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LECTURES ON

PRACTICAL WEAVING:

THE POWER LOOM

AND

CLOTH DISSECTING,

BY

THOS. R. ASHENHURST,

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PREFACE.

If any apology or excuse is necessary for bringing a work of this kind before the public at the present moment, when so many others of a similar kind are being produced, mine must be a desire to present one which, I hope, is as complete as can be conveniently produced, and which will represent machinery and processes up to date.

When I first ventured to bring a book on Weaving before the public 17 years ago (1878) the field was comparatively clear, and the technicalities of the art and science of weaving were not so widely diffused as now. Of works on the subject of weaving there were few. Murphy, Gilroy, White, Watson, and the modest, yet most useful work of Brown, on the "Power Loom," represented practically the whole.

Murphy was the great master, and every writer in the English language, and most Continental writers are indebted to him for much inspiration, whether acknowledged or not, or whether it comes directly or indirectly. Murphy laid down principles with the hand of a master, and although some seventy years have elapsed since his work first saw the light, and the machinery of weaving has been completely revolutionised, yet the principles are the same. The Jacquard was in its infancy, yet the draw loom and contrivances which led to the Jacquard were there, and the figuring machines of to-day are but developments. The power loom was only beginning to see the light; it has now developed into a most important machine. The "Art of Weaving" was well known and lucidly explained by Murphy; the science has been developed since. The science is built upon the art.

During the twenty years I have devoted to teaching, coupled with practical work in the mill, as well as in the years previous when engaged solely in mill work, it has been my lot to be brought in contact with a great variety of fabrics, and the machinery required for, and the methods of producing them, and to explain such to the students under my care.

The progress which has been made since Technical Schools were first established in this country has, in my opinion, rendered it necessary to make the text books more complete and exhaustive. Several works have appeared since my first; many of them excellent, but none of them, I believe, sufficiently comprehensive.

I cannot claim that everything is embraced within the pages of this work, or that any one item is thoroughly exhausted, but I have endeavoured, at least, to give a sufficiently comprehensive survey to enable the intelligent student to grasp a fairly sound knowledge of Practical Weaving.

Of designing and pattern making I have purposely kept clear so that I might be enabled to deal with the loom and all its parts in detail without confusion of ideas. Pattern making and designing I may deal with when I have completed this work.

Whatever may be the shortcomings, I have endeavoured to reduce to readable form the Lectures and Lessons on the subject it has been my duty and pleasure to give to students during the twenty years I have been endeavouring to teach them, and I trust there may be some information and suggestions in the Lectures which will assist students in advancing themselves, and maintaining the supremacy of British Manufactures.

I have to express my indebtedness to the Machine Makers whose names are mentioned in connection with the various machines dealt with, not only for the loan of many of their blocks, but also for the assistance they have rendered in supplying me with details.

T. R. A.

Bradford, May, 1895.

SYLLABUS.

PRACTICAL WEAVING: THE POWER LOOM, AND CLOTH DISSECTING.

LECTURE 1.

WINDING, WARPING, BEAMING, AND PREPARING FOR THE LOOM.

To deal with the subject I have taken in hand thoroughly it will be necessary to trace the yarn from the point where it leaves the spinning frame or doubling machine to the loom. As a preliminary we may first take the yarn as being spun upon cops, as would be the case in woollen or cotton, and follow it through the process of warping, sizing, and so forth. Take cotton as the first illustration. It would be necessary to wind from the cop to bobbins. This is done on a machine commonly known as a cop winder, as shown in Fig. 1, the process being to transfer the yarn from the cop to double-headed bobbins. These bobbins are usually built a little fuller in the middle than at the ends, this being attained by the traverse plate travelling a little quicker at the ends of the bobbin than in the centre. This is usually accomplished by the use of a heart-shaped cam, so constructed as to give exactly the motion or variable traverse required. In other cases what is known as the "mangle wheel" motion is employed, that is, a species of skeleton wheel with teeth on the outer rim, and so contrived that the pinion travels first outside the rim and returns on the inner side, so reversing the motion as shewn in the illustration Fig. 2. Recently an improvement has been introduced entirely dispensing with the double-headed bobbins by winding the yarn upon paper tubes in what are known as cheeses. This is not only economical, but for many purposes gets rid of a difficulty in the regularity of the tension. However well bobbins may be wound there is a tendency to irregularity in tension at the ends of the bobbins, more especially when coming near the bottom, and, as will be shown presently, evenness of tension in warping is an important

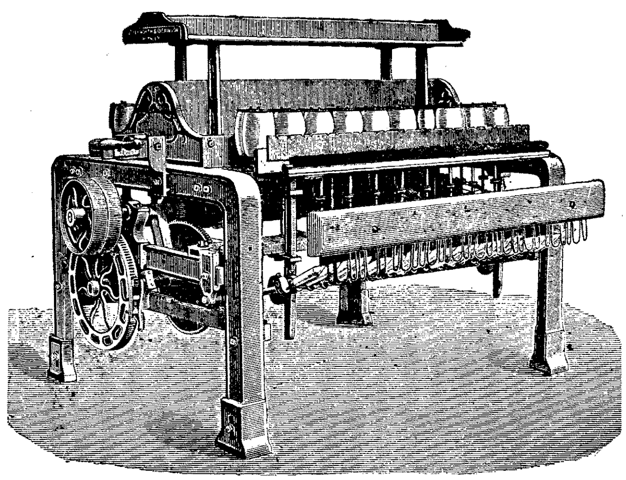


Fig. 1.

factor. Apart from cop winding the yarn has frequently to be wound from hanks in consequence of its being what is termed hank-dyed. Many machines, such as that given in the illustration, Fig. 1, are equipped for either hank or cop winding. The object of hank winding is to prepare for the production of fancy patterns in the warp, as by this means cleaner and better colours are often obtainable, though it is not necessarily the most economical.

Assuming now that the yarn is prepared for the warp, it will be desirable to examine all the various methods in use, as it does not necessarily follow that the method or process best adapted for one material will be equally suitable for another. To go back to the earliest form of warping, and that which is at present practised in the woollen manufacture to some extent, the general principles may be examined and a theory laid down. Taking the cops as they come from the spinning mule they are placed upon vertical pins, on what is known as a creel as shewn in Fig. 3. From the cops the threads are carried through guide eyes, and gathered together in the

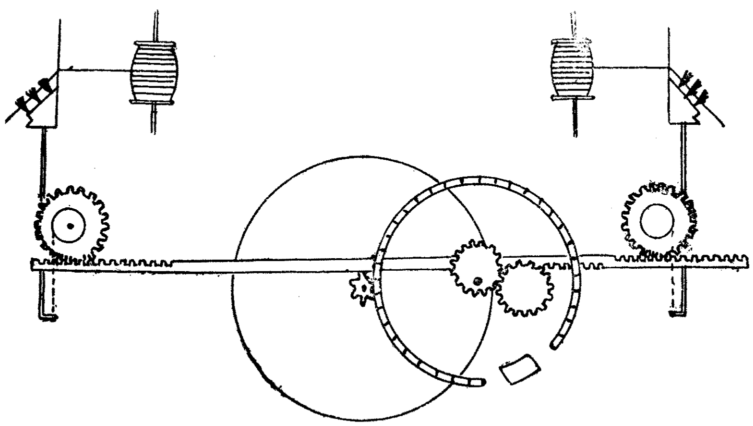


Fig. 2.

hand of the warper. The warp is made upon what is known as the woof, as shewn in Fig. 4, which, although different in some respects from the older forms in use, yet is practically the same. The earlier form simply consisted of a single frame with pins upon one side; the warp threads being taken from the creel the warper picks a "leize" or "lease" with her fingers; taking this "leize" she places the threads on the two pins on the top rail of the frame; then, bringing them from there, they are carried over one of the pins on the vertical bar at the right, across the frame, over another bar on the left, and so backward and forward till the requisite length of warp is formed, when the threads are carried round to two pins at the bottom to form what is termed the "foot lease;" then carried back in precisely the same manner to the top, when the lease is formed afresh, and so this operation is repeated until the number

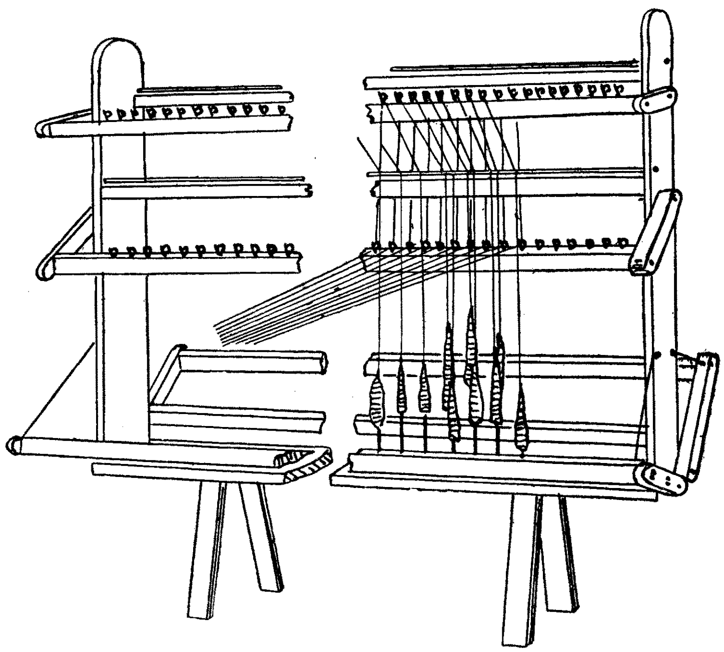


Fig. 3.

of ends required for the warp are put together. The difference between "head leize" and "foot leize" is that every end is leased separately at the top, whereas they are leased in groups at the bottom, these groups forming divisions variously known as "beers" or "porties." The skill of the warper is shewn in this work by keeping all the threads at a perfectly even tension. In the more modern creel and warping woof a ready means of picking the lease is adopted. Instead of the threads being picked up singly in the fingers from guide-eyes, they are passed through the eyes of a series of needles forming a kind

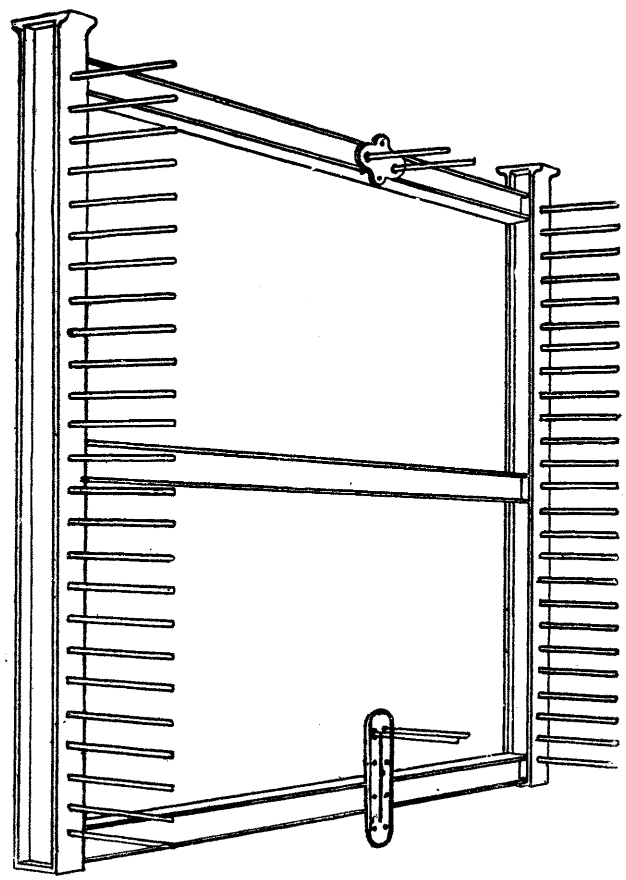


Fig. 4.

of comb, or double comb, and placed in a frame and so arranged that they can be raised and depressed alternately, and so the leize is formed immediately.

The next form of warping mill is what is commonly known as the vertical one, which consists really of a large reel revolving upon a vertical axis, as shewn at Fig. 5. At the head and foot are a pair of lease pins similar to those on the woof, and the yarn is wound round and round upon the reel to the requisite length. For the purpose of distribution of threads upon the reel they are carried through what is known as a heck, precisely similar in character to the combs in the leasing stand.

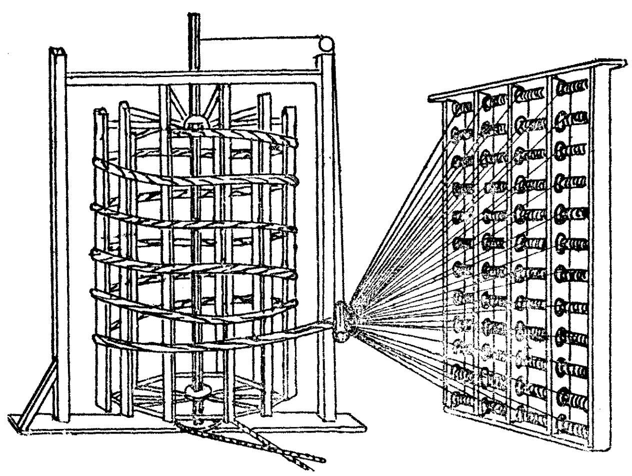


Fig 5.

An illustration of the heck is given at Fig. 6. A few of the needles with eyes, are shewn at each extremity of the bars, one portion being raised and the other depressed, and some of the rollers, or vertical pins, are shewn also for dividing the threads into "Leers" or "porties." By an ingenious contrivance of levers, as seen below, the needle frames may be raised by pulling the handle at the end of the horizontal rod on the left of the drawing; the position of the two needle frames can be reversed; so that the warper has only to place her hand between the threads, place the first lease on the pegs of the warping mill, reverse the position of the needles and place the lease so formed upon the next pin, and so on. There is no need to pick the threads up singly. This heck travels upon a post placed near the reel or mill, and is so arranged that one layer of yarn will not be built upon another more than can be avoided. Should building occur to any great extent the result would be unevenness of tension. The liability to building is probably one of the great

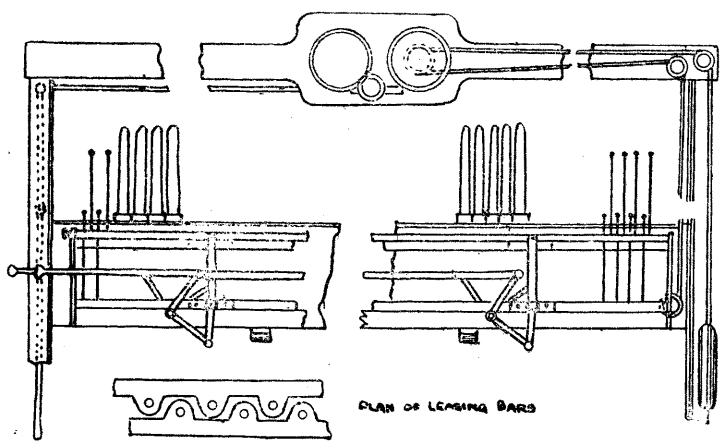


Fig. 6.

causes for the abandonment of the vertical mill in the warping of yarns for many classes of fabrics.

Another feature of this warping mill must be borne in mind; usually the yarn is carried from top to bottom and back, as described in warping on the woof, but this gives rise to serious difficulties in some fabrics, for example in worsted goods. It is well known by all who have carefully observed worsted yarn, that the fibres are laid in one direction in spinning, and were the warp threads carried from top to bottom of the mill and back again, one half would have the lay of the fibres in one direction and the other half in the opposite direction; then in the process of weaving those fibres laying towards the cloth would be smoothed down in beating up the weft and the others would be ruffled; hence an appearance of defect would be produced. This defect is often brought about in another manner; suppose bobbins are re-wound and are then put in the warping creel as though they had come straight from a doubling frame, they would go into the cloth with the fibres laid in the opposite

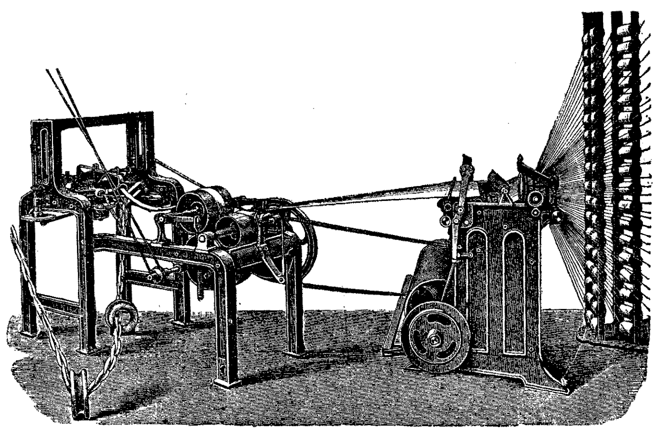


Fig. 7.

direction to the bulk of the warp, and so produce the appearance of a stripe when the goods were dyed and finished.

The next form of warping is what is known as sectional warping; this consists in running all the threads from the creel on to a small section of a beam, as shewn in Fig. 7; those sections are then put together side by side and run direct on to the warp beams for the loom. (Fig. 7 represents a warping machine from which the warp may be balled, but the principle is the same.) This is a very convenient method of making warps for fancy patterns, and, as will be easily understood, possesses the great advantage of keeping all the warp threads at an even tension as in the horizontal reel. So far as the formation of pattern is concerned as many bobbins would be put in the creel as would form one or more complete patterns, so that all the sections run together side by side would produce the requisite number for the complete warp. In all cases of warping on the vertical mill the warp must be pulled off and balled, or, in the case of woollen or worsted warps, linked for convenience of transport. Sectional warping machines or warps made on sectional machine may be dealt with in the same manner, that is, all the sections may be run together and then drawn off into a ball.

As already said the sectional warping machine has in a very great measure supplanted the warping mill, not only as to the warping of warps where various coloured threads are employed, but also in plain warps, because of the superiority of its work. It must be perfectly clear that warps made upon the sectional machine will not only have an equal tension upon each thread, but there will be a practical freedom from the half beers or groups of thread becoming entangled together. Again, there is the advantage of being able to take sectional warped warps and ball or chain them for the purpose of dyeing or sizing where necessary. For this purpose a chaining machine is in use which meets all the requirements, and is illustrated in Figs. 7 and 8. This machine is made by Messrs. Hurst & Co., of Rochdale. The illustration shews the machine in two parts, the first part consisting of the usual creel, rollers and heck or a sectional warping machine—and the second part of what might be termed a drawing off and chaining machine, so that instead of the sectional warp being wound from the roller, or made into a "cheese," it is drawn off in the usual manner as from a warping mill and chained, or it may be balled. It will thus be obvious that all the advantages of a sectional machine as regards evenness of tension on the threads is obtained along with the advantages of the ordinary warping mill. Presently it will be necessary to compare the relative cost of ball warping whether on the mill or sectional machine along with warp dyeing and dressing with the other methods in use.

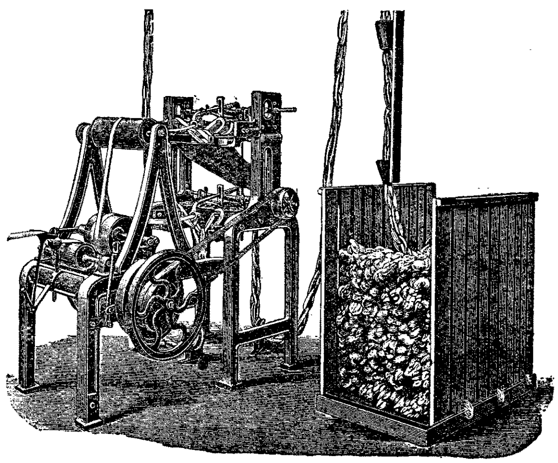


Fig. 8.

The next machine calling for attention is the horizontal warping mill, as shewn in Fig. 9, which really comprises the warping mill and beaming machine.

The mill or reel as will be seen is mounted on a central shaft supported by the end frames of the machine, and the leading feature is the laying of the warp on the reel at each revolution, so as to ensure evenness of tension on all the threads. As seen in the illustration the driving gear is to the left of the machine, there being three

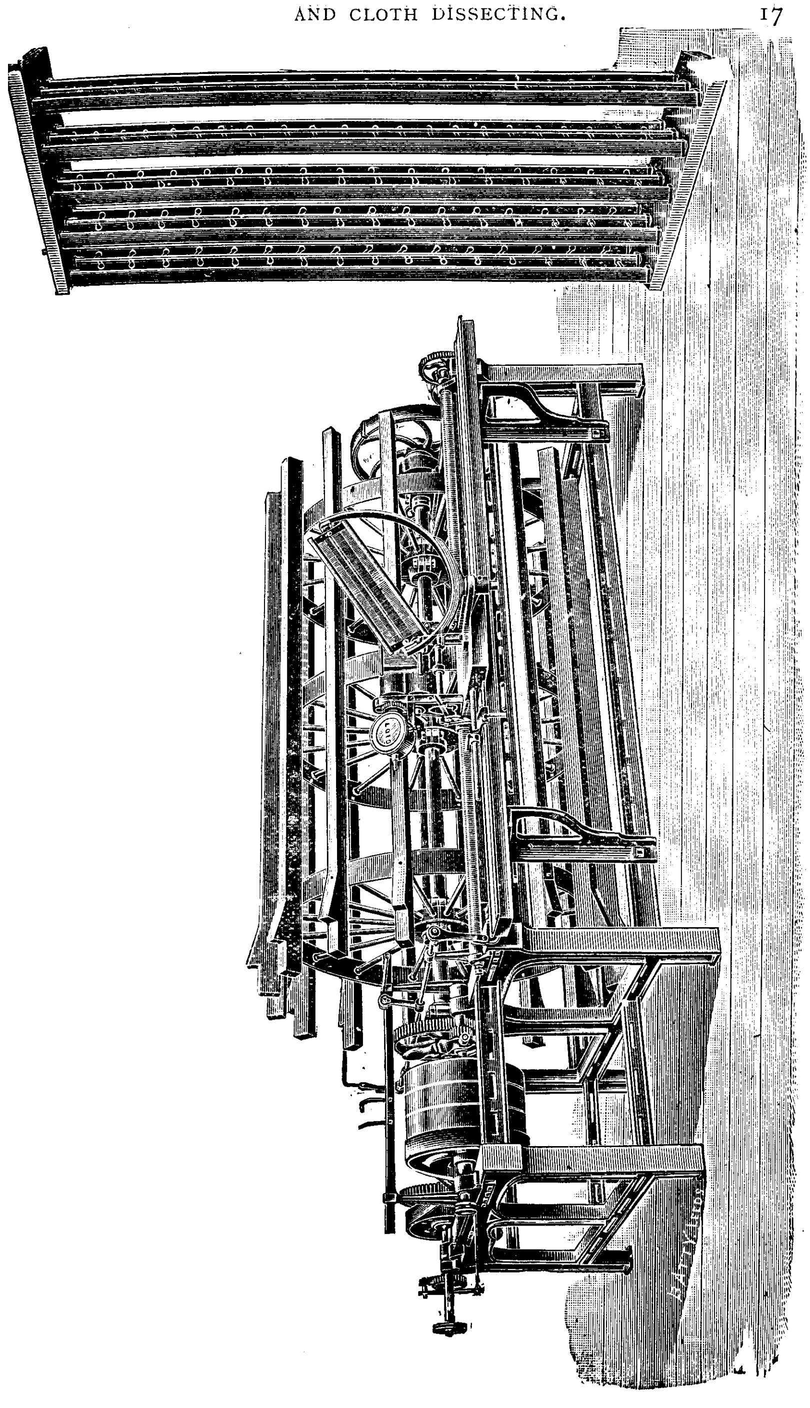


Fig. 9.

pulleys, so that the belt may be either on the loose pulley or the driving pulley at will, or the machine may be reversed for pulling back to find a broken thread. In front of the machine there is a heck differing from the heck already described in having the warp threads carried through a reed to secure perfect distribution. The mode of procedure then is to commence a section of the warp, say for example, 200 ends to the left of the machine and close up to the short inclined planes seen on the staves or bars of the reel to the left; then instead of trying to build the warp in vertical cheeses, or with all the threads laid straight on the top of each other they are gradually moved to the left up the inclined

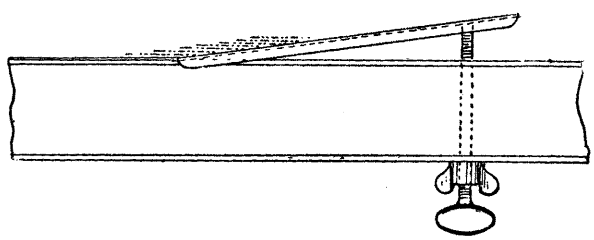


Fig. 10.

plane, forming another with the warp threads on the right and exactly corresponding with that on the left, as suggested in Fig. 9. When one section has been made of the requisite length the heck will be moved to one side and the operation repeated, and so on until the requisite number of threads have been warped.

To ensure accuracy of measurement there is a positive measuring machine attached, the dial of which is seen at the front of the illustration, indicating the exact length put on as the machine is running, and should there be any pulling back the motion registers back, so as to always record the length on the reel. When all the sections have been built the warp can be beamed direct from the reel.

A beaming frame stands in front of the machine, a beam is put in and the flanges adjusted and the warp run direct back, so that all the sections come off together, and at exactly the same tension, thus saving both time and labour.

The machine as shewn here is made by Messrs. Lightowler and Keighley, of Bradford, but the adjustable inclined plate shewn at Fig. 10 is a feature of Messrs.

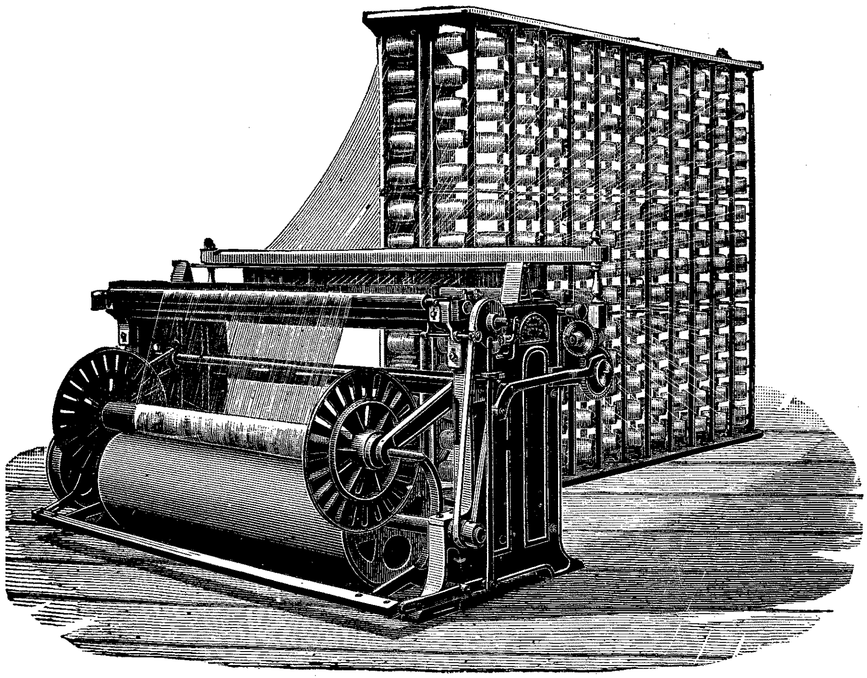


Fig. 11.

Hutchinson and Hollingworth. Messrs. Hutchinson and Hollingworth's Machine differs from this. In the machine just described the heck is made moveable, so as to build the warp up to the inclined plane; but they use a stationary heck and give a traverse to the reel itself, and when one section has been built up the heck is moved a distance corresponding with the width of a section and the process repeated. As each section is completed of the requisite length, the machine is stopped automatically. Still another machine is shewn at Fig. 11, where the warp threads are run direct from the bobbin to the beam. In this case a comparatively small number of threads would be run on to one beam, but there would be a great length, then a number put together to make up the requisite warp.

Assuming that the warps have been made upon one or other of the mills described, other treatment is then

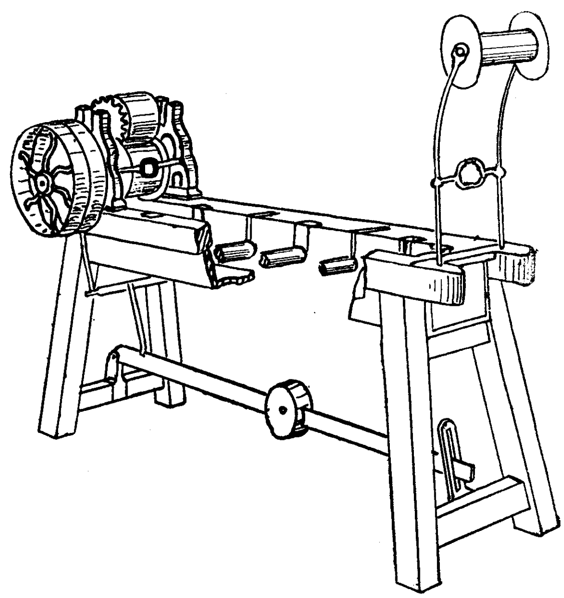


Fig. 12.

necessary. In the case of woollen warps especially they must be sized. As to the nature of the size it is not necessary to enter into the details more than to say that it usually consists of a solution of an animal substance, something of the nature of weak glue. The ordinary process is to pass the warp from the ball through a machine as shewn in Fig. 12. This machine consists of a long trough containing the hot size and a roller and guide eye and a series of rollers in the bottom of the trough for the purpose of immersing the warp in the size. At the other end are a pair of squeezing rollers. A portion of the trough is shewn with the side cut away. After the warp has passed through the size it is necessary that it should be dried and opened out at the same time. The earliest method of doing this was to stretch the warp over a number of rods in a field, or along a wall side. The warp would be stretched at full length, and a raddle, a species of coarse comb, as shewn at Fig. 13,—where it is shewn both with and without cover,—

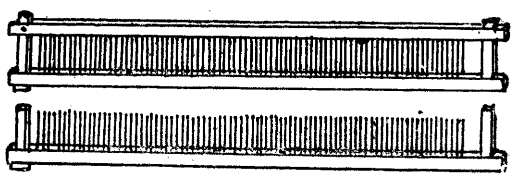


Fig. 13.

would be run through the warp from end to end, so spreading it out to dry and preventing the threads adhering to each other too much with the size. The laying of the warp in the raddle is practically equivalent in beaming to that of slaying in dressing. A given number of threads must be spread over a given width. Then if a raddle is made with a given number of teeth per inch, or per foot, the warp must be spread out to the proper width by filling between a given number of teeth and missing a certain number. This difficulty has been met in a considerable degree by the expanding raddle, which consists of a series of jointed rails or laths, each being pivoted in its centre, one upon one rail and one upon another; these two rails being made to slide upon each other. Upon the laths lying in one direction the raddle teeth are fixed, and the other blank, so that as the two foundation rails are moved backward and forward the angle of those carrying the raddle teeth is altered, and made finer or coarser as required.

The next method adopted was what is known as the balloon process. In this the warp would be passed through a sizing trough, and through the raddle on to the balloon; the balloon was a skeleton reel placed horizontally with moveable cross bars; these bars being inserted in the radial arms of the reel as it revolved, so that the warp was continually being wound upon a succession of rails; then the balloon made to revolve in hot air until the warp was dry, when it could be wound direct to the weaver's beam and so passed to the loom. The strength of size would of course be varied according to the quality of the material; that which would serve well for coarse goods being altogether unsuitable for fine material.

In goods where the warps would not require to be sized they would be taken direct and beamed, or dressed, on to the weaver's beam. There are many forms of beaming or dressing frame, one of the most convenient being shewn on Fig. 14. As will be seen here the warp ball is placed upon a turn table, this facilitating the revolving of the ball in case of there being any twist, then it is carried through a rack, which enables the dresser to give any degree of tension required. From that it is to be carried over a rail at the opposite end and under a roller and back to the beam, the raddle or sley being placed at any convenient point near the beam; the dresser or beamer's business being to see that the warp threads pass evenly through the raddle, or sley, and are properly built upon the beam. This portion of the work, if not properly carried out, may be the cause of many and serious faults in the cloth, as well as great trouble in the process of weaving. For instance, if the flanges are not properly and evenly set, or the warp not properly built up to them, there will be irregularity of tension at the edges. In many cases the warps, for convenience, are made into two or more balls, and these have to be put together in beaming or dressing. In putting them together one of two methods may be adopted; the first is to run them both through the rack at the same time, and either lay them side by side on the beam, or in alternate ends, or groups of ends, such as "half

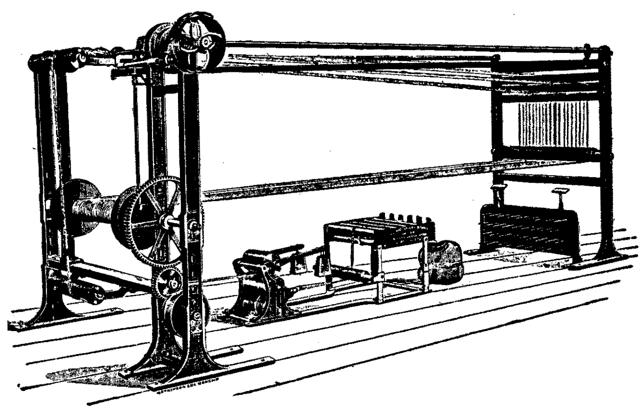


Fig. 14.

beers." In either case every care must be taken to ensure the same tension upon both portions of the warp. Another method is to run one of the warp on to a beam, and then that along with the other half on to a second beam; in that case, the one portion going through the rack and the other being drawn from a beam renders it very difficult to keep the tension even. Another fault often arises from this treatment, in many cases warps are dyed in the warp, and it will be obvious that in process of dyeing the depth of shade at one end of the warp may be slightly different from that at the other.

Supposing two such warps are put together, the light end of one coming to the dark end of the other, and being woven into the piece where alternate threads come to the surface there would be alternate marks of light and dark colour along the piece. Again warps that are dyed in the warp may be so bulky that the colouring matter cannot get evenly through them; they are then split in two and dealt with as two warps after the manner suggested. Very frequently this will obviate any tendency to stripiness, or unevenness, though it can never be looked upon as a perfect remedy.

The slashing machine does its work after the manner of that shewn at Fig. 11, but sizes the warp at the same time.

WARPING FANCY PATTERNS.

We may turn attention for a moment to the warping of fancy patterns, because we have here involved a variety of questions of detail which must receive the most careful consideration. Suppose, for example, we are about to make a warp for a fancy pattern such as a tartan plaid. We should have to determine, first, the number of patterns required in the width of the fabric, then the exact number of threads of each colour required to form the whole warp. Suppose the pattern to be as follows:—a slight modification of the tartan of Campbell, of Loudoun.

16 Black
20 Blue
2 Black
4 Blue
2 Black
20 Blue
16 Black
20 Green
2 Black
6 Yellow

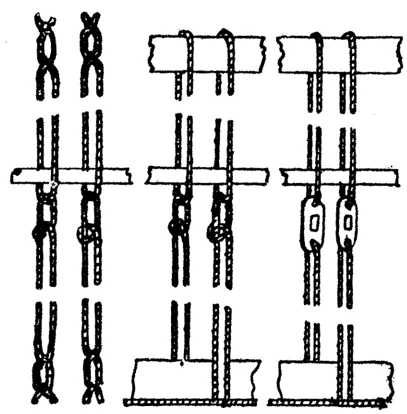
(*Continued.*) 2	Black
20	Green
16	Black
20	Blue
2	Black
4	Blue
2	Black
20	Blue
16	Black
20	Green
2	Black
6	White
2	Black
20	Green
260	ends in the complete pattern.

We should have, say six complete patterns in the entire width of the fabric, with thirty spare threads to be dealt with, those spare threads must be so arranged, that, at least, both sides of the fabric will be alike. Then we must determine how the bobbins should be set on the creel so as to enable us to form the complete warp with the least amount of trouble, such as breaking out threads or introducing extra bobbins. Very often this can be done readily but there are cases such as the pattern in question, where it is practically impossible. Then the warper must arrange the bobbins so that a given number of repeats of the pattern can be warped straightforward with the least possible inconvenience and delay, and the extra threads worked in for the sides conveniently. This system of warping upon the mill is practically abandoned at the present day and the sectional warping machine or the dressing frame has taken its place for this purpose. Suppose for a moment that this warp is being made upon the sectional warping machine, such as that shewn at Fig. 9. We should begin there by building section upon section on the reel until the warp was completed, then run direct from the reel to the weaver's beam.

The system of dressing from the ball, as it is termed in the Bradford trade, is a very convenient method of dealing with this subject. The warps would be dyed in the warp, a sufficiently large number of threads in each one to be conveniently split up afterwards. Suppose the pattern mentioned is the one to be dealt with, there are five colours; the threads of each of the colours respectively being for the whole warp, of six patterns, $80 \times 6 = 480$ of black; $88 \times 6 = 528$ of blue; $80 \times 6 = 480$ of green; $6 \times 6 = 36$ each of yellow and white, and if blue be added to each side, that is, beginning in the centres of blue and ending there, plus a half pattern to each side, then four ends would be added to black and twenty-six to blue. One warp would be dyed to each colour, each of such warps containing say ten times the number of threads required for one, so that these could afterwards be split into ten portions, then those several portions would either be wound upon beams in readiness for running together, or they would be passed through the same rack and run directly to the weaver's beam after being drawn through the sley in exact accordance with the required pattern. This is unquestionably the most economical mode of working, as it saves in the first instance the cost of hank dyeing and winding, as well as considerable waste. Suppose we take sectional warping into comparison, we should have at least 2½ per cent. of waste to allow, for there is the cost of hank dyeing and sizing, which at a moderate estimate cannot be less than ½d. per lb. more than warp dyeing and sizing. In addition to that there is the cost of winding on to the warper's bobbins. Of course it may be said there is a disadvantage; inasmuch as warps specially ordered and dyed for this method of working will involve a loss of time in preparation, as against the readiness with which sectional warps can be prepared, in comparison with sectional warping, where the warp can be immediately prepared from the bobbins in stock. In reality it resolves itself into this, that in the one case coloured yarns wil be kept in stock in warps, which will be of a given length; in the other it would be kept in stock in bobbins where a warp could be prepared *of any length*, so that the balance of convenience in that respect would be with the sectional warping, so that it would be a question for consideration whether economy of cost would not be more than counterbalanced by convenience. So far as perfection in the warp is concerned, that is, evenness of tension upon the threads and perfect distribution upon the beam, the advantage would be with the sectional warping.

DRAFTING AND DRAWING IN.

After the warp is made the next process in preparing for the loom consists in either drawing the warp through the healds or twisting to the remnant of the warp which is already there. We will begin by supposing that we have a complete new set of healds to deal with, so that we can follow the process step by step. First as to the form of heald. Generally speaking they consist of worsted cords mounted, and forming a loop, as shewn in Fig. 16. The lower half of the heald, as will be seen, is a long loop, the upper half is somewhat similar in form with the addition of the small knotted loop in the centre through which the warp thread must pass. This was one of the earliest, and in many respects, one of the most useful forms of healds, it has however has been superseded by what are termed mailed healds, the mail consisting of a metal plate with three eyes, as shewn in Fig. 18, the central eye varying in size and form according to the nature of, or the bulk of the yarn to be woven, the smaller eyes at the extremities being intended for the heald cords to pass through. The next form adopted is what is known as the wire heald, consisting of a series of twisted wires with a loop formed in the centre for the warp threads and one at each extremity for the purpose of mounting on bars or shafts. One of the great advantages obtained from wire healds is the ready facility with which the set or fineness of the healds can be changed or varied, every heald being loose and moveable, the number per



Figs. 16, 17, 18.

inch can be regulated at will. On the other hand the inconvenience of great weight, tendency to bend on the weavers passing their hands through to take up threads, and in some cases a liability to cut the warp in consequence of roughness or fracture of the wire operate against their general adoption. The advantages of the wire healds so far as convenience of changing is concerned has been met by the introduction of cotton or worsted healds looped and mounted in the same manner as shewn at Fig. 18. The advantage of this class of heald for fancy work will be apparent presently when dealing with striped or fancy patterns where various degrees of fineness are required, or where striped healds are employed.

The method of mounting the healds should be explained. As they come from the heald knitters the common heald is simply mounted upon what is termed a "rig band" and leased to facilitate the insertion of shafts, so that the mounter of the healds has only to insert the shaft in the lease as given, taking care to tie each end of every shaft in succession with the extremes, or the first heald cord, exactly the same distance from the extremity of the shaft so that in the loom they will be perfectly straight and even. As will be noticed in the section shewn on Figs. 16, 17 and 18, the lower half of the heald is so leased that the shaft goes through every loop, whereas the upper half has the loops on alternate sides of the shaft. The object of this is to facilitate not only the drawing in of the warp in the first instance, but also the taking up of single warp threads afterwards. When the healds are prepared for the warp drawing through, what is termed a looming shaft is inserted in the lower loop of each heald, as shewn in the sections, the object being to ensure the healds being taken in their proper order of succession. The healds being mounted upon their shafts and the looming shafts inserted they are most conveniently hung or suspended in a frame, the lower portion being screwed down or having weights attached to them so as to keep them perfectly straight, without having too much tension upon them. The warp beam is then placed in the frame, the lease rods being immediately behind these, the operation of drawing may be commenced. Two persons are really required for this work, one to pass the hook through the healds in the proper order of succession and the other to hook the threads upon it so that they can be drawn through the healds. In some cases where only two or three healds are employed the looming shafts may be dispensed with, the drawer-in taking a handful of healds and selecting them with his fingers; in the hands of expert workmen this is looked upon as a quicker method than the other one. The next question is the order of succession in which the threads must be drawn through the healds and also a ready means of conveying to the workman the order and degree of fineness required. Suppose in the first instance, a plain cloth is to be woven, only two healds would be employed and the warp threads drawn upon them alternately, then the draft plan would be shewn in Fig. 19, or in place of the vertical lines numbers might be employed. Now comes the question of variable drafts or variable degrees of fineness. Suppose,

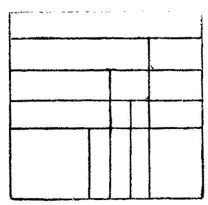


Fig. 19.

for instance, that a cloth is to be made where a stripe is formed, the stripe being of a different material or colour than the ground, and a different degree of fineness in the cloth is involved. For a moment let the ground of the cloth be of cotton, say 60 threads per inch, and the stripe of silk, say of 120 threads per inch; then of course the striped portion will be doubly as fine as the ground. In this case we should simply find an average set for the whole, if the pattern were a small one; suppose, for instance, the pattern consisted of 32 ends of ground and 8 ends of silk, then we should have 40 threads occupying a space which would be equal to 36 of the ground ordinarily, or in other words we should be increasing the number of threads per inch from the ground in the ratio of 36 to 40 or making an average of $66\frac{2}{3}$ per inch, thus $\frac{40 \times 60}{30} = 66\frac{2}{3}$. Or it may be expressed in another form; the ground threads would be two ends in one dent of the reed, so that in the pattern there would be 16 dents of the ground and 2 dents of the stripe, hence that there would be 40 threads in the 18 dents; thus explaining the formula given above; the crowding or cramming taking place here in small quantities would not prevent the use of healds made with an average of $66\frac{2}{3}$ per inch; but if the pattern is a large one occupying, say 2 inches of ground to 1 inch of stripe then it would be more convenient either to have the healds specially knitted for the purpose or use the loose slips as shewn in Fig. 18. This of course is supposing throughout that the cloth is a perfectly plain one and only two healds are required for it.

I must now deal with the two important questions, viz.:—what is known as casting-out in healds, and the arrangement of drafts for either combined patterns distributed evenly over the cloth or in stripe form, and the calculations connected with the determination of the degree of fineness of the several healds required to form a pattern. Approaching the subject in its simplest form first it must be self-evident that as the warp passes from the warp beam through the reed they should form a perfectly straight line, and consequently that the healds should not drag them to either one side or the other.

Suppose a cloth is to be woven with sixty threads per inch, it is obvious that however many heald shafts there may be in use the heald cords must be distributed over them, so as to give a total of exactly sixty per inch, and if there are either more or less there will be a discrepancy between the reed width and the heald width, which will cause trouble in weaving, more especially at the edges. I must not be supposed to say, that it is impossible to work with any discrepancy, for in many goods it is no serious disadvantage to have the healds half an inch wider at each side than the sley, but in such case the warp should be proportionately wider in the beam so that the edge threads will not form a kind of V in passing from the beam to the reed. In many cases the warps are systematically put on the beam a little wider than the reed width, but this should not be carried very far.

Then it must be clear that if the healds have too few cords upon them they cannot be adapted; if there are only fifty per inch they cannot be made to carry sixty threads, but the reverse may be the case, by leaving ten out of every sixty empty. We must be careful however how we cast those ten out, it would not do to simply draw fifty threads through the healds and then leave ten empty ones. In many cases it would make a break in the pattern, and in all it would probably give trouble to the weaver in taking up broken threads. Suppose there are eight healds in use the fifty threads would fill up six "gaits" and two ends over; then leaving ten empty would cause the next fifty to commence at No. 5 heald, and there would be a break in the continuity of the pattern represented by the absence of two threads from Nos. 3 and 4 healds, and this would occur every time. Then it is obvious that the healds must be cast out in "gaits" or one complete draft over the heald. The simplest mode of expressing this would be that as there must be ten healds cast out in every sixty there must be ten "gaits" cast out in every sixty, then divide sixty by ten and every sixth "gait" would have to be cast out, and the warp will be kept straight.

The greatest trouble arises when casting out occurs, irregularly to make the healds suit the pattern, and more especially when occurring in odd heald cords upon one or more shafts. This should never be resorted to for regular work, it may be done occasionally to weave a pattern and utilise a set of healds which may be at hand. Suppose a draft such as that shewn at Fig. 20, which is one of the simplest conceivable; the two front healds weaving a plain ground and the back healds perhaps introducing some thread to form a species of stripe. There are two threads on each of the front healds to

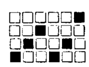


Fig. 20.

one on each of the back ones, therefore if an ordinary set of healds upon four shafts be used one half of each of the back shafts would have to be cast out. This would be troublesome to the weaver, but not nearly so bad as if it occurred in irregular order.

In such a case as this the healds should be made specially, then the question would arise as to the method

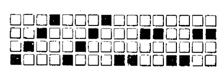


Fig. 21.

of calculating the numbers of threads on such shaft respectively. In this case the matter is easy, as they are in the relation of 2 to 1 throughout, but if the principle is laid down in this it will be intelligible and easily applied to others. I will take a very simple illustration first, so as to make the rule clear, and its application will be more readily grasped. Fig. 21 is a draft for a supposed "hopsack" and twill stripe, on four shafts, and for the purpose of enabling us to weave it on an ordinary tappet loom. There are sixteen threads in the whole pattern, but each heald does not carry the same number of threads, and in fact the discrepancy is so great that casting out would be out of the question. On the first and third healds there are six threads each, and on the second and fourth two threads each. Then suppose there are 80 threads per inch in the cloth, and 16 threads in each pattern will give $\frac{80}{16} = 5$ patterns per inch, and $5 \times 6 = 30$ threads on Nos. 1 and 3 healds respectively, and $5 \times 2 = 10$ on Nos. 2 and 4, or a total of 80 per inch, distributed over the four in the required proportions. So far this seems very convenient, but it does not go far enough, nor is it handy enough for the majority of cases. It is very seldom that the number of ends in a pattern would

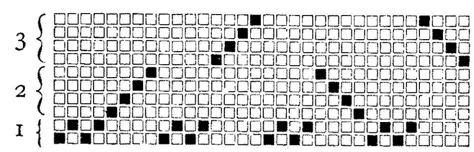


Fig. 22.

be an exact measure of the number per inch. Suppose there are 60 threads per inch instead of 80, then it would not work out; in that case a general formula must come in, and this simply takes the form of a proportion. Thus there are 16 threads in the pattern, 60 per inch; No. 1 heald carries 6 out of the 16; then as $16 : 6 :: 60 : 22\frac{1}{2}$ ends on No. 1 shaft, and as $16 : 2 :: 60 : 7\frac{1}{2}$ ends on 3 shaft, and 3 and 4 are the same, therefore $22\frac{1}{2} \times 2 = 45$ and

$$7\frac{1}{2} \times 2 = \underline{15}$$

$$60$$

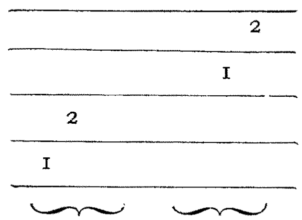
This rule is very simple, and easy to remember, and those engaged in this branch of work should not have to seek for rules and formulæ when wanted, but have them handy.

Take a draft now of a little more elaborate character, but one which can be easily followed. In this the draft is presumably for a stripe, and these are to be their orders of working, therefore the healds may be divided into three groups, the first two forming one group, the next four the second group, and the last form the third, as shown on the plan. There are 32 threads in the pattern, and suppose there are 72 ends per inch, then on each of the first group there are 8 threads, and on each of the second only two, therefore by the rule laid down, as 32 : 8 : : 72 : 18 for each heald per inch, and as 32 : 2 : : 72 : $4\frac{1}{2}$ for each heald per inch, and $18 \times 2 = 36$

$$7\tfrac{1}{2} \times 8 = 36$$

$$72$$

This pattern approaches a class of striped goods requiring special healds, variously known as striped or spaced healds, and for which a special plan should be made for the heald knitter. I will go back for a moment to the plain cloth in striped form. Suppose we are making a cloth perfectly plain but having a ground say of black or any other colour, of two inches wide, and a stripe of another colour, and of a different material, or a finer thread of the same, one inch wide, and in the stripe we have more threads per inch; say the ground 60 and the stripe 120 ends per inch. It will be quite clear that this could not be woven on two healds only, because of the discrepancy in the degree of fineness of the two parts. Suppose an average number of ends per inch be taken, one pair of healds could certainly carry the threads, but it will be well to see what the result would be, 2 inches by $60 = 120$, and 1 inch $\times\ 120 = 120$, and $\frac{120 + 120}{3 \text{ inches}} = 80$ per inch. Now make the healds with 80 per inch, and the two inches of ground will occupy only $1\frac{1}{2}$ inches in the healds, and the 1 inch of stripe will occupy the same space, or in other words, there would be a "draw" at each side of each stripe of half an inch. This could not be tolerated in practice. Then the healds must be drawn on four shafts, thus:—



120 ends. 120 ends,

Fig. 23.

and instructions given to the heald knitter after this manner:

2 shafts, 2 inches, 60 sett, 1 inch space.
2 ,, 1 ,, 120 ,, 2 ,,

and also specifying the requisite number of stripes across the piece.

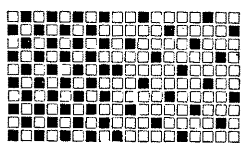


Fig. 24.

Now we come to a question which is a little more intricate, but what has been already said will help to elucidate it, viz.:—stripe healds where there is considerable difference, both in the number per inch and where there may be a great variety of stripe as well as the order of

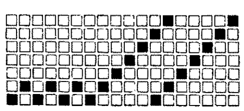


Fig. 25.

interweaving. Take the pattern at Fig. 24, which shews a design for a plain ground with a satin stripe. To begin with, whatever the relative spaces occupied by ground and stripe, or degree of fineness of each, they must be woven on separate sets of healds, therefore, unless the pattern is very small, there must be striped healds employed. I will endeavour to explain not only the methods of ascertaining the number of threads on each heald shaft, but also the method of giving instructions to the heald knitter. Suppose the following to be the pattern, and to be sleyed with the ground two threads in one dent and the stripe five in a dent.

100	ends	ground
100	,,	stripe
100	,,	ground
20	,,	stripe
10	,,	ground
28	,,	stripe
350	ends in the total.	

Now the two sets of healds are in the relation of 2 to 5 in their degree of fineness, and suppose the ground to be 60 sett, then the stripe would be equal to 150, then the instructions might be given thus,

2 shafts, striped, as follows:—

100	ends	60 sett
100 = 24	,,	space
100	,,	60 sett
20 = 8	,,	space
10	,,	60 sett
20 = 8	,,	space

and 5 shafts, striped:

100 = 40	ends	space
100	,,	150 sett
100 = 40	,,	space
20	,,	150 sett
10 = 4	,,	space
20	,,	150 sett

or the number of ends on each shaft may be specified at the rate per inch where they are to be knitted.

Some people prefer to lay off on a long strip of paper the exact pattern for the full width of the cloth. To do this a reed is taken and a strip of paper laid upon its face, then the number of reeds counted off for each portion of the pattern and marked upon the paper, thus giving an exact fac-simile of the whole of the pattern across the fabric.

This mode of treatment and combination of patterns necessarily raises the question of sleying the warp. I shall

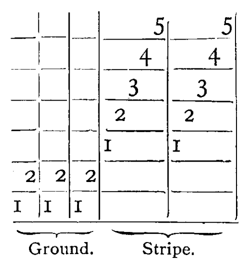


Fig. 26.

not attempt to lay down here any rules as to what should be the number of threads in a dent to suit any given pattern, as that is a matter which properly comes under the head of cloth structure, beyond saying that generally

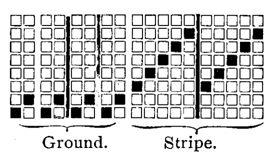


Fig. 27.

there should be some direct relation between the numbers of ends in a pattern and the number in a dent, though it is not imperative that it should be so. Consequently what I have to deal with is rather the mode of expressing or conveying to the operative how the threads should be drawn through the reed. There are really three forms of expression which may be used, the first in writing, thus:

ground, two ends in a dent; stripe, five ends in a dent. For simple patterns that is often all that is requisite, but for broken patterns that would not do, then the method illustrated at Fig. 26 might be resorted to, or on design paper as at Fig. 27. Either of these methods may be adopted, as the only object is to place on record the manner in which the threads are drawn through the reed.

One word more as to the sleying of the warp. I have already suggested that there should be some relation between the number of ends in a dent and the pattern. I will try to make that clear. Suppose a plain cloth is being woven, the threads would usually be sleyed two in a dent: to put three in a dent in a fine cloth would be to court trouble, for as the warp threads are separated there would be the two outside ends raised in one dent, and the centre thread in the next, and it would be difficult, in some cases almost impossible to prevent the weft curling, and so it would be with many other patterns. Loose twills may be sleyed in almost any order, but where there is firm texture, or combinations of patterns, regard must be paid to the relations of pattern and reed.

Again, if coloured or fancy threads are introduced they must be placed in such a position that they will not be liable to be buried at intervals by their companion threads. Let a worsted thread with silk twisted round it be working in a hop sack with two coloured threads, and put the three in one dent with the twist thread in the centre, and it will be buried at intervals by the others closing over it, and it will occasionally come to the top of the others, so giving a most irregular appearance to the fabric. I have simply mentioned this as a typical case, but there are scores of others which would be quite as much to the point.

A very useful little machine is shewn at Fig. 28, for the purpose of extracting water from bobbins of weft which have been wetted for weaving. It is a common practice in some industries, more especially the woollen, to weave the weft wet, and after the bobbins have been

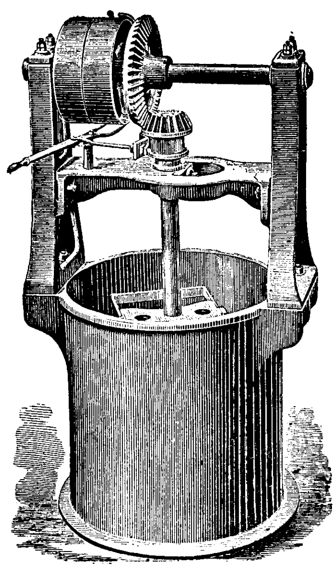


Fig. 28.

steeped it is necessary to remove the superfluous moisture; this was formerly done by swinging them round in a basket or perforated tin can, this little machine takes the place of that and does its work both more economically and better. This is one of Messrs. Hutchinson and Hollingworth's machines.

LECTURE 2.

PLAIN WEAVING.

In approaching the subject of practical weaving it will perhaps be as well to examine it from every possible point of view. We may ask ourselves first what is weaving? What are the operations involved in the process? How shall those operations be performed? And in asking ourselves those questions we have not only to consider what the operations are and their order of succession but the exact nature of each movement in succession. Dr. Cartwright was unquestionably correct in his surmise when he said "that he conceived that for the operation of weaving only three movements were necessary, viz.: the separation of the warp threads, the insertion of the weft threads and the beating up of the weft to the fabric." If we look at the illustrations of weaving as practised by the ancients, whether we take the Egyptians, the Hindoos or the Chinese, we find that they confined themselves strictly to these three operations. They have their warp threads stretched in a frame parallel to each other, and they either separate them by means of a rude flat rod, or form a heald of a simple character and then pass their weft through, either by means of a long hook or something approaching the form of the shuttle of to-day, and next beat it up to the cloth by means of either their "spatha" or their comb. In the hand loom of more modern times the healds for separating the warp threads became a necessity for insuring the repeated movements, or continuation of the work. The shuttle was formerly thrown through the warp threads by the weaver from hand to hand, and reeds separating the warp threads and determining their distances apart served also at the same time for beating the weft up to the fabric.

These three operations occurring intermittently might, in the simpler form of loom, be carried out without any special regard to the particular movement being given to any of the portions of the mechanism performing the several operations. For instance the " spatha " in beating up the weft might be made to give several blows, the shuttle in passing the weft through might be carried across as slowly as one may please, but in dealing with a machine which must perform those operations automatically the exact nature and movement of each part must be carefully considered, so that the several parts of the machine will fulfil their functions in the best possible manner.

Although the three movements mentioned are the only three absolutely necessary to the process of weaving, others must follow when the operation becomes a continuous one, as is the case in the modern power loom; such for example as the letting the warp off the warp beam and the taking up of the cloth on to the cloth beam. In what might be termed, comparatively speaking, the modern hand loom, these two latter operations were performed intermittently; the weaver for instance would let off a certain length of warp, say four or five inches, and he would go on weaving until he had not sufficient room for his shuttle to pass conveniently through between the reed and the fell of the cloth. He would then let off more warp and wind up the already made cloth on his beam, and this would go on continuously. It must be evident that in continuous weaving, where, as in a power loom, the reed must come up to a given point at every stroke, this intermittent taking up of the cloth could not possibly be practised, but that the cloth must be taken forward with perfect regularity, so as to ensure evenness of weaving. The hand loom weaver could bring his reed forward to any given point, and it was with him merely a matter of practice in beating up the weft to obtain evenness and regularity; but in the power loom, where the reed comes to a given point, this evenness and regularity can only be determined by the cloth being carried away from the loom exactly and at the rate at which it is formed; so that those two apparently subsidiary motions become absolutely necessary in continuous or mechanical weaving. Then we may examine the nature of the movements, first as performed by the hand loom weaver, next as they must be performed by the power loom, and having taken a general survey of the whole field, the details of the loom may be closely examined and understood.

Taking then the modern power loom we have, for convenience, the warp threads stretched horizontally in the loom, so that for the purpose of separating those warp threads to allow of the weft being passed through them the healds must be made to work vertically, or to rise and fall; the shuttle must be passed along in the horizontal plane, and the reed beating up the weft to the fabric, must also move horizontally, or at least describe a small arc of a circle, and at right angles to the line traversed by the shuttle; so that we have to consider not only the nature of movements but the readiest means of conversion of motion in the best possible manner, and with the least loss of power. For convenience, power is usually transmitted from the engine, or motor, through the shafting either by means of belt or gearing direct to the machine; so that we may suppose we have received at our loom the continuous circular motion at the main or driving shaft; and that we have not only to communicate power to the several parts of the machine, but to convert them in such a manner as to ensure the work being perfectly done. Taking the ordinary plain loom as the starting point, the conversion of motion really is reversed from that of the hand loom, *i.e.*, the first conversion takes place from the driving shaft to the reed or beating-up motion, the second direct conversion being the picking motion, and the third the shedding or separation of the warp. Before going into the methods of conversion it would be as well to look at the nature of the movements required; for instance the hand loom weaver in separating his warp threads can time the movement of his feet operating the healds, through the medium of his treadles or shedding machine exactly as he pleases, and generally speaking that will be to cause the first movement of his threads, as well as the last part of that movement, to be as easy as possible. He will avoid throwing any unnecessary strain upon his threads; he will carefully time the exact moment of opening or closing the shed to the nature of the material he is working with, and the character of the work to be done. Generally speaking he will avoid any unnecessary strain, especially when dealing with tender material. In weaving heavy goods he will assist the beating of the weft by the crossing of the warp threads exerting pressure upon the weft, and so assisting to press it up to the fabric. On the other hand in weaving light goods he will avoid putting unnecessary pressure or strain upon the warp threads. Generally speaking we may say that we have three distinct forms of shedding in common use: first, what is termed tappet, or open shedding; second, what is termed centre shedding; and third, what is commonly called bottom or jacquard shedding. The majority of hand loom weaver's work will come within the category of the centre shedding, *i.e.*, in the earlier forms of treadle weaving he would so operate the treadles with his feet. In weaving light goods he would cause the threads to meet at the moment when the weft is being beaten up to the fabric, but in heavier goods, or when he desired to distribute the warp threads evenly, he would cause his feet, and consequently the threads of the warp, to meet some time before the weft was beaten up so as to produce, what he would term, cross shedding or assist the beating up of the weft by the pressure of the crossed threads; and this humouring of the shed, along with the evenness of beating up, always constituted an important part of the hand loom weaver's work, and enabled one readily to distinguish a first-class from an inferior workman by his ability to adapt himself to the weaving of the material in hand. Following from the ordinary shedding to what was termed the "witch," or what is now known as the dobby machine, the skill of the weaver was still called into play, and he would be required to time the movement of his foot much in the same way, though not in the same degree of perfection as in the treadle movement, and of course the same remark would apply to the jacquard. As developed in the modern power loom the three kinds of shedding referred to are capable of the finest possible adjustment in the hands of competent workmen. Take first what we term the tappet shedding, which is somewhat analagous to the shedding of the hand loom weaver with treadles, more especially when he was working what was known as "both feet down," *i.e.*, he would have certain healds remaining at the highest and lowest points respectively as long as required for formation of the pattern, and would cause others to change, first by one foot and then the other, as required. The second form of shedding, or what is termed the centre shedding consists in all the warp meeting in the centre after each passage of the shuttle, and then separating for the insertion of the next pick. The third form, or what is known variously as jacquard or bottom shedding consists in the warp, when the shed is at rest, remaining at what might be termed the lowest point, and the portion required for forming pattern being lifted to allow the shuttle to pass through; so that all the threads forming the upper half of the shed would be raised from the lowest to the highest point at each insertion of the weft.

It will be necessary at a later stage to examine very closely the advantages and disadvantages of each of the several methods of shedding, and also, it must be borne in mind, the direct connection of the letting of the warp off from the beam and the taking up of the cloth with the system of shedding. Now we may proceed to examine in detail the nature of the movements. First we may say that the warp threads must be separated with the least possible strain being thrown upon them. Then with tappet shedding as the starting point it must be obvious that the threads forming the upper and lower half of the shed respectively must be at the highest tension when the shed is fully open, and consequently that tension should be relieved as easily as possible; and on approaching the other extremity the tension must be increased with equal care, otherwise breakage of the threads must of necessity follow; this then implies a distinctly eccentric movement of the healds from the highest to the lowest point and *vice versa*. This, of course, will have a direct influence upon the formation of the tappet used in forming the shed, as will have to be shown later. In the same way in dealing with centre shedding the strain must not be thrown upon the warp threads hastily or unequally. Every care must be taken to impart the best possible movement to the healds, and, as will be shown in dealing with some of the dobbies or shedding motions, this is a subject which may contribute very largely to the success, or interfere with the good working of the loom. What is said of dobby weaving may be made equally applicable to jacquard weaving.

We have said that the movements of the healds for separation of the warp threads must be of a distinctly eccentric character; the nature of the eccentricity will differ in the three modes of shedding referred to. Perhaps it will be as well at this moment to follow the warp line so as to ascertain what that line should be and its influence upon the work in each of the methods. First we must consider what is to be the nature of the shed; the object of course in separating the warp threads is to prepare a passage for the shuttle; that means that the shuttle must have a series of threads forming the lower half of the shed upon which it can run with the least possible obstruction. Then the threads forming that lower half must form as nearly as possible the same straight line, and, as far as consistent with good working, the upper half of the shed shall have as nearly as possible the same formation. This implies that the healds furthest from the cloth must be raised higher and depressed lower that those nearest to the cloth. Take for example the illustration given in Fig. 29 where only eight healds are employed, and where the back healds are raised and depressed to such an extent that the shed above and below the shuttle forms a perfectly straight line. It must be obvious that there is greater strain upon the threads passing through the back healds than upon those passing through the front healds. Inequality of strain in almost any class of goods is a serious detriment, and, in

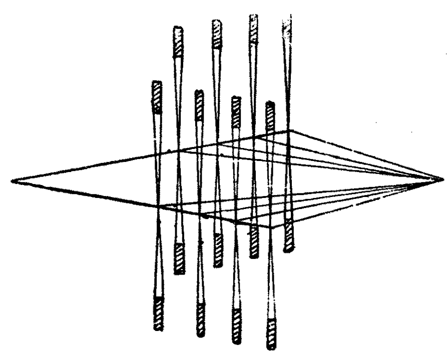


Fig. 29.

many, fatal; consequently this must be obviated as far as possible. The question arises, how can it be done? The only possible means of equalisation is the proper adjustment of the back rail and breast beam of the loom in relation to the position of the healds. Now take for example the illustration shown on Fig. 30 where the lower half of the shed is made even so that the shuttle can pass over it, but the same attention is not paid to the evenness of the shed in the upper half, but rather an attempt to obtain an equality of tension has been made. Make a careful measurement of the actual length of thread upon each of the several healds from the fell of the cloth to the back rail, and it will be seen that the difference is comparatively small, more especially in that portion forming the upper half. Now let the weaver think for a moment what will be the effect of inequality of tension by always raising and depressing the back healds to form perfect sheds without regard being paid to the position of the back rail and breast beam. For an ordinary twilled cloth the difference between the tension of the threads on the back and front healds might be so great that positive stripes in the cloth would result, and this, of course, must be avoided. Generally this setting in position of the rails and of the sheds is a mere matter of

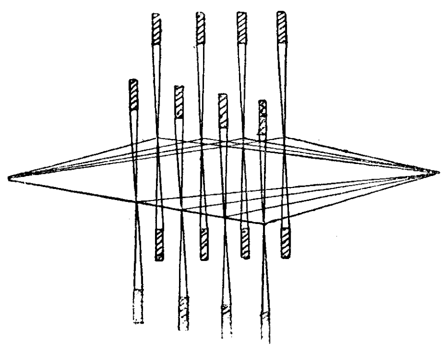


Fig. 30.

chance, or at the most dependent upon a general knowledge on the part of the overlooker, without ever considering the reasons why he raises or lowers either the back rail or breast beam. He has only to consider for a moment that the definition of a straight line is always sufficiently good, that it is the shortest distance between any two given points; then let him draw a straight line from the fell of the cloth, or the breast beam, or both, to the top of the back rail and so form his sheds that the threads through each heald will approach as nearly as possible equal distances from that straight line; by way of experiment to make this clear, let him begin by placing the breast beam and back rail in exactly the same horizontal plane, then form his shed with any number of healds, first all raised or depressed exactly the same distance and he will find that he has an irregular and imperfect shed, both above and below his shuttle, and whatever may be the relative tension upon the several threads the working position is an impracticable one. Next let the shed be formed perfect both top and bottom by raising and depressing the back healds so that the threads form the straight line with those passing through the front; now measure carefully the length of yarn from the fell of the cloth to the back rail or lease rods on each heald separately, and it will be found that considerably greater length of yarn is required in passing through the back healds than through the front ones, consequently those threads must be at a much higher tension and this being maintained throughout will not only throw the work and strain upon them, but produce irregularities in the cloth. Now let the healds be so placed that the threads forming the lower half of the shed are as nearly as possible in the same straight line in front of the healds, but without regard to the straight line of the upper half of the shed. Let the position of the back rail be moved so that approximately the same length of yarn is required to pass through each heald, and it will be found, generally, that the position of the back rail is lower than that of the breast beam by a distance varying, of course, according to the number of healds employed. This variation will be dependent not only upon the number of healds but upon the distance apart of the healds, and in some measure on the depth of shed. The upper half of the shed being unequal necessarily involves a deeper shed upon the whole, because the healds forming the lowest line with its threads must be sufficiently high for the shuttle to pass through without friction; that means that the back heald must be raised high enough for the shuttle to pass under its threads and the front healds sufficiently high to equalise the tension as far as possible. Here of course a difficulty arises, most machines, whether for tappet shedding or otherwise, are arranged on the general principle of raising and depressing the back healds more than the front ones. In tappet work of course this can be regulated more perfectly than in dobbies, although by a proper adjustment of the levers, as well as by the back rail and breast beam, this difficulty can in a great measure be overcome. This statement implies that so far as good work is concerned shedding with tappets is the most perfect; for the majority of work this is undoubtedly true. It is true in a double sense, that more perfect sheds can be formed by it than by any other means and with the least expenditure of power. It has its disadvantages, the chief one being in what is sometimes looked upon as its greatest advantage; what is termed the open shed. This open shedding implies that all the threads are kept at their highest or lowest position as long as necessary to form the pattern, which means that during the time the shed is being changed those threads remaining stationary have to bear all the weight and tension which should be equally distributed over the whole of the warp. This in working with tender material may prove a serious drawback unless every care is taken in the proper adjustment so as to ensure as near equality as can be obtained. Of course it must not be supposed that this absolute equality is always desirable, because it frequently happens that one portion, more especially the lower half of the shed, is required to be kept at a great tension whilst the upper half is comparatively slack, as, for instance, where the warp line is sunk; this is invariably the case where a perfect distribution of the warp threads is desired, such as in plain cloths. Reference has already been made to the hand loom weaver crossing his shed or causing the threads to pass each other before the weft is beaten up to the fabric. This crossing of the threads is more especially necessary when weaving with the warp line sunk, because the great object is to have one half the warp threads tight and the other comparatively slack, so that the weft, as it is beaten up, will force the slack threads into the centre of the space between the tight ones. In plain cloths this is generally resorted to, though in twilled cloths it must be done with care, each succeeding shed being carefully adjusted so as to ensure the most perfect evenness, otherwise the stripiness referred to will become very apparent and produce imperfect goods; so that reduced to its ultimate position the whole question of shedding is dependent for good work upon the eccentric movement of the healds coupled with

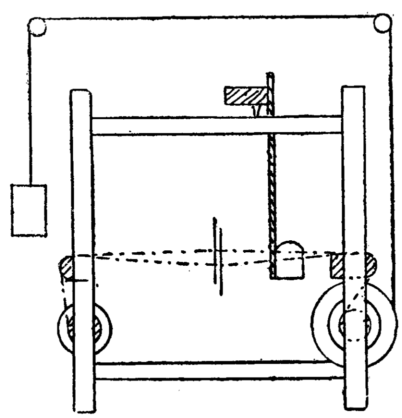


Fig. 31.

the perfect adjustment of the warp line or the relative position of breast beam, back rail and healds to ensure equality of tension. The details of the several different methods of shedding must be dealt with along with the machines made for the purpose.

The next movement or picking is one which will require to be examined very carefully in detail with the several methods in use. At the present moment it will be sufficient simply to ascertain what is the nature of the movement. We have simply to propel a shuttle from one side of the loom to the other within a given time, and we have to consider in what manner this can best be done. If it were the mere propulsion of an object a given distance in a given time there would be little difficulty in the matter, but the shuttle carries with it the weft, which in many cases is somewhat tender and easily broken, and which in all cases should be delivered with as nearly as possible an even degree of tension. It may be said that perfect equality of tension can never be obtained, for instance the shuttle eye through which the thread is drawn is near one end of the shuttle, consequently the length of yarn delivered by the shuttle in passing from one side of the loom must be greater than that delivered in passing from the other side. It might seem that this would only affect the tension upon the selvedge, but in reality it affects the tension all across the fabric, indeed to such an extent is this sometimes apparent that the picking of the shuttle from the side where the least tension will occur must be made coincident with the shed of the warp where, if any difference exists, the greater tension will be upon the warp threads which are raised. Such, for example, as passing the shuttle through when the least tension is upon the weft at the time when the back heald is raised, which would give the greatest tension on the warp threads, and so allow one to neutralise the other, but apart from this consideration it must be obvious that the shuttle carrying the weft must not be thrown with any great amount of jerkiness, nor must there be great liability to rebound. To assist in this, the shuttle boxes are usually provided with a spring or pressure swell which helps to steady the shuttle on entering the box and keeping it firmly in position, this therefore implies that in sending the shuttle out of the box again the pressure must be relieved before the final blow is delivered for propelling the shuttle from one side to the other, so that the first movement of the shuttle must be very slow, gradually increasing until the final blow is delivered, therefore the whole movement is an accelerated one. Every method of obtaining this must be carefully examined later. There is only one movement now to refer to of the three primaries, *i.e.* the beating up of the weft, or more correctly speaking, the movement of the sley or going part. The going part carries the shuttle as well as the sley, therefore its movement is to be so arranged as to give as much time as possible of comparative rest at the moment when the shuttle is being thrown across; of course it can never be brought to an absolute stand-still, it must always be moving backwards or forward, but the slower the movement at the time the shuttle is passing through, the less liability to throw the shuttle out of its course. At the other extremity of its movement, where the weft is beaten up to the fabric, exactly the reverse must take place; a smart quick blow must be delivered, a considerable amount of force exerted, this varying, of course, with the strength and character of the work. In very fast going looms the amount of eccentricity in the movement of the going part need not be so great, because the movement of the shuttle is so rapid that a very brief period is occupied in passing from side to side, but in slow heavy looms the eccentricity must be very great. In fact this difficulty has been found so great that various devices have been resorted to from time to time such as grooved cams, eccentric and even elliptic wheels, and in other cases an ingenious contrivance of cranks has been made to give a double beat, so as to give sufficient firmness to the texture and sufficient dwell to the going part for the shuttle to be readily passed through. Generally speaking however, a sufficient amount of eccentricity can be obtained merely by the movement of the crank itself. This I will illustrate fully at a later stage. Then at the present moment there are only the two movements of letting off the warp and taking up the cloth to be examined generally so that the nature of the apparatus employed will be better understood when examined in detail.

It will be necessary to take the two motions, the take-up and the let off together, because the nature of one must of necessity be dependent upon the other. If we were to go back to the primitive hand looms we should find, as already mentioned, that the weaver, after reaching a point in the process where he could scarcely get his shuttle through the warp, would let off a number of inches from the warp beam by hand and take up a corresponding amount of cloth so that the operation really was intermittent. One of the next forms of taking-up motion following upon that will lead us to understand a more recent form of operating, and one which is largely in use at the present time, generally spoken of as the negative taking up. This will be

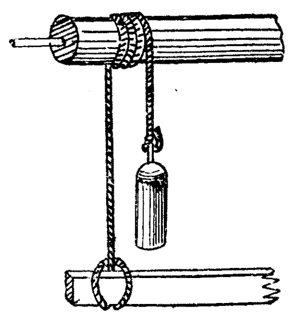


Fig. 32.

more readily understood by reference to Fig. 31, which shows a side elevation of the take-up motion and the loom and the manner in which it is operated. Here it must be understood that all the elements are present which must be present in the power loom; as will be understood the sley of the power loom being operated by a crank must be brought up always to a given point, and at that point always of course cloth must be formed, precisely the same takes place under the present arrangement. The going part of the loom is suspended from the top of the loom frame, and the heavy beam is so balanced that it brings the lower portion of the going part always up to the breast beam, so that the weaver practically pushes back the sley and allows it to come forward with its own weight, aided by the heavy beam above, to beat the weft up to the cloth. On the head of the beam on which the cloth is wound are placed large moveable rollers, but which can be held in position by means of a rachet head and catch. A thin strong rope is coiled round this beam head, carried over a pulley attached to the ceiling immediately above the beam,

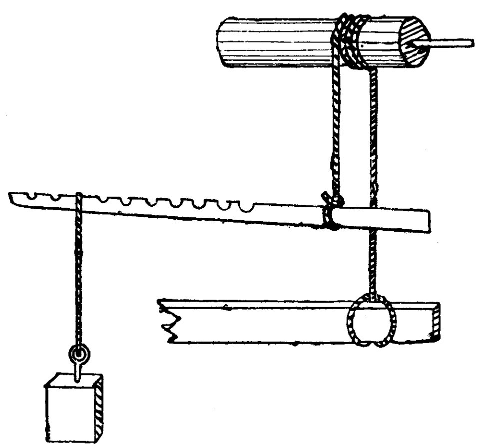


Fig. 33.

and also another near the back of the loom; at the other end of the cord a box would be suspended carrying weights. The arrangement is simply this, that after a pick of weft has been inserted the sley is brought forward up to the cloth, pressing the cloth forward at the same time, and just as much as the cloth is pressed forward the weighted box will pull the beam round and will wind the cloth pressed forward upon it. Then it must be clear that the heavier the box is weighted the more easily the cloth will be carried forward and wound upon the beam, so that the smallest possible amount of compression will take place in the weft. On the other hand the lighter the weight in the box the more force will be requisite to carry the cloth forward and consequently the greater the compression in the weft and the firmer the fabric. This then is the foundation of the negative take-up motion and upon this principle all looms with the negative take-up motion have their mechanism arranged. In conjunction with this form of take-up motion, it must be clear the warp must be let off in a somewhat similar manner, or at least that the warp beam must give off as

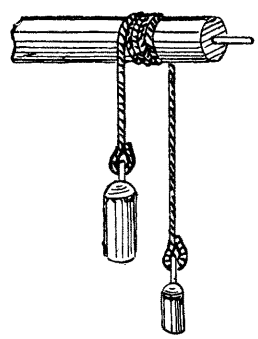


Fig. 34.

the cloth is taken up. The most convenient arrangement is simply to let off the warp, or in other words, to hold the beam by friction. This is most conveniently done by making one end of a rope fast to the loom frame, coiling it a number of times round the beam and attaching a weight to the other end, as shown in Fig. 32. Where sufficient weight could not be obtained by this simple means a lever would be employed as shown in Fig 33, so that the weight could be increased to an unlimited extent. Here again we have the system of letting off, which is largely in use in looms of every class. Even at the present day and where special mechanism is employed, practically, this is the principle upon which they are built. It will be necessary to show that considerable elasticity in the movement of the warp beam must be provided for. As any one will understand at a glance when the warp threads are stretched straight from the breast beam to the back rail, or when the shed is closed, considerable less length of yarn is required than when the shed is fully opened; that being so, if the weft is beaten up to the cloth at the moment when the shed is closed, and which may be taken as a very convenient starting point, the warp would be slack always at the moment when the weft is beaten up unless some provision were made to prevent it. By the arrangement shown now every time the shed is open the warp beam will be drawn forward, and the weight instead of allowing the beam to revolve within the rope, will hold it firmly and slightly rise at the movement, and as the shed closes it will return, only allowing actual movement of the beam to correspond with the warp taken up by the take-up motion; so that this elasticity in the movement of the beam itself ensures something like equality in the tension of the warp, and, it must be borne in mind throughout, that whatever form of let-off motion be adopted this elasticity in the movement of the beam must exist, or some compensation be made for it. In weaving some classes of goods, more especially light ones, a sufficient degree of elasticity could not be obtained by the method shown of having one end of the rope fast to the loom frame. In that case a system which is known as balance weights would be resorted to as shown in Fig. 34. This is merely a small weight attached to the end of the rope in front of the beam, only sufficiently heavy to prevent the heavier weight at the other extremity from running down to the ground. Generally speaking this weight would be so arranged as to rise about an inch from the ground when the shed was closed, and the moment the shed opened, the movement of the beam would bring it to the ground, and so give an ease to the rope which would allow a small quantity of warp to be given off. As the shed closed the beam would return, lifting the weight again and, by putting the full tension upon the rope, would hold it firmly, so that this system of working possesses the double element of giving the requisite amount of elasticity to the movements of the beam and firmness the moment the weft is being beaten up. These two arrangements may be taken as typical of the system of governing the warp beam by friction. There have been, of course, from time to time many inventions connected with the power loom for attaining the same object, and more especially for equalising the tension upon the warp from beginning to end. There must of necessity be a great difference between the amount of tension given to the warp when the beam is full and when it is empty; suppose, for instance, that a full beam has a diameter of 18in., and when empty say a diameter of 6in. The leverage of the full beam is to that of the empty one as three to one. Consequently a good deal of adjustment must be taking place from time to time as the beam is being reduced in bulk; this is not a serious matter for a weaver who thoroughly understands the work and can make the adjustment exactly as required, but any inattention or misapplication of a supposed knowledge of adjustment must cause great irregularities in the fabric, hence the attempts to make the loom do this automatically. It will be necessary to examine many of these attempts in the lecture devoted to this portion of the subject, the present object being to call attention to the matter generally. At the same time that reference is being made to the attempts to perfect these so called frictional let-off motions other attempts have been made to produce let-off motions of a positive character, or such as would give exactly the same rate of delivery as would correspond to the take-up. In all those cases it must be obvious that some system of escapement which would liberate, or adjust, the tension in the event of the warp becoming too tight, or too slack, must be provided. Many of those methods or appliances possess some of the elements of success, but of very few can it be said that anything approaching perfection has been attained. That however we shall be able to determine at a later stage, at the present moment it must suffice to clearly understand the object and purpose of the motion under consideration. That being understood, we may now consider for a moment

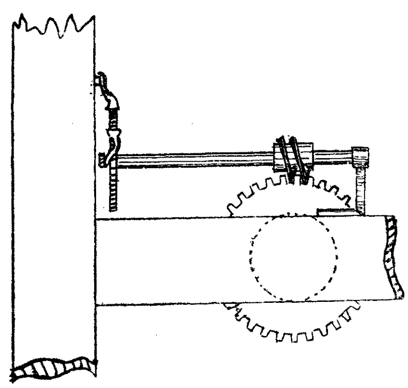


Fig. 35.

other forms of take-up motion. In the great majority of looms in use at the present time what is known as the positive take-up motion is employed. Perhaps in this as in the previous case it might be well to go back to the take-up motion of the hand loom, so as to understand by comparison the exact position of the two motions. One of the best forms of take-up motion in use upon the hand loom is shown in Fig. 35. Fig. 36 shows an end elevation. This consists of a shaft with the worm upon it, and a ratchet at the other extremity, the worm being geared into the toothed wheel on the beam head. At the end of the shaft a lever actuated direct from the going part will cause the rachet head to revolve a given number of times at each stroke of the going part, causing the cloth to be carried forward a determinate length. In this case the cloth is wound direct upon the beam so that as the beam increases in bulk we shall have the rate of speed at which the cloth is taken down accelerated. Then the weaver must have some means of regulating the take-up motion to compensate for this. This he may do

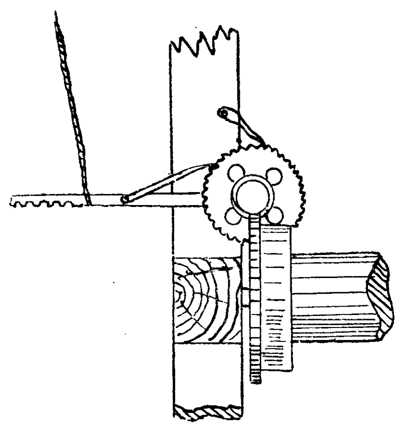


Fig. 36.

by moving the cord connecting the lever on the take-up motion with the actuating lever attached to the going part, so as to shorten the length of stroke and so reduce the rate of take-up in a degree corresponding with the diameter of his cloth beam. This of course will involve constant care and attention on the part of the weaver and in addition to this he will constantly find varying degrees of irregularity caused by irregularity in his movements of the going part. To meet these difficulties he provides what is termed a regulator after the manner shown in Fig. 37, which consists of nothing more or less than a lever of the form of the letter F pivoted at its lower extremity, the lower arm of the F being connected to the catch of the take-up motion by a cord and the upper arm being acted upon by the going part; so that at every stroke of the going part it will just touch the regulator and lift the catch a short distance when the fell of the cloth is in proper position. But the moment that the cloth, from any

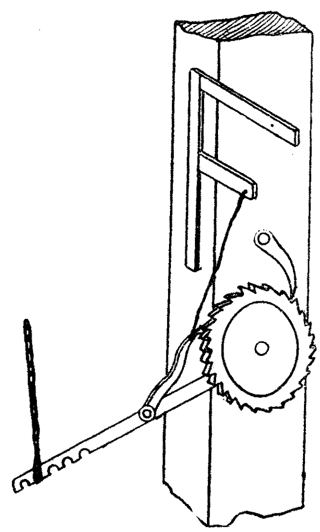


Fig. 37.

cause, has got too far forward then the regulator is acted upon by the going part, thus raising the catch and preventing the take-up motion going forward at the same rate of speed as before. On the other hand if the take-up has not been sufficiently rapid, the going part will cease to touch the regulator, so allowing it to take up the full extent of the leverage given to it. To make the regulator perfectly operative a little elasticity of movement must be given on both sides, *i.e.* the catch must be operated upon slightly when the fell of the cloth is in proper position, otherwise, of course, the effect would be lost entirely in one direction; and a sufficient amount of leverage must be given to ensure a sufficient checking of the action in the event of the take-up being too great. Although this may be looked upon as, generally speaking, a positive motion yet it does not partake of that character in quite the same degree that the positive motion of the power loom does. In the power loom the reed cannot follow the cloth; it must come to one fixed point at each stroke, therefore any irregularity in the movement of the cloth must produce a corresponding irregularity in the cloth itself; so that if it is taken forward too quickly at one point a thin place in the fabric would result, or if not sufficiently quick a thick place would result. In other words the positive take-up motion of the power loom must carry the cloth forward at a determinate rate of speed and in this there must be no variation whatever. If it is set for 60 picks per inch to be introduced, the cloth must be carried forward $\frac{1}{60}$ part of an inch at every stroke of the going part, and neither more nor less whether the yarn be thick or thin. Whatever irregularities may exist in the yarn the same degree of irregularity must exist in the cloth because that number of picks per inch must be inserted, whereas in the negative motion the number of picks per inch will vary under the same weight or pressure exactly as the diameter of the thread varies, consequently each of the methods may have its own sphere of work, but neither of them should be misapplied. Now, it would seem as though the positive take-up motion should have a corresponding positive let-off motion; this has been the great aim of many inventors, how far it has been accomplished we shall be able to see later. For the moment it will be sufficient to say that the great majority of looms in use at the present time with the most perfect positive take-up motion have let-off motions governed by friction, or where friction is not absolutely employed a combination of positive and frictional let-off is in use, or to say the least, the most perfect positive let-off motion is governed by some escapement regulated by the tension of the warp or by some frictional adjustment.

It will of course be impossible, in the lecture devoted to this branch of the subject, to give every form of take-up motion which has been invented, and for each of which perfection of working has been claimed, but at any rate, the leading features of some of the best in use may well be examined. When it is borne in mind that applications for patents for letting-off motions have been made for some years at the rate, I believe, of more than one a week, it will be easily understood that there is a vast variety of them in use. The object here must be not to attempt to deal with more than a few, which will cover the general principles involved, for after all, there is more value in understanding the principle of a required motion well, and knowing some of the best known methods of attaining the object, than in knowing a multiplicity of details of machines which have proved, more or less, useless.

LECTURE 3.

Beating up of Weft to the Fabric.

In going into details of the power loom I propose to deal with each portion in what might appear to be exactly the reverse order to that in which they would actually occur in the process of weaving. I shall do this for two reasons, in the first place, the conversion of motion from the main driving shaft first takes place at the going part for the purpose of beating up the weft, and what would appear to be the next direct conversion takes place at the picking, consequently the shedding comes last in the order of conversion. The second reason is that only one general principle underlies the motion of beating up; practically only one, although obtained by many and varied means in the picking, whereas in the shedding there are large varieties of machines, from the simplest tappet shedding motion up to the most elaborate jacquard machine for the purpose of producing pattern. Those shedding motions will require so much consideration that by far the greater portion of the work must be devoted to them.

Then coming down to the motion communicated to the driving shaft we have, as already said, a continuous circular motion. This must be converted into what is commonly spoken of as a reciprocating rectilinear motion, but as that is not of a perfectly regular character, it is necessary to consider the work to be done. The going part not only carries the reed but also the shuttle as pointed out previously. Then at the time the shuttle is passing across the loom as much rest must be given to the going part as possible, whilst in bringing it up to the cloth a smart blow must be delivered. Some of the first efforts in this direction, notably the first of Dr. Cartwright, were by means of elliptical wheels which would give a sufficiently variable character to the movement, coming to almost a dead rest when the shuttle was being passed across and increasing in velocity as the reed is brought up to the cloth ; eccentric wheels have been employed quite recently for the same purpose, and in many cases grooved cams have also been made use of. In the use of grooved cams the great drawback has been the loss of power, and as a consequence they have never come into general use, but attention has been more generally turned to the use of the simple crank for the purpose. It would appear to the ordinary observer that the conversion of motion by means of a crank will give the same variation at each extremity of the stroke. A very little consideration will show that this cannot possibly be so, for instance, when the crank is at the back extremity of its movement the crank and crank-arm both form the same straight line, but the distance from the shaft itself to the point of connection of the crank with the going part is equal to the length of the crank-arm, minus the crank itself; whereas at the opposite extremity, when the crank and crank-arm again form the same straight line, the distance is equal to the length of the crank-arm plus the length of the crank, therefore the movement from the back extremity to the point midway between the two causes the crank and arm to form acute angles, the difference in the degree of acuteness will govern the rate of speed at which the going part travels. From this point midway to the front extremity a series of obtuse angles are being formed so that the crank being revolved at one rate of speed throughout, it must be obvious that from the point midway to the front extremity the velocity of the going part must be much greater than during the other half of its movement. This will be obvious by reference to diagram shown in Fig. 38. The circle is that described by the crank itself, A to B represents the length of crank-arm, the point A being that connecting with the going part. A to B is a distance corresponding with the diameter of the circle described by the crank, A would be the position of the crank when the reed is in contact with the cloth, B would be the position of the point furthest from the cloth or when the crank is at the back extremity, C would be the position when the crank is midway. Then we should have the positions 2, 2′ occurring when the crank, as indicated by the dotted lines, is in the position corresponding with those numbers. A mere glance will suffice to shew that although the crank in each case from B to 2, 2 to C, C to 2′, and 2′ to B, has travelled exactly the same

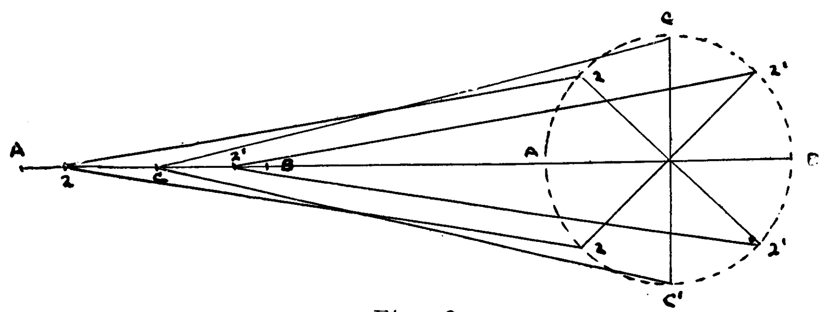


Fig. 38.

distance the going part itself has travelled a variable distance as indicated by the spaces marked from A to B. The distance from 2 to B being approximately half that from A to 2, showing that while the crank is describing one-fourth of a revolution at the back extremity, the distance travelled by the going part is only about equal to half that traversed whilst the crank is describing a quarter circle at the front extremity of its movement. Therefore it is perfectly clear that a considerable amount of eccentricity is obtainable in the mere conversion of motion by means of a crank. It is now necessary to examine how far this can be utilised and in the most perfect manner. There are various reasons why this eccentricity should be varied but only one means of obtaining that variation, and that is, by an increased length or throw of the crank and a decreased length of the crank arm. This will be most readily demonstrated by Fig. 39, where one circle is made much larger than the other and the divisions of the circle exactly corresponding to each other show the variation in the movement of the going part from the front extremity to the back.

Now let us determine what is the exact position, and to enable us to do this we must assume some dimensions for the two circles given in Fig. 39, and also for the length

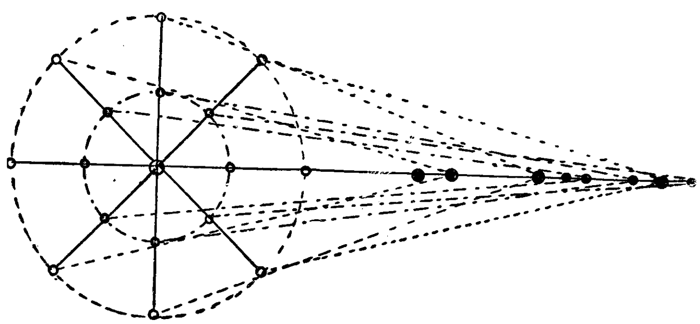


Fig. 39.

of the crank arm. The length of the crank in most fast running looms is from $2\frac{1}{2}$ to 3 inches, giving a stroke to the going part of from 5 to 6 inches. Now suppose we take a medium, and one which is commonly in use, viz.:— $2\frac{3}{4}$ inches, and see what is the exact position with a crank arm of, say 12 inches in length. Then take a second position with the throw of the crank $3\frac{1}{2}$ inches and length of crank arm reduced to 9 inches and a fair comparison can be made in every position of the two cranks. When the crank is at the back centre, as it is termed, the distance from the crank shaft will be $12-2\frac{3}{4}=9\frac{1}{4}$ inches, and when at the front centre it will be $12+2\frac{3}{4}=14\frac{3}{4}$ inches. Now we must find its position from the crank shaft when the crank is at the top and bottom of the stroke respectively. Supposing for convenience that the centre of connecting pin and crank are in the same horizontal plane then a right angled triangle will be formed from the centre of the circle to C and C, the crank being one side, the distance from crank to connecting pin giving the second side, and the length of crank arm (C to C) the third side, so the crank arm forms the hypothenuse of the triangle; and the well-known rule that the hypothenuse is equal to the square root of the sum of the squares of the two sides will at once enable us to fix the exact position of the point C. The length of the hypothenuse is known, 12 inches, the altitude of the triangle C to the centre of the circle—which we will call D is known, thus if C is altitude, D the base, and 3 the hypothenuse, it will be $D^2+C^2=3^2$, therefore $3^2-C^2=D^2$ and $3=12$, $C=2\frac{3}{4}$ or 2·75, then $12^2-2{\cdot}75^2=\sqrt{144-7{\cdot}5625}=\sqrt{136{\cdot}4370}=11{\cdot}68$ inches, so that the point of connection of the crank with the going part has travelled a distance equal to the difference between $12-2\frac{3}{4}=9\frac{1}{4}$ and $11\frac{1}{3}$, which is $11\frac{1}{3}-9\frac{1}{4}=2\frac{1}{12}$ inches; for the going part must be at the distance mentioned from the crank of $9\frac{1}{4}$ inches when at the back position, and of $14\frac{3}{4}$ at the front position; thus the distance traversed by the going part from back towards the front $2\frac{1}{12}$ inches, or less than one half of the total traverse which must be $2\frac{3}{4}\times 2=5\frac{1}{2}$ inches, or the difference is $2\frac{3}{4}-2\frac{2}{12}=\frac{2}{3}$rds of an inch, therefore the corresponding movement of the crank in passing the front centre will be $5\frac{1}{2}-2\frac{1}{12}=3\frac{5}{12}$, and as the crank is revolving at the same rate of speed all the time the difference in the rate of speed of the going part in the two portions of the stroke must be evident.

Then if there is this difference in the distance traversed by the going part during the period when the crank is passing from the back centre to the vertical position and from that to the front centre, there must be an accelerated motion from the vertical position to the front, when the crank and crank-arm are in the same straight line. This degree of acceleration can be determined by the usual rules of trigonometry. It is only necessary to take a given number of points when the crank and crank arm form varying angles, as 90°, 60°, and 30°, or others if necessary, by taking the sine of the angle, which is the length of a line dropped from the circumference of the circle to the diameter, and the versed sine, which is the space between the circumference and the sine measured on the diameter, and following the general rule given for finding the relative lengths of the sides of a triangle to find the actual distance moved by the going part. To the ordinary student and workman this is more easily done by a graphic drawing than by figures, for by making an actual drawing to scale he can determine at once the relative distance travelled by the going part at any point of the stroke.

Then it must be understood that the force exerted is always as the square of the velocities, so that as the distance traversed by the going part at one point of the stroke squared is to the distance traversed at another part, for the same amount of movement of the crank, squared, so is the amount of force exerted at one part to that exerted at the other part. Then take the distance traversed from the point when the crank forms a right angle with the diameter line, and that when it brings the going part midway between that point and the straight line, or $\frac{3\frac{5}{12}}{2} = 1\frac{17}{24}$ inches from the cloth, then the relative velocity will be as $1\frac{17}{24}^2 : 3\frac{5}{12}^2$.

Then it follows that the eccentricity or the relative velocity can be determined for any loom. Suppose we are making light goods we require a very small amount of eccentricity, but in heavy goods we want a good deal. We say that the crank travelling from the back centre has moved the going part $2\frac{1}{12}$ inches by the time it reached the angle of 90°, and $3\frac{7}{12}$ inches during the time it reaches the straight line, or a difference equal to $\frac{2}{3}$rds of an inch, then if we want to increase the eccentricity we must lengthen the crank and shorten the crank-arm exactly in the proportion desired, and the relative velocities will be found by the rule given.

The length of the stroke to be given to the going part must not be overlooked in this calculation, though it must always be conceded that a longer stroke must be given to the going part for heavy than for light work, both on account of the longer time generally required for the shuttle to pass across the loom, and for the required amount of force in beating up the weft to the cloth; so that, put on a broad basis, as the width of a loom and the weight of the work is increased the length of the crank must be increased and that of the crank-arm decreased.

Let the relative widths of the looms be 40 inches reed space and 72 inches, and in the first case the crank $2\frac{3}{4}$ inches and crank-arm 12 inches. In the latter the crank $3\frac{1}{2}$ inches and arm 10 inches and the weight of the going part in the first case 120lbs. Then assuming the force of impact to be the same, it would appear that the revolutions would be in inverse proportion to the width of the loom; but this could not be strictly true, for taking into account the amount of force applied to propel the shuttle across a space of 72 inches, as compared with that required to propel the same shuttle across a space of 40 inches, the former must be greater than the latter, and the time occupied could not be in the same ratio. Again in the wider loom the shuttle would be heavier, so that some retarding influence would be at work to neutralise the difference and bring it more nearly to a direct proportion.

As will be seen by the foregoing figures and details, the force of the blow delivered can be relatively determined with the speed of the loom. Of course the question often arises up to what speed can a loom be run? It is almost impossible to give fixed data for this, but basing the calculations upon the data given, a simple calculation will assist the student in arriving, at least, at an approximation of what can be done.

The next question to enquire into is the position of the crank-shaft in relation to the point of connection with the sword of the going part. Generally speaking it might be supposed that the most convenient position would be that of having the crank and the connecting pin in the same horizontal plane; for light and fast running looms this is a very convenient position, but for heavier looms it is very often somewhat unsuitable. In the first place, by placing the crank in the same horizontal plane, there will be perhaps a better balance of the working parts than by varying that position. If heavier work is required and an increased eccentricity desirable, then from the mere fact that by placing the crank in a lower plane a slight increase in the eccentricity is obtained, and that the crank is more out of the way of the warp than it otherwise would be, there is some advantage gained. Let it be supposed for a moment that the connecting pin at the sword is as nearly as possible in the same horizontal plane as the warp line. Then the force is delivered direct to the cloth, there is practically no leverage, the point of contact of the reed with the cloth being in the same horizontal plane as the connecting pin compels the throw of the crank to be the greatest possible for the shuttle to pass through. Consequently the position of the crank must be placed below the warp line by something more than the radius of the circle described by the crank itself. Hence we are obtaining, quite apart form the relative positions of the crank and pin, all the eccentricity that can be obtained from a large throw of crank. In obtaining this eccentricity we also obtain, as demonstrated by the figures given, an increased velocity of the reed when delivering its blow. Consequently we are gaining apparently all the advantages possible.

If we are gaining apparently everything by this direct action, the question may naturally arise whether, on lowering the crank shaft itself, and at the same time lowering the

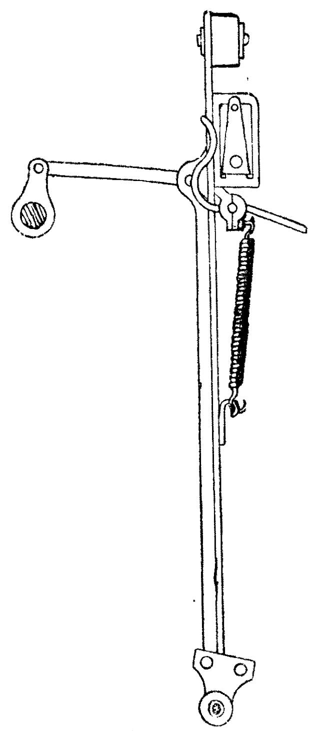


Fig. 40.

connecting pin, we should not gain in force by leverage more than we had lost by direct action. A reference to the end view of a loom as shown at Fig. 40, where the position of the crank and connecting pin can be clearly seen, will show us that by lowering the position of the pin we should obtain an increased length of stroke of the reed. Now this must be looked at from every possible point of view. We have to determine what shall be the stroke of the reed, both as to the amount of force we can deliver in beating up the weft and as to the length of shed of the warp for the shuttle to pass through. Leaving the latter question aside for a moment we may suppose that we are dealing with a fast-going loom, where the length of stroke and the amount of eccentricity may both be reduced to the lowest possible point. Then we should place our connecting pin in the most convenient position in relation to the crank and it would be, comparatively speaking, immaterial whether this position be near the horizontal plane of the fabric or much below it, as the strength or force of blow required would be light. In the fast-going loom, admittedly a small throw of the crank may well be resorted to, and generally speaking the shorter the crank, consistent with reasonably good working the better; and the throw of the reed, or the distance it must traverse will be determined by the position of the connecting pin being placed so as to give the requisite amount of leverage. The question simply becomes one of leverage. We have the going part as shown in Fig. 40 working upon its axis at one extremity, the connecting pin being between this fulcrum and the point where the force is delivered, or in other words, between the rocking shaft and the reed. Now suppose the length of the sword from the rocking shaft to the reed is 28 inches, and from the rocking shaft to the connecting pin is 24 inches, then the throw of the crank is $2\frac{3}{4}$ inches, consequently as 24 inches is to 28 inches, so is $2\frac{3}{4}$ inches $\times 2 = 5\frac{1}{2}$ inches to $5\frac{22}{24}$, or practically 6 inches. Now it may be said we shall determine first what should be the throw of the crank, and second, what should be the stroke of the going part at the reed; then from this data we can find the position of the connecting pin. This, of course, can be readily done, as the whole question is simply one of proportion to be dealt with as follows:—As $5\frac{22}{24}$ is to $5\frac{1}{2}$, so is 28 inches, from the reed to the rocking shaft, to 24 inches the distance of the connecting pin from the rocking shaft. Then in a light-running loom we should make the throw of the crank as small as convenient; but it must be distinctly understood that although the requisite stroke of the going part and an increased force may be obtained by leverage, yet we could never apply this satisfactorily to heavy work. The lack of eccentricity in the movement of the going part would in the first place operate against it, the position of the connecting pin would be even a much more important factor in the matter. Taking this position of the connecting pin we should be applying the force between the fulcrum and the point where the blow is delivered. Everyone having the slightest knowledge of mechanics knows what this means, the power being applied between the fulcrum and the point where the blow is delivered, liability to breakage in the lever must of necessity exist, and this liability would be increased as the leverage is increased. Suppose, for example, that the connecting pin should be placed midway between the two points; at every stroke of the going part there is great liability to break the sword, and not only is this a theoretic proposition, but is one which actually occurs in practice. In the earlier days of the power loom broken swords were a matter of daily occurrence, and comparatively few of the men having charge of the looms could account for it, and those who did know the reason were practically powerless to remedy it. The looms were built in such a manner that they had no means of altering the position of either the crank shaft or the connecting pin; so that all they could do was to minimise in any way they could, either by varying the tension of the warp or careful adjustment of the sheds, the force of the blow requisite to be given by the reed to produce the weight of cloth required. Latterly, by proper attention to the questions referred to already, looms are built and adapted to certain special classes of work, and although a light loom, or one built for the production of light fabrics, can never be made to do satisfactorily the work of heavier looms, without constant risks of derangement and breakage, the heavier loom may do the work of the light one, but at a corresponding loss of speed and production. One general rule might be deduced from this, that the amount of eccentricity is dependent directly upon the relative length of the crank and crank arm, and that the lightness of running may be practically determined in a similar manner; as the smaller the throw of the crank the less the amount of eccentricity obtained, and consequently the less hesitancy in the movement and the greater the ease of the motion. Now the next question arising will be as to the proper position of the fulcrum upon which the lever works, or as it is termed the rocking shaft. Of course for the moment the class of loom having the rocking shaft placed near the floor, or at the bottom, is the only one under consideration, the loom working from above must be dealt with presently. Considerable difference of opinion may exist as to what is the proper position of the going part at the moment when the weft is beaten up to the cloth; one safe position to assume as a starting point is, that the reed should be perfectly vertical when in contact with the cloth; this, of course, is based upon the assumption that the warp line from breast beam to the back rail is a perfectly horizontal line, and that the shed is closed, or that the warp threads all form the same line at the same moment. This is merely taken as the theoretic starting point upon which to base some data, but it must be understood that it is one very seldom occurring in actual practice. If this theoretic starting point is a good and sound one, then the position of the reed should be vertical when in contact with the cloth, for the two reasons, that first, the blow would be delivered finally with the reed at right angles to the warp, or the force would be delivered exactly in the direction of the warp line. In the second place the lever of the going part will be working in what is commonly termed the quarter circle movement, *i.e.* it will never pass its fulcrum. Careful observation of levers working where they have to pass and repass their fulcrum will show that at every moment of passage some vibration must take place. This will vary, of course, and be determined by the amount of loose play of the spindle upon which the lever is working, and it may also be intensified by the amount of power applied; therefore anything that would produce vibration in the going part is likely to prove detrimental to the working. Suppose the fulcrum is placed midway between the front and back extremity of the stroke of the going part, and that a considerable amount of play is allowed in the spindle or rocking shaft; it is quite conceivable that at every passage of the going part backward and forward vibration would occur in passing this centre. Now another theoretic starting point must be assumed. We must suppose that the shuttle is leaving the box at the moment when the reed is midway in its passage from front to back, and is entering the opposite box at a corresponding point of the return stroke. Then if the fulcrum is placed midway between front and back any vibration resulting would occur exactly at the moment when the shuttle is leaving or entering the box; consequently there would be great danger of throwing it out of its course. This must obviously be avoided. As before said, in light running looms this may in some measure be ignored, because the very rapidity with which the shuttle is propelled would enable the picking to take place after this fulcrum had been passed; consequently vibration would be avoided, at least, in its detrimental effects upon the picking. Again the question of advantage would arise as to the balance of parts in working. A lever working equal distances on each side of its fulcrum must work more easily than one working in a quarter circle movement, therefore for fast going looms the advantages are in favour of the fulcrum being placed in the centre of the stroke. But where heavy work is involved it is better as a rule to have the quarter circle movement in preference to the other. It will be necessary to turn to the question of the delivery of the blow to the weft. So far the assumption has been that the warp formed a perfect horizontal line, and the shed was closed at the moment of beating up the weft; but in the larger proportion of cases either the warp line would be sunk at the healds or the back rail would be depressed, so that an inclined plane would be formed by the cloth and the warp. Then if this blow must be delivered at right angles to the cloth the rocking shaft or fulcrum must be placed in front of the fell of the fabric, so that the sword of the going part would be inclined backwards. Again the question might arise whether it is desirable to strike the blow exactly at right angles to the fabric, or with the direction of the force in the warp line. Some will say that the weft should be pressed forward in such a manner as to cause it to rise somewhat up the sley with a view to bringing the weft more to the surface of the fabric. This is based upon the supposition that the weft will ride, more or less, upon the reeds or wires of the sley and so help to form the corrugations which are seen on the surface of a plain fabric, and in greater or less degree to be seen upon twilled ones. This notion, however, is entirely fallacious; the so-called formation of corrugations, or of distribution of threads more correctly speaking, is dependent not upon the action of the sley but on the arrangement of the tension of the warp, determined by the position of the warp line already referred to, and to be more fully demonstrated later on.

Then again it may be said that the conditions should be reversed so that the reed in delivering the blow, would neutralise the angle formed by the depression of the warp, and so assist in the distribution of the threads. This again is a theory upon which no reliance can be placed. As a matter of fact whatever the class of the fabric no reliance must be placed upon the reed in distributing the warp threads, but rather we should look to its fulfilling its proper function of beating the weft up to the cloth; which means, generally speaking, that at the moment of contact the reed and the fabric should be at right angles to each other. This, of course, would involve some little adjustment of the rocking shaft of the loom so as to correspond with any alteration in the position of the warp line. It may seem that this involves an unnecessary interference with the working parts of the machine, but an intelligent overlooker will at once understand that not only is there very little work involved, but that once being adjusted the results must more than compensate for the small amount of labour. Some attention must now be devoted to a class of loom where the going part is worked from above, and although this class of loom is fast disappearing it does not follow that it has no good points; for heavy wide looms there is no doubt that the overhung loom possesses very great advantages for strength and the application of power. In fact for the steady solid work required in the weaving, more especially of woollen goods, there can be no doubt it is very superior to the fast going loom, though not equal to it in rapidity of production. In this case the rocking shaft being placed above, and the driving crank below the warp line the conditions are reversed; the leverage instead of being of what is termed the second order becomes that of the third order, the force is delivered between the fulcrum and the power; consequently greater throw of the crank is required. Suppose the lever from the fulcrum to connecting pin is in this case 28 inches, and the distance from fulcrum to cloth is 24 inches, and the stroke of the loom 6 inches, then the stroke of the crank must be as 24 : 28 :: 6 : 7 inches, then it must be clear a very long throw of the crank is required. Then following the demonstration given in Fig. 38, a considerable amount of eccentricity must be obtained and also a considerable amount of force, or, what is equivalent, acceleration of speed when the blow is being delivered. In some of the looms built specially for heavy goods this has again been increased by having upon the back of the sword a large projection variously known as a "lug" or "horsehead," so as to shorten the length of the crank arm. This of course would give almost any amount of eccentricity required, indeed

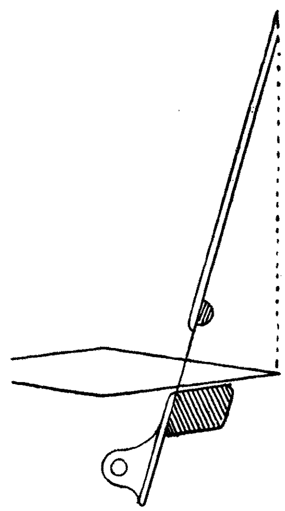


Fig. 41.

to such an extent has this been carried that in many cases a jerky movement has been produced, this, often being detrimental to good working. The amount of force in connection with leverage would be reversed as compared with the illustrations already given, and the force would be increased in the ratio of the increased leverage, so that what is gained in one direction in point of force and eccentricity must of necessity be lost in speed and production. Then the whole is reducible to the general proposition that what is gained in power is lost in speed and *vice versa*. There is one important phase of this question which must not be overlooked. The position of the rocking shaft or fulcrum upon which the going part works will have a material influence upon the bevel of the shuttle race; two things must be considered in connection with the shuttle race, both of which must be always kept in view; first that the bevel shall be such as to coincide with the warp line when the shed is being formed in the most convenient

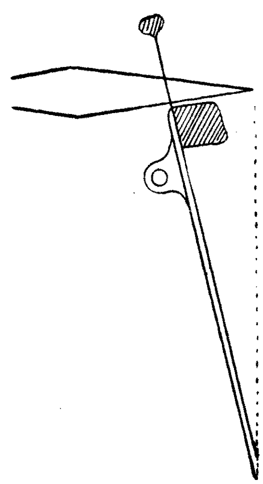


Fig. 42.

manner for the work to be done, and second so as to prevent, as far as possible, any liability to the shuttle flying out. Take two positions as demonstrated by Figs. 41 and 42, one is taken for the sole purpose of showing a deep bevel of the race to keep the shuttle in place in running regardless of the form of shed or position of the going part. Here the race and the reed form almost a V shape or at least a very acute angle; if the shuttle is shaped to this it will not be so readily thrown out of its course or made to fly from the loom. But the question will be, will it be a convenient, or even possible working angle. Take for example the going part working with the reed in a vertical position when in contact with the cloth, the length of the sword is 28 inches. The stroke of the going part is 6 inches. Then at the furthest point from the cloth the position will be as, shown in Fig. 42 and the angle of the shuttle race would be with the horizontal line one of 12 degrees. Now take the actual depth of shed required as being 5 inches at the healds, 12 inches from the cloth, and therefore 6 inches at the reed, the angle formed by the lower half of the shed will be 12 degrees with the horizontal line, consequently it will coincide with the line at right angles to reed of the loom. The figures are taken here quite at random, and might not exactly coincide with any loom, but should the actual dimensions on a loom produce any other angle of the shuttle race when the going part is at the back, not agreeing with the warp line, and which otherwise might be a convenient angle for the shuttle race, that line must be altered to coincide with the warp line with the result that it would form a different angle with the reed, and the shuttle must be formed to it so as to ensure perfect working. Then if this occurs on the assumption of the warp line being horizontal the angle must be increased as the warp line is sunk, and the greater the amount of sinkage the more acute the angles that would be formed. Then arises the difficulty; we should have to have a loom specially built, and with the angle of the shuttle race specially arranged, for every system of sinking or different method of shedding; this is obviously impossible, therefore some medium line must be taken which will give a convenient working position, sufficient to meet the requirements of the majority of cases as they may arise. Now suppose that the position of the going part is altered so as to have it working in the centre of the stroke; then this angle may be varied from a right angle, and the more it varies from a right angle in the obtuse direction, the less protection for the shuttle and consequently greater liability to fly out; in fast going looms where light work only would be wanted this might be of trivial importance, but in heavy goods it would become a serious matter, so that on this ground alone the best working position would appear to be that which places the fulcrum at what might be termed the front extremity of the stroke. Some reference will have to be made to this later when speaking of boxed looms.

When the going part is working from above the conditions as to the bevel of shuttle race must be reversed, and one of the difficulties involved is to prevent the angle being too acute; the longer the sword arms of the going part and the less acute the angle will be of the shuttle race with the sley, when the former coincides with the lower part of the shed as formed by the warp. The shorter the swords and the more acute the angle. One feature here must not be lost sight of, the more acute the angle and the greater the tendency of the shuttle to become, as it were, jamr wedged between the shuttle race and the reed, an sequently the greater the amount of force required to propel it from side to side; whereas in the going parts working from below the nearer the angle of the shuttle race and reed is to a right angle the less the friction, and consequently the less the amount of power required to propel the shuttle; so that the suitability of this class of loom for light work and quick running becomes at once obvious, and has had no doubt considerable influence in the general adoption of this class of loom for light and medium work, and in some measure also for heavy work.

LECTURE 4.

PICKING.

Picking, on the face of it, is the simple act of propelling the shuttle from side to side of the loom, but there is nothing in the power loom requiring such close and careful attention to keep in order, even after the most perfect arrangements have been made for the work, and certainly nothing which can prove so disastrous to the good working of the loom in the event of the details not being perfectly worked out. Apart from the question of the good working of the loom the picking is generally responsible for accidents, not only to the material but very frequently to the operatives, consequently the subject cannot be too closely studied, and everything done that is possible to ensure its smooth and perfect working. In the earliest form of loom the shuttle was simply thrown from side to side by hand, then a system of mechanical propulsion was introduced, but in the hand loom of this form the method of propulsion would be unlikely to produce any serious accident. With the introduction of boxes for changing the shuttles the mechanism became more complicated and consequently accidents became more frequent. In the power loom, more especially in the fast running looms, and in weaving heavy goods, the liability to accident has always been great in consequence of the amount of force required to propel the shuttle in a given time across the loom, or to overcome the resistance offered to it in weaving heavy goods.

We cannot look at the shuttle as an ordinary missile projected through space. In the first place it carries the weft, which must be drawn from the bobbin, spool or tube, and this weft must have a certain amount of drag, or tension upon it and for convenience the weft issues from the shuttle through an eye near one end. So that whatever tension, or drag, is put upon the weft must be within the shuttle itself, and as that must be near one end there must be a tendency to drag the shuttle out of its straight course, simply by the pulling of the thread upon it. Now suppose the shuttle eye is near the left hand extremity, and the shuttle is being propelled from the right of the loom, the whole of the drag of the weft will be upon that end which is foremost, and consequently will easily divert the shuttle from its course, as it will have a tendency to pull the shuttle outward from the reed, and this diversion may cause the shuttle to fly from the loom or produce the breakage of the warp threads. Then suppose the shuttle is going in the opposite direction the drag upon it will be reversed and the point of the shuttle will be directed towards the reed; this then suggests careful attention to the winding of the yarn upon the bobbins or cops, as any inequality in the winding will cause a sudden strain to be thrown upon the yarn, which in most cases is quite sufficient to divert the shuttle and throw it out. Or this tension on the yarn being maintained evenly throughout, the slightest obstruction in the warp will have the effect of diverting it for similar reasons, hence the question will naturally arise as to the weight of the shuttle to overcome obstructions. In dealing with light yarns, or yarns of a very smooth character, the amount of tension will not be very great, and a comparatively light shuttle may be used; but in heavy yarns, or yarns of a rough character, where there is liable to be catching or interference with the free passage, then the shuttle must have sufficient weight to enable it to overcome this resistance. It will then be obvious that for light goods a light shuttle may be employed, and for heavy goods the shuttle must be weighted proportionately.

The tension on the yarn is an important factor in the production of good cloths, apart from the consideration of throwing the shuttle out of its course, and it must always be borne in mind that the tension is increased as the bobbin becomes empty, as the thread has a resistance offered to it in dragging along the whole length of the bobbin. The question of the drag upon the shuttle by the weft involves the consideration of the direction of force to ensure direct propulsion. The first question that would strike one as having an influence upon this would be the exact movement of the picker, and the position of the spindle upon which it runs. Suppose the shuttle to be an evenly balanced body being propelled in a perfectly straight line without any interference, such as that already mentioned, or such interference as would be caused by the movement of the going part, then it would seem that the force must be exerted in a line exactly parallel with the sley. But it is often argued that some pressure must be applied which will keep the point of the shuttle always rather in the direction of the sley than otherwise; this is an extremely difficult matter to settle definitely, because the influences at work are so varied in the different classes of looms, and therefore the subject can only be treated in a general way. Take the direction of force as exerted by the picker as the most important factor, and we may start with the proposition that that force shall be directly parallel with the sley.

In the hand loom and in weaving light goods this would be practically true, because there would only be the resistance of the weft, practically speaking, offered to its passage; but in the power loom the pressure upon the shuttle in the box, for the purpose of keeping it firm and steady and preventing rebounds, as already mentioned, become very important factors in the process. Suppose for a moment this pressure is due only to the presence of a light spring in the back of the box;

this spring will be probably placed so as to press, as nearly as possible, upon the centre of the shuttle; consequently we may take it for granted that when the shuttle is at rest the whole of the front will be in contact with the front of the box, and that the back of the shuttle will be free from contact with the back of the box, but in contact with the spring in its centre. Now suppose the back and the front of the box to be parallel, which is the theoretic position of the two, then as the shuttle is brought forward by the picker the pressure of the spring upon the rear will tend to make the forward tip point towards the reed, and even if the direction of force is parallel with the sley there should be a slight tendency to throw the shuttle towards the reed; but it is often argued that this is not sufficient, and that it may be intensified by having the box front a little further from the back at the inside, or the point nearest the cloth, than at the other extremity. This it is claimed serves a double purpose: first, that it enables the shuttle to be thrown a little more in the direction of the reed than it otherwise would; and second, that it permits the shuttle to enter the box more readily than if the sides were parallel. There may be some reason in the latter proposition; as to the former it is perhaps open to question. Another arrangement is often advocated in respect to the position of the spindle. If the direction of the force is parallel with the sley, the spindle must be perfectly parallel with the sley, as it is the chief factor determining the direction; but many overlookers aver that the spindle should point outwards a little at the front of the box, or having the box forming this wedge shape the spindle should be parallel with the front rather than with the back, so as to assist in throwing the shuttle towards the reed. Advocates of this method of working always insist, when putting on a new picker, in cutting a small hole where it strikes the tip of the shuttle, so that the picker can "get hold" of the shuttle and so ensure the direction of force being towards the sley. Another question of course follows upon this, that is, what should be the exact position of the shuttle tip? Should it be exactly in the centre of the shuttle end? Should it be above or below that centre? Or placed to the front or rear? It is often said it should be a little nearer the front than the back, and a little nearer the top than the bottom, as by so placing it the direction of force exerted, in the manner suggested, will be such as to keep the shuttle up to the reed, and exercise a little pressure upon the shuttle race, and so prevent, and counteract, any tendency to fly out. On the other hand it is sometimes said that the tip should be placed rather low down, mainly on the ground that in its passage across it often encounters threads that are more or less entangled, or "feltered"; hence it would pass under those threads readily, whereas if the tip were raised it might be liable to rise over them and so fly out of the loom altogether. Every consideration points rather in favour of the higher than the lower position for good working. But not only must this position of the shuttle tip be dealt with carefully, and its position moved in the slightest possible degree from the centre, but also that the direction of force must be maintained, if not absolutely parallel, it must remain very nearly so.

The influence of the movement of the going part upon the movement of the shuttle cannot be ignored. As demonstrated in Fig. 38, there is considerable variation in the rate of speed at which the going part moves, and taking the theoretic time of the starting of the shuttle from one box and its entering the opposite one as being when the going part is midway in its passage from front to back, or, as overlookers term it, when the crank is at the bottom, and at the corresponding point of the return stroke, or, when the crank is at the top, the shuttle will be leaving and entering a box precisely at the moment when the going part is travelling at its highest rate of speed. So that it would seem as though the shuttle describes in its passage something approaching an arc of a circle; the highest velocity of the going part being when the shuttle is at each extremity of this arc, but the highest velocity of the shuttle is at the moment when it has received its impetus from the picker; then if the direction of force is such as to throw the shuttle towards the reed, of course, the direction will be in that of the reed itself; and as the going part is losing velocity from the moment the shuttle is thrown out of the box until it reaches its back extremity, and from there increasing in velocity on its return, it will follow that if the amount of force exerted in propelling the shuttle has been in the direction of the reed it will keep it well up to the reed until the back extremity is passed, when, as the velocity of the shuttle is gradually diminishing, the increased velocity of the going part towards the shuttle will practically serve the same purpose, so that *prima facie* this will appear to be the best, or at least, the most convenient solution of the problem.

An important question naturally arises at this point, viz.: when is the shuttle most likely to be thrown out? Or at what point of its passage will any obstruction placed in its way have the greatest influence in diverting it? This is a question which undoubtedly affects the use of the shuttle-guard, and, all other things being properly adjusted, it seems as though the positions are mainly when the shuttle is entering the warp, or when it is about to leave it. As it enters the warp it is travelling at the highest rate of speed, or with all the force imparted to it; therefore, even supposing the force to be well directed, any obstruction would be liable to throw it out with great velocity; on the other hand, it may be argued that this very force will enable it to overcome the obstruction. In a measure that is true; but if the obstruction should be such as to throw it upwards, and outwards where there is the least line of resistance, then it must fly from the loom; but if the resistance should tend in the slightest degree in the opposite direction then the tendency must be to retard the shuttle. Should this occur when the going part is at, or about, the back extremity there is practically no interference with the movement of the shuttle by the movement of the going part, but on the return stroke any obstruction tending to throw the shuttle upwards must have a serious effect, both on account of the loss of momentum of the shuttle and the increased velocity of the going part in its forward movement, as both will tend to throw the shuttle outwards.

This may be demonstrated in the most practical manner in any loom by placing a little "thrum," or "beeting" in the warp at either one side or the other and note the effect upon the shuttle; this will be more noticeable if a greater amount of force is being exerted than necessary in propelling the shuttle. If the obstruction is placed near the side from which the shuttle is being propelled, the tendency will be to cause it to fly out with very great velocity, and at a low angle, so that it might travel a distance of even half way across a shed, to the imminent danger of any one in the course of its passage, before it loses its momentum; but if the obstruction is placed at the side where the force is being expended the tendency is to cause the shuttle to rise, and the greatest danger will be to the weaver at the next loom. In some cases it might rise clear of the loom and drop within a few feet. As a result it must be obvious that the most dangerous element in shuttle flying is where the obstructions occur when the shuttle has the greatest force behind it, or might equally arise, or be intensified, by a misdirection of that force.

Having now disposed of the question of direction of force two others necessarily follow upon it, first, as to the nature and character of the force employed, and second, as to the amount of energy required. As to the nature of the force, whatever class of loom we deal with it partakes generally of the same character; there must be something in it of the nature of a blow, but this blow must not be delivered too abruptly but rather as a gradually accelerated force. For instance, we say that we must have in the shuttle box a spring, or lever, which will serve the purpose of steadying the shuttle and preventing rebounds; that means a considerable amount of pressure upon the shuttle, and when this pressure is utilized for the purpose of operating a stop motion, such as is known as the stop-rod, then it may be increased. The consideration of the details of this pressure, and the means of relieving it, must in some measure, at any rate, be dealt with along with the consideration of the several stop motions employed. At the present moment it is sufficient to consider generally the influence upon the pick and the character of the force employed.

A shuttle is driven into the box and held firmly by the pressure of the spring or lever; then in picking the first consideration must be the best means of relieving this pressure, next, the application of the force for propulsion. To relieve this pressure it is most convenient to begin to move the shuttle slowly, gradually increasing the velocity of movement until the pressure is virtually removed; then, what might be fairly termed the blow can be delivered for propelling the shuttle; so that from beginning to end the movement may be said to be one of gradually accelerated motion up to a given point when the force is suddenly augmented. It will remain to determine afterwards which of the various forms of picking motion in use will best accomplish this. For the moment let it suffice that we have what might be termed three factors; 1st, the amount of force required to relieve the shuttle from the pressure in the box; 2nd, the amount of force required in propulsion, and to overcome the resistance; and 3rd, the amount of force required to overcome the resistance to the shuttle on entering the box. The consideration of those three factors will afterwards determine the form and character of the picking tappets employed, and also assist in determining which of the systems in use is most likely to be satisfactory in its working. Of course it must be understood that the speed of the loom is an important item as determining the nature and character of the pick.

We have assumed so far that the time occupied in passing the shuttle from side to side is equal to one half of a revolution of the crank or driving shaft. In a slow loom, and where considerable pause is given to the going part at the back extremity of its stroke, the whole of this time may be said to be fully occupied; and the slow movement of the shuttle will be assisted by the long, easy "dwell" of the going part, obtained by the long throw of the crank; so that the whole movement would be one of comparative ease, but in nearly every case this would be accompanied by a large heavy shuttle; and, all the facts taken into consideration, there would be little liability to throw the shuttle out; but in fast running looms the conditions would be very different. Instead of the time occupied in the passage of the shuttle being equal to half a revolution of the crank it might probably not exceed one-third, or even less than that; then the nature of the movement would be, of necessity, of the character of a blow sharply delivered; in fact a general comparison of the two movements necessary in the class of looms referred to would be, that one might be described as a long "slinging" stroke and the other as a sharp blow. Of course it will be easily seen that the relative speeds of the two looms referred to will tend to assist in the production of the character of stroke required. As to the amount of force or power required. Here difficulties appear on every side. If the question was only one of propelling a body of a given weight through a given space in a fixed period of time, then the matter would be easy; but when we have to take into consideration all the items of resistance it becomes very intricate. First, the obstacles just referred to, of relieving the shuttle of pressure; of resistance of warp threads which will be variable, not merely in proportion to the varying thickness of the yarn, but in proportion also to the pattern; then the resistance offered to the shuttle entering the box. Assume a loom is running at 180 picks per minute, the shuttle weighs 12 ozs. and the space passed through is 6 feet, then we can easily determine the velocity per second—$\frac{180 \times 2 \times 6}{60 \times 1} = 36$ feet per second, assuming the time occupied to be equal to half a revolution of crank shaft. But this is only the average velocity, not the velocity at any point of passage. Then the energy required to perform this work is, on the usual formula, where W would be the weight of a projectile, V the velocity at which it travels, and G the influence of gravitation at 32·2, or as usual, $2 \times 32{\cdot}2$. $\frac{{\cdot}75 \text{ lbs.} \times 36^2}{64{\cdot}4} = 15{\cdot}09$, or in round numbers 15 foot lbs. per pick of the loom; or taking the power as generally stated at 33,000 lbs. lifted 1 foot in 1 minute as indicating 1 horse-power, then the energy developed would be equal to $\frac{18}{650}$ horse-power per pick. But this is altogether ignoring the resistance as mentioned. It is also ignoring the fact that what will hold good of the force required in a given width of loom, in weaving light goods, will not hold good of the same width of loom in weaving heavier goods.

There is a common expression current amongst overlookers, or those who have charge of looms, that as you change your work you must also change your pick; *i.e.*, as you vary your pattern, or weight of cloth, the force exerted in picking should be increased or decreased so as to meet the requirements of the case. It may be said that the weight of the shuttle should be altered, that is quite true where the change is a very great one, but it would be a difficult matter to be constantly changing the shuttle for every weight of fabric, though there can be no reason why, say, two weights of shuttle should not be in use for the heavier and light classes of goods.

Broadly speaking there are two kinds of shuttle in use, those running upon wheels and those running without. There are many different classes of each species, if they may be so-called, all of which will have to be examined more carefully later on, but at present it will be sufficient to say that each one must be treated differently in the act of picking; the wheeled shuttle is generally used for heavy work and for comparatively slow going looms, and the nature of the movement in picking there is that which has been described as the "slinging" stroke; as anything in the nature of a sharp blow might tend to cause a rebound of the shuttle upon the wheels, and so, perhaps retard, instead of accelerating the motion. This of course would be materially influenced by the resistance offered by the warp; where the warp is heavy and bulky the retardation would be very great, but upon a light warp it might be comparatively small. The "sledge" shuttle as it is termed, or the one without wheels, may be described as thrown across the loom, so that the nature of the force imparted in propelling this must partake more of the character of a blow. Hence the difference in the nature of the picking apparatus in the several classes of loom.

Of the several forms of picking motion it will be simplest perhaps to deal with what is known as the lever pick, which is probably the best known form of under pick, a view of which is represented in detail at Fig. 43. Placed at the side of the loom and outside the frame, the picking arm is working upon a stud, and attached to a frame carried by the rocking shaft of the loom, which is very near the floor; the object of so attaching it to the rocking shaft being that it shall oscillate to and fro with the going part; this being rendered absolutely necessary by the fact that the picking arm passes through the bottom of the shuttle-box so that it may act direct

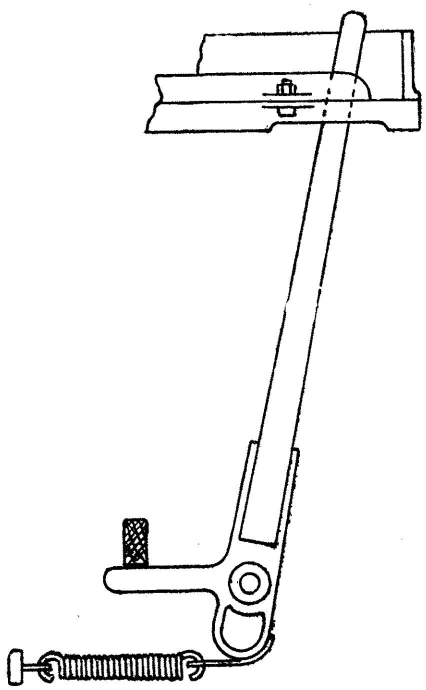


Fig. 43.

upon the shuttle. The mode of actuating it is by means of an arm or lever fastened to the lower, or tappet shaft, and revolving with it; or what is equivalent, bolted to a species of face plate upon the large toothed wheel of the lower shaft. Beneath this is placed a lever, generally of wood, having its fulcrum near the back of the loom and passing forward to the front of the loom, where it is passed through a slot keeping it in position over an arm of the lever, at right angles to the picking stick itself. When the roller on the lever carried by the picking shaft strikes the wooden lever the latter is depressed, this in turn striking the arm connected with the picking stick, as seen in Fig. 43, depresses that also, thus causing the upper end of the picking stick to travel along the length of the box, and the picking stick having a leather picker running within the shuttle-box strikes the shuttle direct and propels it across the loom. Now suppose that the lever arm having its fulcrum at the back of the loom was a perfectly straight one, and the arm upon the tappet shaft striking it as it does, the movement would be, following that described in the revolution of the crank shaft, an accelerated one, the degree of acceleration being dependent upon the position of the lever in relation to the tappet shaft. If the lever was so placed that the arm upon the tappet shaft came in contact with it when in a horizontal position, and continued to depress it until it reached the vertical position, then the acceleration would be of that truly eccentric character which is approximate to what is known as harmonic motion; but in that case the length of stroke would be too great, as only a very short stroke is required to give the requisite movement to the picker; the relative length of the two arms of the lever, of which the picking stick is the longest, being such that the shorter arm must travel through only a small arc of a circle to give the necessary traverse to the picker. Again a considerable leverage is gained by the fact that the arm on the tappet shaft acts upon the horizontal lever at a point between the fulcrum and where the force is delivered; and so the position is necessarily one in which the revolving arm can be in contact with the lever for only a very brief period, hence the movement instead of being one corresponding with one of harmonic nature will be in the nature of the direct blow. This must be modified as the character of such a movement could not be for a moment entertained in a good working loom. To meet this then what is termed a picking plate is placed upon the lever, and so formed that as the revolving arm strikes it, it will give the requisite character of movement, viz.: that described as an accelerated motion. In this form of picking arrangement there is one item which is not to be taken into account, viz.: the picking strap or leather. In any of the picking motions where the picking stick is connected to the picker by a long strap there must be a

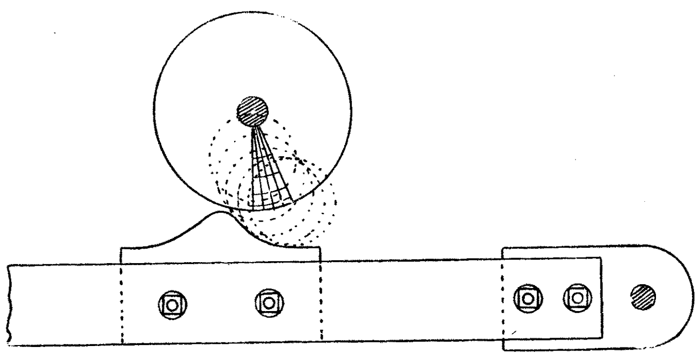


Fig. 44.

certain amount of slack, or extra length, given to the strap. In many cases, because of the picking strap having to bring the picker back to its normal position, it must have a very long traverse, so as to ensure not only the picker travelling the full length of the spindle, but also returning without any tension being thrown upon the spindle by the picking strap itself, as is the case in what is known more especially as the cone pick. In the lever pick the stick may be said to act direct upon the shuttle consequently only as much movement need be given to it as is requisite for propelling the shuttle. Then as to the question of the form of picking plate and the amount of leverage to be given, suppose we take the lever as illustrated in Fig. 44, the fulcrum being at the back part of the loom; then we shall have the power applied from the tappet shaft. Now suppose the picking arm must traverse a distance of 15 inches, the full length of the shuttle-box, or at least sufficient of that length for effective work, because it must never be supposed that the force is applied to the whole of the traverse of the length of the shuttle-box. If it were so the picking stick would strike the end of the groove with such force that breakages would occur; but the application of force must cease a sufficient distance from that point to allow of the impetus expending itself so as not to cause too great a concussion. If the picking stick which is the long arm of the lever travels 15 inches the short arm travels, say 3 inches, and consequently the arm of the wooden lever must travel a corresponding distance at the point where it delivers the blow; then to determine the length of the arm upon the lower shaft of the loom we should simply say as the distance from the fulcrum to the point where power is applied, is to the distance from the lever end to the fulcrum, so is the distance travelled at one point to the distance travelled at the other; or in other words that would be the length of the stroke given by the arm on the shaft of the loom. This determines the depth of the picking plate from what might be termed the flat to the highest point of rise; the exact mode of drawing it is as follows:—Let the stroke to be given by the lever on the loom shaft be 3 inches, and the total length of the picking plate, say 6 inches. Then the time ccupied in the delivery of the pick must be determined. The usual period being about one-eighth, or a little more, of a revolution of the crank shaft. Then describe a circle equal to the distance from the centre of the shaft to the centre of the roller on the lever, and mark off the period of time allotted for the pick. The path of the centre of the roller will be indicated by this circle.

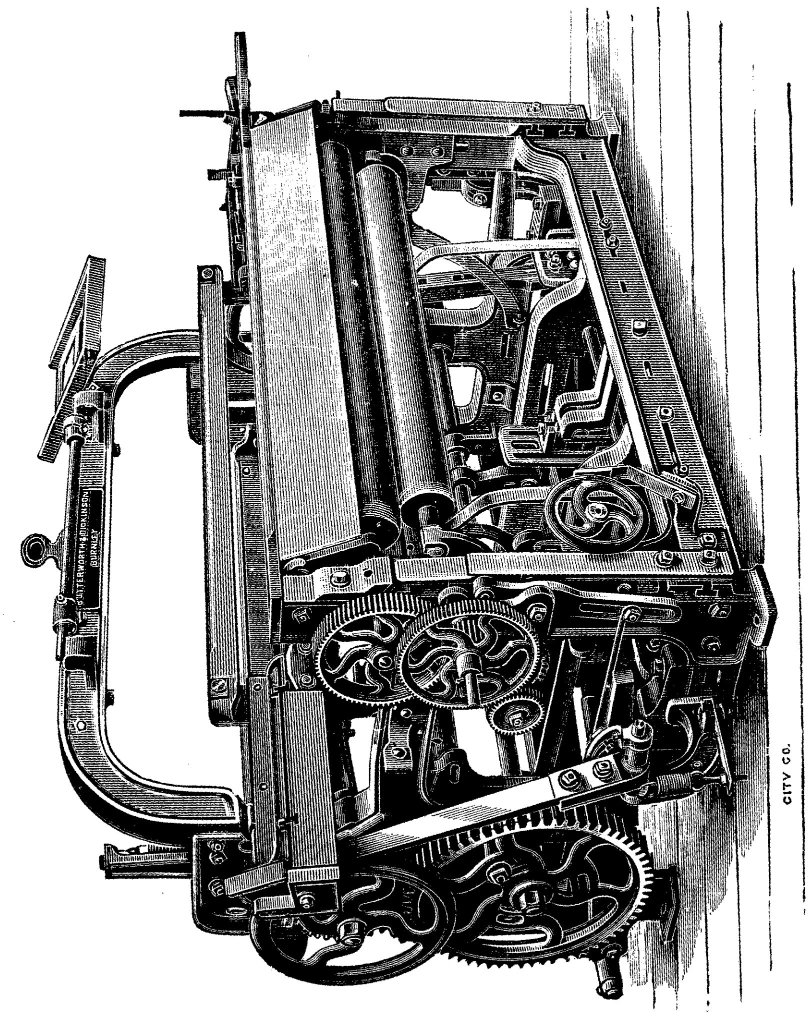


Fig. 45.

The roller must impart motion to the lever, and this motion must be an accelerated one, the degree of acceleration being determined by the nature of the work to be done. Let it be taken that the increase is regular. Then divide the space marked off on the circle into any number of equal parts, say, for convenience 4, and lay off the distance the picking lever must travel, say one inch on the radius of the circle, and upon this segment of the circle a line must be drawn indicating the movement of the picking lever. Place the line from the centre in a vertical position and find the fulcrum of the lever, from there strike an arc of a circle from the vertical line which will indicate the course of the point of contact of the roller and lever inverted. Now divide the space already marked off upon the radial line into divisions corresponding with the degree of acceleration, say six, in the ratio of 1, 2, 3, &c., that is, the distances apart increasing in that ratio, and from the centre of the circle strike arcs of circles cutting the arc drawn from the fulcrum as a centre, and taking each point of intersection in succession describe arcs of circles, commencing where a line has first been drawn indicating the lower surface of the plate, and a line touching the peripheries of all the circles will indicate the true line of the picking plate surface, up to where the vertical line is dropped. From that point the plate may be drawn in any suitable form to allow the picking lever to return to its normal position, as no force is to be exerted. It is best to allow it to return easily and without jerking. Another form of the same class of motion is shown in the illustration Fig. 45, where the pick is virtually of the same order and carried out in the same manner but different in detail. In the illustration, which is that representing a heavy linen loom, it will be noticed that instead of the straight arm projecting from the bottom of the picking stick as in Fig. 43, there is what is termed a half-moon, and a strap connects this half-moon with a lever acted upon in precisely the same manner as in the other loom, but obtaining greater smoothness of action. In very heavy work this is a most important fèature, the details of the arrangement will be better understood by reference to Fig. 46 where the motion is separated from the rest of the loom. Another form of motion is shown at Fig. 47 applicable

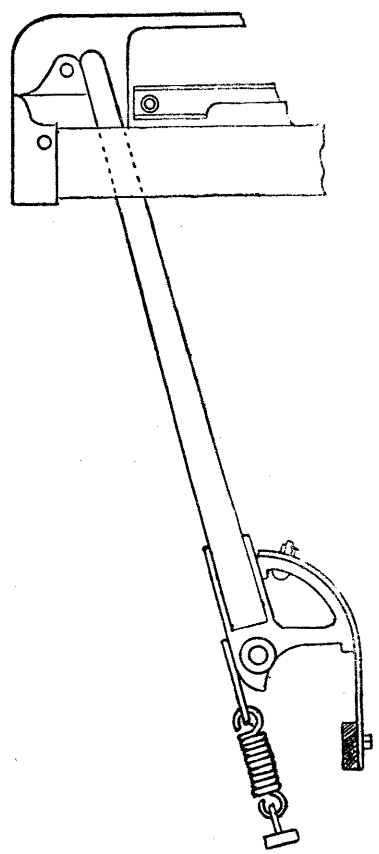


Fig. 46.

to heavy cotton or fustian looms, in this case the working mechanism, with the exception of the picking stick itself, is placed within the loom frame so as to be out of the way of other apparatus required to be placed outside. The details of the mechanism are somewhat different but the principle is the same. This will be better understood by reference to details in Fig. 48.

There are several other arrangements of what are known as under-pick motions and although differing in detail from those just described are virtually the same in character and effect, notably two, one of which is driven direct from the

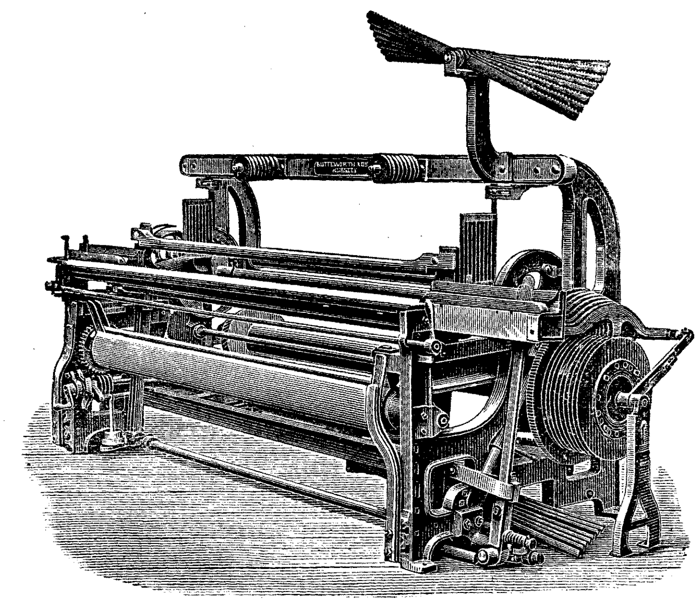


Fig. 47.

crank shaft and the other known as the scroll pick; these are made only for special looms and comparatively speaking little in use. Therefore it may be sufficient to describe the general principles involved with one or two detailed descriptions to make the matter clear and intelligible.

The object of driving from the crank shaft is to obtain greater force, by utilizing the speed of the crank shaft as is done in the high-topped or slow looms, all of which pick from the top shaft; for the usual rate of speed of the two shafts—crank and tappet shaft—being as two to one, their relative powers with a lever describing a circle of the same

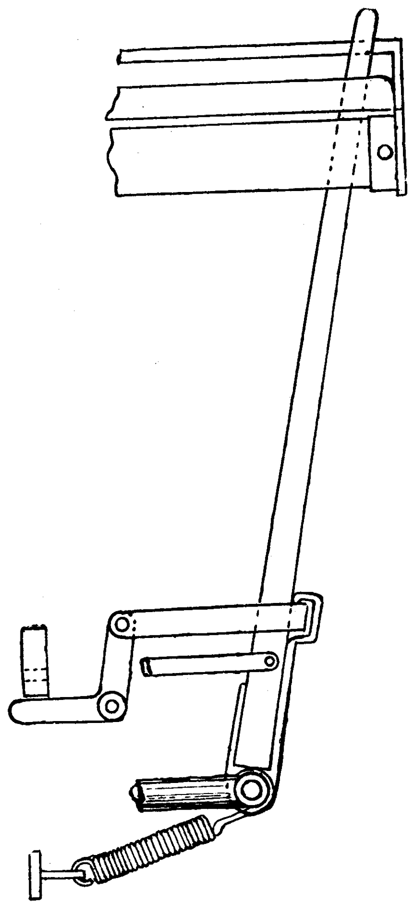


Fig. 48.

radius will be as one to four, as the power must be in the ratio of the square of the velocity; but one important fact is overlooked, viz., that the same effect may be obtained by having a lever on the lower, or slower, shaft of the loom, which will make up for this difference. Again, there is the advantage in the longer lever of being able to arrange and adapt the shape to the exact requirements, whereas in the short lever of the crank shaft this is not so easy. In the slow running loom, picking from the crank shaft becomes almost a necessity, and, as will be shown, works well, but in fast running looms, in most forms, it is liable to be jerky in its action.

What is known as the "scroll" pick consists, as its name implies, in having a scroll formed on the surface of

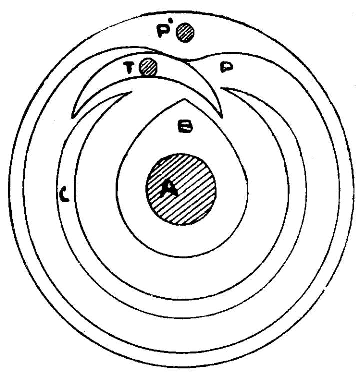


Fig. 49.

a disc, or it may be called a grooved cam, and in such a manner that two grooves run into each other. Suppose a surface plate to be arranged as shown at Fig. 49, where the shaft A forms the centre, and a pointed cam B is formed upon it, a scroll or bead C is cast upon the face of the disc, so that the grooves on the inside and outside merge into each other near the point of the cam at P. A movable plate P″ is so formed as to throw the crescent T from one groove into the other. The disc then travels first in the inner groove and then in the outer one as the disc revolves, and by means of a shaft placed diagonally at the loom side, and which is really a fulcrum of an intermediate lever communicating the power received from the scroll to the picking stick, somewhat after the manner of the under-picks already described, propels the shuttle from side to side. (I am afraid the drawing is not strictly accurate in its proportions, the points of the governor or crescent T are a little too long. This has not been drawn to scale, but is only a rough indication.)

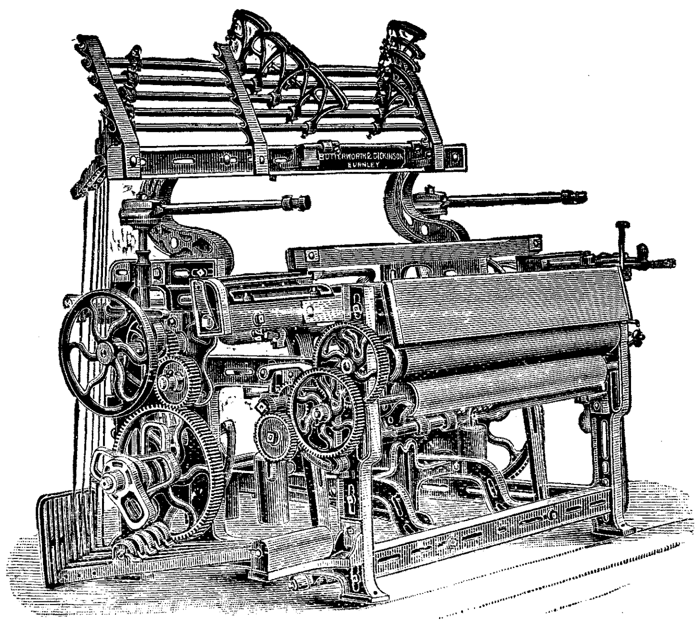


Fig. 50.

Now having dealt with the under-picks there are only two forms to refer to, both of which may be termed over-picks; the one most largely used in the worsted looms and light cotton looms, the other on what are known as high-topped looms, or more generally known as the Dobcross type. By far the largest number of looms in use have the over-pick motion of what is sometimes termed the Bradford type. This consists, primarily, in a picking stick moving in a horizontal plane with the extremity over the top of the shuttle-box. This picking stick is placed on the top of a vertical shaft bolted to the outer loom frame, sometimes inside the loom frame and sometimes outside, as shown

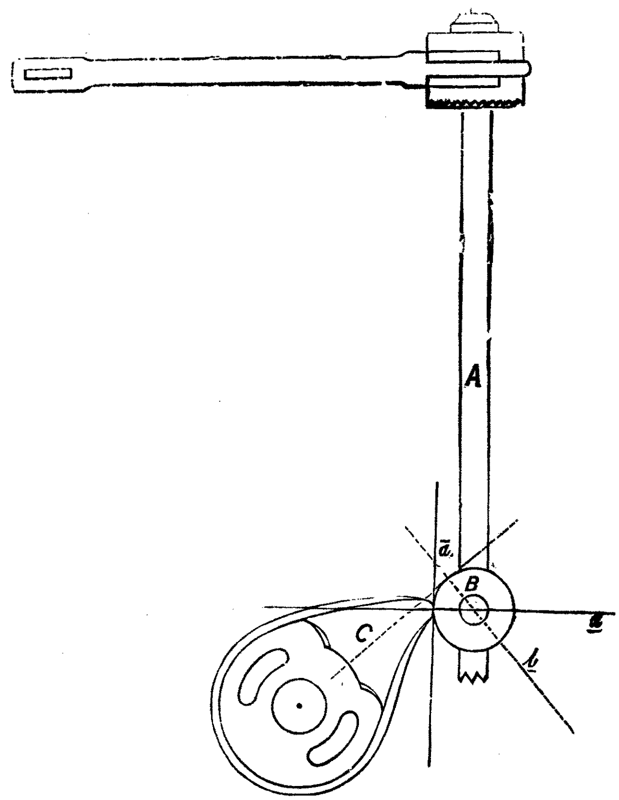


Fig. 51.

in Fig. 50. The general arrangement is shown detached from the loom in Fig. 51 where the upright shaft would be resting in a socket attached to the loom frame near the foot and supported by a bracket near the top.

Some little distance from the lower extremity a cone-shaped roller revolves upon studs attached to the upright shaft at right angles. This stud is really one arm of the lever and the picking stick is the other arm, in precisely the same manner as the lever is formed in Figs. 43 and 44, only that in this case the fulcrum instead of being a short horizontal stud is a long vertical shaft. This lower arm of the lever is acted upon directly from the lower shaft of the loom by what is termed the picking tappet as shown at Fig. 51. It must be perfectly clear that the picking tappet on the shaft, which corresponds to the lever arm on the shaft of the under-pick loom, cannot act directly upon the cone as in the other case it acts upon the long lever; the long lever in the under-pick motion serves as an intermediary, in this there is no intermediary, the revolving lever acts directly upon the lever communicating directly with the shuttle, consequently every care must be taken not only to impart precisely the character of motion required for the work to be done but with the least amount of friction, the least waste of power and harshness, and the least possible re-action in the several parts.

Then the first question to consider is the direction in which the force is to be exerted for, as in other forms of picking motion, the force must be utilised in the best possible manner, and from the nature of the arrangement in this case the difficulty of maintaining the direction of force is much greater than in any other form. We have first the tappet revolving with the tappet shaft, that shaft being placed in the horizontal plane, then we have the upright shaft revolving at right angles to it and forming the fulcrum of the lever through which the motion is communicated from the tappet to the shuttle, consequently we have the two levers, the tappet and the cone-shaped roller, moving when in contact through arcs of circles at right angles to each other. Consequently the surface of each must be so shaped as to not only preserve the full surface contact but also to assist in maintaining the direction of force. Then we may ask the question, what is the direction in which the force should be exerted?

As pointed out in my "Treatise on Weaving and Designing" the direction of force to be utilised to the fullest extent must be at right angles to the upright shaft, or the fulcrum upon which the lever is working, for it needs very little demonstration that if the force should be exerted either downwards or upwards it must either be pressing the shaft down into the socket or lifting it up out of it. The maintenance of the direction of force can be most readily shown by determining beforehand the position of the upright shaft in relation to the tappet shaft, as well as the distance of the tappet from the upright shaft. Here dimensions must be very carefully taken into account, for instance the picking cone must always be in contact with some part of the tappet, so that that implies that the diameter of the disc or shell of the tappet must be sufficiently large for the cone to rest upon it when not in contact with the tappet nose; or another form of expression may be used to make the matter more clear. Suppose that the disc of the tappet is a perfect circle and the cone of the picking lever is at rest upon it when the picking stick is in its normal position. So long as no movement is intended to be imparted to the picking stick the two would remain in that position and the surfaces would simply run upon each other; then it may be assumed as a starting point that when the two circles are so in contact that the centre of the cone is parallel to the tappet shaft, but it must be clearly understood that it is only supposed for the moment as a matter of convenience.

Leaving aside then the consideration of movement being imparted to the cone by adding a projection to the disc which will push the cone from this parallel position, there would be no need for a conical shaped roller, or for any bevelling of the tappet disc, as the two centres being parallel to each other the surface of the roller and the disc might also remain parallel; and further supposing that this cone has only to move from this parallel position a given distance and then return to it, the shaping would have to be to suit the position and extent of movement; but the moment the shape of the cone is altered to suit the movement from this true parallel position then the shape of the disc must be altered to correspond with it on its return; so that reduced to simplicity the amount of bevelling or shaping must be divided between the two extreme positions, and in a great proportion of cases the object aimed at is to have the tappet nose as near a parallel as possible with the shaft upon which it revolves.

Now another question must arise which will determine the relative positions of the two shafts and that is the amount and the nature of the movement imparted to the cone. For instance we say that the cone must travel through a given number of inches. This will be determined by two considerations—the length of the shuttle-box and the amount of leverage given to the picking arm. Suppose for instance that the picker must travel through 15 inches, then the picking arm at its extremity must travel not only that distance but something more. There must be some amount of slack in the picking strap, *i.e.* the picking stick must travel outward some inches beyond the extremity of the shuttle-box, and of necessity a corresponding number of inches in the opposite direction beyond the spindle stud so that if the picker travels 15 inches and 3 inches is given at each extremity for slack leather, then the total distance travelled by the picking stick will be 21 inches. Now we have the length of the picking arm to take into account, and its position whether inside or outside the loom frame, as also the angle it forms with the shuttle-box at each extremity of its movement.

Let it be supposed for convenience that at each extremity it forms an angle of 45 degrees with the shuttle-box then it would be at right angles exactly in the centre of its passage, which of course means that the arc of a circle formed by it in its traverse will be equal in distance at both extremities from the picker spindle; so that the direction of force as delivered by the picking stick will be the nearest possible approach to a line parallel with the spindle. The position so assumed is often very difficult to maintain more especially when the upright shaft is placed inside the loom frame. To have it placed in such a position as to have the angle indicated it would imply that the upright shaft should be opposite the centre of the shuttle-box which in many cases is a practical impossibility. Then the angle at each extremity must be varied, but following the assumption already adopted we can determine the length of picking arm from the position of the upright shaft or *vice versa*. Suppose the upright shaft is 18 inches from the picker spindle when the going part is in the centre of its stroke, that will immediately determine the length of the picking stick as being equal to that distance, *i.e.* with the point where the leather is fastened to the picking stick being directly over the picking spindle, so that the going part travels the same distance beyond it in each direction, or in other words the picking stick and spindle are at right angles to each other when the going part is in the centre of its stroke, and the picking leather is parallel with the spindle at the same moment. This then it will be seen is the most convenient starting point which could be adopted. As to its practical application we must see presently.

The amount of traverse given to the picking stick must always be an important factor in determining its length, as if it be too short the arc of the circle formed in travelling will be such that the distance on each side of the parallel line spoken of will be too great, and it is obviously better to have this arc formed as large as possible for the purpose of avoiding strain upon the spindle and friction; then if the distance traversed is 21 inches, and allowing a distance of 3 inches on each side of the spindle, we should have a length of picking stick of 18 inches necessary. Then that will determine the position of the upright shaft, and we must now take the leverage into account for determining the length of the cone. If the picking stick is 18 inches long, and travels 21 inches, then the cone to be of convenient length should be certainly not less than about one-fifth of the picking stick, otherwise the arc of the circle which it describes will be too small for good working. Then those two important factors being determined we must consider whether the centre of the cone should be parallel to the tappet shaft in the centre of its stroke, or whether it shall be in that position at or near the extremity of the stroke. That of course will determine the diameter of the disc, and the length of the tappet nose will be determined by the amount of movement to be imparted to the cone; for instance, we have already determined that the picking stick must travel 21 inches at its extremity, and that the cone should be to the picking stick in length as one is to five, then the cone must travel $\frac{21}{5} = 4\frac{1}{5}$ inches at its point of contact with the tappet, so that the whole length of the tappet nose from the disc must be that number of inches. Now as to the movement of the cone. The quarter-circle movement has been considered by many to be the best, for the simple reason that in adopting that movement the arm of the lever never passes the centre of its fulcrum.

As any one will know who has ever observed the movement of a lever, especially when working upon a shaft as in this case, there must be a certain amount of vibration occur at the moment when it crosses the centre; and as in picking this vibration would occur exactly when the force is being delivered, if the lever were allowed to travel the same distance on each side that would be the most critical period at which it could possibly occur, for the reason that it would then be imparting force to the shuttle at almost its highest rate of velocity, and also at the moment when the shuttle would be practically relieved of the pressure of the spring or swell in the shuttle box; any vibration occurring in the picking stick might be communicated to the shuttle and divert its course and throw it out of the loom. This of course need not necessarily be a fatal objection to the placing of the picking stick in this position, because proper care and attention to the working parts, so as to check undue wear and tear, would have the effect of reducing this vibration to a minimum, but there are other objections to this position even greater than that.

No doubt theoretically that is the best position, but practically it is one difficult to maintain. When the position of the upright shaft in relation to the tappet shaft is taken into account, along with the shortness of the cone in the lever arm, it will be seen that the angle formed would be so acute that the bevel on the surface of the cone, and of the tappet shell, or disc, becomes almost an impossibility, and the larger this disc and the more difficult this angle would be to deal with. Then a little must be given on the one side or the other. If we must run the risk of this vibration it is best to let it occur at a time when it will be least likely to be injurious. Suppose it is determined that the lever shall pass its centre at a point near the commencement of its stroke, say mid-way between the point where it commences and when the picking stick is at right angles to the shuttle box, that determines definitely the position of the upright shaft. Then we must see what angle the centre of the cone will form with the picking shaft, and for the disc of the shell we should divide this angle equally between the disc of the shell and the cone itself, so that that portion of the question will be easily settled; the length of the tappet nose has already been determined by the leverage given to the picking stick. Knowing now what is the angle of the cone, and assuming that the extreme nose of the tappet is parallel with the tappet shaft, the angle formed by the cone upon the surface of the tappet should be determined at every point of the stroke. This will not be a difficult thing to do, as taking about 3 points between the highest and the lowest, the intermediate positions may be readily inferred. With the dimensions given, those three intermediate points would be as follows:—The tappet nose in contact, at its extreme point, with the cone, and the centre of the cone parallel with the tappet shaft, the angle of the cone surface with its axis may be supposed to be 5°. It may be anywhere from 5° to 10°, then the tappet nose must form a corresponding angle with its axis. Now let the picking stick move a distance of from $7\frac{1}{2}^\circ$ to 10° in tightening the picking strap, say 10°, then the angle formed will be equal to 15°. If the time occupied in delivery of the force is about one-eighth of a revolution of the crank shaft, it will be equal to one-sixteenth of a revolution of the tappet shaft, or $\frac{180}{16} = 11\frac{1}{4}^\circ$. So that the angle now becomes one of $15 \times 11\frac{1}{4} = 26\frac{1}{4}^\circ$ on the surface of the cone, then the intermediate points will be $15 + \frac{11\frac{1}{4}}{4} = 17\frac{13}{16}^\circ$. The next will be $17\frac{13}{16} + 2\frac{13}{16} = 20\frac{5}{8}$. Then $20\frac{5}{8} + 2\frac{13}{16} = 23\frac{7}{16}^\circ$ respectively. Then from this the tappet can be drawn with perfect accuracy.

Now that the leverage, position and angle of the cone and tappet have been determined, the questions arising are as to the magnitude of force and the correct form of tappet required to produce the peculiarly eccentric motion referred to. As to the magnitude of the force it has already been pointed out that it is practically impossible to determine it for all cases, simply because the amount of resistance offered is so varying in quantity that what will serve, and be perfectly correct, in one case would be utterly inadequate, or far too much, in another. Generally it may be stated as follows :— Let the loom be making 240 picks per minute, and the time occupied by the shuttle in passing across the loom be equal to a little more than one quarter of a revolution of the crank shaft, or for convenience say exactly a third of a revolution, then the time would be $240 \times 3 = \frac{1}{720}$th part of a minute. Now let the shuttle weigh three quarters of a pound, and the distance it is projected 6 feet, then the energy developed would be equal to $\frac{3}{4}$lb. projected 6 feet in $\frac{1}{720}$th part of a minute, or $\frac{180 \times 3 \times 6}{60 \times 1} = 54$ feet per second, and the energy would be—taking the work done on the usual basis of W = work done, V = velocity, and G at 32·2— $\frac{12 \times 54^2}{16 \times 2 \times 32{\cdot}2} = \frac{12 \times 54 \times 54}{16 \times 2 \times 32{\cdot}2} = 33{\cdot}96$ foot lb. per pick of the loom, or each projection of the shuttle; and as one horse power is indicated by 33,000 lbs. raised one foot in one minute, thus $\frac{33{\cdot}96 \times 60}{33{\cdot}000} = {\cdot}0617$ of a horse power expended each time the shuttle is propelled across the loom.

As to the form of tappet necessary to the production of the proper kind of movement, the simplest method of drawing it is as follows :—

Make a plan showing the exact position of the upright shaft: the picking cone in the two extreme positions, the picking, or lower shaft, and the tappet, as in the upper part of the drawing at Fig. 52. T is the tappet shaft, U the upright shaft, C is the cone, and D the disc or shell of the tappet.

The centre lines C^1 C^2 represent the exact distance traversed by the cone, which at the point of contact with the tappet is 3 inches. The diameter of the disc, or shell,

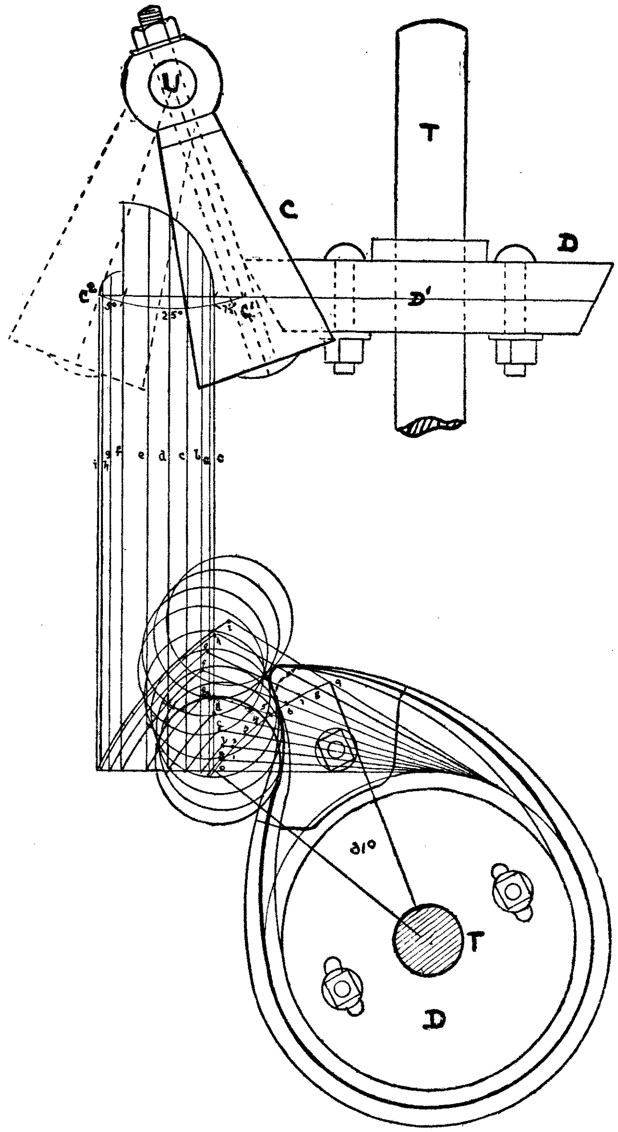


Fig. 52.

of the tappet is 8 inches at the centre line, or midway between the edges of the surface as shown by the line D¹ and the length of the tappet nose is 3 inches. The point of contact of the centre of the disc is $4\frac{1}{2}$ inches from the fulcrum, the length of the cone being 6 inches. Now take the angle enclosed by an arc drawn from C^1 to C^2 at the point of contact with D^1, and it will be found to be about $38\frac{1}{2}°$. This $38\frac{1}{2}°$ may now be divided up for the work to be done. Take $7\frac{1}{2}°$ for taking up the slack leather, 25° for the delivery of the accelerated force, and 6° for amelioration, or gradual

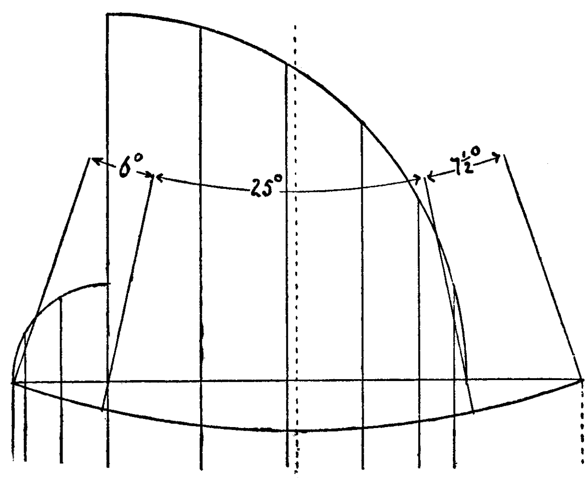


Fig. 53.

reduction of force, so as to bring the picker to rest without the violence of concussion with the spindle stud being too great, and lay off those angles as shown in the drawing. The next thing is to divide the several parts of the arc according to the movement to be given. The first $7\frac{1}{2}°$ requires but little attention, as it requires to be only a gently accelerated movement. The 25° should have accelerated motion in harmonic ratio, and the last six reduced in a similar ratio.

The determination of this ratio will be best understood by reference to Fig. 53, which represents an arc of a circle of $38\frac{1}{2}°$ and divided as mentioned. Take the 25° as laid off in the chord and erect a quadrant. Divide the quadrant into six, or any number, of equal parts, and drop perpendiculars, cutting the horizontal line, and the divisions thus produced will represent what is known as harmonic ratios.

Then the 25° having this accelerated movement, the next 6° must be reduced in the same ratio as shown.

Having proceeded thus far, next project the proportions by dropping perpendicular lines to the lower portion of the drawing, where the lettering again corresponds to the same parts. The line D^1 representing the centre line of the tappet surface, it is most convenient to draw to that. Then draw the horizontal line H tangent to the circle D^1, and let the vertical lines indicating the movement of the cone cut it at the points marked *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*. From the point where the line *i* cuts this horizontal line draw a line to the centre of the circle or tappet T, and lay off from that $38\frac{1}{2}° - 7\frac{1}{2}°$ as shown. Next divide this 31° into as many equal parts as the horizontal line H has been divided unequally, as at 1, 2, 3 to 9, on an arc struck from the point *i* on the line H. Then from the centre of T strike arcs of circles from *a* to *i* in succession, and through the points 1 to 9 draw lines tangent to the circle D^1 until they cut those arcs, and a line connecting all the points of intersection will represent the direction of force as required to be delivered by the tappet. From each of those intersections, and with the radius of the cone as at D^1, draw circles representing the exact position of the cone at each point in the movement, and a line tangent to all the arcs in succession will be the true line of the tappet on the surface, or continuation of D^1. The intervening space between the first arc and the true circle D^1 being filled up by a suitable curve to draw up the slack of picking strap, and coinciding with the $7\frac{1}{2}°$ allowed for that purpose.

Having now found the true line for the centre of the tappet surface, it only remains to fill up and make the angle of the surface correspond with the surface of the cone as already pointed out, and fill up the back of the tappet nose in such a manner as to allow the picker to return gently to its position at the back of the box.

There is but one other form of picking motion now to refer to, that is the picking motion attached to what are known as the high-topped looms, and this is so similar in character to the under-pick, and this class of loom is so

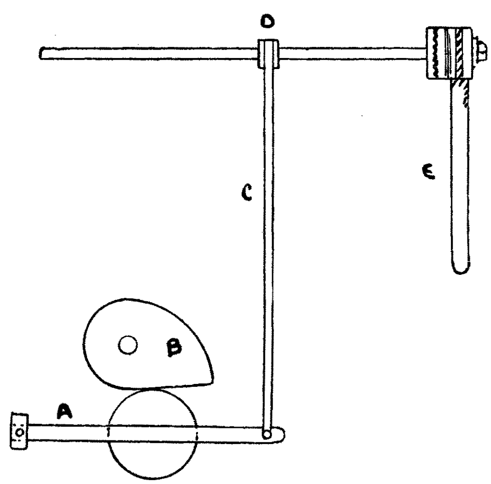


Fig. 54.

rapidly going out of use that little need be said upon the matter. The general arrangements are as shown in Fig. 54 and also at Fig. 55, one of which shows the side and the other the front view. A lever A has its fulcrum near the back of the loom and passes directly under the main driving shaft, upon the driving shaft is placed a cam B. The free end of the lever is connected by a rod C to a short lever arm D. The other arm of the lever E being the picking stick. It will thus be seen that this is virtually the same as the under-pick motion described in Fig. 43 reversed, but with this exception that instead of an anti-friction bowl or roller being placed upon the lever arm revolving upon the shaft, and the picking plate upon the lever, a picking tappet is placed upon the shaft and the anti-friction roller upon the lever. The drawing of this tappet is comparatively simple as compared with the tappet for the cone picking; the surface of the tappet itself always being parallel with the shaft upon which it is placed.

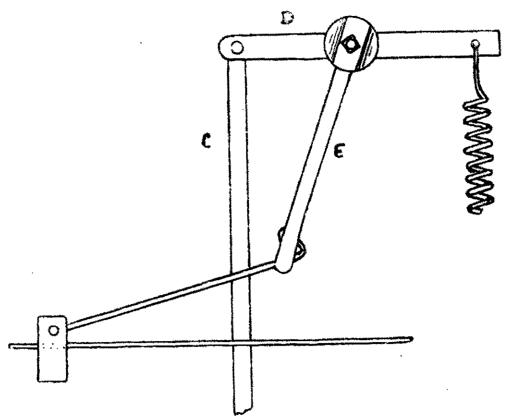


Fig. 55.

Of course the general form of the tappet will be determined by the same rules as to acceleration of speed as in the previous cases, but, generally speaking, a straight line drawn from the disc, at the point where the tappet nose begins to be formed, to the extreme end of the tappet gives a sufficiently accelerated movement for all practical purposes. This loom being invariably used for heavy goods and built for slow running there is not the same necessity for strict attention to the accuracy of form and the exact balancing of parts as in the fast running looms.

It might appear at first sight as though far too much attention had been devoted to this portion of the loom, but any one familiar with the working of looms of any description will at once recognise the necessity of paying the closest possible attention to every detail. From the very nature of the movement there is no part of the loom which is capable of giving so much trouble, or can be so productive of mischief as the picking mechanism. In the first place, the character of the force and the manner in which it is delivered, partaking as it does so much of the character of a blow, the force being withdrawn suddenly, and at the time when it has attained its greatest impetus, must cause a reaction; this reaction, of course, is always dangerous as affecting other parts of the loom, and unless well controlled may be productive of endless mischief; so that the easier the movement can be executed, and the better the parts are balanced, coupled of course, with proper timing in relation to the several working parts, the better for the work of the loom in general. Again, of course, the proper adjustment of everything having reference to the picking, so as to reduce the liability of throwing the shuttle out of the loom, must be considered of sufficient importance to warrant the closest attention to every minor detail.

Many means have been resorted to from time to time to relieve the pressure upon the shuttle in the box both at the moment of picking and also of entering the box, some of these are very ingenious and simple: for instance, taking what is known as the stop-rod motion, a simple connection of the upper arm of the lever at the back of the box with the crank arm by means of a short rod, as shown at Fig. 56, would effectually remove the pressure at the moment when the picking would take place. The picking usually commencing when the crank is descending, or approaching the lowest point in its revolution, and the action being completed about the corresponding point in the return stroke, this method of connecting would ensure pressure being taken off both as the shuttle leaves and enters the box. Another method answering the same purpose, is an arm carried back from the stop-rod as a lever and made to travel over a bridge so placed as to give relief during exactly the same period as in the other case. Other aids are resorted to such as anti-friction rollers in place of the swell at the back of the box; all more or less effectual and tending to reduce the amount of work required.

There are several other matters connected with picking which must not be treated lightly, as having, not only an influence upon the good working of the loom, but also

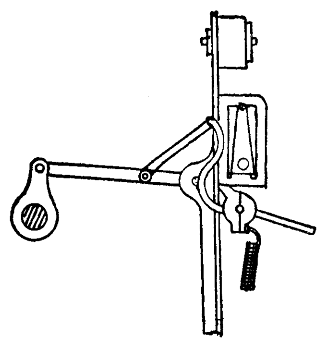


Fig. 56.

upon the amount of wear and tear. Manufacturers often look with dread at the annual bill of costs represented by the wear and tear in the picking arrangements of the looms. To begin with there is the wear and tear of the pickers, which will always be great unless the pickers are well made, properly seasoned and well used. When the nature of the work the picker has to accomplish is considered, the amount of wear and tear upon it must be evident, for not only has it to bear the strain of delivering the blow sufficient to propel the shuttle across the loom, but it also has to act as a check upon the shuttle as it enters the box, and the shuttle tip in striking it must of course tend to wear it away; though the wear and tear in this part is not so great as might be anticipated, because, after a hole has been worn in to a moderate depth the force of the blow is not received from the extreme point of the tip alone, but practically from the whole surface. It will generally be found that pickers break most at the shoulders, more especially when they are not sufficiently pressed in making, or not sufficiently dried or seasoned.

In making pickers, the great bulk of which are made from buffalo hide, the skin must be softened so as to permit of its being readily moulded to shape, cut, punched and rivetted to the proper form and size; then subjected to great pressure so as to compress them and make them as solid a mass as possible. After this they must be thoroughly dried, and from the nature of the substance, this can only be accomplished by keeping them a long time so that the drying shall take place gradually. After that they are usually steeped in oil for a considerable period, this period should not be less than one month—but is much better if even for a longer period—after which they may be dried again; so that generally speaking a buffalo picker is not fit to put on the loom for at least six months after it is made, and if a longer time is taken the results are generally better.

The next point of interest and importance is the picking strap, and although considerable expense may be incurred through the wear and tear of the picker, much greater expense probably will be brought about by the picking strap. There are several considerations in this connection which must always receive close attention.

First the stopping of the picker without throwing too violent a strain upon the picking strap; this implies two things, one of which has already been referred to, viz.: the exhaustion of the force some time before the picker comes up to the spindle stud, and the second is the use of a buffer to reduce the force of the concussion. Both these are items which may have an important influence upon the amount of leather consumed. In this direction, as in many others, repeated efforts have been made to minimise the difficulty, such as check straps upon the picking stick, springs and so forth, so that the picker would not be carried up to the stud with the full force of the picking stick. But practically the old fashioned buffer still holds its own. The general arrangement consists simply of a piece of leather picking strap with a number of holes punched in it and doubled backward and forward upon the spindle, so making a species of leather spring to receive the picker at each stroke. Of course what applies to pickers, as to seasoning of the material, applies equally to the picking straps, which are usually made of green, or oak-tanned leather, properly seasoned and steeped so as to give them all the strength and flexibility possible. Supposing now that every precaution has been taken as to the use of the buffers, &c., then the method of connecting the picking strap with the picker, and with the picking stick, are items to be borne in mind. The general method of attaching the picker to the strap is by passing the strap through a groove in the top of the picker and then threading it through a hole made in the end of the strap. A very cursory examination will show that as the picker is being drawn forward the strain will not be equally distributed over the whole width of the strap, but will be borne almost entirely by one side; as a consequence after the leather has stretched as far as it can fracture will occur at the tight side, and it will not be long before this goes across the strap. Then the fractured portion is cut away, a fresh hole made, and the strap re-attached, and this goes on until the strap is too short, when the remaining portion is thrown aside to be afterwards converted into buffer leather. In attaching the leather to the picking stick the general method is to pass the leather through a slot in the end of the picking stick, coil it a number of times round the stick itself, and finally attach it to a pin. Now the question for consideration is, will such an attachment be likely to give distribution of strain over the width of the leather? In a great majority of cases it will not, but something like the same result will follow as that which arises from the method described of attaching

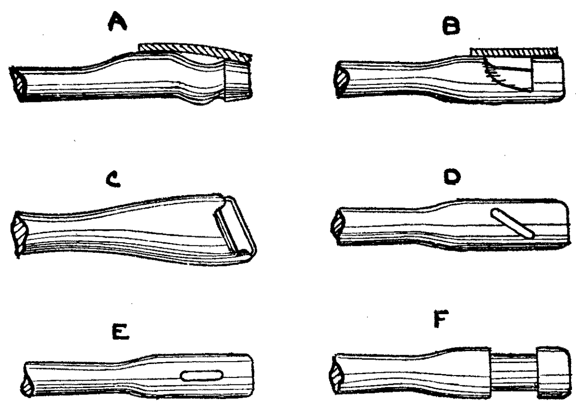


Fig. 57.

to the picker, though the wear and tear at the end of the picking stick is not, as a rule, nearly so great as at the picker. Then several methods of attachment are in use, both in connection with the picker and the picking stick, such as using a pin, or a rivet, or other means at the picker, and shaping the ends of the picking stick as shown in Fig. 57A, 57B or 57C, where the end of the stick is formed so as to obtain even distribution as nearly as possible over the width of the leather, and which if properly arranged will answer its purpose pretty completely.

57D shows simply a diagonal slot through which the leather is passed for the same purposes, whilst the most common form is shown at 57E, and another at 57F. The next item, and although of less importance as regards wear and tear than the other method referred to is the use of the check strap, yet it is still of sufficient importance in the work it has to do to call for attention. As its name implies the object of this check strap is to check the movement of the picker, and more especially the shuttle as the latter enters the box. Suppose the picker; after delivering its force, is brought back to the extreme end of the box, and the shuttle, on entering it again is allowed to come in contact with it without anything to modify the force, the result must be disastrous to the picker; a certain amount of check is given to the impetus of the shuttle by the presence of the spring or swell of the stop-rod in the back of the box, but this is not sufficient in itself, hence the necessity for the check-strap. This contrivance is simply a short strap carried over the end of the spindle and inside the box at each side of the loom, then a long strap is carried right across the front of the going part and buckled to each of the short ones; the length of this is so adjusted that as the picker goes to the back of the box at one side of the loom it draws the check strap some little distance from the end at the other side, so that each picker in turn going back to the end of the box draws the check strap from side to side, and this action, and the drag upon the picker, slight as it may appear, offers sufficient resistance to the shuttle, and modifies the force of the concussion of the picker with the box end sufficiently to prevent injury. Another important factor in the case is the tendency that would always be present of causing the yarn to fly off the bobbin or cop if the shuttle were stopped too suddenly, so that the check strap is of quite sufficient importance in the working of the loom to justify a considerable amount of attention being devoted to its adjustment. Briefly put it may be said that neither too much nor too little play must be given to the check strap, otherwise its functions will be impaired.

With reference to the questions of the yarn flying off the bobbin, many contrivances have to be resorted to to meet this difficulty, some of which I shall refer to in dealing with shuttles, &c.; but it may be generally mentioned here that such arrangements as brushes in the sides of the shuttles, of such a kind as to press lightly upon the yarn on the bobbin are most resorted to. The strength of the brush will depend very much on the strength and smoothness of the yarn. For silk, for example, a piece of hare or rabbit skin is often used; for other yarns velvet or plush, and for the strongest, a series of hog's bristles, as in an ordinary brush. In dealing with smooth, slippery yarn, this matter often gives a considerable amount of trouble.

The most important item in connection with picking now to be dealt with, is the arrangement and working of changing boxes, which must form the subject for a separate lecture.

LECTURE 5.

CHANGING SHUTTLE BOXES.

In the lecture on picking arrangements all the details referring to the methods of propelling the shuttle have been dealt with. It now remains to deal with the various methods of changing from one shuttle to another when several yarns are employed. In the earliest form of hand loom weaving this was done by the weaver having, what he termed, a shuttle board at the side of the loom, upon which the shuttles containing the different colours of the weft were placed; these he would pick up with his hand, each in its proper order of succession; and after the introduction of the fly shuttle, by Kay, this practice still remained in vogue. Then came in a system of what is known as rising boxes, that is, a series of shelves attached to a vertical frame, each containing a shuttle, and which could be operated by the weaver by means of a simple contrivance of levers so as to bring any of the shuttles to the level of the shuttle race at will. This has remained in vogue, not only in hand looms, but is still admittedly the best system for power looms for weaving heavy goods at the present day. Another system came into vogue immediately after that, known as the Paisley sliding box. In this case the shuttle boxes were placed in a horizontal position and were actuated by the feet of the weaver instead of by the hands as in the previous case. In fast running looms, however, circular boxes have been found more advantageous.

In reality there are only two questions to consider in connection with this subject, the one is the exact moment when the change shall take place, so as to bring the shuttle required into position for being propelled by the picking stick;

the second is that of the exact method of changing from one box to another. The first question is easily disposed of, but the second involves careful consideration of a vast amount of detail; for not only must the method of changing be considered, whether the boxes be rising, sliding, or revolving, but all the mechanism connected with the system of changing, whether it should be in consecutive order, or skipping from one box to another, and also all the safeguards to prevent accidents by false movements must be considered. Leaving the mechanical arrangements aside for the moment, the first general principle may be dealt with. It has been laid down generally that the shuttle should leave and re-enter the box at a point when the going part is mid-way between the front and back extremities of the stroke. That being so the time for changing the shuttle box is easily determined. A shuttle has entered the box as the going part comes forward to the cloth, and at the point indicated, and another shuttle, or the same, must be propelled from the box again at the corresponding point in the return. Therefore the time when the change must take place is definitely fixed as being that when the reed is actually in contact with the cloth, the movement commencing slightly before, and being completed slightly after passing that point. This determines the actual time within which the change must be made, but in many cases some little allowance must be made for the return of the picker. This may not be very much, still it must not be overlooked. Wherever direct acting picks are employed, as in some of the under-picks already mentioned, the return of the picker is very prompt, partaking as it does of almost a positive motion, but the over-pick loom is not so prompt in the return, as the slack of the picking leather must be taken up in full. This loss of time however is comparatively trifling, though it should always be reduced to a minimum, so as to give as much time as possible to the movement of the box; whether we are working with circular or rising boxes, everything must be done that is possible to reduce the amount of jerkiness in the movement. In the earliest form of circular boxes this was extremely difficult to deal with. Perhaps this will be better understood by reference to Fig. 58, which gives a view of one of Hattersley's

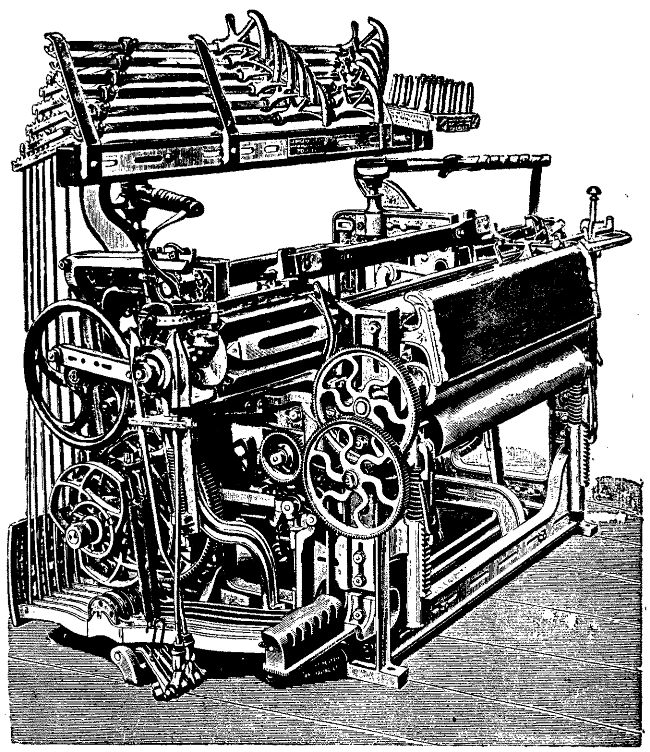


Fig. 58.

ordinary plain box looms. There are six holes in the box represented, and the box is so arranged, that it can be pulled over by means of the two catches, or pawls, as seen at the end, acting upon a toothed circular head. This will be more clearly seen in the detail drawing at Fig. 59, where the arrangement of the levers, and the teeth upon the circular head, is such, that the box is pulled round a distance exactly corresponding with one hole in the box, and also showing the arrangement of the hammer, with a helical

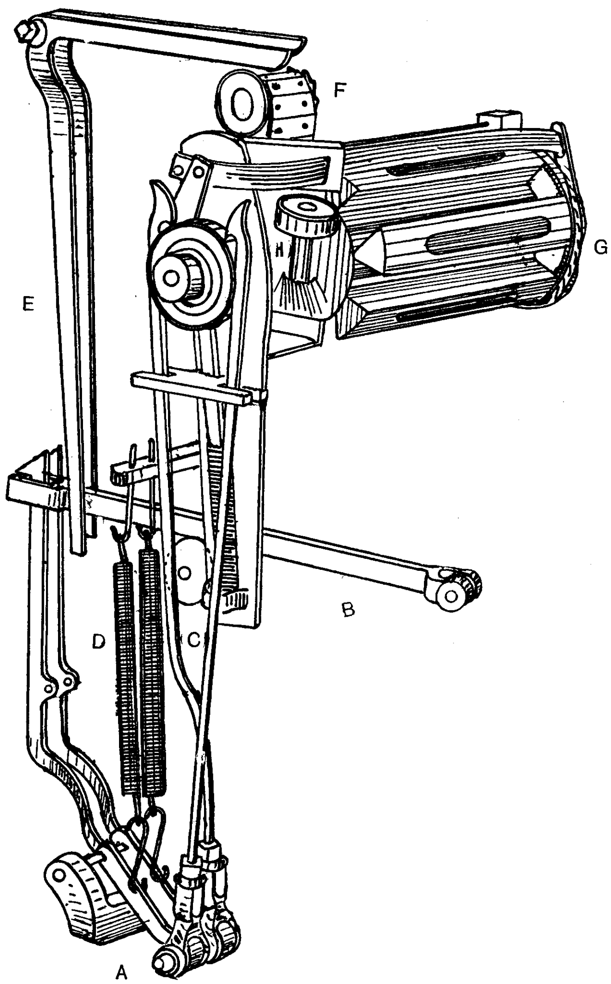


Fig. 59.

spring on its vertical spindle, keeping it in contact with the projections upon the head, in such a manner as to hold the box firmly in position whenever one of the holes is brought opposite the shuttle race.

It would be well for the moment here to make a comparison between this method of working and some of the earlier forms of box looms. Here it will be seen that the box is pulled gently over, whereas in the earlier forms it was simply forced over by being brought into violent contact with a fixed lever on the loom end. Suppose for a moment that instead of the box head, as shown in the illustration, that two ratchet wheels were placed, one having the teeth pointing in one direction and the other in the opposite direction; then two catches or levers are placed upon fixed spindles at the loom end, so that they can be brought into play, one to come in contact with one of the ratchet heads and the other with the other ratchet head, at will. Then supposing the box is required to be turned, the upper or lower catch would be brought into contact with the ratchet head, just as it was desired to turn the box forward or backward, and as the going part comes forward towards the cloth the ratchet head comes in violent contact with the lever, so forcing the box over. This class of box loom is very appropriately termed the "tupper." The liability to breakage and the general interference with the working of the loom by this system of "tupping" will be easily understood, but it has the one quality of determining definitely the exact moment of turning, as it must be evident that the box must be turning exactly when the reed is in contact with the cloth. Therefore the operation is completed in a sufficient time to allow the box to be settled steadily to rest in its position by the time the shuttle is to be propelled from it. In the illustration shown here the movement is easier, but requiring quite as much attention and skill on the part of the overlooker in its proper adjustment. Now look for a moment at the details: the two long catches which serve to turn the box are fulcrumed at their lower extremity to an end of levers A of a peculiar bent shape. The upper end of this bent lever has a catch upon it which is passed through a slot in the end of the lever B. This lever B is acted upon by a cam C upon the tappet shaft, and is raised at every pick of the loom; so that should one of the two levers A have the catch thrown over the end of the lever B it would pull the box over one hole forward or backward as required; then the lever A would be returned to its normal position by the spring D. The method of operating the levers A is by means of bell crank levers E. Each of those levers E having a pin at the upper extremity so arranged that it may drop into a hole on the card cylinder F. A set of cards are placed upon the cylinder perforated in such a manner as to cause the box to turn in the required direction. Suppose, for instance, that the box is required to be turned forward, then a hole left in the card under the lever acting upon the front catch will cause that catch to be pulled by the lever B. Or if it is required to be turned backwards the other catch will be operated in a similar manner, so that broadly speaking the arrangement of cards would be as follows:— Suppose the pattern to be made is a common check, in two colours, and say there are eight picks of each colour alternately, one shuttle would be placed in the box and seven blank cards would allow the box to remain stationary for that number of picks; on the 8th card a hole would be cut to cause the front lever to pull the box forward, when the second shuttle would be brought into play; again seven blank cards allow it to remain in that position, and at the 8th the back lever is pulled over, so returning the box to the position of the original shuttle. Consequently there are as many cards required as there are picks in the pattern. It should be said here that the reference is to a loom having a box at one side only, each card will act for two picks of the loom, or as it is commonly spoken of as one double pick. It is necessary to make this explanation otherwise the reader might be under the impression it was a double box loom. There being a box at one side only it is obvious that the pattern must be in double picks. The method of giving instructions to the card-cutter will be as follows:— $\frac{\begin{matrix}8F\\8B\end{matrix}}{16}$ indicating clearly to him that at the 8th card the box must move forward, and at the 8th again from that point it must move back. Of course in working with two shuttles the system is perfectly easy, but with a number of colours it becomes somewhat difficult as the designer of the pattern must so arrange his colours that he can move from one to the other with perfect ease. In many cases, although only three or four colours are employed, all the six holes in the box may require to be used, simply because they must rise in regular succession. There is no provision made for skipping from one shuttle to any other, consequently the box will have to be revolving continuously in one direction, or it may have to go a certain number of holes in one direction and then return; extra shuttles being introduced for the purpose of bringing the correct colour up when required. For instance, the two checks on the coloured plates will readily illustrate both these features, and the method of cutting the cards to produce the required pattern.

The first of these is the Tartan of Cameron of Erracht, and as will be seen, contains five colours. Yet it is necessary to use all the six boxes, because of the position in which they fall in relation to each other. The pattern would be as follows:—

Box.		Threads.		Colour.		Movement.
1	...	16	...	Black	...	F
2	...	2	...	Red	...	F
3	...	16	...	Purple	...	B
2	..	6	..	Red	...	F
3	...	6	...	Purple	...	F
4	...	4	...	Yellow	...	B

Continued.

Box.		Threads.		Colour.		Movement.
3	...	6	...	Purple	...	B
2	...	6	...	Red	...	F
3	...	16	...	Purple	...	B
2	...	2	...	Red	...	B
1	...	16	...	Black	...	B
6	...	16	...	Green	...	B
5	...	6	...	Red	...	F
6	...	4	...	Green	...	B
5	...	2	...	Red	...	F
6	...	8	...	Green	...	B
5	...	2	...	Red	...	F
6	...	4	...	Green	...	B
5	...	6	...	Red	...	F
6	...	16	...	Green	...	F
		164				

Then the black is placed in box No. 1, and each other in succession for the first portion of the pattern, but when the second portion comes on we cannot get from the green to the red shuttle without skipping, and as the box is not made to skip, but to move one hole at once in either direction another red shuttle must be put in, thus permitting the perfect working of the pattern.

In the next, which is the Tartan of the Clan of Munro, the method of working is even more notable. In this there are only four colours, red, yellow, purple and green, yet six shuttles are again necessary; there must be two red and two purple shuttles. Then it will be seen that the box makes practically a complete revolution in one direction and then one in the opposite, so as to bring all the shuttles into play in their proper order.

I have selected some of the most difficult to illustrate the point clearly. Generally there is little trouble, but it is well to know thoroughly the principles.

The following is the pattern and working:—

Box.	Threads.	Colour.	Movement.
1	48	Red	F
2	2	Yellow	F
3	4	Purple	F
4	8	Red	F
5	32	Green	B
4	8	Red	B
3	4	Purple	B
2	2	Yellow	B
1	8	Red	B
6	16	Purple	F
1	8	Red	F
2	2	Yellow	F
3	4	Purple	F
4	36	Red	F
5	4	Green	B
4	4	Red	F
5	4	Green	B
4	4	Red	F
5	4	Green	B
4	36	Red	B
3	4	Purple	B
2	2	Yellow	B
1	8	Red	B
6	16	Purple	F
1	8	Red	F
2	2	Yellow	F
3	4	Purple	F
4	8	Red	F
5	32	Green	B
4	8	Red	B
3	4	Purple	B
2	2	Yellow	B
	336		

Several features of this arrangement may now be examined in detail, some of them are of apparently trivial importance, yet they should all be thoroughly understood to enable one to arrive at a proper grasp, not only of this particular machine, but of other and more intricate ones which will have to follow.

Now first with regard to the levers E. They must be so constructed that the weight of the arm towards the card cylinder F is sufficient to bring the levers A, with their catches, over the end of B when required; and yet this weight must not be so great as to throw too much pressure upon the cards. Of course, from the very form of the levers, this is not difficult of attainment, but a little more difficulty may exist in regard to the levers A. In the first place they must be jointed to a faller as indicated, otherwise of course the levers E could have no power over them, and again, from the peculiar position, and the bent form it must assume to bring it from the loom side to the extremity of the box end, as will be seen in Fig. 58, renders it of the utmost importance that care should be taken both as to the proper adjustment of leverage and the position of the fulcrum. There are two considerations here which must not be overlooked, one in relation to the position of the fulcrum of the catches which turn the box, and the other with regard to the character of lever B and its work.

We will take the position of the two catches first. The question has often been asked why does the box turn more rapidly as the reed comes up to the cloth than it does when moving in the opposite direction? A careful examination of the position of the sword of the going part, the fulcrum of the long catches and the manner in which they work will readily explain this. Suppose the fulcrum of the catches is placed too far forward as the going part goes back, receding from the vertical line, the catch acting upon the back of the box causes it to move more rapidly than the opposite catch would in the forward movement. This is self evident as it is practically equivalent to a shortening of the catch which has its fulcrum placed at some distance in front of the turning point. Now reverse the position and place the fulcrum of the levers behind that of the sword of the going part, and the box will revolve more rapidly in the forward movement than in the backward one, so that the whole question resolves itself into one of the proper placing of the fulcrum of the levers, a careful adjustment of the length of the levers or what is equivalent the length of the catches themselves; as from the position in which they are placed and the nature of work they have to do they become practically part of the lever arm. Now as to the second point it has been shewn already that when a blank card is placed upon the cylinder no movement of the box takes place, but when a hole is cut opposite one of the levers E the box is made to turn in one direction or the other. Now suppose the possibility of an accident arising; one common form of cards in use for boxes of this kind has both holes cut and a clasp of tin or other material is used to cover one of them, so that the same set of cards may be used over and over again. Suppose this tin clasp is either left off or falls off, then both levers will drop and both of the levers A will be brought into action, each trying to turn the box its own way; then breakage must occur unless provision is made to prevent it. This provision is made in the form of the lever B which is made in the form commonly known as a "broken backed" lever as shown in Fig. 60. Anywhere near the centre of the lever a hinge is formed and on one side of the hinge there is a projection, or lug; from this lug a strong spring is attached to any point on the other side of the joint, so that as the cam C revolves and raises the lever it will bend at the hinge, or joint, and return by the strength of the spring, so that all risk of injury or damage is avoided.

One point here must not be omitted. It has been already said that the box may be caused to revolve continuously in one direction. A difficulty would arise with regard to the disposal of the weft threads if the box were carried upon a spindle which went entirely through it. This is not the case. A spindle certainly is inserted in the box and extended beyond the point where the catches act upon it, but it is not passed through the other end of the box, the end nearest the cloth is carried in a spring holder as shewn at G in Fig. 59. This holder is firmly fixed to the framework of the going part on the lower

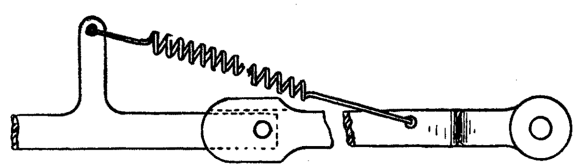


Fig. 60.

side, and to the back at the sword, but the front portion is left practically free. The form is such as to cause it to embrace a little more than one half of the periphery of the box itself, and a corresponding band encloses the box to ensure easy working. Then the upper extremity or the free end of the holder has a loop formed so as to permit of the passage of a check strap as shewn in the illustrations 58 and 59. Inside each hole in the box a small spring is placed for the purpose of steadying the shuttle as described in Lecture 2, and behind the box a couple of rollers are placed marked H, for the purpose of pressing the shuttle gently back as the box revolves, in the event of its having been driven too far in by the force of the pick. With reference to the spring at the back of the box, something will have to be said in a subsequent lecture when dealing with the safety motions, such as stop rods and loose reeds. At the present moment of course it must be understood that the function of this spring is simply to steady the shuttle and keep it firmly in its place. Another feature of the arrangement will now strike the most ordinary observer. The bulk of the box and the mass of machinery attached to it, projecting as it does some distance from the sword of the going part, will suggest a difficulty in keeping it steady and well balanced. This is overcome by two provisions, the one is a bent arm extending from the rocking shaft to the extreme end of the box, and the other is a steadying crank from the fly wheel also to the end of the box, so that, between the two, the one extremity of the box is held as firmly in position as the other, so preventing vibration and enabling the loom to be run at a high rate of speed.

Another feature of the ordinary revolving box must be looked at next. In the one already dealt with the box changes only at one side of the loom, so that it could only weave patterns having an even number of picks of each colour; frequently it becomes necessary to have odd picks introduced more especially in making fancy goods. Then there must be changing shuttle boxes at each side of the loom. To accomplish this the two boxes at each side of the loom are sometimes connected by toothed gearing and a shaft running across the loom; this simply ensures the boxes working simultaneously, but accompanying it another provision also must be made. In using double box looms the picking arrangement must be so contrived that the shuttle can be sent from either side of the loom at will. This is generally done by having a contrivance connecting the box cards with the picking tappets. The most convenient arrangement and the one most generally adopted is to have a fixed disc to the lower shaft and a free sliding tappet;

the tappets at each side of the loom are connected together, so that the moment one is disengaged from one disc, the other is engaged with the opposite disc. The whole arrangement consists in having the two sliding tappets connected by a rod and a lever attached to them which can be actuated by the box cards in the same manner as the lever described in Fig. 58, and a notch in the rim of the disc which will take hold of the tappet, as soon as brought

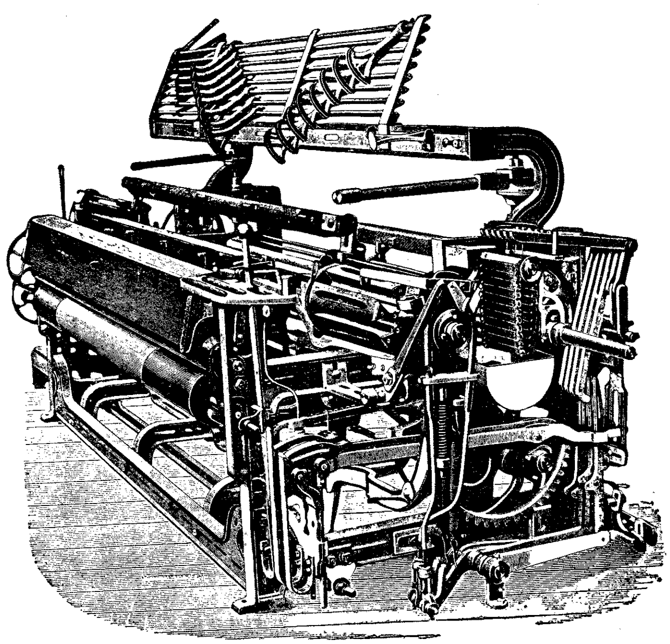


Fig. 61.

up to it by the lever, and so cause it to revolve and deliver a blow to the picking cone. There is little more to be said of this arrangement as it is simply an extension of the single six shuttle box. Of course as will be readily understood it gives an immense power of pattern producing from the mere fact that not only can six shuttles be employed but that any number of picks can be inserted by each shuttle at will. Another arrangement for pick and pick looms is shown at Fig. 61, where there are six boxes at each side of the loom, each of which can be moved independently of the other. The movement of the boxes is controlled by a chain of pattern cards and the picking of the shuttle is also under the control of the same cards, so that the shuttle can be sent from either side of the loom in conformity with the movement of the box.

As will be seen there are six levers to be acted upon by the pattern cards, two for operating the tappets to control the picking so as to bring one or other into play at will; two for actuating the box at one side after the manner described in Fig. 58, and two for actuating the box at the other side in like manner.

By this contrivance any number of the shuttles may be made to follow each other from one side, or by a judicious arrangement of the movement of the boxes any number of shuttles up to eleven may be used, though great skill would be required in the arrangement of the pattern. Still these looms lack the skipping arrangement which will have to be described presently.

Before entering upon the details of the skipping box it will be as well to examine another feature in the arrangement of ordinary box looms. In weaving handkerchiefs or other articles having cross borders a pattern is formed at each end distinct from that of the middle of the handkerchief, and that would involve, in the ordinary box loom we are dealing with, the employment of two sets of pattern cards, which would have to be changed by hand each time the pattern was changed from border to ground; the object of this invention is to make the change automatic. There are two sets of pattern cards one corresponding with that shown in the illustration Fig. 58, which is cut for the pattern constituting the small check of the ground, and which may be repeated any number of times required for the length of the handkerchief. Suppose, for instance, the ground contained, say 200 picks in the pattern, and twenty repetitions of this pattern would be required to form the ground of the handkerchief. Then the cards would be worked ten times forward and ten times backwards. Then the pattern cards for the border would be attached to those of

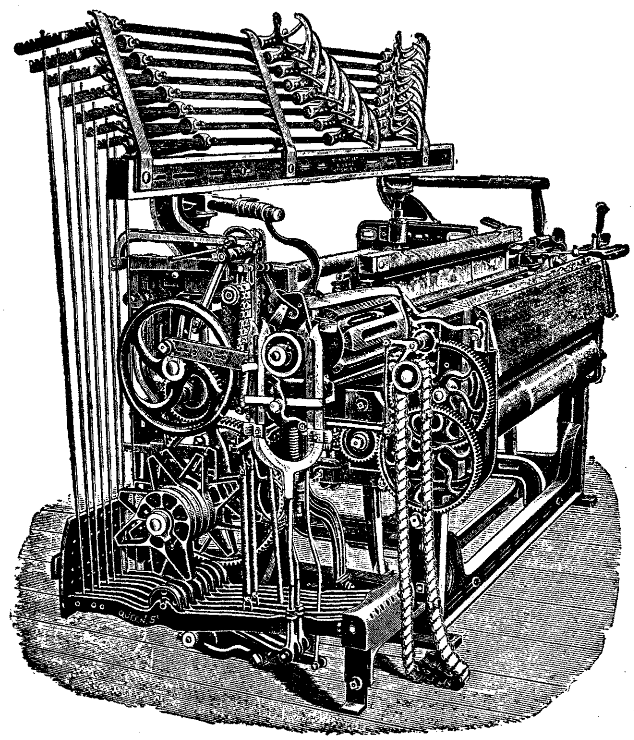


Fig. 62.

the ground and as soon as the ground pattern is completed the border cards are brought upon the card cylinder and they in the same manner would be repeated as often as necessary for the completion of the fabric. The contrivance is simply as follows:—The cards placed upon the usual card cylinder consist of the two sets, for the ground and border respectively, and acting upon the box in precisely the same manner as in Fig. 58. But a second set of cards working from the cylinder at the front of the loom, as shown in the illustration Fig. 62, will cause the operating catches to be reversed. This will be understood by an examination of the details shown in Fig. 63. Each of the pulling catches is made double, so that it can pull the box backward or forward at will, and these are so coupled together that by means of the lever, actuated by the projections on the

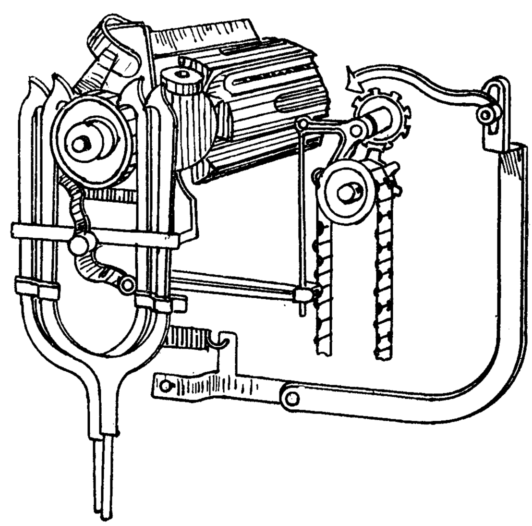


Fig. 63.

chain at the front part of the loom, their order of working is reversed. Suppose for a moment that the chain is working in the ordinary course as it would be in Fig. 58; each of the levers will operate the box in its ordinary manner, pulling it forward or backwards, and so long as the links in the front chain are of the ordinary kind this will continue, but the moment the links have a projection placed upon them then the conditions are reversed, and the box would be caused to revolve in the opposite direction. The secondary chain is moved one card with each repetition of the pattern chain, so that by the simple insertion of a peg into the secondary chain the pattern chain can be reversed in its working, and thus any number of repetitions of the pattern can be made without any increase in the number of cards; hence both a large saving of cards and economy of space are secured.

SKIPPING BOXES.

When the principle of the ordinary circular boxes is understood little more is required to understand the action of the skipping boxes. As the name implies, this box is arranged to enable us to skip from any one shuttle to another in the series, but it must not be supposed that it is necessary to skip over the whole circle. For instance we have six holes in the box and we can move it either forward or backward, so that if we have the power of moving any number from 1 to 3 in each direction we have the power of reaching any shuttle at will. Let it be supposed, for instance, that we have No. 2 shuttle in work and we wish to skip to No. 4, then we should have to pass over one, or move two boxes; to go to No. 5 we should have move three boxes, and to go to No. 6 we should go two boxes in the opposite direction; so that it is quite clear that we have no trouble in reaching any one of the boxes required. Numbers of arrangements of mechanism have been attempted but none have attained the same degree of perfection as the one shown in the illustration Fig. 64, of Messrs. Hattersley, of Keighley. This machine is perfect, not only in the certainty with which the box is changed from any one shuttle to another, but also in the ease with which the change is accomplished. As will be seen here, there are three principal levers. The first P being for turning the box either backward or forward, the second L being for locking the box firmly in position, and the third R for determining the direction, or reversing the movement of the box. Each of those levers is provided with a corresponding lever acted upon by the card cylinder C, exactly as in the ordinary box. Attached

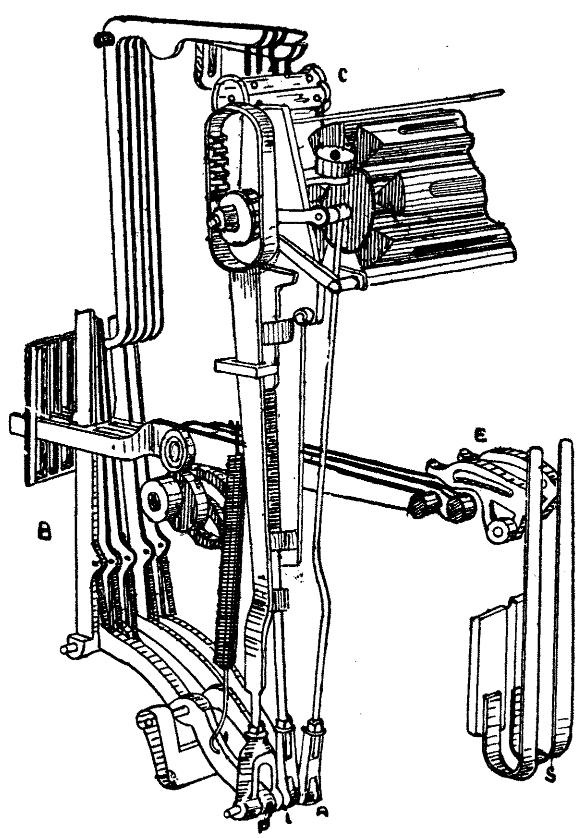


Fig. 64.

to the operating lever is a vertical bar with a toothed head, so arranged as to act upon a toothed wheel at the end of the box; this toothed head is so contrived that when in its normal position, and held by the strong spring, as seen, it would pull the box forward, but if it is desired to reverse the motion then the reversing lever would engage the set of teeth on the opposite side at the lever head, disengaging those in the front, and so cause the box to be pulled backwards. It will be necessary to follow carefully the levers acted upon by the cards, and their connection with the pulling, locking, and reversing levers, as well as the arrangement of the lifters; the pulling and reversing levers are both connected, or passed through the end of one of the lifting levers so that the locking bar is removed at all times when the box is to be turned, and along with it the reversing lever may or may not be used; but the reversing lever can never be brought into play without the locking lever being operated at the same time. To the free end of the pulling lever there are three vertical catches, and the lifting levers connected with them are so arranged that it may be operated by any one of three cams. Suppose the box is to be turned one hole then a cam would lift the first of the levers just a sufficient distance to give the amount of movement required; if it must be turned two holes a larger cam moves it a greater distance, and if it must be turned three holes then a still larger cam is used. Then the method of selection is easily determined. First we have the card cylinder, and we have all the bell crank levers, with their pins corresponding to the holes so that we have only to cut the cards in such a manner as to first determine the direction of the box by acting upon the reversing lever, which will at the same time remove the locking bar, and then cut a hole corresponding to the lever which will pull the box over one, two or three holes so as to bring it to any shuttle we may desire. Now suppose we are weaving a tartan plaid, say for instance, the Victoria Stuart, or sometimes called the Dress Stuart, one of the most difficult tartans to weave, not merely because of the variety of colour, but the necessity of skipping from one shuttle to another, then the arrangement for the card cutting will be as follows :—

The pattern is shown on the plate opposite, and consists of a white ground with blue and red lines, a green check edged with black, and yellow and white lines; this having in turn a red check with black and white lines. There are therefore, six colours, viz. :—white, blue, red, black, yellow, and green. Now let the number of threads of each be as follows :—

Threads.		Colour.
8	...	White
8	...	Blue
32	...	White
4	...	Red
32	...	White
8	...	Blue
8	...	White
8	...	Black
2	...	Yellow
4	...	Black
2	...	White
4	...	Black
12	...	Green
8	...	Red
2	...	Black
4	.	Red
2	...	White
4	...	Red
2	...	Black
8	...	Red
12	...	Green
4	...	Black
2	...	White
4	...	Black
2	...	Yellow
8	...	Black
196 threads in all.		

One good practice may be observed here: divide the pattern into its leading parts by marks on the left as shown, so that the eye can follow the pattern in writing as readily as it can in the actual colours. It must be borne in mind that in making patterns the designer or pattern weaver has not always the actually coloured pattern before him, and he must therefore have something to assist his imagination.

The pattern having been written down in this manner the next proceeding is to determine in which shuttle-box to place each of the successive colours. Some would say make the plan of your shuttles first and then proceed to determine the movements. Probably it is easier to do the two things at the same time, thus. Write down the pattern as already done, then begin with the ground weft in No. 1 box, thus:

Box.		Threads.		Colour.		Movement.
1	...	8	...	White	...	F1
2	...	8	...	Blue	...	B1
1	...	32	...	White	...	B1
6	...	4	...	Red	...	F1
1	...	32	...	White	...	F1
2	...	8	...	Blue	...	B1
1	...	8	...	White	...	F2
3	...	8	...	Black	...	F1
4	...	2	...	Yellow	...	B1
3	...	4	...	Black	...	B2
1	...	2	...	White	...	F2
3		4	...	Black	...	F2
5	...	12	...	Green	...	F1
6	...	8	...	Red	...	B3
3	...	2	...	Black	...	F3
6	...	4	...	Red	...	F1
1	...	2	...	White	...	B1
6	...	4	...	Red	...	B3
3	...	2	...	Black	...	F3
6	...	8	...	Red	...	B1
5	..	12	...	Green	...	B2

Continued.

Box.		Threads.		Colour.		Movement.
3	...	4	...	Black	...	B2
1	...	2	...	White	...	F2
3	...	4	...	Black	...	F1
4	...	2	...	Yellow	...	B1
3	...	8	...	Black	...	B2
		196				

White being the ground is the most convenient starting point, therefore we may call the box in which it is placed No. 1; this means nothing but that the first box in which a shuttle is placed is numbered 1. It may be any one of the six. Then blue is the next colour, therefore move the box forward one hole when the requisite number of picks of white have been put in. To indicate this to the card cutter place F1 to the right of the line, and the number of the box containing the colour to the left. When the blue is woven in the box must return to the white, therefore opposite blue write B1. Then red comes next, and as the red comes in the centrè of the white, or it may be said the white is between blue and red, then put the red shuttle in No. 6 box, therefore the box must move back one from white to red, and so on till the white ground and its lines are woven. Then come the yellow and white lines upon black, so yellow must go into No. 4 box; after that the red check on green, so green must go into No. 5 box, so placing it within reach of all the other colours. Now the lettering and numbering to the right must be made so as to bring up the required shuttle at the proper time. From red to black three boxes must be moved, from green to black two boxes, and so on. Now go over the whole and the same number of movements will be found to have been made in each direction. It does not follow, however, that this is necessary, as in some patterns the box, as already pointed out, must make more or less continuous movement in one direction.

By this method of working, any check, however elaborate, may be arranged in a few minutes, and with very little risk of mistakes.

It will be seen then from this brief description, that although at first sight the mechanism is of a most intricate character, yet in reality it is simple and easily understood. One word should be said as to the safeguards, which are prominent in this as in other box looms, in the event of the pulling levers being brought into play accidentally without the locking bars having been removed. The lifting levers are fulcrumed near the front of the loom upon a peculiarly shaped joint, behind which are very strong steel springs, and should the levers, by any means, be put into action without the box being able to turn, this joint will give way, throw the spring back, and instantly the pressure of the cam is released the spring will force the lever back into its normal position. This is generally accompanied by a sufficiently loud noise to call the attention of the weaver to the fact that something is wrong. There are several forms of skipping boxes in use, but in nearly every case they are based upon the principles involved in this, and only differ from it in slight matters of detail.

Very frequently the boxes are operated from the Dobby or Jacquard, in fact it sometimes becomes a necessity. Suppose, for instance, a figured pattern is being made where various colours of yarn are used, and the boxes and figuring machine working independently, the slightest error on the part of the weaver, the turning by accident of the figuring or the box cards, even only one card, and the two cease to work in perfect unison; and in spite of every precaution this may happen at any moment, but if the boxes are worked direct from the Dobby or Jacquard there can be no risk of such accidents. The same cards which control the figuring control also the shuttles.