thread had to be drawn off in the usual way.

The shogging is done by suitable cams placed at the ends of the comb bars; but when a greater number of movements are required, as in making spots, a chain of tappets or cams, like a Diggles chain (see Fig. 317), is used.

John Heathcoat was born at Duffield, near Derby, August 7th, 1783. He was the son of a small farmer who had the misfortune to become blind, in consequence of which affliction he removed with his family to Long Whatton, near Loughborough, about the year 1790. At this place he embarked some money in the purchase of warp machinery, which he let on hire to the smaller manufacturers in the neighbourhood, and it was from this circumstance that his son John became connected with the Hosiery manufacture. After leaving school he was apprenticed to a Mr. W. Shepherd, a Hosiery manufacturer and frame smith at Long Whatton, and was employed in making and fixing Hosiery machines. At the age of twenty-one he married the daughter of Mr. W. Caldwell, of Hathern, and removed to Nottingham, where he entered the employment of an excellent machine-maker named Elliott. He afterwards removed to Hathern, to join Mr. Caldwell and his son, who were also in the machine trade, when they all became engaged in making and carrying out a new invention. It was at this time that Mr. Heathcoat resolved in future upon devoting his energies to invention. On the completion of the machine alluded to, a patent was taken out for it in 1804, in the names of Caldwell and Heathcoat, "for a new apparatus to be attached to warp frames, whereby all kinds of thread lace may be made," but it was found afterwards that the invention had already been anticipated.

He now turned his attention to the long-sought problem of making pillow lace, which he completely mastered in 1809. Many attempts were made to show that he was not entitled to all the credit of the invention, but that certain important steps had previously been made by others which had led to the successful result.

The most important of these claims was in respect to the invention of the thin bobbin and carriage which was claimed for Robert Brown, a very ingenious man, who had constructed a fishing net machine. In this contrivance he had made use of thin bobbins, but the twisting of the threads as required in making bobbin-net is not at all mentioned in Brown's specification.

Mr. Felkin had ample means to arrive at the truth of this matter, and gives the sole credit of the invention to Mr. Heathcoat. He says, "that no model or actual machine, or combination of these or any other parts of Heathcoat's machine can be shown to have been previously put together, upon which bobbin-net *twisted and traversed from side to side* could be or ever had been made."

In order to carry out the making of the machines, and the manufacture of lace, Mr. Heathcoat took into partnership a gentleman named Lacy, who supplied the necessary capital. A factory was established at Loughborough, and the business proved highly successful, but Mr. Lacy, after realizing some 50,000*l.* therefrom, lost it all in mechanical experiments.

In 1816 the factory was burned down by a gang of Luddites, and machines valued at 10,000*l.* were destroyed. The Luddites took their name from one Ned Ludd, and they had for years been in the habit of destroying machines whenever differences occurred between the masters and their work-people. Several of them were hanged, and ultimately the league broke up.

To avoid further interference, Mr. Heathcoat determined to leave the district altogether, and having, during a visit to Devonshire, noticed a woollen factory at Tiverton that appeared suitable for his purposes, he transferred his work-people thither.

He took out several other patents, one amongst them being for a steam plough.

The business at Tiverton became thoroughly established, and after amassing a large fortune, he died in January, 1861.

As in the stocking frame and the Jacquard loom, numerous modifications have been made in the bobbin-net machine, but the essential principle upon which the twisting of the threads depends still remains unaffected by them.

CHAPTER XXXIV.

THE STOCKING LOOM—KNITTING BY HAND—WILLIAM LEE—INVENTION OF THE STOCKING LOOM—JAMES LEE—DESCRIPTION OF THE LOOM AND PROCESS OF KNITTING—JEDIDIAH STRUTT—BUTTERWORTH—FROST—CRANE'S WARP LACE MACHINE—DAWSON'S WHEELS—SIR M. I. BRUNEL'S CIRCULAR FRAME—BOSWELL'S FISHING-NET MACHINE—PATERSON'S.

WHEN the crude state which every branch of the mechanical arts was in previous to the 16th century is taken into consideration, it may be claimed for William Lee's invention of the stocking loom that it was one of the most extraordinary examples of mechanical ingenuity that has ever been achieved.

In every other process of weaving various threads are made either to intersect or to twist round each other, in order to bind or connect them together to form the web; but in stocking weaving, in its simple form, only one thread is used, and it is by this alone that a series of loops are made, in such a manner as to intersect each other, and thereby form the looped fabric which is the distinguishing feature of this system of weaving.

The invention of the stocking loom was not, as is generally the case, the result of the efforts of many inventors, but was the product of the genius and perseverance of one man.

As to the invention of the art of knitting by hand considerable uncertainty exists. It is not only a question of who the inventor was, but even the country in which it was first practised is not known. In Henry VII.'s reign knitted woollen caps were in common wear, and several Acts of Parliament were passed in that and the succeeding reigns relating to knitted articles. Previous to this time hose were made of cloth sewn to the proper shape, and Henry VIII. wore them of that kind, "except there came from Spain by great chance a pair of silk stockings." It is thought from this circumstance, and the fact that Sir Thomas Gresham presented the young

King Edward VI. with a pair of silk stockings, which probably came from the same country, that the art originated in Spain, or that the Spaniards may have learnt it from the Moors. Then there is the popular statement given by Stow, to the effect "that in 1564 one William Riley, apprentice to Master Thomas Burdett, having seen in the shop of an Italian merchant a pair of knit *worsted* stockings from Mantua, borrowed them and made a pair exactly like them, and these are said to have been the first stockings of woollen yarn knit in England." But it is said that worsted stockings were at that time made in England, and that they were probably silk stockings—coming from Mantua—that young Riley imitated, and which were worn by the Earl of Pembroke. To this may be added the well-known story of Queen Elizabeth, who was presented in the third year of her reign with a pair of black silk stockings by Mrs. Montague, the Queen's silkwoman, whose assistants had become "so dexterous in knitting that from thenceforth Elizabeth never wore cloth hose any more."

Beckmann refers to many other circumstances relating to the early history of the subject, from which it would appear that towards the end of the reign of Elizabeth knitting had become a most important branch of industry, and from its nature it was admirably adapted for domestic employment. It was not only practised as a common household requirement, but numbers of persons were engaged and employed by masters who carried on the business on an extensive scale.

To this period may be traced the rise of the manufacturing arts in England. Weaving and spinning had been introduced, and were widely practised, but machines of an automatic nature may be said to have been unknown. The various manufactures depended upon the handicraft skill of the workman, for he had little assistance from any mechanical contrivance. A change, however, was about to take place, the effect of which is in full force at the present day. This was caused, it need scarcely be said, by the invention of the stocking-frame by William Lee. The great peculiarity of this invention is that it is probably the first of any kind for the purposes of manufacture that may be classed as an automatic machine.

Respecting the life of William Lee many conflicting accounts are given. It appears that he was born at Woodborough in Nottinghamshire, but as the Parish Register only commences in 1547, it does not contain an account of his baptism. "He is said to have been heir to a good estate, and was matriculated as a Sizar of Christ's College in May, 1579. He subsequently removed to St. John's College, and as a member of that house proceeded B.A., 1582-3. It is believed he commenced M.A. 1586, but on this point there appears to be some ambiguity in the records of the University. In 1589, at which time it is stated he was Curate of Calverton, about five miles from Nottingham, he invented the Stocking Frame." This statement was given to Mr. Felkin by Mr. Cooper, the late town clerk of Cambridge.

Concerning this period of his life many romantic tales are told—his secret marriage and expulsion from the University—his depending upon his wife's earnings by knitting for a livelihood—his watching intently the process, and ultimately, after innumerable other incidents, inventing the machine to relieve his wife from further labour and bring wealth and prosperity as well as the patronage of their Sovereign Lady the Queen! Unfortunately the few facts that are known make sad havoc with these happy legends, for there is no proof that he was ever married, and after years of patient toil, instead of wealth and patronage being his lot, he was driven to a foreign country, where he died in obscurity and poverty!

In 1833, Dr. Ure, assisted by Mr. Felkin and other gentlemen of Nottingham, made a thorough inquiry respecting the history of the Lee family, and all information that could be obtained about Lee and his invention. Unfortunately nothing of importance was added to what was already known; but the Doctor gave his opinion that the following is the more probable statement of the case.

"It being an ancient tradition around Woodborough, his birthplace, that Lee in youth was enamoured of a mistress of the knitting craft who had become rich by employing young women at this highly prized and lucrative industry. By studying fondly the dexterous movements of the lady's hands, he became himself an adept, and had imagined a scheme of artificial fingers for knitting many loops at once. Whether this feminine accomplishment excited jealousy or detracted from his manly attractions is not said; but his suit was received with coldness, and then rejected with scorn. Revenge prompted him to realize the idea which love first inspired, and to give days and nights to the work. This ere long he brought to such perfection as that it has since remained without essential improvement, the most remarkable stride in modern invention. He thus taught his mistress that the love of a man of genius is not to be slighted with impunity."

Be that as it may, it is admitted that having become curate of the church of his native village of Calverton, it was there that the invention was carried into effect. Nottingham, at that time, as at present, was famous for the skill of its artisans, and with their help and the assistance of his brother, he applied himself for about three years to the task, and in doing so, had expended not only a large portion of his patrimonial means, but had even suffered privation from the cause. At last the machine was completed, in the year 1589, and was worked for about two years, but finding a prejudice against it, he removed it to London, where it was set up in a house in Bunhill Fields, St. Luke's, where he met with varying success. In order to secure the profit arising from his loom, he endeavoured to obtain a patent from the Queen (Elizabeth) who had heard of the new invention through her kinsman, Lord Hunsdon, and she consented to see the machine. For that purpose she went to Lee's lodgings in Bunhill Fields, accompanied by Lord Hunsdon and his son, and there saw it worked by Lee or his brother. She expressed her sense of the ingenuity of the invention, but was evidently disappointed when she found it was knitting coarse worsted and not silk hose. Lord Hunsdon, however, had faith in the enterprise, and not only assisted Lee, but endeavoured to obtain a patent for the invention. After repeated applications Elizabeth refused to grant a patent, and in reply to Lord Hunsdon, said, "My Lord, I have too much love for my poor people who obtain their bread by the employment of knitting, to give my money to forward an invention that will tend to their ruin, by depriving them of employment, and thus make them beggars. Had Mr. Lee made a machine that would have made silk stockings, I should, I think, have been somewhat justified in granting him a patent for that monopoly, which would have affected only a small number of my subjects; but to enjoy the exclusive privilege of making stockings for the whole of my subjects is too important to be granted to any individual."

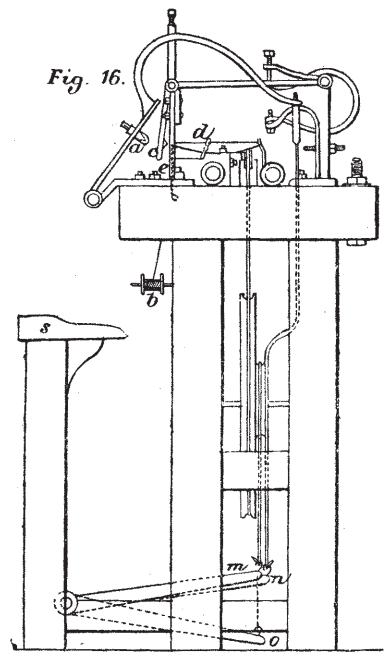
It was evident that the Queen was disappointed with the first products of Lee's invention, but he did not lose the hint concerning the silk stockings. At last, in 1598, he succeeded in making a machine by which he made a pair, and he presented them to the Queen. But it added nothing to his advantage, and he obtained no patent. Other misfortunes fell upon him. Lord Hunsdon died, upon whom he had hitherto depended. He was neglected and fell into a deep melancholy. Some time afterwards he was invited over to France, by the minister of Henry IV., and he went, taking with him his machines. Before he could make arrangements for establishing his new business the king was assassinated. Lee thereby lost all hope, and died in Paris in 1610. During his illness, Mr. James Lee, a brother of William, who was at that time at Rouen, where it was intended to carry on the manufacture, went to Paris, but he found on his arrival that his brother was dead and buried. On his return to Rouen he, with seven of the workmen who had gone with them from England, returned to London, taking with them the machines they had brought. These machines were set up in Old-Street Square, and became the foundation of the London Hosiery Manufacture. Thus, the business narrowly escaped being introduced into France, but was fortunately brought back in time to prevent it. The machines were sold, and Mr. James Lee went to Nottingham, for the purpose of making more. He found out one of his brother's old apprentices, named Aston, who was at the time in business as a miller. They joined in partnership, and began making new frames in 1620. It appeared that Aston had made an important improvement in the machine by dispensing with a set of "sinkers," and this was perhaps the first and probably the best improvement that the machine in its simple form has ever received.

In 1621, the Venetian ambassador in London engaged one of James Lee's apprentices to go to Venice and establish the business there, and James Lee was paid 500*l.* for releasing his apprentice, and providing a machine for him to take with him. But the enterprise failed altogether, for although the Venetian smiths were excellent workmen, they were not equal at that time to the task of making or repairing a stocking frame.

From this period the business rapidly extended, and in 1657 the Company of Stocking Weavers, or "Frame Work Knitters," obtained their charter. London, Godalming, and Nottinghamshire were the chief seats of the trade. For a long time disputes were of frequent occurrence, owing to the custom of taking great numbers of apprentices and learners, which gave rise to competition of a very severe and impoverishing nature. Various attempts were made to improve the condition of the trade, and to prevent it being carried abroad, but with little or no effect. Some slight improvements had been made in the construction of the machine, from the time of Aston's, but it was not before the middle of the next century that various additions were made to the frame by means of which considerable changes were made in the fabrics produced.

An ordinary stocking loom is shown in Fig. 16, which represents an end view of the machine. The working parts are supported on a framework of wood, opposite to which is placed a seat *S*, for the workman. The thread is supplied to the needles, or hooks *e*, from the bobbin *b*. The handles of the frame are shown at *c*; the presser bar to close the hooks at *a*, which is pressed by means of the treadle

Fig. 16.

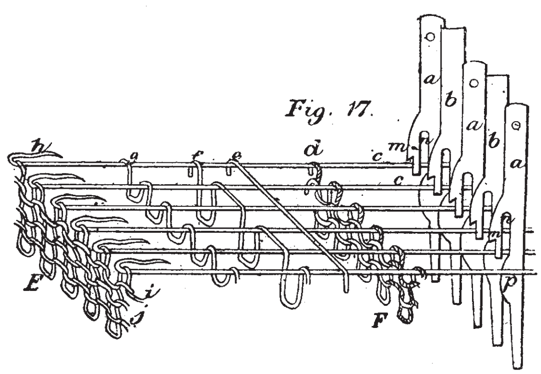


n. The treadles *m* and *o*, are for "drawing the jacks," and are attached to a cord passing round the smaller of the two pulleys fixed upon a shaft in front of the weaver, as seen in the sketch. The cord used for drawing the jacks passes round the larger pulley, so that the treadles can draw the required length of cord.

The action of the machine will be readily understood by referring to the diagram Fig. 17. In this sketch the needles, or hooks, are drawn considerably longer than used in the machine, in order to give space to show each separate operation required for the formation of a row of loops. Only six hooks are shown, and between each will be seen the thin curved plates or "sinkers" *a*, *b*.

Each of these sinkers has an "arch" or hook *n*, and a projection *p*, also a "nib" shaped like a saw cut formed upon it. Every alternate sinker *b*, *b*, is fixed to a bar, and they can be depressed between the needles *c*, *c*. All the sinkers can be depressed together or be drawn forwards towards the hooks *h*. The sinkers, marked *a*, *a*, are each separately fixed to the end of a lever or "jack," consequently they are called the jack sinkers, and they can be depressed separately.

Let it be supposed that a portion of work has been woven, as shown at *d* and *F*, and it is required to add another row or line of loops to it. Then the first operation of the weaver will be to draw the thread over the hooks as at *e*. But when this is done the sinkers *a*, *b*, *a*, *b*, are shifted so that the cloth *d*, *F* is placed beneath the arches *n*, *n*, and not in the position shown in the sketch, which is



drawn so merely to prevent confusion. Therefore the thread *e*, really passes under the nibs *m*.

The action of the machine is as follows :—After the thread is laid as shown at *e*, the jack sinkers *a*, *a* are depressed—say an inch deep. By that means the thread will be forced down between the needles as shown at *f*. Then by again raising the jack sinkers and afterwards depressing *all the sinkers together*, *a*, *b*, *a*, *b*, the thread will be sunk as shown at *g*, but of course to only half the depth of the sinkings at *f*. Then by advancing the sinkers *a*, *b*, *a*, *b*, the thread *g* is pushed under the hooks *h*, and the presser bar *a*, Fig. 16, is now pressed down upon them, which has the effect of closing the opening at the point of the hooks. It will now be evident that by advancing the fabric *d*, *F*, by means of the curved part *p* of the sinkers *a*, *b*, it can be *pushed over the ends of the hooks* and thereby passed over the loops *g*. Thus *the loops* g *will form the top row of loops*, and by means of the arch or hook on the sinkers the work *E* can be drawn back to the position *F*, and the process be repeated. It may be mentioned that the points of the hooks are pressed into a hollow or groove made in the needles, so as to allow the web to slide freely over them.

It will be noticed that in sinking the thread as at *f*, the sinkers *b*, *b* must be sunk only one at a time, otherwise the thread could not be depressed as shown. To do this the cord from the larger pulley draws backwards and forwards a sliding wedge or "slur," which raises the opposite ends of the jacks as it passes beneath and consequently depresses the sinkers at the other end. By this means the thread is sunk between the needles in consecutive order from side to side of the machine. This operation was done by William Lee by means of a separate set of sinkers, but by attaching each alternate sinker to a series of levers, the special set, as provided by Lee, was dispensed with. This was the improvement made by Aston, who joined James Lee in the business in 1620.

It is the action of the "slur" upon the jacks and sinkers that causes the peculiar grating noise so well known in connexion with stocking weaving.

The thread is used without breakage in a continuous length, and is passed by hand from side to side of the machine. But it will be evident, as in ordinary weaving, that the thread may be changed for one of a different colour or texture, or various threads may be used alternately, and thereby vary the appearance of the work. The width can also be varied according to the distance the thread is carried over the needles, and thus the shape of the stocking web is made before being sewn or looped together. The tops and heels of stockings as well as wristbands are made by transferring the web to another machine adapted for it, for looped work can be easily transferred and joined to other work by simply forcing the web upon the hooks and proceeding with the loops as above described.

It may be easily seen that by means of a pin any of the loops may be removed from its hook and transferred to the adjoining hook or to one further off still, and yet at the formation of the next series or row of loops all would be bound together. By means of a pin or point, called a "tickler" needle, fixed in a small handle, numerous variations can be made in this way and patterns be formed.

Various numbers and different arrangements of tickler points may be fixed into a movable bar placed opposite the hooks, and by their means numerous effects can be produced, such as ribs, twills, &c. Thus in Fig. 18 a bar containing the same number of tickler needles as hooks has been used. It has been inserted under every loop and by raising (as shown at *d, d* and *i*, Fig. 22), and then "shogging" or moving the loop sideways to the left hand; and placing the loops so raised on the adjoining hook, has produced the effect shown at *a, a*, Fig. 18, where it will be seen that each loop now covers two hooks, and not one only as shown at *a, a*, Fig. 19, before the ticklers were used. Fig. 20 shows the hooks *a*, about half full size, with a section of the slide bar *l*, containing the tickler needles *r*, in the act of moving a loop, and at the same time enclosing a separate thread, shown in section at *i*, also seen in front view at *i, i*, Fig. 19.

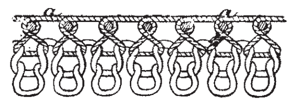
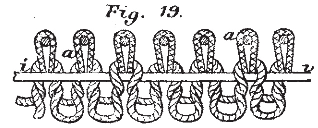


Fig. 18

Fig. 19.



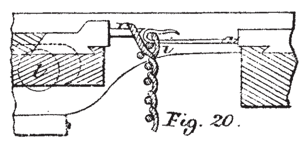


Fig. 20.

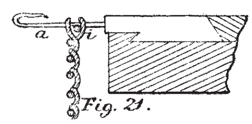


Fig. 21.

Fig. 22.

In this case the thread so enclosed may be an elastic or other cord, and thereby produce an elastic or a stronger material. Fig. 21 shows in section the cord after it has been inserted at *i* on the hook *a*.

Not only can tickler points be used, but different arrangements of hooks can be inserted, and the loops transferred in a similar manner. Thus a ribbed or striped appearance can be produced; for it will be observed in knitted work that the back of the web is different in appearance to the front. Therefore by reversing the loops from one, two, or more hooks, in any order desired, a series of narrow or wide ribs can be made, as in ribbed stockings.

This plan was the first important modification of the stocking frame, and was made in 1758, when Mr. Jedidiah Strutt added to the frame an apparatus by means of which ribbed goods could be made. The contrivance was called the "Derby rib machine." The advantages derived from this invention were so great that the attention of many ingenious men was directed to it, with a view to still further improvements. Numerous inventions were the result, and they met with more or less success. One of the most important of them was that patented by Morris and Betts in 1764, "For making by a machine fixed to a stocking frame eyelet holes or net work, having an additional row of frame tickler needles."

This invention, although patented by Morris and Betts, was the work of one Butterworth, a stocking weaver at Mansfield, who having devised the plan had to reveal it to Betts, a smith, for the purpose of getting the working parts made; Butterworth was unable to find money for the patent, so Betts obtained it from one Shaw, and in conjunction with T. and J. Morris took out a patent in their joint names. When the three were in London, Betts sold the entire interest in the patent to Morris, so that not only Butterworth was robbed of his invention but Shaw also of his money to pay for the patent.

The history of many inventions during this period of the progress of the manufacturing arts is unfortunately disgraced with conduct of this kind, and even such men as Arkwright did not hesitate to use the inventions of others and claim them as their own. Not only were inventions pirated or infringed in the most shameless manner, but in some cases the inventors were deliberately ruined in various ways, so that they were unable to defend their claims. In one instance, it is related, that in order to obtain possession of a new invention a press-gang was actually sent from London to seize the inventor, and he only escaped through the timely information given him by a magistrate's clerk who knew of the proceeding.

In 1769 the first figured lace-web was made by Mr. Robert Frost on a frame arranged by Thomas Taylor of Nottingham. This led to further improvements and a Mr. Broadhurst of Nottingham improved Frost's machine by reversing its action. In 1771, Marsh and Horton took out a patent for knitted or knotted hosiery, which was further improved upon by Horton in 1776. He aimed at and succeeded in knotting every loop of the web, thus making an elastic and sound fabric that would not run when the thread was broken.

A most important and curious modification of the stocking frame was made in 1775, by a Mr. Crane of Edmonton, which has since given rise to numerous improvements and adaptations for the production of both useful and fancy articles. The invention consisted in the application of a warp to the stocking frame. Each warp thread was threaded through an eye made in the end of a guide pin, and there were as many warp threads and guide pins as hooks in the stocking frame. There was also a contrivance to plait or loop each separate warp thread, in a similar manner to chain-stitch, or the way children plait a single string. But this operation of itself would merely plait each string, and the result would be so many separate plaited threads.

Now, by the movement of the guides to the right or left, the loops on each string were joined or connected with the loops on the adjoining threads, and by various movements a great variety of work could be produced, although the web has not the advantage of being elastic.

In the various modifications of the stocking frame, for the purpose of producing figured work, numerous plans were adopted, either by moving by hand or arranging in various ways tickler needles for the purpose, and notching the presser bars to act upon certain hooks, &c. But it occurred in 1790 to a framework knitter, William Dawson, of Leicester, that the edge of a wheel might be notched in such a manner that when rolled over the parts controlling the figure it would act upon them accordingly, and produce a similar effect as the use of pegs in a barrel organ. These wheels are admirably adapted for circular machines, and are still known as "Dawson's wheels." This talented man produced "a machine for making all kinds of hosiery," which was patented in 1791, and on the expiration of the patent he applied for an extension of it, but being refused he destroyed himself.

The numerous modifications of the stocking frame that were made during the latter part of the last century and the beginning of the present, led to the invention of the bobbin-net machine by Mr. Heathcoat, and the Levers Lace Frame described in Chapters xxxii. and xxxiii.

In the year 1816 Mr. Brunel (afterwards Sir M. I. Brunel) obtained a patent for a circular knitting machine, which he termed "The Tricoteur." The machine consisted in placing the needles on the external rim of a frame or ring, which is suspended and fixed to a spindle, so that as the fabric is knitted in the form of a tube it can be removed from below the machine. The needles and other working parts of the machine operate in exactly the same manner as in the ordinary knitting-frame, excepting that the thread is supplied by one or more feeders revolving round the frame; and a small wheel which travels with the thread operates upon the needles as it revolves round the fixed wheel to which the needles are attached.

The machine could be made of any diameter, even large enough for "the largest carpets," and several sets of wheels, with a bobbin to supply the thread, &c., as before mentioned, may be applied to work at one and the same time, so that an expeditious and uninterrupted working could be carried on. The instrument could be put in motion, says Mr. Brunel, "by hand or by machinery connected with it;" and at the present time the principle of applying a circular action to the knitting-frame is in very extensive use, from its being so well adapted to be worked by power.

In Lee's first machine it is said that there were only twelve needles or hooks, occupying a space of eight to an inch. Now they are made to contain as many as thirty and upwards per inch, and of various sizes.

By hand-knitting about 100 loops may be formed in a minute by a skilful knitter; but Lee succeeded in producing 1500 loops in that time. Circular machines have been made to produce nearly 300,000 loops per minute, or equal to 1200 square yards of webbing per week.

Sir M. I. Brunel was born at Haqueville, Normandy, in 1769. He entered the French navy, but during the Revolution he, being a Royalist, emigrated to the United States. In 1799 he came to England, where he constructed the well-known Block-making machinery at Portsmouth, for which the Government awarded him 16,000*l*. Numerous other inventions were carried out by him, including nail-making machinery, veneer cutting, shoemaking machines, &c. Amongst the various engineering works upon which he was engaged mention of the Thames Tunnel is sufficient to show his great ability and versatile genius. He died in 1849, aged eighty.

Stocking knitting, similar to that done on the common frame, is now extensively worked by power. The machines are constructed so as to comprise about six ordinary frames in one; consequently, one workman can produce an equivalent amount of work. During the introduction of these machines a difficulty was found in supplying the thread to the hooks at an even tension, which is an important matter. This was at last overcome by passing the thread through two eyes, and suspending a small wire ring, of any required weight, on the thread between the eyes. By this means *the slack was always taken up*, and an equal tension given at all times to the thread, and at once did away with a great amount of complicated and expensive contrivances. See also the doubling-frame, page 392.

In the account of the introduction of the Jacquard machine, page

145, mention is made of Jacquard's attempt to produce a net-making machine, in order to compete for a premium offered by a society in England. It appears that the Society of Arts (no doubt the Society Jacquard alluded to) awarded a premium of fifty guineas, in 1795, to a Mr. J. W. Boswell for the invention of a machine for that purpose, in which loops were made in a similar manner to those made by the stocking frame, and a binding thread was, by means of a wire hook, drawn through them and a true knot was formed. It does not appear that any use was made of this invention by Mr. Boswell; but a similar system was introduced in Scotland and extensively used, as will be seen from the following account given by Mr. Brenmer.

James Paterson, a cooper at Musselburgh, being connected with fishing and conversant with the making of nets, patented a machine in 1820, and established a factory for making nets in Musselburgh. He had been in the army for many years, but leaving it after Waterloo he devoted his time to carrying out the idea he had long entertained of being able to make nets by machinery, and in which he ultimately succeeded.

In 1839 Mr. Paterson had eighteen looms at work; and about that time his manager, Mr. Low, succeeded in making an improvement by producing the knot similar to that formed in hand-made nets.

In 1849 Messrs. J. and W. Stuart acquired Mr. Paterson's works and patent-right, and they have further improved the machine so as to make nets with much smaller meshes.

Each loom requires the space of three or four common power-looms, but resembles the ordinary knitting frame, some portions being identical in shape and name, having hooks, needles, and sinkers, one each being required for the making of every knot. They are from six to eight feet long by six high. There are about 600 looms in Scotland. Cotton twine is used for machine-made nets, and is found to last for nine or ten years, or nearly twice as durable as hemp-made nets.

The mode of working the loom is as follows:—"The operative moves a lever which draws the last completed row of meshes off the sinkers, and transfers them to the hooks. Another lever is moved and the meshes are caught by the levers. The effect of these changes, and the movement of the other parts of the machine, is to twist the lower part of each mesh into a loose knot. The foot of the operative touches another lever and a steel wire is thrust across the machine through all the knots. There is a hook at the end of this wire—or shuttle as it is called—into which the end of a piece of twine is fixed. The wire is then withdrawn, and as it goes takes the twine along with it.

"Now the sinkers play their part. They consist of thin slips of brass, having a hook or notch formed on the upper end, and are situated between the needles. When the twine has been drawn across through the loops of the meshes the sinkers are released in succession, and as they descend each draws down the cross thread into a loop sufficient to form two sides of a mesh, the other two being formed by the same parts of the previous row. One or two movements more remove the knots off the needles and draw them firmly, thus completing the operation.

"In forming each row of meshes the worker has to press upon half a dozen levers in succession, and pass from one end of the machine to the other."

CHAPTER XXXV.

SUBSTANCES USED FOR WEAVING—COTTON—FLAX—WOOL—HAIR—JUTE—SILK—PROCESS OF SPINNING—SILK CULTURE—SHODDY—SELECTING DIFFERENT FIBRES FROM WASTE FABRICS—DRESSING MACHINE—WILLIAM RADCLIFFE—SIZING MACHINES, ETC.

THE most important substance at present used for the purpose of weaving is cotton. It is not only used separately, but is often combined with flax, wool, silk, and other fibres. Sometimes they are mixed and spun together into a thread, but in ordinary cases they are spun separately—the cotton being used for warp and other materials used for weft. Formerly, to almost within a century ago, cotton was used only as weft, the warp being of linen.

The cotton plant is a native of India, where its manufacture into articles of clothing was carried on long before any allusion to it occurs in history. It was, also, cultivated and used to a great extent by the Egyptians and other ancient nations. England is said to have been the last nation in Europe to adopt its use, although it was applied here for making candlewicks before the year 1298.

In consequence of the extraordinary advancement made in cotton machinery the demand for cotton wool has been proportionately extended, and various countries are extensively employed in its growth. At the present time the Southern States of America not only produce it in the largest quantities, but the best in quality.

The value of the unmanufactured and manufactured cotton imported and exported from the United Kingdom probably exceeds all other textile materials and manufactures combined, as may be seen by referring to the Tables in the Appendix. Its importance as an article of general use and adapted for clothing purposes far exceeds all other known substances.

The vast extent of the cotton manufacture now carried on in various countries, and the quantity of cotton wool used therein, are shown in following tables as given by Messrs. Ellison and Co., in their "Annual Review," the best authority on such matters of the cotton trade, for the season 1876—1877, respecting the total amount of cotton consumed and the number of spindles employed. The amount per spindle depends upon the thickness of the yarn spurn.

	No. of spindles.	lbs. per spindle.	Total lbs.
Great Britain .	. 39,500,000	33	1,303,500,000
Continent .	. 19,500,000	53	1,033,500,000
Total Europe .	. 59,000,000	40	2,337,000,000
United States .	. 10,000,000	63	630,000,000
Grand Total .	. 69,000,000	43	2,967,000,000

Cotton Mills of India.

1,231,000 spindles; 10 to 11,000 looms; 75lbs. per spindle.

	Spindles.	lbs.	Cotton consumed. Bales, 390lbs.
1861 . .	338,000	25,350,000	65,000
1877 . .	1,231,000	92,325,000	237,000

Messrs. Ellison and Co. estimate the probable import of cotton into Europe 1877—1878 as follows:—

American	. 1,314,000,000
East Indian	. 472,500,000
Egyptian	. 270,450,000
Brazillian	. 65,600,000
Sundry Mediterranean .	. 35,000,000
Peru, West Indies, &c. .	. 18,450,000
Total lbs. . .	. 2,176,000,000

The average consumption of cotton and the number of spindles employed on the Continent at the same period is estimated at:—

	Spindles.	lbs. per spindle.	Total lbs.
Russia and Poland .	2,500,000	65	162,500,000
Sweden and Norway	310,000	80	24,864,000
Germany . . .	4,700,000	55	258,500,000
Austria	1,558,000	67	104,386,000
Switzerland . .	1,850,000	25	48,250,000
Holland . . .	230,000	60	13,800,000
Belgium . . .	800,000	60	48,000,000
France . . .	5,000,000	48	240,000,000
Spain . . .	1,775,000	48	85,200,000
Italy . . .	880,000	67	58,960,000
Total . .	19,603,000	53.2	1,044,460,000

The approximate value of cotton factories is generally estimated at 1*l.* per spindle; thus a factory containing 80,000 spindles would represent in round numbers 80,000*l.*

One acre of ground will produce 100 lbs. of cotton, and this amount when spun into yarn can be woven by one power-loom weaver in about a fortnight.

Cotton yarn is made up into hanks of 840 yards each, and the designation or No. of the yarn is named from the number of these hanks that go to make up a pound.

At the beginning of the present century No. 150 was considered to be the utmost degree of fineness that cotton could be spun into, and one pound of it would extend a distance of seventy-one miles.

The finest yarn ever spun in the East does not exceed No. 400, but in England as fine as No. 600 is spun for useful purposes; and at the Great Exhibition, 1851, Messrs. Houldsworth exhibited an experimental specimen of the extraordinary fineness of No. 2150. A single pound of this yarn would reach 1026 miles; but for practical purposes it would be useless. Mr. Houldsworth has ascertained that in No. 2000 there are only four fibres of cotton that compose the thread, which is perhaps the utmost limit of their power to cohere together. No higher than No. 800 could be made into a hank.

No. 540 single and 670 double are the finest that have ever been woven, the former producing the most beautiful muslin ever made.

In the reports of the jury on the linen manufacture (Class 14), Great Exhibition, 1851, it is stated that—

"The specimens from Ireland are also very creditable; that spun by Jane Magill, eighty-four years of age, being the finest (760 leas), and that by Ann Harvey (about 600 leas) being the most perfect in quality and spinning." They were awarded 10*l.* each.

A "lea," or cut, contains 300 yards, and ten leas, or 3000 yards, equals one hank. 760 leas would amount to nearly 130 miles per lb.

The old process of spinning the thread from cotton by the distaff and spindle, was first to pick and clean it from dirt and impurities. It was then brushed or carded with coarse wire brushes. The carding was done by hand-cards about twelve inches long and five inches wide, the carder holding one in each hand. The cotton, after being picked and cleaned, was spread upon one of these cards and brushed, scraped, or combed with the other, until the fibres of the cotton were all disposed in one direction. If was then taken off in soft fleecy rolls about twelve inches long and three-quarters of an inch in diameter. These rolls, called cardings, were converted into a coarse thread or roving by twisting one end to the spindle of a hand-wheel, something similar to that shown in Fig. 35, by turning the wheel, which moved the spindle, with the right hand, and at the same time drawing out the carding horizontally with the left. The motion thus communicated to the carding twisted it spirally; when twisted it was wound upon the spindle; another carding was attached to it, drawn out and twisted: thus was formed a continued coarse thread or roving, the spindle performing two operations, namely, spinning or twisting the thread and winding it up afterwards. The rovings were then taken to the spinner to be converted into weft. The hand-wheel was again used for this purpose, and the rovings were drawn out into fine yarn nearly in the same manner as the cardings were made into rovings.

These two processes were necessary, because the cardings could not otherwise be drawn out fine enough into a level and even thread fit for the loom by one operation only.

By the introduction of cotton machinery during the last century the above-named processes had been closely imitated by automatic means. The carding is done by rotary motion, and the drawing out of the fibres is accomplished by means of rollers, as will be hereafter shown. Within the last thirty years a combing machine has been introduced into the cotton manufacture, by means of which longer fibres can be worked, which could not be done by carding, and much finer yarn thereby produced. This invention was made by M. Heilmann, of Mulhouse, in 1846, but he died in 1848, before reaping any advantage from it.

Wool, hair, and flax are, also, materials of the highest importance in the textile manufactures, and within the last fifty years a new material, jute, has been introduced from India and most extensively used. The preparation and spinning of these substances are analogous to the processes adopted in the cotton manufacture, and, in fact, are in many respects modifications of them.

The peculiar property of felting, which makes wool so valuable, arises from the circumstance that each single hair is covered with scales attached at their bases only to the cylindrical part of the hair, and each scale pointing towards the point or tip of the hair. If the hair be bent and examined by the aid of a microscope, the scales will be seen to be detached from the body of the hair except at the base. Now, if two of these hairs be placed reverse ways together—the point of one being at the base of the other—the scales will be found to interlock if the the hairs are drawn in opposite directions, with the scales facing and touching each other.

In all countries except Egypt wool was greatly esteemed. The property of felting more important in short staple wool, and in the merino species the scales number three or four thousand per inch of fibre, but in long and coarse wool about two thousand scales per inch are found.

If a quantity of wool be spread in a layer, and wetted and beaten with a flat piece of wood, the fibres will interlock into each other and form a felted cloth, and by this means boots, coats, hats, &c., can be made; but the oldest remains of woollen clothing have been woven and not felted.

The annual consumption of wool is more than 350,000,000 pounds.

Wool has been spun by hand into remarkably fine yarn, and a Miss Ives, of Spalding, is said to have produced 168,000 yards, or 95½ miles of yarn from a pound of wool, or more than four times finer than ordinary superfine yarn.

Long-staple wools are for cloths called *worsted* goods, and short-staple wools are for woollen goods.

Gold and silver wire, horse-hair, willow shavings, asbestos, and even glass are also used for weaving purposes. The last-named substance was introduced about thirty years ago, but was, notwithstanding its brilliant appearance when woven as damask wall-hangings, soon discarded on account of small broken pieces of fibre flying off and entering the lungs and causing great irritation.

The most beautiful of all materials used for weaving purposes is silk, and it displays to the best advantage the art of the weaver. Its preparatory processes are also the most simple required by any of the textile substances, and as it is desirable to show the process of spinning, upon which in a great measure the beauty and quality of all cloth depends, the throwing of silk is, as in the case of weaving, therefore selected. Automatic spinning machinery was applied to silk long before it was invented for cotton, the former substance being, in consequence of the great length of its filaments, more adapted for the purpose, and the carding and combing processes, excepting for *waste* silk, are not required.

Mention is made of the silk manufacture in England so early as the year 1363, in an Act of Parliament passed in the reign of Edward III., but it was then of very slight importance. In France it was not introduced for more than a century later; but during the 16th century the mulberry-tree was extensively cultivated there, and the manufacture of silk was encouraged to such an extent that titles of nobility were conferred upon some manufacturers who had persevered and had been successful in the business. James I. of England observed that the French were deriving great benefit from this comparatively new manufacture, so he determined to encourage the trade in England. For this purpose he sent letters to all parts of the country recommending the people to cultivate the mulberry-tree, and it became fashionable to do so. Thus it is related of Shakespeare, Milton, and others having planted trees of that description. The king, also, by a like proceeding requested his subjects in the American colonies to cultivate the mulberry-tree instead of that "detested weed" tobacco. He encouraged Mr. Burlamach, a London merchant, to introduce throwsters, weavers, and dyers from the continent, and in 1629 they became of such importance that the throwsters formed themselves into a company under the name of "The Master, Wardens, Assistants, and Commonalty of Silk Throwers." In 1661 they are said to have increased to such an extent in London that 40,000 men, women, and children were employed in the business. But this statement, although mentioned in the preamble of an Act of Parliament, is probably very far from being correct.

Although the cultivation of the mulberry-tree was encouraged, it does not appear, from that time to the present, that the production of silk has ever been in England attended with any degree of success. The raw silk, therefore, upon which the manufacture depends, is procured from countries more favourable for its production, and large quantities are imported from Italy, India, China, and Japan. Before silk throwing became well understood in England the silk imported, at that time from Italy, came already thrown or spun. At first the English throwster could only spin "tram," or the most simple process of spinning as required for weft. The "organzine" used for the warp was for a long time afterwards imported ready thrown.

In 1702 a gentleman named Crotchet thought he saw a good opening for profit-able speculation ; he, therefore, erected a small silk mill at Derby, but he did not succeed, and he became insolvent. Some time afterwards Mr. John Lombe, who was a good draughtsman, went to Italy to obtain the secret of the process, and he succeeded in doing so by corrupting the workpeople at one of the Italian mills. His plans were discovered and he had great difficulty in making his escape.

On arriving in England he fixed upon Derby where to commence the business, and rented from the Corporation of that town a small island formed by the river Derwent, where he built a new mill adjoining the one lately used by Mr. Crotchet. During the building of the mill he obtained the use of the Town Hall, in which he carried on the process under protection of a patent obtained in 1717, with such great success that it is said the new mill was gradually built and filled with machinery from the profits derived from the work done in the Town Hall![1]

In three or four years after he had obtained his patent John Lombe died, when the proprietorship devolved on his brother William, and subsequently to his cousin Thomas, who afterwards became Sir Thomas Lombe, and who obtained 14,000*l.* from the Government in lieu of an extension of the patent. Hutton says that the Lombes had amassed 80,000*l.* before the expiratian of the patent.

One of the conditions the Government exacted for the payment to Sir Thomas was, that he should deposit in the Tower of London—perhaps the only available public place at that time—a complete set of models for the benefit of the public, showing the process used by him. These models, some thirty or forty years ago, were destroyed by order of the then Governor of the Tower! Three or four pieces remain, however, and are to be seen in the Patent Office Museum. They consist of a spindle belonging to the throwing mill, a reel, and a portion of a "sledging-bench," or the rail *p*, Fig 7, page 391.

There is a tradition that John Lombe was followed by a woman from Italy, and that his death was attributed to poison administered by her in revenge for his obtaining, surreptitiously, the secret of the Italian process of throwing.

The Derby silk mill was long afterwards considered a great wonder, although in reality the process was exceedingly simple, for it was in the combination of numerous spindles into each machine that really formed the value of the new introduction. A second mill was shortly afterwards built at Stockport, and from that time Congleton, Macclesfield, and Leek followed the example.

Silk is the production of the silkworm, or bombyx, which is a species of caterpillar, and feeds upon the leaves of the mulberry-tree. During its existence it undergoes three changes, viz. :—the caterpillar, the chrysalis, and the moth. The moth lays from 250 to 400 eggs, and so minute are they that 40,000 of them weigh only one ounce. The eggs are usually hatched by artificial means, to suit the best season for the mulberry-leaf. After the worm is hatched it arrives at its full growth in three or four weeks' time, when it weighs about one-sixth of an ounce, consequently it has increased in bulk about 9000 times in that short period of time.

During its growth it throws off its skin three or four times, according to the species, to allow for its increase in size. When full grown it selects a place amongst the leaves or small branches in which to spin, and in the space of three or four days it completely encases itself in a cell composed of silk filament, which is called the cocoon. The filament consists of two threads of silk, which proceed from two small apertures situated under the jaw of the silkworm, and they are gummed together during the process of spinning or making the cocoon. In this process the silkworm moves with an oscillatory motion, at the same time fastening the thread at every turn to the sides of the cocoon. When

[1] Hutton's History of Derby.

the cocoon is completed and the worm encased, it changes from a caterpillar form to that of a chrysalis, and in that state it remains from fifteen to thirty days, after which time it changes into a moth, when it *pushes* its way through the layers of filament forming the sides of the cocoon and escapes into the open air. In this last state of its existence it lives but three or four days, during which time the female moth lays its eggs and dies.

About two per cent. of the finest cocoons are reserved for the purpose of maturing the moth and obtaining the necessary quantity of eggs, and the remainder are subjected to a sufficient heat to kill the enclosed chrysalis, thereby preventing damage to the cocoon through forcing its way out.

One cocoon will produce from 600 to 1300 yards of silk weighing eight and a-half grains, and 1090 cocoons will yield one pound of silk. Also, twelve to twenty pounds of mulberry leaves produce one pound of cocoons, and 100 cocoons weigh one pound. The whole process of rearing silkworms requires great attention and a variety of artificial means.

Mr. B. F. Cobb,[2] secretary to the Silk Supply Association, in his treatise on silk, draws the following very important and suggestive conclusions relative to the advantages that might be obtained by a more general cultivation of the mulberry-tree :—

"There are in the world ten times as many acres of land available for mulberry cultivation as there are for cotton. An acre of suitable land will grow 500 trees. From each of these when three years old 20 lbs. of leaves can be gathered; from 20 lbs. of leaves 1 lb. of cocoons can be produced.

"The Agricultural Bureau of the United States gives the highest yield of clean cotton per acre to be in Louisiana at 300 lbs., all other states being less. Thus the comparative money values from an acre are—

300 lbs. of cotton at 1*s.* equal 15*l.*
500 lbs. of cocoons ,, 1*s.* 6*d.* ,, 37*l.* 10*s.*

Thus showing that a knowledge of sericulture, if more widely spread, would be able to compete in quantity and value with vegetable and all other fibres."

Mr. Cobb also states, that "The value of the cocoons grown in the whole world in 1870 was said to be as follows: France, 4,334,000*l.*; Italy, 11,260,000*l.*; Spain and other European countries, 984,000*l.*; giving a total for Europe of 16,588,000*l.*; China, 17,000,000*l.*; India, 4,800,000*l.*; Japan, 3,200,000*l.*; Persia, 920,000*l.*; other Asiatic states, 2,192,000*l.*; giving a total for Asia of 28,112,000*l.*; Africa, 68,000*l.*; America, 20,000*l.*; making a general total of 44,788,000*l.*"

[2] Published by Stansford.

In Fig. 1 a cocoon is shown with the course of the filament at *a*, as worked layer after layer by the silkworm as it oscillates its head and attaches the fibre to the sides of the cocoon, until it becomes a compact hollow shell of silk in which the worm is enclosed. At *b* a portion of the filament is shown magnified, in which the layers of filament are more clearly seen.

The first process in the manufacture of silk is to unwind the fibres from the cocoons. For this purpose a trough of water is used, provided with a stove to keep it sufficiently warm so as to soften the gum on the fibres of silk. The threads from five or six cocoons are wound together to form one thread of silk. In Fig. 3 and Fig. 4 the winding apparatus is shown in elevation and on plan, and the letters refer in both Figures to the same parts. *R* is a reel revolved rapidly by the cord *c* and *P*. The trough is shown at *T* in which the cocoons are placed. The fibres from five or six cocoons are collected at *d* and carried over a glass rod *a*, thence through the eye fixed on the rail *s*, and finally through the eye of the movable guide *g* to the reel. Two sets of cocoons are used, and at *x* the two sets of fibres are twisted several times round each other and divided again as shown. It would seem that this twisting would prevent the threads being carried forward, especially during rapid motion, but it does not do so, for they roll over and are carried on almost as freely as though they were kept separate. The twisting has the effect of consolidating the fibres together, and as the gum immediately

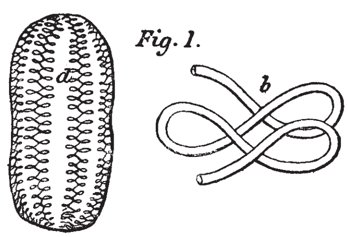


Fig. 1.

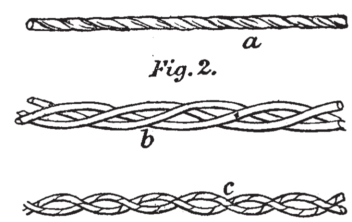


Fig. 2.

becomes hard they form one solid thread. Thus two skeins or hanks are wound upon the reel at once. The twisting, also, has the effect of throwing off any foreign matter that may attach itself to the fibres.

Should any of the cocoons become completely unwound or the filament break, all that is required is to throw with the fingers a fresh filament against those that are being wound so as to strike them before they reach the bar *a*. The new thread immediately adheres in consequence of the gum, and is carried forward with the others. A number of spare cocoons lie ready at the corner of the trough with their ends hanging over the sides, as shown at *e*, Fig. 4. To find the end of the filament a small wisp is used, and by merely touching the cocoon with it the filament adheres to it with ease.

One of the bars of the reel is made to slacken so as to allow the silk to be taken off, when the hank is tied in a knot or slip. Bengal silk is tied into small slips about twelve inches long as shown at *m*, and Italian slips as at *n*. In this state they are packed in bales and are received by the silk throwster.

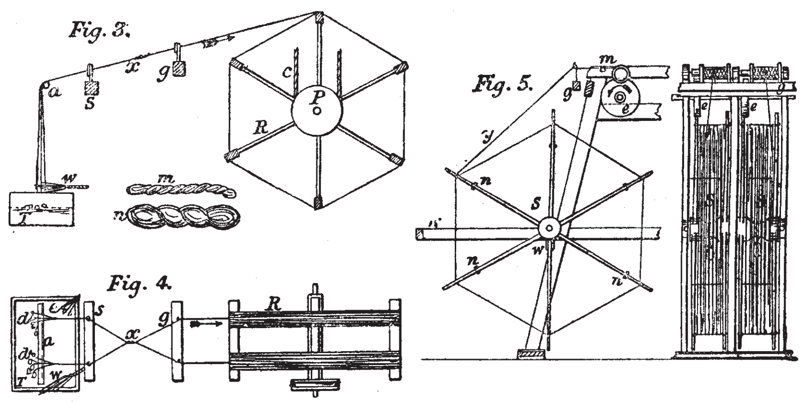
In Fig. 2 a thread of silk is shown twisted at *a*. It appears as a single thread only, but when the dyer boils off the gum it is found to consist of ten or twelve filaments, namely, if wound from five cocoons it would contain five double, or ten filaments. Therefore, unless these fine threads were twisted before the gum was discharged they would be too fine and flossy to do so afterwards. This kind of thread is called "singles," or single twist, and is generally used for fine warps. When two such twisted threads are spun together, as shown at *c*, they are still required for warp, but of course they are stronger. In this state it is called "organzine," meaning extra spun. For weft the threads, whether two, three, or more, are simply put together and twisted as at *b*, and the three threads would contain altogether thirty or more separate filaments held together merely by a slight twist. This kind is called "tram," which means soft, spongy, or tender thread, and is used for weft.

To spin the silk suitable for weaving, the following operations are required for Organzine as shown at *c*, Fig. 2:—1. winding; 2. cleaning; 3. spinning; 4. doubling; 5. spinning; 6. reeling. The first spinning (single thread) having about fifteen turns, and the second (two or more threads) about eight turns per inch in length.

For weft, as shown at *b*, the operations are similar, excepting that No. 3 is omitted, and No. 5 has only about four turns per inch.

In spinning singles, as shown at *a*, the operations are Nos. 1, 2, 3, and 6. In some instances singles are twisted as many as sixty turns per inch as required for weaving fine silk sieves.

Winding is performed by means of a frame containing a number of reels called swifts, upon which the hanks of raw silk are spread. They are made (see *S*, Fig. 5) about three feet in diameter, with a block of wood forming a knave into



which six pairs of thin round sticks, made of lancewood, are inserted. The silk rests upon thin cords tied in loops, which connect each pair of sticks. To make them firm a stretching piece or bridge, of wood, is wedged below the cord as shown at *n n*. The cords and bridges can be easily moved to suit the size of the hank to be unwound or to balance the reel. To prevent the swifts moving too readily a weight, *w*, is hung to the blocks to give friction, so as to throw a slight tension on the thread *y*, in order to wind it more firmly on the bobbin. The bobbins are fixed upon spindles provided with heads or small rollers, and are turned by means of friction wheels *e*. At *m* is a slot into which the spindle can rest when taken out of contact with the friction pulley or wheel.

Now the operative finds "an end" in the slip or hank, and by slightly wetting it, in the mouth, it is caused to adhere to the bobbin. After doing so it is turned round the ring which forms the eye made of wire and inserted in the guide bar *g*, which causes it to be wound regularly upon the bobbin. When the thread breaks or is exhausted a fresh end is found in the slip, and tied with a common knot to the end on the bobbin—thus the bobbin contains one continuous thread. Although it is only a common knot that is used, the mode of making it is peculiar, and by long practice it is done in an exceedingly rapid manner in all the process in silk throwing.

The guide bar is moved so as to wind the thread upon the bobbin in an even and orderly manner, and to do so various differential motions are used for the purpose. A common crank would cause ridges at the sides of the bobbin to be formed, and the threads would be likely to be laid time after time in one place—the disadvantage being that when the thread broke it would be difficult to find it again, and would thereby cause much waste of silk and loss of time. The motions used for guide bars of all sorts are preferably obtained from heart-shaped cams, elliptical wheels, sun and planet motions, or combinations of these motions.

Swift engines or frames generally contain about thirty or forty swifts on each *side*, or double that number for the complete frame. Only one swift, *S*, Fig. 5, is shown, in elevation, but a front view of two is also shown. Children under the guidance of women attend to the winding, and it was to this class of work that Hutton, the historian of Birmingham, was put when a child, and was so ill-treated and lamed for life by the overlooker. The height of the frame is about four feet from the floor, consequently young children had to stand upon small stools—but they tied stools to Hutton's feet! Formerly children were paid according to their height. A factory-book, that belonged to a factory in Congleton about a century ago, contains "A Standard to take Children by," which is a scale of wages regulated in proportion to the height of the child!

From the swifts the bobbins are taken to the cleaners, which process is merely to pass the thread through a slot formed by two blades of steel screwed together so as to regulate their distance apart. The advantage of cleaning is that it ensures the thread being more perfectly wound, and any large knots, "slubs," or other imperfections which will not pass the slot or guage are removed. As in all other silk machines a number of separate sets are fixed in one frame. Fig. 6 shows one set only. The bobbin *a* is unwound, and the thread *n* is passed over the rod *m* and through the guage or cleaner *c*, which is fixed in the guide rail *g*. The thread is wound upon the bobbin *b*, which is turned by the friction-wheel *S* in the usual way. At *d* a front view of the cleaner is shown to a little larger scale.

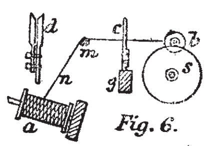


Fig. 6.

In making organzine the next operation is to spin each thread separately. The process of spinning either single or double threads is the same, with the exception that when the single thread is spun for organzine it is twisted in the contrary direction to that when the doubled threads are spun. Each spinning-mill or frame contains several hundred spindles, and they are placed in several tiers one over the other so as to economize space. The spindles are driven by cords passing over a cylinder (one to each tier) and round the small pulley fixed upon the spindle. Before the introduction of cylinders the spindles were arranged in convex curves, and a strap was made to press against them, and by its friction the whole of the spindles in its path were turned without any pulley being placed on the spindle. It was the curious arrangement of the spindles so that great numbers could be used, that was one of the secrets upon which spinning machinery depended. It is only necessary here to show the action of one spindle. Fig. 7 represents one running in a brass bearing *r* and step *d*. On the upper part of the spindle the bobbin containing the thread to be spun is firmly fixed on the conical part of the spindle. Above the bobbin is the "fly," which is a small cylinder of wood fitting loosely on the spindle, and kept from flying off when the spindle revolves by the button or top *g*. Fixed to the cylinder is a wire with an eye at each end, bent round a groove made in the cylinder and curved as shown. The bobbins upon which the thread is received are screwed together upon shafts, but only one is shown at *K*.

Now the thread, whether single or double, is carried from the bobbin *e* and passed through the eye *h'*, thence through the eye *h*, and through the guide eye *i*, and finally to the bobbin. If the bobbin *K* be turned round it will draw the thread off the bobbin *e* without any twist, excepting one for each turn of the flyer; but if the spindle be turned in a proper direction it will twist the thread, and according to the speed with which the bobbin *K* moves or the number of turns, so will be the proportionate amount of twists. The fly travels not only as fast as the spindle, but as much faster in proportion as the thread is unwound.

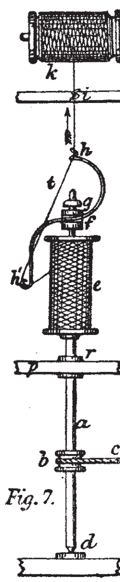


Fig. 7.

Spinning may be, and is frequently, performed without the aid of the fly, for its use is really to keep the thread in its place and deliver it clearly off the bobbin. Still it has another advantage. If the flyer be made heavier or weighted it will consolidate or put more tension on the spun thread. When the thread breaks, the spindle is held by the hand and the threads are tied whilst in motion. In cotton spinning several contrivances to supersede the fly are used, but the effect in all cases is the same and for the same purpose.

In cotton spinning the fly acts upon the reverse principle, namely, it is screwed fast upon the spindle and the bobbin itself is loose. Fig. 9 represents a spindle and fly, in which it will be seen that the thread is wound upon the bobbin on the spindle and not drawn off it. The fly is made with double sides, so as to balance it. In this case the bobbin rests upon the guide rail *S*, and as the rail is moved up and down so the thread is distributed upon the bobbin. Should the thread break, the spindle still travels, but the bobbin remains stationary, therefore it is the pulling of the thread by the fly that draws the bobbin after it, and according to the speed with which the thread *t* is delivered so will be the speed of the bobbin *e*, for it is, as above stated, the drag of the bobbin that winds up the thread.

In the same figure the famous drawing rollers are shown, which were invented by Paul in 1738 and claimed by Arkwright, who patented them in 1775; but his patent was afterwards disputed and upon trial it was annulled. The principle upon which they work is, that the two pairs of rollers *m* and *n* grip the fleecy cotton thread, and as the rollers *n* travel faster than the rollers *m*, so in proportion they draw out and extend the thread with similar effect as in spinning by hand. But there was an important difficulty to be contended with, namely, that after the fleecy yarn had left the rollers, the spindle, in the action of spinning and winding up the yarn, necessarily caused some degree of strain upon it, which, if very fine, it could not withstand. Now Compton overcame this difficulty by his invention of the mule, which still more nearly imitated the method of spinning by hand, for he adopted the simple and important principle of drawing the thread away from the rollers as it was delivered, without strain being put upon it. This was done by causing the spindles to travel backwards and forwards, at the same time spinning and then winding up the thread with the least possible strain. The mule spins the finest threads, but not the strongest.

Before the invention of the doubling frame by Mr. Crawford, who patented it in 1770, the process was done by simply holding between the fingers and thumb of the left hand the threads from two or more bobbins, and winding them altogether upon a bobbin fixed upon the spindle of a common hand wheel, such as is shown at Fig. 35. It is evident that one person could only wind or double threads upon one bobbin at once; but by Mr. Crawford's plan a large number could be arranged in a frame, and one person could attend to from ten to twenty sets.

Fig. 3 is a diagram showing one set of bobbins on Mr. Crawford's principle. The friction pulley *a* is one of a number placed at several inches apart on a shaft *b*. A bobbin is screwed or otherwise fixed upon a spindle which is turned by means of the pulley *a*, the head or small pulley *c* resting upon the friction pulley *a*. Part of the head *c* is of larger diameter, and ratchet teeth are cut into it as shown at *d*. There is a balance lever *p* with its fulcrum at *i*, which when raised as at *p'* comes into contact with the ratchet wheel and stops its motion. At *g* are three (or more as required) small levers having their fulcrums at *k*.

Now, if two or more threads are required to be wound together or "doubled," they are put in a frame as at *e e e*, which shows the ends of three bobbins. The threads from them are carried upwards and over two glass or wire rods *z z*, between which each thread is passed through the eye of one of the small wire levers *g*, there being a separate lever for each thread. The three threads are then carried forward to the guide eye *m*, where they converge, and proceed forward to the bobbin on the spindle, where they are all wound together as one thread. Should any one of the threads break, or any of the bobbins *e e e* become exhausted, the corresponding lever *g* will fall (for it is supported by the thread), and by falling upon the tumbler lever *p* at once stops the bobbin at *d* by raising the opposite end of the lever.

By the use of the Doubler a person can attend, as above stated, a number of sets, and as the threads break the bobbins remain stationary until they are repaired.

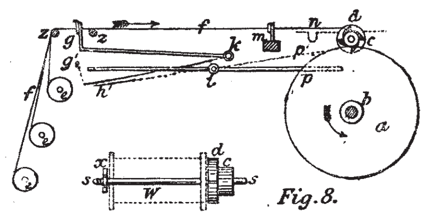


Fig. 8.

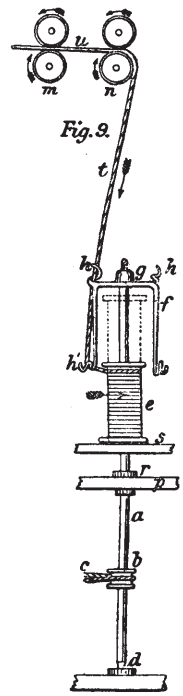
This principle of using tumbler levers has been modified in numerous ways, and the weft stop-motions in looms and warping machines are based upon it. In Mr. Crawford's time the friction pulley *a* had V shaped teeth cut in it, and the spindle head had similar teeth also—in fact, forming together a wheel and pinion. They were also used in the winding "engines" or frames (as in the No. 2 process), and owing to the shape of the teeth were called "star-wheels," which name they still retain although they have long since been converted into friction-wheels. Therefore, in Mr. Crawford's contrivance, the spindle head had to be raised out of gear with the star-wheel in order to arrest its motion.

Whilst the threads are being attended to the bobbin and spindle are taken clear away from the friction-wheel and placed in the notches *n*.

An enlarged sketch of the spindle is shown at *W*, upon which the bobbin is represented in dotted lines. In this sketch *c* is the spindle head or friction pulley; *d* is the ratchet wheel, and *x* is a nut to secure the bobbin upon the spindle. The two ends *s s* work in slots in the framework of the machine.

The last process in throwing is to reel the silk off the bobbins and make it into hanks ready for the dyer. As each hank ought to contain an equal length, they are sorted in sizes according to their weight, and numbered to several degrees of fineness. The hanks being packed in neatly formed bundles are then ready for the dyer.

Many attempts have been made to combine two or more processes in throwing into one only. Thus, winding and cleaning, and even doubling and spinning have frequently been tried, under the impression that the spinning would be more satisfactorily done; but the result does not appear to have ever been successful. It is evident that a greater number of processes gives a greater assurance that the thread will be more perfect, and thereby save the weaver a vast amount of labour which ought to be avoided, especially as the threads can be more easily repaired before they are put in the loom.



There are differences in opinion respecting the combination of doubling and spinning at one operation, and in silk throwing it has not been effected in a satisfactory manner. Mr. Cobb states that "When two threads are wound together in a parallel manner on a bobbin, and one is, as is generally the case, finer in size than the other, the number of coils being the same, the finer thread occupying less space will certainly be shorter than the coarser thread, from which it follows that in unwinding and twisting the doubled thread there will be more tension or strain upon the finer and shorter than upon the coarser and longer thread. This evil becomes more manifest in the loom, where considerable strain is applied to the threads; for unless they possess the due resisting power of combination they will have no more strength than single threads, a defect well known to all weavers.

"The cotton doubler overcomes this difficulty to a great extent by doubling and twisting simultaneously, whereby the finer thread has a tendency to wrap itself round the coarser thread, which is invariably the shorter of the two, and can, therefore, the better sustain any excessive strain to which the double thread may be subjected. The cording of threads doubled and twisted together in one operation, is more perfect than when the process is accomplished in two operations."

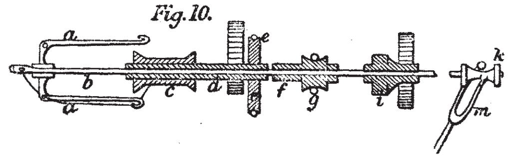
It may be mentioned that in some kinds of silk the gum is so strong that the slips, particularly at the place that has pressed upon the reel when wound from the cocoon, require to be "washed" or, properly speaking, soaked in warm soap and water. By this means the gum is softened and the slips can be unwound.

Spinning is best performed in damp or cool rooms, which from moistening the gum on the silk prevents, in a great measure, its wiry and curly nature. In hot, dry climates this was a great obstacle, and Mr. Lombe alludes to this fact in his patent. He says, "We shall be able to work this fine organzine silk in England at all seasons of the yeare, and even be able to perform the work by daylight, whereas the Italians work it all day long by lamp-light in dark, close, hott rooms without windows." In like manner various substances require to be spun and woven in a damp or wet state.

In a work recently published by Professor Grothe, of Berlin, it is said that the invention of the fly, as shown in Fig. 9, is due to the great painter Leonardo da Vinci, so well known as the painter of "The Last Supper," but of which picture only copies exist. Leonardo was born at Vinci, near Florence, in 1452, and died in 1516 at Fontainebleau. The papers left by this remarkable man have been examined by Dr. Grothe, and they were found to contain many extraordinary inventions, and amongst them is a flying machine, steam gun, boring mill, skew bevil wheels, planing machine, file-cutting machine, cloth-shearing machine, washing machine, chains, pumps, draw bench, and what the Doctor supposes to be a forecast of the Jacquard apparatus. It is also said that he anticipated Galileo, Kepler, and other great men, in several of their discoveries.

Fig. 10 is a copy of the sketch of the fly which Dr. Grothe found

Fig. 10.



among Leonardo's papers. The Doctor states that the earliest description of this invention appeared in a work called "La Machine," by Branca, published in Rome in 1629, or upwards of a century after Leonardo's death. And as the name of the inventor of this valuable contrivance has, as yet, not been otherwise named, the Doctor's conclusions may, in all probability, be correct in reference to Leonardo.

The spindle and fly shown are intended for hand spinning. In the sketch *a*, *a* represents the flyer; *b*, the spindle; *c*, the spool; *d*, the hollow shaft for driving it; *e*, the pulley by which motion is given to the shaft carrying the spool; *g* represents the pulley for actuating the flyer, which is moved up and down by the fork *m*, for the purpose of distributing the yarn evenly on the spool; *i*, is a bearing for the flyer shaft.

Previous to dyeing silk, the natural gum is "boiled off," and this reduces its weight from about sixteen to twelve ounces. In dyeing it, the weight of the dye stuffs slightly recover the lost weight; but, unfortunately, advantage is taken of this operation by the use of heavy dye stuffs, and in many cases the fibre is almost painted with with them. In "A Practical View of the Silk Trade," by Mr. J. Prout, Macclesfield, 1829, when, referring to this subject, the author says, "The shute is dyed in the gum, and the dyer, instead of returning twelve ounces of silk, returns from sixteen to twenty ounces; the article, when finished, resembling paper for its stiffness, and when made into dresses, frequently cuts at the seams from the hardness of the shute as compared with the warp, while the public are imposed upon by having drugs instead of silk." But what would Mr. Prout say to the practice at the present time, when "the weight is increased for broad silks and ribbons to double the weight, and for fringes four times the weight is often given"? In the Exhibition, 1873, silks were shown which had been weighted to *six times their original weight*, produced by iron, gambia, &c.!

Not only does the weaver suffer from this practice, which appears to be carried to a great extent on the Continent, being scarcely able to weave the material owing to its brittleness, or, as they say, its "rottenness;" but many trades have suffered greatly from its use. The elastic boot-spring trade of Derby appears to have declined greatly thereby, for the manufacturers there have been unable to compete with others who use heavy-weighted silks, and the use of side-springs has been affected considerably by it. In the "Leather Trades Circular and Review," 1877, Mr. J. Dean, a manufacturer of Derby, states that heavy dyes have had much to do with the falling off in the use of elastics. Certain it is that silk dresses, formerly so highly prized, do not at the present time hold much favour with the wearer, and thus the most beautiful textile manufacture is ruined by this wretched means.

Before the gum has been boiled off the silk it is said to be *hard* silk, but when boiled off it becomes *soft* silk—terms very expressive of the actual condition of the fibres. Silk is woven in both these states, but more generally when the gum has been discharged.

In the process of throwing, the various degrees of fineness are ascertained by weighing skeins of a given length separately. In France a skein measures 520 yards, and is weighed in deniers, one denier being equal to ·825 of an English grain. The English method is to weigh skeins of 1000 yards in deniers or in drams.

For the protection of traders in raw silks, there are establishments for ascertaining the actual weight of silk when divested of moisture and substances used in throwing, &c.

In the manufacture of crape the application of heavy or thick dyes or dressing is used, in order to produce its well-known crimpled appearance.

Crape may be woven with any description of twill. The peculiarity of its texture arises from the method of dressing after it is woven, and each manufacturer affects some peculiar process which is kept secret. It is woven with silk in its raw or natural state, or without the gum with which the filaments are covered being dissolved and washed off, or in the state above named as "hard silk." The warp is spun or twisted far greater than in ordinary cases;

and when the threads are made thicker with size or gum, they have a tendency to frizzle, curl, or "créper"—hence the name. Therefore the process consists in extra spinning, sizing, and stoving, and not in any peculiarity in weaving, although imitations of crape called crape-cloths, by weaving a twill to resemble crape, or pressing between crimped rollers, are frequently made.

In 1872 the manufacturers of Lyons, Mr. Cobb states, occupied 120,000 looms, of which 30,000 were in the city, and 90,000 in the neighbouring departments.

These 120,000 looms consume annually 2,200,000 kilogrammes of silk, and produce goods valued at 460 millions of francs, of which 350 millions are exported, and 110 millions consumed in the country.

The most important of these manufactures comprise—

	Millions Francs.
Foulards	50
Crapes	8
Tulles, plain and coloured	14
Velvets, silk and mixtures	30
Satins	25
Taffetas and "Failles," black	165
Ditto, coloured	120
Other plain thin goods	10
Brocades, for dress	8
Ditto, for furniture	10
Sundry mixed tissus	20

For the material of this enormous production France is indebted—

To China, Japan, and Bengal for	40 per cent.
To Italy for	22 ,,
To Broussa, Persia, and the Levant	8 ,,
Raised in France	30 ,,

Waste silk, such as is produced in the throwing process, and from cocoons that are either defective, or too fine to be unwound, has long been spun in a similar manner to cotton wool. To accomplish this the fibres were cut up into short lengths, so that they could be carded. As far back as 1671, a patent was obtained by a Mr. E. Blood, for "A new manufacture being a rich silk shagg, comodious for garmente made of silke waste hetherto of little or no use." And this was probably the first attempt to spin it in a similar manner to wool and cotton. An even and fine thread could scarcely be produced by means of carding, although silk so spun has been in extensive use. But within the last few years Mr. Lister, of Bradford, has succeeded, after an immense expenditure, in adapting combing machinery to this purpose, and the result is of very great importance. In the event of cocoons being more extensively grown and worked up in this manner, instead of the tedious and costly process of winding and throwing, a comparatively new and extensive manufacture will arise.

Rag wool, or shoddy, is now a manufacture of considerable importance. In this business woollen rags are torn up and re-converted into yarn; thereby saving from waste a large amount of valuable material. In 1874 there were 1437 power looms employed in the business, which is carried on at Batley and the surrounding district. It is said to have been first introduced by Mr. Benjamin Law, at Batley, in the year 1813, and machines were erected there, at Howley Mill.

Mr. S. Jubb, in his "History of the Shoddy Trade," states that 25,000 persons were engaged in the business, and the value of the cloth produced at the date he wrote, 1860, amounted to between five and six millions annually. The Government account, 1874, gives the number of persons employed in the mills as 3431, but probably Mr. Jubb includes the whole population dependent upon the trade. Numerous fabrics are made of shoddy, amongst which may be mentioned Druggets, Irish Frieze cloth, Witneys, Pilots, Tweeds, Petershams, Union and Prison cloths, Sealskins, Army goods, Coloured Blankets, and Canadian cloths.

In order to select the fibres of wool from cotton and other vegetable substances, as required for the re-conversion of the wool or hair contained in rags and worn-out fabrics, various methods are adopted. Animal fibre being of much greater value than vegetable, recourse is had to chemical solvents, such as are capable of destroying the less costly material, yet do not affect the more valuable. Thus Mr. J. Stuart, in a patent obtained in 1869, No. 410, says, "In 100 gallons of hot water I dissolve 100 lbs. of the sulphate of alumina of commerce; I then add 50 lbs. of chloride of sodium. When this last-named ingredient is added a re-action takes place. Sulphate of soda is formed, also chloride of aluminium. With this solution I now saturate the material to be treated, which is then placed upon hurdles to drain, after which it is placed in a drying-room, and by means of a steady temperature of 200 deg. F. when the chloride of alumina decomposes, and as the volatile products pass off they act upon the vegetable fibre and rot it, but leave the animal fibre uninjured. The material is then scribbled and the vegetable matter separates in the form of dust."

With respect to silk, nitric acid turns it yellow, and hydrochloric acid is a solvent of it, while it leaves cotton and wool, which have been combined with it, unacted upon for a lengthened period. By this means Mr. B. F. Cobb states that "To detect cotton, hemp, flax, and jute in mixture with wool and silk, boil the sample in an aqueous solution of soda containing ten per cent. of hydrate of soda; wool and silk dissolve, while the vegetable fibres remain unacted upon. The whole is thrown upon a cotton filter, and the undissolved matter is then washed with hot water, and afterwards acidulated with five per cent. of hydrochloric acid, to which, if the residue is black, or dark coloured, a few drops of chlorine water are added. Meantime the original alkaline filtrate can be tested for wool with the acetate of lead. If a white precipitate is formed, which dissolves on stirring, silk alone is present. A black precipitate indicates wool. The nitro-proxide of sodium gives a violet colour, if wool is present. If the tissue is deeply coloured, it may be cut up and steeped for fifteen or twenty minutes in a mixture of two measures of concentrated sulphuric and one of fuming nitric acid. Wool, silk, and colouring matters are destroyed, while the cellulose is converted into gun cotton."

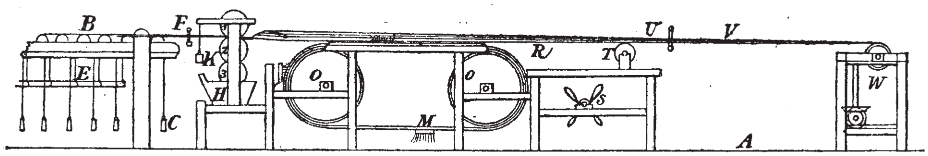
All threads that are composed of short fibres spun together have a more or less rough surface which arises from the ends of the fibres not cohering with the surface of the thread. This is more particularly the case with threads composed of cotton, the fibres of which material vary in length from three quarters of an inch to an inch and a half. The coarse threads are spun from the shortest, and the finest from the longest fibres—simply because the longer the fibre the greater is its power to cohere with others.

Yarn composed of two or more threads spun separately, and afterwards spun all together, naturally has a greater power of cohesion than a thread composed of one strand only. Therefore single twist yarn in particular needs some assistance in order to bind and consolidate the short fibres together, or the thread would scarcely be able to undergo the strain and friction of the process of weaving.

For this purpose the warp is brushed over with some glutinous material, such as paste made of flour, and the operation is known as "dressing."

In Dr. Cartwright's time the warp was dressed in the power loom in the same way as practised by the hand loom weaver, and as only a short length could be done at once it either necessitated a frequent stoppage of the loom for the weaver to attend to it, or otherwise it would require the assistance of another hand to keep on dressing as the weaving progressed. In fact in the early stage of power loom weaving this course was generally adopted. The warp was woven while still wet, for if allowed to dry it would be difficult to break its stickiness.

Now it was perceived by William Radcliffe that this operation of dressing should be effected before the warp was put into the loom, when a great saving of the time and labour of the weaver would be effected. He, therefore, set to himself the task of inventing a machine for performing that operation, and he succeeded in producing the first dressing machine, as represented in the following figure copied from his specification, dated March, 1803, of which the following is a description :—



A represents the frame of the machine, made of wood; *B* the beams, each containing a portion of the warp, twelve being used in this case, but not all shown. *C* are weights with cords attached, passing over the ends of the beams *B*, to give the necessary amount of tension on the threads. *F* is a reed to keep the threads in order. The rollers, 1, 2, 3, are covered with flannel, the lowest one 3, being half immersed in the "Sow," or paste contained in the tub *H*, and supplies the rollers 1, 2 with paste as they revolve. *K* is a weight and lever to press the rollers together. After passing the rollers the warp is opened by rods and dressed by the brushes *M* as they revolve on a strap, passing over the drums *o, o*. *R* are lease rods. *S* is a winnow or fan to dry the warp as it passes over it; *T*, a roller of wood to support the warp in its passage; *U*, a reed to keep the warp distended at a proper width; *V*, lease rods to take the cross, and which are taken away with the warp beam when filled, and other rods inserted; *W*, the warp beam on which the warp is wound. Motion is applied to various parts of the machine by suitable straps and gearing.

The action of the machine consists in uniting the threads contained on twelve rollers, so as to form one warp, and at the same time applying the paste and brushing and drying the threads as they pass to the warp beam in a condition ready for weaving. Thus, if the twelve beams have received 150 threads each, 3600 yards long, at the warping machine, when united they would form a warp containing 1800 threads, and consequently fill twelve beams with 1800 threads 300 yards long.

Mr. Radcliffe wrote a book professedly on the subject of power-loom weaving, but in reality it contains very little concerning it, the bulk of the work being a strange display of one-sided political notions. From his intimate knowledge of the first attempts to introduce the power loom, no one could have been better able to have described them; and as his book was not published till 1828, he must have had opportunities of seeing many things that would have been of interest to know at the present time.

The title of Mr. Radcliffe's work is "Origin of the New System of Manufacture commonly called Power-loom Weaving, and the purposes for which this system was invented and brought into use, fully explained in a narrative containing a candid statement of the strenuous, persevering, and uncompromising endeavours of William Radcliffe. Stockport, 1828."

From it we learn that the author was well descended; his great-great-grandfather, George Radcliffe, Esq., of Mellor Hall, owned nearly all the township of Mellor, and was slain at Stockport in 1644 in a contest with the Roundheads.

Mr. Radcliffe was born in 1761, and brought up as a weaver. At that time cotton yarn was exported, for the looms could not work it up so fast as it was spun, and this to Mr. Radcliffe appeared to be a sin.

The merchants and manufacturers held meetings to get the exportation prohibited, and Radcliffe promised to use his best endeavours to discover means to work up the yarn in his own country, and not to enrich the "foreigners" with it.

His first step was to employ some looms, and divide as much as possible the different processes, similar to the plan adopted by Arkwright, and which in his case led to such great success. Instead of dressing the warp in the loom as was hitherto done, he had it dressed by a separate process, which relieved the weaver of the trouble. Here he discovered that if the sizing or brushing the paste on the warp was done in a contrary direction to the weaving, the slay would not fray the threads, and the warp could be woven dry, and thus avoid the practice of weaving in damp cellars or rooms.

He obtained the services of a young man named Thomas Johnson, who proved himself to be a clever mechanic, and Mr. Radcliffe patented his inventions in Johnson's name, in order that "foreigners" should not find out his plans by seeing his name in a specification, and thereby put them off the track. With the assistance of Johnson and several other mechanics, he not only followed up the perfecting of the dressing frame, but constructed a loom that was long known as the "Dandy Loom." (See page 245.) Before completing these various inventions, many of the contrivances failed or were imperfect, and on one occasion all his men left work, and adjourned to the tavern to discuss the state of things. They concluded that all was lost, and the outlay of 70*l.* per week, which had long been incurred, was gone. They therefore deputed one of their number to tell Mr. Radcliffe their opinion. To this Mr. Radcliffe asked "where the difficulties were, and which was the most serious one?" "If I overcome the worst one," he observed, "will you overcome the rest?" To this offer they agreed, and very shortly afterwards the work was satisfactorily completed. No doubt these men were of great importance to Radcliffe.

Thomas Johnson above mentioned was named Mr. Radcliffe's "conjuror;" Daniel Wild was foreman of mechanics; Samuel Wild, foreman of weavers; and Edward Partington, foreman over all. Mr. Baines states that Johnson received by deed the sum of 50*l.* in consideration of his services.

In 1808, when Dr. Cartwright appealed to Parliament for a remuneration for the expense he had incurred in bringing out the power-loom, witnesses were called and examined before a Committee on the subject. Mr. Joseph Taylor, having been Dr. Cartwright's engineer, proved that the Doctor was the inventor, and Mr. Radcliffe referred to the advantages that might accrue to the cotton trade from the general adoption of Dr. Cartwright's loom. The committee were satisfied with the evidence of these two witnesses, and a grant of 10,000*l.* was allowed to the Doctor.

In a similar case Mr. Radcliffe was not so fortunate, for he himself petitioned Parliament for some recompense for the loss he had sustained in promoting the cotton manufacture, but he met with no reward.

While carrying out the "Dandy" loom, Mr. Horrocks (see page 241) came to see it, and Radcliffe strongly asserts that he carried away his idea of the take-up motion contrived by Thomas Johnson, and claimed it as his own.

Mr. Johnson was also inventor of the first circular or revolving temples.

Mr. Radcliffe ultimately became unfortunate in business. He lived to be eighty-one years old, and was buried in Mellor churchyard in 1842.

The process of "*sizing*" is an extension of the principle of dressing. In sizing, the yarn is not merely coated with paste to allay the loose fibres, but the thread is thoroughly saturated with it. Numerous machines have been introduced since Mr. Radcliffe's time for this purpose, and one in particular has been long in use, called the "Slasher," made by Messrs. Harrison and Sons, of Blackburn.

At the first glance sizing seems to be a matter requiring no very great nicety in its process, for so long as the yarn is well soaked with size, and quickly dried, it may, perhaps, appear all that is necessary. This, however, is not the case, for there are several important conditions that must be observed, but more especially as regards the sizing of fine yarns.

In the first place the yarn must be properly saturated and not merely coated with size, otherwise the surface of the yarn will be rough and the size peel off. To avoid this defect the yarn must be kept immersed a sufficient time, and the heat must be kept up to boiling point, or the air in the yarn will not be expelled so that its place can be taken up with size. The machine should be so arranged that all unnecessary strain arising from the contraction of the yarn during the process, or from its being drawn through the machine should be avoided. It is also found that drying the yarn on the surface of heated cylinders is not so desirable as the system of drying by hot air.

Many of the machines hitherto used for this purpose are evidently not intended to admit of any great degree of adjustment, to enable light and fine materials requiring careful treatment to be as satisfactorily done as those of a coarser description. This object, however, has recently been accomplished by Messrs. Baerlien and Co., of Manchester, who have succeeded in producing a powerful machine which is capable of executing every description of work for which such machines are required.

CHAPTER XXXVI.

SUMMARY AND GENERAL REMARKS.

THE process of weaving may be divided into seven distinct classes, under one or more of which every kind of woven cloth can be produced. They are as follows:—

1. PLAITING.
2. PLAIN WEAVING.
3. FIGURED WEAVING.
4. CROSS WEAVING, or GAUZE.
5. PILE, or VELVET WEAVING.
6. KNITTING, or LOOPED WORK.
7. LACE.

The order in which they are arranged above not only proceeds from the most simple to the most elaborate systems, but it corresponds with the age and progress of the art.

PLAITING appears to have been the process first practised, for short fibres, such as grass, rushes, &c., can be used without the aid of spinning by this means. The earliest remains of any woven fabric yet found have been plaited work, as discovered in the Swiss Lake Dwellings belonging to the Stone Age.

PLAIN WEAVING, even of the most simple kind, can scarcely be practised without the aid of spinning. It is therefore probable that spinning, for the production of cords, ropes, fishing-tackle, &c., may have preceded plain weaving, and evidence that this was the case is again found in the remains of the Lake Dwellings. As to the age or country in which either spinning or plain weaving was first practised, it is unknown.

FIGURED WEAVING is practised either as a handicraft process or the weaver is assisted by the aid of machines. The process of ornamental weaving, as used at the present time in India, is perhaps the same as it has been practised there from the most remote times. It consists in interlacing differently coloured threads of various substances and thicknesses; and this is done by inserting them in the warp as in plain weaving. By this means the effect is produced by the different colours and materials, rather than by the ornamental decussations of the threads, in which the skill of the weaver is shown.

When assisted by mechanical contrivances the art at once assumes a new feature, for by this means, with only one or two colours or varieties of thread, endless effects can be produced on the surface of the cloth.

Whilst India seems to have always depended on their simple looms and handicraft processes, China appears to have shown more reliance on their mechanical ability; and there is reason to believe that not only the draw loom but diaper weaving emanated from that country.

When the silk manufacture was brought into Western Asia from China doubtless the draw loom was introduced also. In this way it was established at Damascus, and the rich silken cloths produced were named therefrom. Neither the ancient Egyptians, nor the Greeks and Romans, appear to have had any looms of a similar nature to the draw loom, for their skill rather depended upon the manufacture of fine linens, and did not resemble the ornamental works of India or China.

It is very probable that the draw loom and diaper weaving were introduced into Europe in the early part of the present era, for diaper weaving was known in England in the 11th century, although the draw loom was not used before the middle of the 16th century.

The *draw-loom* system of weaving consists in the use of two harnesses, which have each a separate control over the warp threads. One portion is required for drawing up the threads in large numbers so as to form the outline of the figure, whilst the other part of the harness is for weaving the separate threads in detail.

In the Chinese draw looms, still used by them, the draw boy, or weaver's assistant, stands on the top of the loom and draws up the clusters of threads in consecutive order (which have been previously arranged to form the pattern), whilst the weaver works the treadles to form the smaller intersections.

This plan was practised in Europe until 1604, when M. Simblot, in

France, connected a separate series of cords called the "*simple*" (probably a corruption of his name), so that the draw boy could draw the cords when standing at the side of the loom instead of at the top.

The next improvement was to dispense, when possible, with the draw boy's services, and for that purpose Joseph Mason, in 1687, obtained a patent for a "*draw-boy engine*." Since Mason's time this class of machine has undergone numerous modifications, and was in general use until the Jacquard machine, or "new French draw loom," supplanted it about forty years ago. The Jacquard was so named because it could be used in every way similar to the draw loom.

Diaper weaving consists in using two or more sets of treadles, each set being attached to the same headles, but in a different order. By this means if one set of the treadles were used, striped cloth of two different twills, satin or other ground, could be produced. By using the other set of treadles another series of stripes could be woven. Now, by simply alternating the stripes a square or check may be woven, and this method is the system known as diaper weaving.

When treadles only were used and several sets were required, they became not only inconvenient to use but were therefore limited in number. A contrivance was consequently adopted, about a century ago, to use one set of treadles only, and to bring the different changes into operation by other means. This effect was produced by means of slack cords. Let a number of bells be attached to one bell-pull in such a manner that all the cords or wires are slack, and upon drawing the handle none of the bells will be rung. Now, if by means of of a cord, or other contrivance, any of the connecting wires be drawn aside it will be equivalent to making tight the slackness of the wire, and then the particular bell whose cord has been so acted upon can be rung by drawing the bell-pull. Thus a series of cords can be arranged in the same manner as completely as one cord.

It will be evident that for the production of large patterns or designs, great complication in the tying-up of the harness of the loom was unavoidable; and it is probable that attempts had been made to remedy it, and at last it was successfully accomplished.

In 1725 M. Bonchon, a Frenchman, tried an experiment to throw in or out of gear the "simple" cords of the draw loom by means of a paper band operating upon needles, the pattern being arranged by having holes punched in the paper. Here was the foundation of the Jacquard principle, which nearly a century later was brought into operation. In 1745 Vaucanson improved upon Bonchon's contrivance, and arranged a machine with perforated paper on the top of the loom, in the position occupied by the draw boy in the old looms. A cylinder or prism and cards had already, in 1728, been tried by M. Falcon, but from some cause or other the plan was not brought into practice until taken up by Jacquard about the commencement of the present century. Since that time it has proved to be one of the most important contrivances ever introduced, and is now applied to all kinds of textile figure-producing machinery.

Since the introduction of the power loom and the lace frame, the Jacquard machine has undergone various modifications in order to make it more effectual and rapid in its action, as well as to apply it to purposes not originally thought of. Thus it is made to govern the action of the shuttle-boxes in figured weaving, and in the slide-bars of the lace frame, &c. As applied to the power loom it is singularly applicable, for had it not been for this contrivance figured weaving would have been almost impossible to effect, to any great extent, by other means.

But the nature of the motion of the ordinary Jacquard machine is of the worst and slowest kind used in weaving; therefore numerous attempts have been made to improve it and make it more rapid. This has been effected by using two griffes, so that the suspended wires and weights can rise and fall simultaneously, and thereby perform the work in about half the time.

In the Levers Lace Frame this class of Jacquard is of most ingenious construction. In some looms two cylinders are used, one to raise those headles that are required to be raised and the other to sink those that are to be sunk. But the system now being gradually carried out is to combine two griffes, or sets of lifting-bars, so that the rising and falling motion is made perfect and carried out in one action only.

Gauze and Velvet Weaving seem to have been first practised in the early part of the present era. The former is said to take its name from Gaza in Asia, whilst the latter is supposed to be named from Velutio, in Italy. But gauze weaving is probably of Chinese origin.

Gauze, or Cross Weaving, consists in crossing the warp threads as follows. Let the following numbers represent, in section, a series of warp threads, as in plain weaving, where every other thread is alternately raised for passing the shuttle, thus, 1 2 1 2 1 2. Then if a thread be dropped down between any of the threads 1 2, and after passing under the thread 2 let it be looped round the thread 1. Now, by drawing the looped thread upwards it will carry with it the warp thread 1, which will be drawn under the thread 2, and on the next passage of the shuttle it will be bound in the cloth *out of its normal position*, and in fact, it will be *crossed* under the thread 2. But when the loop is slackened again the thread will return to its normal position, when the plain, or other weaving, can be proceeded with. The looped threads may be used in any number or order, for they are merely an addition to the ordinary harness, and used for the purpose of drawing the warp threads under and across the paths of the other threads. See also *Kutar* weaving, page 311.

VELVET WEAVING consists in the production of a brush-like surface to the cloth, called the pile. A separate warp-beam is used for the purpose of supplying the pile threads, for they are used in much greater lengths than the plain warp threads, with which they are combined. When the pile threads are raised by the harness, a wire is passed under them similar to a weft thread, and woven in as such. Now, if the wire be withdrawn a row of loops will be formed on the surface of the cloth. In this case, on repeating the operation, terry velvet similar to Brussels carpets would be produced; but if, by means of a sharp knife, the loops be cut before the wire is withdrawn—by passing the edge of the knife along a groove made in the wire—then the loops would be cut and form velvet.

Both gauze and velvet weaving can be woven in the power loom as in the weaving of curtains and carpets. When terry velvet is woven, the wires are inserted and drawn out by suitable motions; and when the pile is cut to form velvet, a sharp blade is attached to the end of the wire, which on being withdrawn cuts the loops. Or two pieces of cloth are woven face to face and the pile threads passing from one to the other are cut asunder during the process of weaving and thereby form two pieces of velvet.

THE PROCESS OF KNITTING by hand was known in England at the end of the 15th century, although it is not known to what country it belongs nor when first used. In 1589 William Lee invented a machine for performing the work in a much more rapid manner than could be done by hand. The principle of Lee's invention is still used. In 1816 the celebrated engineer Brunel gave a rotatory action to a modification of the machine. Knitting is a process by means of which a series of loops are made which intersect each other. By hand about 100 per minute can be formed; but machines have been made on the rotary system by which 300,000 loops per minute can be produced.

Lace is the last of the seven classes of weaving. It is not only the most recently invented system of weaving but by far the most complicated. There are two kinds of lace, viz., point and pillow. The former is produced by means of the needle, and is an ancient process. The latter is made by twisting a series of threads round each other, to form meshes, by means of numbers of small bobbins and a pillow upon which the fabric is formed. Pins are inserted in the pillow to form the pattern, and the threads are twisted round them. The pattern is drawn on parchment, which forms a guide for placing the pins in the cushion. This method of weaving was invented by Barbara Uttmann in 1561. Many attempts were made during the last century to produce lace by machinery similar to pillow lace, and in 1808 John Heathcoat succeeded in doing so. Since that time numerous modifications have been made in the process, and the Jacquard machine has been applied to produce figures on the lace.

The Levers Lace Frame, which is based upon the system adopted by Mr. Heathcoat, is composed of a series of contrivances that are so perfect and extensive in their application that it is worthy the careful study of every mechanician. It can, and has been, modified in numerous ways. Far greater numbers of slide-bars have been used than in the machine herein described, and various modifications of the carriages and combs have been used. But the principle is still the same, for whatever alterations or additions it may receive, the basis of its action can scarcely be deviated from.

Tapestry and *Braid-making* may be said to be branches of the art of weaving. Tapestry is really a fine art, although the process is simply one of weaving. There are two kinds of tapestry, one in which the surface of the cloth is similar to plain weaving, and the other having a pile or velvet surface. The first kind is employed for the production of pictures, and the second is for use as table-cloths, &c.

In both classes the design is produced by means of various coloured weft threads interlaced and knotted between or upon the warp threads, which may be composed of cotton, worsted, or silk. The warp is strained upon beams placed sometimes horizontally, as in the common loom; but more frequently the warp is held vertically. Another plan is to place the warp beams vertically. The instruments used by the artist in this work are of the most simple description, and a comb is used to beat the threads together after they have been arranged. The work produced is the most costly and effective of the textile manufactures. It is comparatively a modern art, for formerly tapestries were wrought by the needle on the surface of cloth, as in the Bayeux tapestry, and not interwoven in the body of the cloth as it has been customary to do during the last three centuries.

Braid-making is done by machines constructed with spindles carrying bobbins and made to travel in a serpentine course. In so doing the threads are plaited round each other or entwined together. By this means braid, stay and other laces, upholsterers' cord, covering to india-rubber threads, crinoline wire, whip handles, &c., are made. Webbing of various widths can be produced by this means, and tubes. Braiding machines are made of various sizes, some having but a few spindles, whilst others have nearly a hundred.

The power loom.—During the period when several of the above inventions were being carried out, the hand loom was undergoing various improvements, and motive power instead of manual labour was ultimately applied for performing the work of the weaver.

In 1678 a French officer, M. De Gennes, constructed a model for weaving cloth by power, but it was practically of no use. In 1745 Vaucanson produced a loom, now in the Conservatoire des Arts, Paris, which not only contains his improved Jacquard apparatus, but the whole loom is arranged to be worked by motive power. Twelve years previously John Kay, in this country, had invented the fly-shuttle, and it was perhaps not known to Vaucanson or he might have adopted it, instead of trying to carry the shuttle through the shed by means of levers, as was proposed by De Gennes. Had he done so the system of power-loom weaving would have advanced much earlier than it did. In Vaucanson's loom the friction-roller take-up motion is applied; but he failed through want of the fly-shuttle. He shortly afterwards (about 1760) succeeded in making the Dutch ribbon-loom self-acting, and this was probably the first loom capable of being driven by power.

Shortly before the commencement of the present century the power loom, for weaving broad goods, began to be used; but its successful introduction by Dr. Cartwright and others was a long and tedious task.

In order to weave by power there are many things necessary to be overcome which are not required in hand-loom weaving. For instance, a self-acting motion must be applied to stop the loom when the weft breaks, or the weft bobbin requires to be renewed. Also a take-up motion for winding up the cloth as it is woven must be provided, and a temple that does not require being moved, as in the case of hand-loom temples. These look simple matters of themselves, but they took, in time, upwards of half a century to bring to a satisfactory result.

The first steps towards the accomplishment of power-loom weaving were doubtless the inventions of the fly-shuttle and metallic reed by John Kay, the former being patented in 1733. But it was not till near the end of the century that any practical result was attained. In 1796 Mr. Robert Miller successfully applied the stop-rod motion, to stop the loom instantly when the shuttle stuck in the shed or was thrown out of the loom. This contrivance was not perfected till 1845, when Mr. John Sellers applied a brake to it.

Self-acting nipper temples were introduced by Dr. Cartwright in 1787; and in 1805 Thomas Johnson used revolving temples formed like bevel wheels. Temples have undergone numerous modifications on the roller principle since that time, and are now comparatively perfect. During the same period the fork and grid weft stop-motion has been brought to a high state of perfection. Contrivances for this purpose were attempted by Dr. Cartwright in 1786. In 1834 Messrs. Ramsbottom and Holt applied the fork and grid plan, which was greatly improved by Messrs. Kenworthy and Bullough in 1841, and a brake added by Mr. James Bullough in 1842.

The take-up motion for winding up the cloth as woven was first applied by Vaucanson to his loom in 1745, before mentioned, in which friction-rollers are used, being the same in principle as now adopted.

The letting-off motion to the warp-beam, as applied to the power-loom, was at first similar to the ordinary plan used in the hand loom; but as the alterations of the strain or tension should be regulated in the power loom by self-acting means, numerous inventions have been introduced for that purpose.

In the *process of weaving* whether performed in the hand loom or the power loom, the operation is the same and dependent upon exactly the same principles. Amongst power loom weavers much difference of opinion exists as to the treatment of the warp when in the loom, and the best way of producing a sound cloth, and having, at the same time, the best appearance or surface.

Upon the proper proportions of the warp and weft the strength and quality mainly depend; but with the same materials a very much better cloth may be produced, simply by a difference in the operation of weaving.

This effect can be best observed in the weaving of silk fabrics, for owing to their fineness of texture, and the care required in weaving them, any defect is more distinctly shown, and the cause of it is more anxiously traced than in the weaving of other substances.

Apart, therefore, from the question as to the proper proportion that should be made in the warp and weft, and other matters relating thereto, it will be found that the quality and the appearance of the cloth very much depend upon the weaver.

The evenness of the selvages is greatly affected by the manner in which the shuttle is used; but the appearance and quality of the web principally depend upon the shedding, and the amount of tension applied to the warp threads.

Some substances require different treatment in order to weave them, according to the strength and elasticity of the fibres, but more particularly with respect to the class of fabric to be woven. Thus it was thought that linen might be woven in a common cotton power loom, but owing to its rigid nature it necessitated the invention of a vibrator, to counteract the strain of the headles.

The action that is desirable in the process of shedding is to throw as little strain as possible on the warp threads; and although considerable tension is often required, an undue share is often given to some if not all parts of the warp. This defect generally arises from opening the shed too wide, or by raising or sinking some of the healds unequally, as well as from other causes.

In *weaving silk goods* of different kinds, a different treatment is absolutely required, so that no general rule can be made that would be applicable to every case. Thus glacé, sarsnet, or fine tabby silk, requires to be well weighted on the warp-beam, in order to produce a desirable "skin"-like surface on the cloth. On the other hand umbrella silk must be very lightly weighted, in order to look and wear well. Should it be overweighted the cloth would be hard and wiry, and would cut itself in wearing. The difference that may be effected both in the appearance and quality of silk of this class is so great, that even two or three pounds weight added to the beam will make it at once observable.

Ducapes, or corded silks, require a soft covering to the weft, therefore they must not be heavily weighted. Satins of the same texture require more weight than ducapes in order to produce a sharp, bright face.

In *weaving velvets* and other descriptions of pile fabrics in which two or more separate warps are combined, it is necessary that the warp forming the pile or surface of the cloth should have much less tension than the ground warp in order to make it cover well.

In *double cloth* weaving tubes or sacks may be made, or cloth of double the width of the loom may be woven. Also fabrics of considerable thickness and of different colours or textures on each surface may be produced by this means.

In order to vary the appearance of certain parts of the web a shuttle with thicker weft is sometimes used, to give it a ribbed appearance; but the same effect may be produced by passing the shuttle containing a fine thread through the same shed two or three times, but of course it must be bound in by shedding the selvages.

The blow of the reed, after the shuttle is thrown, must be given when the shed is closed and not before, or the weft will recover itself and a loose cloth will be the result. If the blow be given on the rising of the next shed, then there will be too much strain on the warp, and it will not only be liable to breakage, but a hard, dry, wiry effect will be produced.

In *weaving satins* and other fabrics requiring a number of headles, and only one or two are required to be raised at a time, then a rising shed with a standing bottom is to be preferred, as in the tying-up shown in Fig. 68, although in weaving linen in the power loom this plan is frequently reversed by drawing the headles downwards, although the principle is the same. But care must be taken not to raise the headle, or headles, too high, or too much strain will be thrown upon the raised threads, and the result will be that the weft threads will overlap or "ride" over each other, and the evil effect will be observable on both surfaces of the cloth.

When the work requires the headles to be raised in about equal numbers to those remaining down, then a rising and falling shed is preferable, as in Fig. 71. In this case the strain will be equal and easier, and less tension will be thrown upon the warp.

In all cases an easy balanced motion is to be preferred. The shed should never be opened deeper than barely sufficient for the shuttle, and all jerking and unsteady actions must be avoided.

It is too often the custom to put greater strain on heavy, rich warps than is beneficial, merely for the purpose of obtaining as clear a shed as possible without using a breaker treadle (see p. 106), which would prevent the sticking together of the threads in the sheds and the defects arising therefrom, such as floats and hang-shoots. A *float* is caused by the shuttle passing either above or below the thread or threads intended, consequently it is not intersected, as it ought to be, but floats loosely upon the surface of the cloth. A *hang-shoot* is caused by warp threads sticking together and preventing the weft being laid in a straight line, so that it is bent round the obstructing thread, and causes a kink or loop in the weft thread. A bow, made of two or three horse-hairs twisted together, is fixed to the front of the shuttle so as to project and form a flexible wedge of the shape of the letter ⊃. By this means the sticking threads of the warp are divided, and the weft is in consequence laid evenly, and hang shoots are avoided.

Comber marks are great defects in silk weaving, and should be guarded against as much as possible. They are caused by an unequal tension on the warp threads. Thus the threads raised by the front leashes in the comber board will have a different degree of strain upon them than the threads raised by the leashes at the back of the board, so that the effect produced upon the cloth will present a rib-like appearance.

The threads from front to back of the comber board may be twenty-four in number, therefore the ribs will be of the width of twenty-four threads.

This defect arises from the faulty action of the shedding, which has been already referred to at p. 274, &c. Owing to the impossibility of arranging the leashes in one line, so that an equal strain can be put upon each of the threads, various contrivances are used to avoid the defect as much as possible (see Figs. 296 and 305).

Sometimes the harness has been tied up in an irregular manner, or some defect, such as the sagging of the bottom board of the Jacquard machine (which for hand loom purposes is often made too light) will cause an irregular face on the work; therefore great care is required to avoid anything that may tend to throw uneven tension on the warp.

In the silk loom the stretch of the warp between the harness and the warp beam (the "porry") is much longer than in power looms, and this shortness of stretch is probably one of the defects in power loom construction.

In some instances two or more sheds are used for the passage of two or more shuttles simultaneously. In this case, to prevent uneven tension on the warp threads, separate warp beams should be used, as shown in Fig. 331.

The position of the lease rods is by some weavers taken into consideration. In the silk loom, where the length of the stretch of the warp is considerable, little notice is taken of it; but in the power loom where the stretch is very short, the position is of more importance, although the shortness of space does not give much room for choice. It will be found, however, there will be more equality of strains on opening the sheds if the lease rod next the harness be made as small as possible, and not placed far from the back rod. In some instances two separate rods, one above and one below the warp, are placed in front of the lease rods nearest the harness, so as to form a narrow opening and not allow any headle to raise a shed with a different angle to another. In this case there will always be a more equal strain upon the warp threads than there would otherwise be.

As so much depends upon the proper weighting of the warp beam, so that any given tension can be put upon the warp, it follows that a self-action motion that will not vary, but will always keep the warp at one degree of tension, is a matter of very great importance. The difficulty that has to be overcome is to keep the strain always the same, as the warp becomes unwound from the beam, and several of the most recent contrivances for this purpose have been described in Chapter xxiii.

The shuttle should be of sufficient weight to enable it to draw with it the weft thread, and overcome the drag or strain caused by the unwinding of the weft. If it is too light the drag of the thread will draw it out of its course, and it will be liable to be thrown out of the warp and will miss the opposite box. In this case a plug of lead must be inserted at each end of the shuttle, to give it greater momentum.

When thick or heavy weft is used, or a large weft bobbin, then a proportionately heavy shuttle must be used, and a small roller inserted at each end of the shuttle for it to run upon. The rollers are made as wide as the shuttle will allow, for they are enclosed in the shuttle and only project slightly on the under side.

When quills or pipes are used for the weft to be wound upon, it is of little consequence as to the mode of winding the thread upon them, for the thread will be readily drawn off as the pipe revolves. But if a bobbin is used, so that the weft unwinds off the end without the bobbin revolving, then care must be used in filling the bobbin. The winding must be commenced at the base, and gradually wound in a tapering shape until filled to the point of the bobbin, otherwise the thread would not leave the bobbin freely, and would be liable to stick and break. When bobbins are filled by machines, the guides are arranged to wind the thread in this manner.

The French method of using the fly-shuttle in the hand loom is very different to that practised in England. Instead of using the picking stick, as shown in Fig 27, two pulleys are placed on the front of the cross bar of the batten, and a cord from each picker passes over one of the pulleys, so that the ends of the two cords terminate at a handle suspended over the middle of the reed. Each picker is kept drawn to the far end of the box by a spring cord. Now, by pulling down the handle both pickers are thrown forward, and whichever box the shuttle be in, it will be thrown also. A wooden flap is made to press against and retain the shuttle in the box, similar to the ordinary swell in the power loom, and the pickers are drawn back by springs in a similar way to that used in the drop-box system.

In the power loom the principle of throwing the shuttle is the same as in the ordinary fly-loom; but as it is done by automatic means, care must be taken to avoid any defects it may be liable to.

The picking motion must not be too strong or the swell springs too weak, or the shuttle will rebound and the stop-rod will fall and stop the loom. The check strap must be short enough to prevent the picker being forced against the end of the box, or it will rebound and cause the loom to "knock off" or stop. By picking too late, too weak, or two slow, bad selvages will be made. Wide looms require to pick sooner than narrow ones, to allow more time for the shuttle. Picking too strong will knock the cops off the shuttle-spindle, and when bobbins are used will often cause the tongue to break. A loose spindle, or if not set true, or a broken picker, or an uneven reed, will cause the shuttle to turn or to be thrown out of its course. Broken weft, fringed edges, &c., are often caused by some defect of the picker. The stop-rod may throw the loom off, owing to some defect or wear of the swells, or from a shuttle being too small.

The loom is liable to throw off, owing to the wear or other defect connected with the stop-rod, or the catch may be set too low. If the shuttle-box be too wide or the shuttle too small to force the swell back, it will also have the same effect.

If a larger shuttle than usual be used on account of its being able to carry more weft, and so, on the score of economy, save a more frequent change of bobbins, it may prove to be of much less advantage than at first sight would appear. A deeper shed would be required for it, and, consequently, greater strain thrown on the warp threads. This would give rise to more breakages of the threads; and as a weft thread can be replaced several times more quickly than a broken warp thread, the use of larger shuttles, to say nothing of any other disadvantage, would have a doubtful result.

The various defects above named offer no serious difficulty to the experienced weaver, for if he cannot entirely remove them, he, at all events, knows the cause of the evil and how to contend against it.

But there are other obstacles which are, unfortunately, completely out of the control of the weaver, and which cause him far more trouble, loss, and annoyance, than matters concerning the adjustments of the loom. He is too often supplied with threads that have not been properly spun. The fibres may have not been carefully cleaned or divested of the rough and thick portions. Thick and thin fibres are indiscriminately doubled and spun together, so that when the necessary strain is put upon the warp, the weaker strands will give way.

Heavy dyed silks.—Perhaps the greatest difficulty that operates against the silk weaver, and destroys the elasticity and strength of the fibres and makes them brittle, rough, and sticky, is the comparatively new and baneful practice of using heavy dyes (see page 394). Not only does the weaver suffer greatly thereby, but the work when produced is devoid of the beautiful appearance and strength of the properly manufactured substance.

Formerly the practice of overweighting was confined to coarser materials and fabrics, such as in the sizing of cotton cloths; but at the present time silk seems to suffer far more from such practices than any other material. Silk when properly dyed is actually *reduced* in bulk and weight; but when it is returned at from *twice to six times* its own weight, it is evident that the purchaser or wearer of such articles must suffer by them.

At the present time the American silk manufacturers claim that "the American article contains a smaller percentage of dye-stuffs than the foreign, and hence is purer." Still their use is admitted and may soon equal the amount used in other countries, as in Germany, France, and England.

Before the improved system of spinning was introduced by Arkwright and others, cotton yarn was used for weft only, but when it began to be used for warp also it was found to be unable to stand the strain and friction of weaving, without some further assistance to hold the short fibres together. This was effected by the application of a thin flour paste. Unfortunately the practice began to be taken advantage of and to be carried beyond its original purpose. No doubt it suggested a similar course to be adopted in the silk manufacture, which has led to the result above mentioned.

The process of sizing has for some time past attracted considerable attention, as being not only detrimental to the quality of the cloth, but very prejudicial to the interest of the purchaser, and likely to injure the reputation of the English cotton manufacture. It is an old practice, but it has gradually been carried to a questionable extent, as the following extract from a letter that appeared in the *Manchester Examiner* will show:—"Testing Yarn consists in wrapping the weft from the cloth in order to calculate the counts of weft used; but you cannot know the weight of size in a piece of cloth unless you have the counts and weight of the warp as well. The bulk of the plain cloth made to-day is out of all proportion. Take, for instance, a 7 lb. T cloth, 15 by 15, and, instead of being, as its name implies, equal in counts of yarn and picks, you will find it made from 16's warp and 40's weft, instead of 16's weft to equal the warp. Such cloth is very little worth to the wearer, as the warp, being so much stronger than the weft, breaks it before it is half worn. The bulk of the China drills are even worse, 16's warp and 36's to 40's weft; the merchants who buy the cloth must know the quantity of size in the cloth they buy, as it is easy to tell by washing a piece. I believe there never was a time when manufacturers used heavier sizing than at the present time. Only yesterday I was talking to a sizer who sizes for various manufacturers; he said 'Only let me have a good warp, and I will guarantee to put 20 lb. of size to every 20 lb. of yarn, and the warp shall be dry and in good workable condition, and very little will come off in the weaving.' He also said, 'I can even do more than that, if it is required, but I can do that easily.' Those who buy grey calicoes to wear are the real sufferers. I have no hesitation in saying that cloth made from yarn of equal counts will wear for more than double the time the heavy-sized cloth will wear. In fact, the bulk of the grey cloth manufactured to-day is absolutely spoiled in the making."

On the subject of *calendering* Mr. Beaumont, referred to at page 324 respecting his investigations on the strength of linen cloth, observes, that "it is of no benefit to cloth. I can tell no other reason that could have introduced this custom further than a feeling smooth to the hand, and making it appear much thicker than it will be after one washing or two, for then nobody is able to tell whether it were calendered or no, and the sleaziness appears without any disguise."

The power required to drive a common power loom has been for some time a question of considerable interest, for it is assumed by many that a great saving might be made in that respect. When the same class of goods is woven both in the hand loom and the power loom, then the difference of power required by the two looms appears extraordinary.

The gearing of a power loom may be made considerably lighter, and less power would be thereby necessary to work it; but by so doing another defect would arise. The power loom is a machine which is subjected to sudden shocks and strains, and if its parts were not able to withstand them a constant cause of accident would result. Thus, when the shuttle fails to reach its box or becomes trapped, the loom is brought to an instantaneous stoppage. Before the brake was applied to the stop-rod the damage done by this means was very great, and the loom still requires the necessary strength in all its parts to withstand it. Therefore it may be questionable whether much saving of power could be gained by reducing the weight and strength of the loom.

Perhaps the act of throwing the shuttle takes up at least one-half of the power required to drive the loom, for the ordinary shuttle is of considerable weight, and must be driven at a great speed to accomplish its work. It may be said that the shuttle is too heavy, weighing about twelve ounces with the bobbin and weft. But if it were made much lighter it would not have sufficient strength to withstand rough usage, or weight to force the swell back as required. It is a question which has thoroughly engaged the attention of power-loom makers, but at present there does not, in this respect, appear much hope for any great alteration to be made.

If it is granted that one-horse power is required to drive ten looms, then each loom would absorb power equal to the raising of 3300 lbs. one foot high per minute, or one-tenth of a horse power. The power required to drive the shuttle may be assumed to be equal to raising a similar weight fifteen feet high; then if the loom be driven at 200 picks per minute the power required will be $200 \times 15 \times \frac{3}{4}$ lbs. (the weight of the shuttle) $= 2500$ lbs. raised one foot high per minute, or more than two-thirds of the power required by the loom.

But if the power be estimated as equal to raising the shuttle ten feet, then $200 \times 10 \times \frac{3}{4}$ lbs. $= 1500$ lbs. one foot high per minute, or not quite half the power given to the loom.

The ordinary cam-picking motion has one disadvantage. The picker is not only too far from the driving motion, but the speed of the crank-shaft, when transferred to the tappet shaft, is reduced to one-half, consequently, the action of the picking-cams, by being reduced in speed, work at a disadvantage.

In substituting springs, or other equivalent means for cams, the advantage of an equal blow is obtained at whatever speed the loom may be driven at. The spring is simply wound up and let off suddenly in order to throw the shuttle. But it has been found that the power given to a spring to wind it up is nearly double to what it is capable of exerting in its re-action, therefore in such case there does not seem to be any advantage to be gained over the ordinary cam-picking motion.

The method of driving the shuttle by *pneumatic* means has still many advocates, for they believe that by supplying compressed air from one source to each loom, not only could a more regular picking motion be obtained, and a great saving in the wear and tear of pickers and other parts of the loom be avoided, but a great saving of power would also be effected.

The formation and general *construction* of the loom is also a matter of great importance. The inverted batten makes the loom more compact, but this contrivance was first adopted by Mr. Almond in his improved hand loom (see page 245). The early power looms were heavy and clumsy, but Messrs. Harrison, of Blackburn, made such great improvements therein that the looms they exhibited in the Great Exhibition, 1851, have perhaps never been surpassed. One of these looms is now in the Patent Office Museum, Kensington.

The calculations that are required by the manufacturer are merely such as are necessary to enable him to ascertain the length and weight of yarn required to produce a given amount of cloth, and is a matter of simple arithmetic. Rules and tables have been frequently given to assist in the computation, as in the case of ordinary ready reckoners, but they seem scarcely necessary to the intelligent manufacturer of the present time. If he wishes to produce more goods of the kind he usually produces, or if he desires to make any alteration in them, it is not a matter of much difficulty. Or if the manufacturer desires to produce, or is required to imitate some new fabric, the question is rather concerning the cost and quality of the materials; for as regards the quantity required, it can offer no great difficulty for him to arrive at.

It has been already shown that the unit of measurement adopted by weavers (page 328) tends rather to confuse matters than to simplify them. Mr. Beaumont, who was perhaps the first to systemize the subject, believed he had succeeded in doing so. It may be, therefore, curious to see the first rule he gives. He states that,—

"A four hundred reed (at yard wide) will require yarn of four cuts two loops in the pound; a standard hank, or one dozen, will weigh two pounds thirteen ounces three drams; ten dozen of that yarn will make twenty yards of that cloth.

	lb.	oz.	dr.
Half a yard warp	00	05	13
One yard ,,	00	11	11
Two yards ,,	01	07	06
Three yards ,,	02	03	01
Four yards ,,	02	14	12
Five yards ,,	03	10	07
Ten yards ,,	07	04	15
Twenty yards ,,	14	09	15
The whole webb	29	03	14

Half a hundred of that warp, or one hundred threads of that yarn, twenty yards on the warping bars, will weigh one pound thirteen ounces and three drams. Twenty-two shoots or threads of that yarn must be struck into one inch of that cloth."

For different reeds other instructions of a similar nature are given. The strange custom of counting the splits in the reed, and not the threads in the cloth, is still used. One split being equal to two threads —although two threads are by no means always used, for in silk weaving from one to twelve threads are placed in each split.

Mr. Beaumont also gives instructions to purchasers of linen cloth, so that they may obtain the best quality. From the table given it appears that cloth one yard square made in a—

	lb.	oz.	dr.
400 reed[1] should weigh	1	2	1
600 ,, ,,	0	12	5
800 ,, ,,	0	8	15
900 ,, ,,	0	8	0
1000 ,, ,,	0	7	4
1200 ,, ,,	0	6	1
1400 ,, ,,	0	5	4
1600 ,, ,,	0	4	9

[1] 400 reed equals 800 threads per yard.

	lb.	oz.	dr.
1800 reed should weigh	0	4	1
2000 " "	0	3	10
2200 " "	0	3	5
2400 " "	0	3	0
2600 " "	0	2	13
2800 " "	0	2	9
3000 " "	0	2	7

From the above list it appears that linen cloth one yard square should weigh, if woven in a 900 reed, eight ounces, consequently if woven in an 1800 it should weigh four ounces.

It will be evident that the number of threads in an 1800 reed will be double in number to those in a 900, consequently they must be only one-half the diameter, so as to occupy the same space when laid flat. But a thread of *half the diameter* of another weighs only *one quarter* the weight—according to the square of its diameter,—therefore if double the number are used in the same space, the cloth will weigh only half the weight, and this corresponds with the weights given in Mr. Beaumont's table.

Now as it has been found that the most approved plain cloth is that in which the warp and weft nearly correspond, it follows that the number of threads and the weight of various counts, if composed of the same substances, must necessarily bear, when properly woven, a definite proportion to each other. All, therefore, that is necessary for the formation of a rule to ascertain what weight or count any plain cloth should be, is simply to fix upon some unit of measurement, and in the table above given the 900 reed cloth being eight ounces, it affords an easy means of comparison with the other counts.

Threads composed of different substances vary greatly in size in proportion to their weight, and in this respect the difference between the weight of linen and cotton is very apparent. Yet, extraordinary as it may appear, Dr. Ure came to the conclusion that the *specific gravity* of cotton and linen were alike when the air was expelled from between the fibres of both substances. And he believed that all vegetable fibres had about the same specific gravity, viz. 1.50, or $1\frac{1}{2}$ times the weight of water.

The animal fibres, such as silk and wool, he found to have a specific gravity of about 1.30, or nearly $1\frac{1}{3}$ the weight of water, and he concluded that all animal fibres might be the same.

The strength of vegetable fibres differs considerably, some kinds of flax being twice as strong as others. If the average be taken, the strength of silk is about double that of flax, and probably other animal fibres would be similar in that respect.

The units of length and other counts connected with weaving not only differ, but in one instance the weight used is of doubtful value. Thus the *denier* weight is often described as being equal to two grains. Dr. Ure, in his "Philosophy of Manufactures," understood it to be equal to 0.693 of an English grain, but upon testing a denier weight he found it to be 0.833 grains. In the last edition of his "Dictionary" it is said to be $\frac{1}{24}$ of an ounce *Poids de Marc'*. The pound avoirdupois is to the pound Poids de Marc' as 10 is to 17 nearly. Mr. Simmonds, in the appendix to the "Philosophy of Manufactures," says that "the custom of the trade is to reckon 32 deniers to a dram, and that the standard of silk measure is about 400 yards; that lengths of a single filament of China cocoons will weigh 2 deniers, and of French or Italian 2½." In some places 1000 yards are measured and weighed as a means of comparison. At Macclesfield 530 yards of silk are weighed, and 530 deniers equal one ounce. Mr. B. F. Cobb, secretary to the Silk Supply Association, gives the weight as 200 (? 20) deniers equal 16½ grains. In addition to the above there are various other definitions on the subject, but these will be sufficient to show the uncertainty that exists through the want of some fixed unit that would apply to some, if not all descriptions of threads.

It is scarcely to be wondered at that men acquainted with the application of *electricity* to telegraphy and other purposes should have believed it equally serviceable in some of the operations of weaving. As might be expected, the Jacquard apparatus seemed to offer an excellent opportunity for the needles to be worked, not by the direct pressure of a card, but by the connexion of a series of electro-magnets. By this means it was believed that paper might be substituted for cards, and the magnets might operate upon the needles through the perforations in the paper, or by passing a current of electricity through the medium of a metallic conducting surface on a sheet of paper or cloth representing the design to be woven, and thereby act without the use of perforations. It was also thought that one apparatus would suffice to work a number of looms, provided they were weaving the same design. But doubtless this substitute for Jacquard cards would be far more complicated and costly, and would not be readily understood by the weavers; and so far as one apparatus being able to govern a number of looms, it evidently did not occur to the inventor that when one loom was stopped through the breaking of a weft or warp thread all the rest must be stopped accordingly. Still there may be some purposes connected with weaving to which electricity may be applied ultimately with success, as it is at present done in spinning machinery.

In 1853 Chevalier Bonelli obtained a patent for an apparatus to dispense with the use of tappets or perforated cards, "and employ electricity to operate on the warp threads. For which purpose a series of electro-magnets are employed, the armiture or keeper of each of which is fixed to a suitable wire or hook, by which means, when the armature or keeper is attracted to its magnet, the particular thread or threads in connexion will be acted on."

For a similar purpose M. Bolmida obtained a patent in 1856 "for plain or figured weaving with the aid of a Jacquard, the needles of which are actuated by a peculiar arrangement of electro-magnets. One portion consists of a mode of elevating the griffe of the Jacquard, which is effected by means of a horizontal vibrating arm working on a centre at one end, and actuated at its free end by a stud or pin in a revolving disc, the pin working in a slot formed in the end of the arm. To this arm the 'lifter' is connected by suitable rods and levers. In like manner a smaller Jacquard for working the headles is used, which is actuated by a pair of levers below and connected by rods and levers to the griffe. The hooks or vertical wires of the Jacquard and the horizontal needles are arranged in the ordinary manner, with this exception, that, in place of being pushed backwards, they are impelled forwards, those not intended to be acted upon being prevented from moving by stops presented by the electro-magnetic apparatus. It is preferred to produce the pattern by the use of a thin sheet of metal cemented on to a sheet of paper. On this metallic surface is traced the outline of the design, and the ground is then coated over with any non-conducting varnish, leaving the pattern alone uncovered." Each needle of the Jacquard is provided with a separate magnet, and "the current is made to pass through the whole of the magnets, by means of several coils which are connected at one end to the conducting plates, which are supported by a wooden cross-bar and are insulated one from another. On each of the conducting plates rests the point of a copper plate or tracer, the opposite end of which rests upon the pattern cylinder or surface. Between the cylinder is a similar but shorter plate resting at one end on a transverse copper bar, and at the other end on the pattern surface or cylinder. The transverse copper bar is connected by a wire with the negative pole of the battery. The copper plates or tracers, and the short intermediate plates, are insulated from each other by having their sides covered with paper or other suitable non-conducting material. It will thus be obvious that the current will be established only when the point of a tracer and the point of its intermediate plate rest on the conducting metallic surface of the pattern cylinder."

It has also been suggested to employ electro-magnetism for governing the changes of the drop-boxes of looms.

Provisional protection only was obtained in 1856 by Eugenio Vincenzi for working Jacquards and the reading of the patterns by means of an electric current.

It is probable that electricity may prove of service in this operation and for recutting cards. Type-setting by this means has been very successfully done, and cutting punches may be arranged in like manner. Vincenzi describes his invention to "consist in cutting out, by means of a metallic point, the outlines of each of the coloured spots of which the pattern is formed in a thin sheet of tin or other suitable metal fixed to a sheet of stout paper, paste or card-board, or other suitable material; thus isolating these outlines from each other. On the margin of the sheet of paper are traced as many lines as the pattern contains colours, and on the back of the sheet each of these lines is made to communicate with its corresponding colour by means of small strips of tin, pewter, or other metal, and thereby causes the electric current to communicate with its corresponding colours without touching the others. By placing, consequently, the comb of the electric apparatus on the entire surface of the pattern, those teeth only will come into effect that touch a described colour, whereas, by bringing the current in contact with other lines on the margin, other colours of the pattern come into action."

It has also been proposed to carry the shuttle through the shed by means of a magnet, thus: J. Meus, in a patent obtained in 1844, says, "I propose to employ for this purpose the power of a magnet acting upon an iron shuttle." In 1851 Mr. R. Whytock claimed also to cause a shuttle to "travel under the influence of a magnet," and in 1854 M. F. Durand obtained provisional protection for actuating shuttles by means of magnets attached to shafts placed under the shuttles, small plates of steel being fixed to the underside of the shuttles for the purpose.

Another mode of employing electricity to purposes relating to weaving has been already alluded to (see page 213), viz. to cut or rather burn the pile threads in double velvet weaving by means of a thin platina wire heated by an electric current.

The principles of the various branches of the art of weaving having been described, it need scarcely be added that in order to obtain full effect from the various mechanical contrivances that have been shown depends principally upon the ability of the designer. It is not only necessary that he should be a good draughtsman, but it is requisite that he should be thoroughly conversant with all the artifices that the weaver can apply, so that every advantage can be taken of the means he has at his command. This, however, rests entirely upon the knowledge, experience, and skill of the designer, and can only be acquired by actual practice. New descriptions of cloth, having some special advantage, either as regards its strength, usefulness, or ornamental purposes, are frequently being introduced. So great are the changes made, and of such great importance, that the texture or mode of decussation is often secured by patent, and we have shown several examples of the kind. This, however, is the work of the designer rather than of the weaver. He knows the nature of the materials he has to deal with, and to make the best use of them depends almost entirely upon his skill and judgment.

We will conclude our summary by quoting the following passage from Mr. Charley's excellent work on "Flax and its Products in Ireland:"—

"It is interesting to watch the various motions in the machinery of a power loom;—the roller quietly pulling on the cloth as it is made, the sleigh driving tight home the weft which the little shuttle slips in between the divided yarns of the warp; the headles raising the alternate sets of yarn to receive the next shot of weft; the striker, which represents the weaver's arm, at regular intervals propelling the shuttle by a blow across to the other side of the loom; a regular game of battledoor and shuttlecock. All these actions going on with each loom, and hundreds of looms in the same building, causing a din resembling the crash of battle. In this peaceful strife, however, no blood is shed, but food and raiment are earned by willing hands for themselves and the little hungry mouths at home."

APPENDIX.

THE following Statistics relating to Factories in the United Kingdom, in which spinning and weaving are carried on, are taken from the most recent Parliamentary Reports on the subject, and may be found to be of considerable interest and importance.

It may be mentioned that the Lists do not include any persons except those engaged in Factories, consequently an allowance must be made on that account, for in some cases the business is carried on to a great extent at the workpeople's houses and other places not included in the Factory Return. Thus in the Hosiery and Lace trades probably four times the number given are employed, and in the Silk trade about twice. But in those trades which require motive power, such as the Cotton manufacture, the number of persons employed out of the Factories is considerably less in proportion.

GENERAL SUMMARY OF FACTORIES, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	6,379	42,293,772	4,812,127	572,460	231,692	328,494	454,528	783,022
Scotland . .	680	2,436,947	446,429	74,195	44,350	44,269	110,650	154,919
Ireland . . .	235	1,062,388	25,580	21,056	11,464	21,281	46,463	67,744
Total for the United Kingdom	7,294	45,793,107	5,284,136	667,711	287,506	394,044	611,641	1,005,685

Summary of Cotton Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	2,542	36,034,232	4,024,883	431,389	148,341	180,607	259,729	440,336
Scotland . .	105	1,373,454	337,760	29,171	14,122	5,830	30,274	36,104
Ireland . . .	8	108,086	3,374	2,558	1,169	1,183	1,892	3,075
Grand Total of Cotton Factories	2,655	37,515,772	4,366,017	463,118	163,632	187,620	291,895	479,515

Summary of Woollen Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	1,483	2,604,610	98,780	45,025	33,975	54,119	51,252	105,371
Scotland . .	257	529,011	56,904	11,758	7,546	11,816	15,912	27,728
Ireland . . .	60	31,948	2,628	307	240	782	724	1,506
Grand Total of Woollen Factories	1,800	3,165,569	158,312	57,090	41,761	66,717	67,888	134,605

Summary of Shoddy Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	123	101,134	946	1,437	686	1,568	1,856	3,424
Scotland . .	2	...	..	...	...	3	4	7
Ireland . . .	...	...	...	...	...	...	...	...
Grand Total of Shoddy Factories	125	101,134	946	1,437	686	1,571	1,860	3,431

Summary of Worsted Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	648	2,128,890	381,560	75,591	36,737	53,995	77,835	131,830
Scotland . .	43	53,330	17,846	6,156	3,200	3,052	7,203	10,255
Ireland . . .	1	572	252	...	...	3	9	12
Grand Total of Worsted Factories	692	2,182,792	399,658	81,747	39,937	57,050	85,047	142,097

Summary of Flax Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	141	291,735	47,287	5,264	3,120	6,856	15,471	22,327
Scotland . .	159	275,119	15,432	18,529	12,279	12,752	33,064	45,816
Ireland . . .	149	906,946	18,616	17,827	9,730	18,323	41,993	60,316
Grand Total of Flax Factories	449	1,473,800	81,335	41,980	25,129	37,931	90,528	128,459

Summary of Hemp Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	45	6,448	1,019	22	9	1,465	1,574	3,039
Scotland . .	12	9,744	3,861	...	...	581	1,250	1,831
Ireland . . .	4	1,098	372	...	...	221	120	341
Grand Total of Hemp Factories	61	17,290	5,252	22	9	2,267	2,944	5,211

Summary of Jute Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	15	21,754	1,278	927	897	1,510	3,423	4,933
Scotland . .	84	185,419	7,658	8,325	7,058	9,543	21,350	30,893
Ireland . . .	11	13,738	338	347	308	479	1,615	2,094
Grand Total of Jute Factories	110	220,911	9,274	9,599	8,255	11,532	26,388	37,920

Summary of Hair Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	21	46	8	53	5	464	322	786
Scotland . .	6	60	...	...	...	48	377	425
Ireland . . .	...	...	...	...	...	...	...	...
Grand Total of Hair Factories	27	106	8	53	5	512	699	1,211

Summary of Silk Factories, 1874.

	Number of Factories.	Number of Throwing Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	812	1,103,893	214,740	9,759	5,936	12,772	31,647	44,419
Scotland . .	4	10,810	6,968	226	127	109	631	740
Ireland . . .	2	...	...	17	17	290	110	400
Grand Total of Silk Factories	818	1,114,703	221,708	10,002	6,080	13,171	32,388	45,559

Summary of Elastic Factories, 1874.

	Number of Factories.	Number of Spinning Spindles.	Number of Doubling Spindles.	Number of Power Looms.	Number of Power Loom Weavers.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	88	1,030	41,626	2,633	1,986	3,114	2,156	5,270
Scotland . .	2	...	...	30	26	35	19	54
Ireland . . .	...	...	...	...	...	...	...	...
Grand Total of Elastic Factories	90	1,030	41,626	2,663	2,012	3,149	2,175	5,324

Summary of Lace Factories, 1874.

Counties.	Registration Districts.	Number of Factories.	Number of Lace Machines.	Number of Persons Employed.		
				Males.	Females.	Total Males and Females.
England and Wales.						
Wilts, Dorset, Devon, and Somerset	South Western.	5	527	900	1,030	1,930
Leicester, Rutland, Lincoln, and Nottingham	North Midland.	273	2,609	5,270	2,045	7,315
Derby	...	33	326	775	353	1,128
Total of Lace Factories .	...	311	3,462	6,945	3,428	10,373

Summary of Hosiery, 1874.

	Number of Factories.	Number of Heads of Circular Frames.	Number of Feeders of this Number of Heads.	Number of Flat Frames.	Number of Inches on the same.	Number of Persons Employed.		
						Males.	Females.	Total Males and Females.
England and Wales	150	15,414	23,130	3,457	176,747	5,079	5,835	10,914
Scotland . .	6	,90	180	293	7,264	500	566	1,066
Ireland . . .	...	...	...	...	...	...	...	...
Grand Total of Hosiery Factories	156	15,504	23,310	3,750	184,011	5,579	6,401	11,980

IMPORTS.

TOTAL QUANTITIES AND VALUE OF ARTICLES RELATING TO TEXTILE MANUFACTURES, IMPORTED IN THE YEAR 1876.

		£
Cordage and Twine . . . . . £	558,374	558,374
Cotton, raw . . . . . . cwts.	13,284,454	40,180,880
,, yarn . . . . lbs.	1,937,063	183,259
,, Manufactures of India and China pieces	117,685	53,498
,, ,, of Europe . . . £	1,757,261	1,757,261
Embroidery and Needlework . . . £	106,483	106,483
Flax and Tow (dressed and undressed) cwts.	1,405,838	3,539,501
Hair, cow, ox, bull, or elk . . cwts.	44,725	175,023
,, goats', or wool . . . . lbs.	5,988,473	729,535
,, horse . . . . . . cwts.	24,311	202,472
,, manufactures of . . . . £	147,651	147,651
Hemp and Tow (dressed and undressed) cwts.	1,174,859	1,958,208
Jute . . . . cwts.	3,825,259	2,804,597
,, yarn . . . . lbs.	1,706,330	60,593
Lace . . . . £	509,323	509,323
Linen yarn . . . . lbs.	3,414,205	185,747
,, manufactures . . . . . £	240,827	240,827
Silk, raw . . . . lbs.	6,016,927	5,770,341
,, knubs or husks, and waste . cwts.	29,663	406,051
,, thrown . . . . lbs.	164,040	199,293
,, manufactures out of Europe . . £	260,331	260,331
,, ,, in Europe . . £	11,555,409	11,555,409
Wool, sheep and lambs . . . . lbs.	386,568,323	23,244,554
,, Alpaca, Vicuna, and Llama . . lbs.	3,487,436	393,255
Wollen manufactures . . . . . £	4,920,711	4,920,711
,, yarn . . . . . . lbs.	14,042,780	1,737,248

EXPORTS.

TOTAL QUANTITIES AND VALUE OF ARTICLES RELATING TO TEXTILE MANUFACTURES, THE PRODUCE OF THE UNITED KINGDOM, EXPORTED IN THE YEAR 1876.

			£
Bags and Sacks, empty	dozen	4,020,211	1,211,728
Cordage and Twine	cwts.	96,766	266,460
Cotton Yarn	lbs.	232,554,627	12,781,733
Cotton manufactures—			
Piece goods, white or plain	yds.	2,667,423,176	31,454,280
Printed or dyed	„	990,147,298	18,494,492
Of mixed materials (Cotton predominating)	„	11,833,900	429,401
Total piece goods	yds.	3,669,404,374	
Lace and Patent Net	£	1,016,051	1,016,051
Stockings and Socks	dozen pairs	1,105,666	364,054
Thread for sewing	lbs.	9,635,363	1,763,586
Hosiery and small wares	£	1,337,671	1,337,671
Haberdashery and Millinery	£	3,770,171	3,770,171
Linen and Jute Yarn—			
Linen Yarn	lbs.	22,278,259	1,449,513
Jute „	„	16,709,239	226,813
Linen manufactures—			
Piece goods, white or plain	yds.	146,666,075	4,365,072
Checked, printed or dyed	„	13,181,129	449,918
Sailcloth and sails	„	3,121,784	186,922
Total piece goods	yds.	162,968,988	
Linen Thread for sewing	lbs.	2,638,131	349,549
Unenumerated	£	269,175	269,175
Jute manufactures	yds.	120,813,966	1,558,256
Silk—			
Thrown, Twist, and Yarn	£	1,080,678	1,080,678
Broad piece goods	yds.	3,943,737	648,047
Other sorts	£	1,146,518	1,146,518
Wool—			
Sheep and lambs	lbs.	9,817,249	757,832
Woollen and Worsted Yarn	„	30,854,160	4,417,241
Cloths, Coatings, &c.	yds.	40,479,373	6,451,410
Worsted Stuffs	„	221,561,999	9,141,605
Blankets and Blanketing	„	6,157,539	606,499
Flannels	„	7,764,765	408,387
Carpets and Druggets	„	6,298,479	911,873
Of other sorts	£	1,083,704	1,083,704

FOREIGN AND COLONIAL PRODUCE EXPORTS.

TOTAL VALUE OF ARTICLES RELATING TO TEXTILE MANUFACTURES, OF FOREIGN AND COLONIAL PRODUCE AND MANUFACTURES, EXPORTED IN THE YEAR 1876.

	£		£
Cotton—		Silk—	
Raw	4,534,464	Raw	2,801,240
Yarn	76,069	Knubs or husks and waste	54,264
Manufactures	228,929	Thrown	56,100
Flax—dressed and undressed	57,026	Of countries out of Europe	50,408
Hemp—ditto ditto	205,220	Ditto in Europe	252,646
Jute	704,904		

	£
Wool—sheep and lambs	11,340,645
Woollen manufactures—	
Cloth and stuffs	182,229
Unenumerated	123,429

INDEX AND GLOSSARY.

LONDON:
GILBERT AND RIVINGTON, PRINTERS,
ST. JOHN'S SQUARE.

JOHN CROWLEY & Co., SHEFFIELD,

MANUFACTURERS OF EVERY DESCRIPTION OF

Castings suitable for Weavers, in ordinary Cast-Iron & Malleable Cast-Iron.

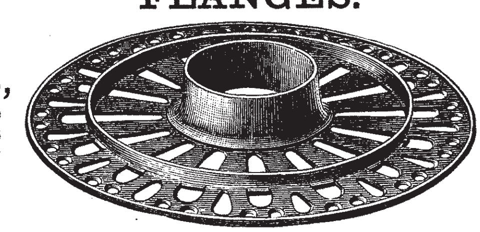
IMPROVED PATENT CARBURETTED

MALLEABLE IRON CASTINGS,

OF EVERY KIND.

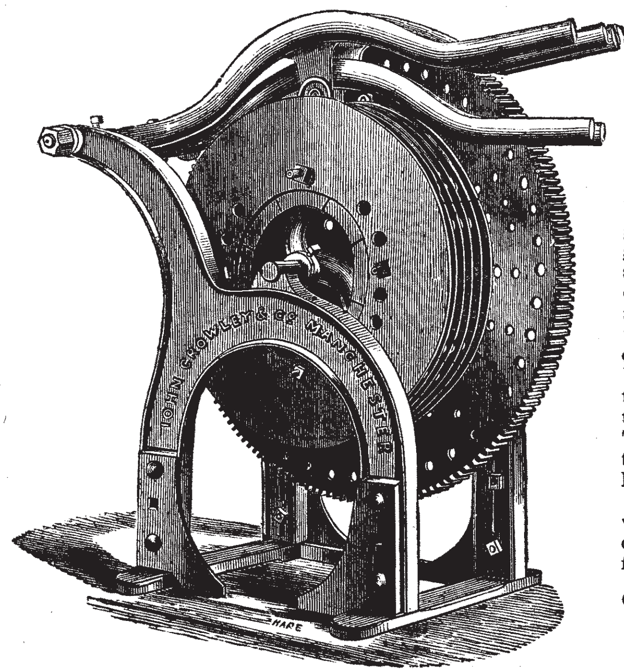
FLANGES.

WARPING
AND
Loom Beam
FLANGES,
Made of Malleable Cast-Iron, are fast superseding ordinary Cast-Iron, being much lighter and not liable to break.



MULE SICKLES
OR
FALLERS,
And Fingers.
Also, Skew, Bevel-Worm, Segment, and other Wheels; Loom Fingers, Steps, and Catches; Scutcher-Bar, and Arms.

Sole Makers of B. Woodcroft's Patent Section Tappet & Jacquards.



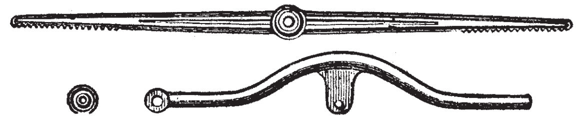
The Patent Tappet possesses the following advantages:—

The Plates of the Section Tappet are parallel to each other, whereby less amount of friction is produced against them by the Treadle Studs and Bowls than by the common plates. The Jiggers, or parts in relief, which give motion to the Bowls, are set out on a geometrical principle, so that the Shafts rise and fall equal distance in equal times. By these means the blow of the Reed is borne by each Warp thread equally, whether the Weft be struck home with the Shed open, shut, or crossed. The consequence is that fewer threads are broken and the healds are less worn.

This Tappet will also weave weaker Yarns than the ordinary one, and is now in general use for

Cotton, Woollen, Linen, Silk, Worsted, &c.

Tappet Wheels, Jacks, Treadles, and Bowls of every kind.



MALLEABLE CAST-IRON SPANNERS.

Illustrated Catalogues on application to

JOHN CROWLEY & Co., SHEFFIELD;

Or to the Stores, Corporation Street, Manchester.

London:
SAMPSON LOW, MARSTON, SEARLE, & RIVINGTON,
CROWN BUILDINGS, 188, FLEET STREET, E.C.