shipped to foreign countries,—is unwound from the cops upon reels, and thereby made up into skeins or hanks.

The Mule, or Mule Jenny, is a machine which consists of the following four distinct members:—1. Of the drawing mechanism, or twin-roller system, which comprehends a great many fluted portions, each portion usually serving, as in the throstle-frame, to operate upon two parallel threads. 2. A movable carriage of a length equal to the roller-beam, mounted with as many spindles as there are threads to be spun. This member runs upon wheels, along three or more ground rails, horizontal, or nearly so, which allow the carriage five feet of forward and backward motion, relatively to the roller-beam. 3. The head-stock, or the machinery driving parts with the frame-work. In some mules the head-stock is placed in advance of the roller-beam towards the middle of its length, thus dividing the range of threads into two portions. The carriage here works beneath the level of the head-stock, and also divides the spindles into two corresponding portions. In many mules, however, the head-stock is put behind the roller-beam, so as to leave the whole length of the roller-beam and carriage without interruption. In the earlier and shorter mules the head-stocks were placed at one end of the roller-beam—a construction not suited to the longer mules of modern times. 4. The creel-frame, erected behind the roller-beam, for holding the bobbins filled with the rovings to be spun.

This important machine, in one of its newest and most improved forms, is represented in figures, 1, 2, and 3, plates V. and VI., being the construction preferred for the most delicate operations of fine spinning, one which combines all the varieties of mechanism introduced into the mule. The frame-work is of a solidity and mobility calculated to spin 1,000 threads in one line.

Plate V., fig. 1, is a front view of the middle portion of the mule; the spindles and other apparatus being similarly extended upon both sides of the portion represented in the engraving.

Plate V., fig. 2, is a cross section of the mule, for the purpose of exhibiting the spinning parts; the carriage being shown by full lines in the position nearest to the roller-beam, and by dotted lines in its position when fully run out. Fig. 3, is a cop of yarn.

Plate VI., fig. 1, is a view of the head-stock; the carriage, front roller-beam, and creel being removed.

Plate VI., fig. 2, is a cross section of the mule, and an end view of the head-stock, to show how motion is given from the latter to the front rollers, the carriage, and spindles. Fig 3, is a plan of the spindle-drums.

Fig. 70 is a gas-light perspective view of a small apartment fitted up with mules, upon the older construction of head-stock apparatus, for spinning low numbers of yarn. Here the overlooker, spinner, piecer, and scavenger, are shown in their respective positions.

When the spinning operations begin, the rollers deliver the equably attenuated rovings, as the carriage comes out, moving at first with a speed somewhat greater than the surface-motion of the front rollers. The spindles meanwhile revolve with moderate velocity, in order to communicate but a moderate degree of twist. When the carriage has advanced through about five-sixths of its path, the rollers cease to turn or to deliver thread. The carriage thenceforth moves at a very slow pace, while the speed of the spindles is increased to a certain pitch, at which it continues till the carriage arrives at the end of its course. The spindles go on revolving till they give such an additional twist to the threads as may be desired, the degree of it being greater for warp than for weft, and for bobbinet and book-muslin yarns than for the yarns of softer fabrics. The spindles then stop, and the whole machine becomes, for the moment, insulated from the driving shaft of the factory. Now the delicate task of the spinner begins. First of all, he causes the spindles to make a few revolutions backwards, by turning a winch-handle that acts on a pulley which moves all the spindle-drums at once. In this way he takes off the slant coils from the upper ends of the spindles, to prepare for distributing the 54 or 56 inches length of yarn just spun properly upon their middle part. This retrogradation of the spindles is the process already described under the name of backing off.

The spinner having seized the faller-rod with his left hand, gives the faller-wire such a depression as to bear down all the threads before it to a level with the bottom of the cop, or conical coil, of yarn formed, or to be formed, round the spindles. While his left hand is thus nicely applied, under the control of an experienced eye, his right hand slowly turns the handle of the pulley in communication with the spindles, so as to give them a forwards rotation, and his knee pushes the carriage before it at the precise rate requisite to supply yarn as the spindles wind it on. Three simultaneous movements must be here very delicately and dexterously performed by the mule-spinner; first, the regulation of the faller, or guide-wire, continually varying in obliquity; secondly, the rotation of the spindles, perhaps 1,000 in number, at a measured speed; and thirdly, the pushing in of the carriage at such a rate precisely as to supply yarn no faster than the spindles take it up. In fine spinning upon a mule, like the one represented in the engraving, where nearly 1,000 threads were spun at once of almost invisible tenuity; the skill and tact required in the operator deserve no little admiration, and are well entitled to a most liberal recompense. In the process of winding-on, so as not to break the threads, and in coiling them into the shapely conoid, called a cop, the talents of the spinner are peculiarly displayed. As the carriage approaches to its primary position, near to the roller-beam, he allows the faller-wire to rise slowly to its natural elevation, whereby the threads once more coil slantingly up to the tip of the spindle, and are thus ready to co-operate in the twisting and extension of another stretch of the mule. Having pushed the carriage home, the spinner immediately sets the mule again in geer with the driving-shaft, by transferring the strap from the loose to the fast steam-pulley, and thus commences the same beautiful train of operations. It is during the few instants after the carriage starts that the lively little piecers are seen skipping from point to point to mend the broken threads. Whenever it has receded a foot or two from the delivering rollers, the possibility of piecing the yarn being at an end, the children have an interval for repose or recreation, which, in fine spinning at least, is three times longer than the period of employment. The spinner likewise has nothing to do till after the completion of the fresh range of threads, when he once more *backs off* the slanting coil, and winds on the "stretch."

A, A, plate V. figs. 1, 2, is the triple pair of drawing rollers working in heads fixed upon the roller-beam, B.

C is the *creel,* or rails, in which the roving bobbins are arranged in three, or sometimes in four rows, one over and behind another, according to their size and the smallness of the cop upon the spindles. The creel and roller-beam are both supported by frame-pieces of strong cast-iron, such as D.

E, E, is the carriage to which are attached three or four horizontal bars, F, which rest upon the axes of the wheels, G, G. The wheels run upon the rail-way, H. The carriage is constructed of two long planks, *a* and *b,* extending through its whole length, and bound with cross pieces of wood or iron made fast by screws. There are likewise diagonal braces to prevent any tendency to warping or vibration. Moreover, two, or sometimes four iron rods are attached diagonally along the bottom of the carriage from end to end, or from the middle to the end, and secured at their extremities with screw bolts and nuts, for the purpose of drawing it into a straight or square form, in case it should become uneven, or, as workmen say, untrue, in the slightest degree. Upon the carriage planks, or beams, a frame-work, *c, d,* is built, in the forepart of which the top-bushes and bottom steps of the spindles, I, are fixed. The spindles themselves are set in an inclined position, sloping towards the roller-beam, so that in their usual revolution they may twist the threads round their points without tending to wind them upon their surfaces, during the coming out of the carriage. *e, e,* are little pulleys called wharves, fixed upon the under part of the spindles, each at a different height, throughout a range of eight or sixteen adjoining spindles. By this means the echellon arrangement, seen in fig. 1, plate V., is produced.

K is a series of drum cylinders made usually of tin-plate, each being furnished with two grooves round their upper end, for receiving their driving bands. Their smooth sides receive and work the moving bands or cords of two ranges, containing from sixteen to thirty-two spindles. The uppermost cord impels the first spindles of the adjoining two rows; the second cord moves the second spindles of the same ranges, and thus in succession. *f* is a long, slender iron shaft, lying in the bearings *g*, over the carriage from end to end, and provided with small arms *h, h*, called the *fallers*. These bear the faller-wire *i* (pl. V., fig. 1), which serves to depress all the threads from the points of the spindles (see dotted lines under *i* in fig. 2), and to bring them upon a level with the bottom of the cop in the act of winding-on already explained. The gradual rise of this wire allows the thread to be duly distributed upon the cop. Since the most expert spinner can hardly be expected to apply the faller with geometrical precision, so as always to coil on the yarn proportionally to the rotation of the spindles and to the advance of the carriage before his knee, there is another regulating wire called the counterfaller. This consists of lever arms *l*, fig. 2, having a fulcrum attached to the frame-work of the carriage. These arms bear at their points *m*, a wire which extends horizontally like the faller, from end to end, but beneath the surface level of the threads. On the other ends of these levers are weights n, which cause the wire m to rise so as to balance the threads nicely after their depression by the faller-wire i, and to straighten them when loose. Should the tension be too great, the counterfaller lever itself must be depressed. It is obvious that the weights, n, should be directly proportional to the number of the spindles, and inversely to the fineness of the yarn.

L, L, pl. VI. figs. 1 and 2, show the containing frames of the head-stock, which serve partly to support the roller-beam, B. Two mules are generally fitted up together, back to back, so that the frame of the head-stock of each mule sustains partly its own roller-beam, and partly that of the next mule, as may be understood from inspecting the broken-off arm, o, pl. VI. fig. 2. By this arrangement, two neighbouring mules stand always with their faces fronting each other, and are worked together by one spinner, who conducts the winding-on of the yarns, and the *putting up* of the carriage of the one mule, while the mill-shaft power is driving the other mule in the process of drawing, twisting, and stretching. *See* fig. 76.

The motions are communicated as follows :—

M, M′, M″, are three horizontal driving or steam-pulleys, plate VI., figs. 1 and 2, set upon an upright shaft p. They are driven by a band from a broad pulley upon an upright mill-shaft, see plates I. and II., which impels the two mules which stand back to back. M, the lowest, is usually the loose pulley, to the surface of which the strap is shifted when the machine throws itself out of geer after finishing a stretch. The pulley M′, is fixed along with the toothed wheel 1, upon a boss (or thick part of the shaft), which turns loose upon the shaft, p, p. The pulley M″, is *fixed* upon the shaft *p*, along with the toothed wheel, 2. These wheels, 1 and 2, are constantly in geer with the wheels 3 and 4, fixed upon the upright shaft, *q*, from which the twisting motion is conveyed to the spindles by the twist-pulley, N. This pulley is provided with six grooves of progressively increasing diameters, calculated to vary the velocity of the spindles.

Upon the shaft, *p*, is a bevel-wheel, 5, which moves the bevel-wheel, 6, turning upon a horizontal shaft, *r*. From this shaft motion is given to the drawing-rollers in the following way. The bevel-wheel, 7, upon the shaft, *r*, drives the wheel, 8, upon the shaft, *s*; whence the motion is communicated by two bevel-wheels, 9 and 10, to the shaft, *t*, which connects the front rollers of each side of the machine. The motion of the rollers is stopped by pushing aside the wheel, 8, out of geer with 7, by means of the lever, *u*; for this reason, the shaft, *s*, has been called the tumbling shaft.

From the shaft, *r*, two motions with different velocities are produced in succession to take out the carriage of the mule. The first and quicker motion is given by wheel 11, to the large horizontal bevel-wheel, 12, called the mendoza, upon the upright shaft *v*; the lower end of which bears a rope pulley O. Upon this upright shaft, *v*, is another horizontal bevel-wheel, 13, of the same size as 12; which wheel is thereafter put in motion by the small bevel wheel, 14, fixed upon the axis of the large wheel, 15. This is driven by the pinion 16, and therefore gets a slower motion than the wheel, 14. The bevel-pinion, 11, is put in geer with its bevel-wheel, 12, in consequence of the shaft *v* being lifted up by the rising of the bearing step *x*, under the action of the lever, *y*. (Pl. VI., fig. 1, and 2, at bottom.) By the subsequent depression of the lever, the shaft *v* falls, and brings the wheel, 13, in geer with its driving-pinion, 14. After the carriage has run out to the end of its course, these bevel-wheels, 13 and 14, are also thrown out of geer by the depression of the wheel, 15, and its attached bevel-pinion, 14; which are thus disconnected with their respective wheels, 16 and 13. How these various motions are given will be presently explained.

We shall now describe how the carriage is taken out by the rope pulley O. In the front of the mule, at the spot to which the carriage comes on completing its stretch, is a horizontal rope pulley, P (plate V.) turning freely upon an upright stud or bolt, fixed to the floor, and is, with the shaft of the pulley O, in a line parallel to the course of the carriage. Round these two pulleys an endless rope, *z*, passes; with one looped branch of this rope, a bolt, *a'*, is connected, which is attached to the carriage E. Hence, by turning the shaft, *v*, with the pulley O, first quicker and then slower, a correspondent rate of motion will be communicated to the carriage; and when the shaft stops, the carriage will be fully run out.

We shall next explain how the spindles receive their whirling motion all the time they go out and in with the carriage. *See* plate V.

From the twist-pulley, N, in the head-stock at the back of the mule, an endless band proceeds, one branch of which goes round the grooved horizontal pulley, *b*, beneath the carriage, and then turns over the guide-pulley, *c'*, (pl. V. fig. 1), for the purpose of driving all the drums, K, situated on the right-hand side of the carriage, by passing round their topmost grooves, and returning round their second grooves in order to get at the left-hand side of the carriage. After driving all the drums there, it then proceeds to the middle of the machine, passes over the guide-pulleys, *d′* and *e′*, in the carriage (as shown by dotted lines in fig. 43), to a horizontal pulley, Q, which revolves freely upon the same upright stud or bolt, with the rope-pulley, P, and joins thereafter with the end of the band at the twist-pulley, N; from which the line of its course began. Thus it appears that the drums, K, are turned by the twist-pulley N, quite independent of any motion or position of the carriage, as the endless band is kept of uniform length in consequence of the end pulley Q, and the guide-pulleys *b′ c′ d′ i′* of the carriage, revolving within the coils of the endless band.

A general idea of the working of these band-coils round the twist-pulley, N, the end pulley, Q, and the carriage drums, K, may be formed by inspecting plate VI., fig. 3, in which the carriage, represented by the line, E, E, is seen to be movable backwards and forwards between the fixed centres of the pulleys, N and Q; while the coils of the band continue to move round the drums. In fig. 3 the revolving parts are shown in one plane; whereas in the mule itself they lie in different planes, as may be seen in plates V. and VI., and are conducted through their changes of plane by the several guide-pulleys.

Upon end of the shaft, pl. VI. *r*, there is a worm which drives the wheel, *f′*, attached to an oblique shaft, *g′*, on the under end of which are two little arms, *h′* and *i′*, by which the strap is made to shift upon one or other of the pulleys, M, M′, and M″, by the guide-fork, *k′*. In beginning to stretch, the spinner moves this fork opposite to the top pulley, M″, by means of the handle, at top *l′*, which draws up the rod, *m′*. To this rod a small shoulder, *n′*, is fixed, which moves in a slot of the bracket, *o′*, and rests at the beginning of the stretch on the top notch of the serrated crank lever, *p′*, which is pressed against it by a weighted end. The slant shaft, *g′*, in its revolution, at a certain period of the stretch, strikes with one of its arms, *h′*, against the top of the lever, *p′*, and thus permits the rod, *m′*, to fall into its second notch, by which the fork, *k′*, shifts the strap to the pulley, M′, under the first one. In the former motion, the wheel 2, was driving the twist-pulley shaft 4; in the latter, the wheel 1 is driving the wheel 3; and in consequence of the different ratios of their diameters, the twist-pulley is driven with increased speed, which takes place, as before said, when the stretching is completed. After the stretch is finished, the shaft, *g′*, strikes with its second arm, *i′*, against the lever, *p′*, and thus lets the fork, *k′*, fall upon the undermost pulley, M, which being a loose one, brings the machine to repose. Below is a little arm, *q′*, upon the lever, *p′*, which is connected by a bell-crank and a wire lying upon the floor, which may be drawn if any accident should occur during the stretching, in order to stop it, by letting the rod, *m′*, fall down out of the notches, and thereby shifting the strap to the loose pulley, M.

At the same time that the twist-pulley gets its quick motion, by shifting the strap from the pulley M″ to the pulley M′, the drawing rollers are disconnected from the machinery, and brought to rest by moving the wheel 8 out of geer with 7, by the lever, *u*. The shaft, *v*, is also depressed, so as to throw the wheel 12 out of geer with 11, and to place wheel 13 in geer with wheel 14, by which change, the rope-pulley, *o*, upon the mendoza shaft, v, moves the carriage during the rest of the course at a slow speed, to give the finishing stretch to the length of yarn already given out by the rollers, while it continues to receive twist.

R, plate VI., fig. 2, is a balance lever, turning on a fulcrum, r', furnished at the one end with two hooks, s' and t', and at the other end with two catches, which act upon two different pins, u' and v', on the ends of the upright levers, S and T, (seen in plate VI., fig. 2, and partially in fig. 1.) These upright levers swing with two fulcrum shafts, x' and y', in bearings fixed to the frame of the head-stock. To the shaft, x', are fixed two curved arms, a'' and b'', fig. 1. The first, a'', working in a slot of the curved lever, u, and the second, b'', connected by a rod, c'', with the lever, y, in which is fixed the bearing, x, of the mendoza shaft, v. When the carriage, in its recession, makes the handpiece, w', press on the hook, s', of the balance-lever, the catch, u, at the other end of the lever, is raised a very little, so as to disengage the pin of the upright-lever, S, whilst the longer catch of v' retains its hold of the other upright lever, T. The bottom of the lever, S, swings back, and is caught against the pin, d'', on the balance lever, R, while, by its upper arm, a'', it moves the curved lever, u, and throws the wheel, 8, out of geer with 7,—thus setting the rollers at rest. The other arm, b'', attached o the lever shaft, x', by letting down the step, x, of the mendoza shaft, v, brings the wheel 13 into geer with 14. These two motions take place at the commencement of the quick twisting; and as this point varies for different numbers and qualities of yarn (as warp and weft), the hook, s', may be shifted on the balance-lever, R, to its proper place of adjustment, according to the judgment of the spinner. After the carriage has reached to nearly the end of its course, the hand-piece, *w′*, strikes upon the second hook, *t′*, depresses the end of the balance-lever still further, by which the catch, *v′*, is lifted from the pin at the lower end of the lever, T. By this means, the lever is allowed to swing with its axis, *y′*, and to depress with the curved arm, *e″*, of the shaft the wheel 15, and of course the bevel-pinion 14, which revolves on a stud fixed to the end of that arm; by which process the mendoza shaft is now disconnected with every motion, and causes the carriage to stop, while the additional twist proceeds till the strap is shifted upon the loose steam-pulley, as above described. *See* fig. 2, plate VI.

Now the spinner's task begins: he lays hold of the handle, U, and pulls its shaft, *f″*, along with the bevel-wheel, 15, into geer with the bevel-wheel, 16, fixed on the upright shaft, *c′*, which carries at its lower end the band-pulley, *b′*, already described. The shaft, *f″*, is sustained in its present place by the pressure of the end of the bar, *g″*, against *its* end. The bar, *g″*, slides up and down in a staple guide, *i″*, by the action of a weight on a lever attached, with one end to the bar, and its fulcrum on the carriage, (as shown at *k″*, *k″*, pl. V. fig. 1,) and thereby presses with its end the step-bearing, *h″*, of the shaft, *f″*, which bearing swings round about the fulcrum, *l″*. The handle, U, of the box-organ being connected by the wheels, 15 and 16, with the pulleys, *b′* and *c′*, and the drums, K, which drive the spindles, the spinner now turns the handle slowly, causing the spindle to revolve backwards through a few turns, by which means he backs off the oblique coil of yarn last spun; whilst, with his left hand, he depresses the faller to begin the winding-on from that part of the cop which has already acquired the proper diameter which the middle cylindrical parts of the cop is to have. At the same time he begins to push in the carriage, and to turn the handle in an opposite direction, so as to wind on the yarn at the same rate as he approaches to the roller-beam, gradually lifting up the faller so as to form a conical surface above. On his coming near the rollers, a piece of iron projecting from the plank, *a*, of the carriage, strikes against the lever, S, and replaces it in its catch, u', of the balance-lever, R; while the fork, m'', attached to the lever, S, guides and pushes the other upright lever, T, into its catch, v'. The mule being thus made ready to begin a new stretch, the spinner lays hold of the lever-handle, l', and thereby slides up the rod, m', and brings the strap upon the uppermost steam-pulley M''. With the rod, m', is connected an S arm, n'', (plate VI., fig. 2,) which goes underneath the weighted end of the lever, k'', (seen in dotted lines, plate V., fig. 1,) and lifting it up presses down the bar, g'', which kept the bevel-wheels, 15 and 16, in geer, whereby the shaft, f'', with the wheel, 15, is allowed to fall down by its weight out of the teeth of the wheel, 16. Thus the handle, U, remains out of geer while the carriage is in the act of stretching.

The spinner requires much skill and dexterity: first, to back off; secondly, to wind on the yarn without breaking; and thirdly, to give the cop such a shape as may facilitate the winding off, either in the shuttle, or upon the reel. Much time is often lost by the spinner at the beginning of the winding-on, in the formation of the double cone, or foundation of the cop, as represented in plate V., fig. 3, which shows the double cone, *a, d, b, c,* first formed, on the upper part of which the cone is built upwards, so as to form a cylindrical middle part, *a, b, e, f.* Such a cop as contains most yarn in the least dimensions, is the best for unwinding, but it is very seldom formed with due accuracy by hand.

From the front roller, motion is transmitted to the back roller of each side of the mule by the usual carrier-wheels, as in other spinning-machines, (see plate VI., fig. 2;) and from the back roller to the middle roller, by wheels on the right-hand end and left-hand end of the roller-beam.

In the mules, generally, and sometimes in the throstles, instead of covering the top rollers with flat boards faced with flannel, a series of loose friction rollers, covered with flannel, are laid in the hollow between the front and middle top rollers, which, revolving with different velocities, give an intermediate velocity to the loose one, which thus wipes or rubs off any adhering fibres of cotton.

The proprietor of one of the best fine-spinning mills in Manchester informed me that in good mule-spinning there should be no more stretching than is indispensable to make the yarn level. The second stretch, in fine spinning, amounted formerly to 12 inches, now it never exceeds 6.

The creel-steps, in which the lower ends of the bobbin-skewers stand, both in mule and throstle-frames, are minute conical cups made of glazed pottery, which cost two-pence halfpenny per gross.

The time taken to make a stretch and wind it on, increases with the fineness of the yarn, and differs considerably for the same numbers in different mills, according to the quality of the yarn, the goodness of the machinery, and the dexterity of the spinner.

In one very large factory at Manchester, in a mule containing 512 spindles, which was spinning No. 30's. weft, three stretchers of 56 inches each were made in 68 seconds, being a stretch in rather less than 23 seconds. Another mule in the same factory, which contained 340 spindles, and was spinning 40's for warp, took 74 seconds for three complete stretches, being a stretch in rather less than 25 seconds.

The *stretcher* mule of a fine-spinning mill makes four stretches in 65 minutes, being one stretch in about 16 minutes.

In the lower counts of 34's and 36's, 25 hanks weekly per spindle may be considered a fair average of mules in well-going mills.

One experienced cotton spinner informed me that warp is twisted to the left hand, and weft to the right.

In one factory a fine-spinning mule made a stretch of yarn, No. 170's, excellent quality, in one minute. In another, I found that a minute and a half was consumed in making similar yarn. When the number exceeds 220's, nearly two minutes are taken to a stretch in some factories. The number of breakages of threads is also an important object of comparison. In one fine-spinning mill at Manchester I have observed the number of threads which require piecing at every stretch to be three times as great as those in another mill spinning like numbers. The quality of the yarn is tried by several tests. The weight which is just requisite to break it determines its strength; and if this weight be uniform over successive lengths, the yarn is of uniform strength. Its levelness is tried by drawing it in a wet state between the fore-finger and thumb, a test in delicate hands susceptible of great precision. The uniformity and sufficiency of the twist, as well as the softness, smoothness, and firmness of the texture, must all be taken into account, and are readily ascertained by the experienced *taker in of work* in a cotton-mill.

The second stretch, to draw down and equalize the yarn, is seldom used in spinning the low numbers, by which much time is saved.

About 14 years ago, 13 per cent. of the threads used to break at every stretch; 3 or 4 per cent. are reckoned a large proportion now. In fact, the best spinning mules that I have observed, both in this country and in Alsace, seldom break more than 1 per cent. of the threads in each stretch—a circumstance indicating surprising perfection in the manufactures, if we consider the feeble cohesion of the finer yarns.

The degree of twist communicated to a given length of yarn may be readily found in the throstle by comparing the surface motion of the delivering rollers with the rotatory speed of the spindles: thus when the front rollers, one inch in diameter, turn 90 times per minute, they give out $282\frac{3}{4}$ in that time, while the spindles make 5,000 revolutions; the twist communicated is therefore 17 7-10th turns in every inch; but in the mule the relative velocities of the front rollers and the spindles are not so directly observable.

In the mule the speed of the spindles should never exceed 4,500 turns in the minute, lest their upper part may be made to oscillate and damage the yarn. Mr. Montgomery has given the following Table of Draughts, calculated for a crown wheel of 72 teeth, a back roller wheel of 56 teeth, and a front roller pinion of 18 teeth, the diameter of the front roller being one inch, and of the back roller 7-8ths; showing the draughts produced by any grist-pinion containing from 20 to 35 teeth.

Grist Pinions.	Draughts.	Grist Pinions.	Draughts.
20	12·8	28	9·14
21	12·18	29	8·82
22	11·63	30	8·53
23	11·12	31	8·25
24	10·66	32	8·00
25	10 24	33	7·75
26	9·84	34	7·52
27	9·48	35	7·31*

In the Scotch cotton-mills, 25 twists are allowed to the inch for warps of No. 50, and wefts of No. 60; from which, if a standard be taken, we may calculate approximately the proportional number of twists to be given to another number of yarn,—say 70, by the following rule:—

$$\text{As } 50 : 25^2 :: 70 : x^2$$

$x^2 = \frac{625 \times 70}{50} = 875$; of which the square root is 29·6, showing on this principle that warp-yarn, No. 70, should have 29·6 twists per inch. This rule requires, however, to be modified in its application to fine numbers. The following empirical rule has also been offered as affording a ready approximation. Multiply the square root of the intended number of hanks per pound by $3\frac{3}{4}$, if for warp-yarn, and by $3\frac{1}{4}$, if for weft-yarn; the products will be the respective twists per inch. Thus in the above example; the square root of 70 is 8·366, which multiplied by $3\frac{3}{4}$ is

* Theory and Practice of Cotton-spinning, p. 176.

31·372, being nearly two twists above the quantity given by the former rule. Were the square root multiplied by $3\frac{1}{2}$, the product would give a better accordance. The former rule may, therefore, be considered as the more correct of the two.

But the exact calculation for mule spinning, or the elongation of a given number of roving in passing through the drawing-rollers, and degree of twist which the thread receives from the spindles, may be readily made on the following principles. Suppose the central wheel on the rim to have . . . 48 teeth

The second conical wheel fixed on the upper end of the bevel or tumbling shaft	54
The third bevel-wheel, on the lower end of this shaft	35
The fourth bevel-wheel, on the shaft joining the back rollers . . .	52
The pinion on the same shaft . .	24
The spur-wheel on the adjoining parallel shaft driven by that pinion . .	90
The change pinion	21
The wheel on the end of the back rollers, driven by the pinion . . .	42
The wheel on the outer end of the back rollers	25
The pinion on the outer end of the middle rollers	22
The diameter of the back and of the second rollers	$\frac{3}{4}$ inch
The diameter of the front rollers . .	1

After a complete revolution of the rim, or great fly-wheel of the mule, we shall have the following changes of position according to the common calculations of toothed-wheel work:—$\frac{48}{54} \times \frac{35}{52} = \frac{6}{10}$ or 0·60; whence 1 : 0·60 denotes the relative velocity or movement of the rim-wheel to the front roller; that is to say, when the rim-wheel has made one complete turn, the front roller has made only six-tenths of a revolution.

$\frac{24}{90} \times \frac{21}{42} = \frac{13}{100}$ or 0·13; whence we have the relative velocities of the rim-wheel, the front roller, and the back roller as the three numbers:—1; 0·60; 0·13, or 100; 60; 13.

As the diameter of the front roller is one inch, its circumference is about $3\frac{1}{6}$, or 38 twelfths; but as it makes only $\frac{6}{10}$ of a turn, the movement of its circumference will be $0{\cdot}6 \times \frac{38}{12} = \frac{228}{120}$ or 22 twelfths and $\frac{4}{5}$, whilst the rim makes one revolution.

The back roller being $\frac{3}{4}$ or $\frac{9}{12}$ of an inch in diameter, has a circumference of about 28 twelfths; but as it makes only $\frac{13}{100}$ of a revolution, its surface movement by one turn of the rim will be $\frac{9}{12} \times \frac{13}{100} = 3{\cdot}64$ twelfths of an inch only. Hence the 3·64 twelfths of roving taken in by the back roller, furnish 22 twelfths and $\frac{4}{5}$ of elongated thread; showing the draught to be $\frac{2280}{364} = 6{\cdot}26$ times. Hence, if the roving in the creel furnished by the fine bobbin-and-fly frame was of No. 8, the resulting yarn upon the mule, without any stretching by the gain of the carriage, would be No. 50; that is the number 8 multiplied by 6·26.

The slight draught which takes place between the back and middle rollers, in consequence of the difference in the number of teeth in their respective wheels, can introduce no change in the total elongation now stated; this being made merely at two steps, the first and smaller portion between the back and middle rollers, the second and greater between the middle and front rollers.

The relative speed of the back and front rollers may be changed by substituting greater or smaller pinions, for the existing change pinion previously described.

As to the twist of the thread, it may be calculated still more readily from the following data:—the diameters of the groove in the rim or fly-band groove, that of the twist-pulley groove, the drum-band grooves, and the wharves on the pulleys. The guide-pulleys merely change the direction of the motion, without affecting its degree. We shall, therefore, find that for each turn of the fly, which causes 22 twelfths and $\frac{8}{10}$ of an inch of thread to be delivered, the spindles will make with the above dimensions 68 revolutions and $\frac{4}{10}$, or 36 turns for every inch of yarn given out; but this twist is only about two-thirds of what ought to be given, the remainder being communicated after the stretch is finished, as already described.

The pinion on the shaft which joins together the front fluted rollers has 16 teeth, and drives the Mendoza wheel of 90 teeth; their relative motion is denoted by $\frac{16}{90} = 0 \cdot 18$ nearly, for each turn of the pinion shaft; but as with the front rollers it makes only $0 \cdot 6$ of a turn, the Mendoza wheel will consequently make only $0 \cdot 11$ of a turn $= 0 \cdot 60 \times 0 \cdot 18$, in the same time that the rim-wheel makes one complete revolution. If the diameter of the Mendoza pulley which takes out the carriage be 68 twelfths of an inch, its circumference will be 213 twelfths; but as it makes only $\frac{11}{100}$ of a turn, its surface motion will be only 23 twelfths and $\frac{43}{10}$ of an inch, exceeding by $\frac{63}{100}$ of a twelfth the length of thread delivered by the front rollers. This quantity, equal to about $\frac{1}{19}$ of an inch, is the elongation which the yarn receives from the motion of the carriage, or the gain upon the stretch for every revolution of the rim. If the stretch be 56 inches $=$ 672 twelfths of an inch, the carriage will come out in about $28\frac{2}{3}$ revolutions of the rim $= \frac{672}{23{\cdot}43}$, and the twist will be completed by $14\frac{1}{3}$ turns, constituting in all $50\frac{1}{3}$ turns of twist for No. 50, at the rate of one twist per inch for each number. The wheel which works in the worm cut in the boss on the end of the rim-shaft, should have therefore 50 teeth in this construction. The gain of the stretch, produced by the excess in the motion of the carriage above the surface motion of the front rollers upon each series of threads, will be equal to $50\frac{1}{3} \times 0{\cdot}63 = 31\frac{1}{2}$ twelfths of an inch, or 2 inches $7\frac{1}{2}$ twelfths in a mile, where no second stretch is employed.

If two and a half stretches $=$ 140 inches of yarn, or 11 feet and 8 inches, be formed per minute upon each spindle, 700 feet will be made each hour, and 8,050 feet in $11\frac{1}{2}$ hours $=$ $2{,}683\frac{1}{3}$ yards $= 3\frac{1}{5}$ hanks nearly of 840 yards each; and if each mule contains 360 spindles, of which a spinner works a pair, he will turn off $3\frac{1}{5}$ hanks $\times$ 720 $=$ 2,204 hanks of 50's, $=$ 40 lbs. of yarn in the day's work.

As the spinner works a pair of mules at a time, were the headstocks placed in the middle of the roller-beam of each mule, they would interfere with each other, for which reason they are placed each a little to the right of the centre, leaving the larger space to the left where the spinner stands. This inequality varies, but is frequently in the proportion of two to three, so that in a mule of 360 spindles, 144 are on the left side of the head-stock, and 216 on the right.

The following method of computing the draught and twist in the mule is somewhat simpler than the preceding. As the wheel on the rim-shaft has in many mules the same number of teeth, namely 50, with that on the front roller, both may be left out of view. Multiply the number of teeth in the driving-wheels for one product, and the number of teeth in the driven wheels for another. Divide the former number by the latter, and the quotient will be the relative revolutions of the front roller, which, multiplied by the revolutions of the rim per minute, will give the speed of the front rollers in that time. Let there be 35 teeth in the wheel upon the lower end of the bevel-shaft, and 54 in that upon its upper end $\frac{35}{54} = 0 \cdot 648$; and if the rim make 90 revolutions per minute, then $90 \times 0 \cdot 648 = 58 \cdot 82 =$ the number of revolutions of the front roller per minute.

The rotation of the spindle, compared with the speed of the rim-band, may be thus computed. If the diameter of the rim be 36 inches, the groove for the band in the twist-pulley be 14 inches, and that of the drum band be 15, the whorls or wharves being one inch in diameter; multiply the diameter of the rim by that of the drum groove, and divide the product by the diameter of the twist-pulley groove; thus, in the above case, $\frac{36 \times 15}{14} = 38\frac{4}{7} =$ revolutions of the spindle for one of the rim. If this number be multiplied by $90 =$ the rotations of the rim per minute, the product $3{,}471\frac{3}{7}$ is the revolution of the spindle per minute.

In the second speed of the rim, its revolutions may be 115 per minute, whence $115 \times 38\frac{4}{7} = 4{,}553$ turns of spindle per minute in second speed.

General Explanation of the Self-actor Mule.

The rollers deliver the yarn, the carriage is taken out, and the spindles are turned by bands from tin drums to which motion is given by the twist-pulley, M, as in a hand-mule.—*See* fig. 77 and 79.

The next motion is backing-off the spindles to uncoil a sufficient quantity of yarn to allow the faller to descend, and carry with it the yarn to the point where it is to begin to be wound on the spindles. The carriage is then drawn in, and the spindles receive the yarn so distributed as to form a cop. These operations are regulated by machinery, instead of by hand, as in a common mule.

On the rim-shaft, *a*, are three pulleys of equal diameter, of which one, C″, runs loose on the shaft to receive the strap, D, when out of action. C′ is always revolving, and works a leather friction-pulley to turn the cam shaft, *b*, one quarter round to perform a change at four different times during one complete motion of the mule; these four changes are,—1st, to put the front rollers in motion to draw out the carriage, to turn the spindles to give twist to the yarn; 2d, to stop the rollers and carriage, and give an extra quantity of twist to the yarn if required; 3d, to back off the spindles, and lower the faller to the point where the yarn should begin to be wound on; 4th, to draw in the carriage by means of a band working on a scroll, F, and to turn the spindles at the required speed to receive the yarn distributed so as to form a cop. C is turned by the strap, D, to take out the carriage, and give twist to the yarn, while the carriage is going out, and after it is stopped.

C is then released from the strap, D, and a crossed strap, D′, slides from the loose pulley, C″, to C′, to back off the spindles and lower the faller. To draw in the carriage and wind on the yarn, strap D slides again on to C′, and thereby gives motion to the scroll F, to the quadrant, P, which regulates the winding-on of the yarn, and to the faller which gradually rises and guides the yarn to be wound on the spindles. The winding-on of the yarn is performed thus:—there is a drum, or barrel, G, connected by wheels with a pulley *v*, placed horizontally, and driving the tin drums which give motion to the spindles, fig. 78. To this barrel, G, are attached two cords or chains, one end of each of which is fastened to its circumference, and the other end of one is fixed to a movable nut worked by a screw along the radius of the quadrant, P, as less speed is required to be given to the barrel, and thence to the spindles, on account of the increasing size of the cop. The end of the other cord or chain is conducted over pulleys to the back of the mule, and to it a weight *d″*, is attached, which thus pulls at the external circumference of the barrel, and causes it to revolve as fast as the other cord or chain, connected with the quadrant, will allow. A weighted lever *h‴*, has one end resting on a stud fixed on the mule, and which moves in and out with the carriage, the other end of the weighted lever hangs by a chain on the fallers, and as the cop gets larger, the spindles winding on too fast, cause, by the tension of the yarn, the lever *h‴*, to descend a little, and press a strap against a fixed point; and as the carriage goes in it draws with it the strap, causing the nut, *w*, to go towards the circumference of the quadrant, and let off less cord so as to turn the barrel, *o*, fewer times during the going in of the carriage, and consequently the spindles revolve more slowly.

Description of the Self-actor Mule.

A self-actor is a mule in which not only the stretch is performed by the moving power, but also the backing off, the return of the carriage, and the winding-on of the yarn,—the operations succeeding each other without any interruption by certain disengagements of mechanism performed by the machine itself; so that attendants have nothing to do but to watch its movements, to piece the broken ends when the carriage begins to leave the roller-beam, and to stop it whenever the cop is completely formed, as indicated by the bell of the counter attached to the working geer. (A similar counter is attached to the automatic reel, p. 214.)

The self-acting mule of Messrs. Sharp, Roberts, and Co., differs from the fine spinning mule just described. It has its headstock advanced in the front of the roller-beam, near to the middle, and thus separates the spindles of the carriage into a right-hand and a left-hand series, and will serve to illustrate that class of mules. Fig. 77 exhibits a side view of the headstock, or a cross section of the mule close to the headstock, with the carriage shown, in the position of about the half-stretch.

Fig. 78 is a plan of the headstock, with part of the adjoining rollers on the right and left hand. In this plan, the top part of the headstock has been removed to show the parts underneath; but it is shown in a separate plan, fig. 79.

Fig. 80 is a cross section of the mule, exhibiting its spinning parts.

Fig. 81 is a front view of the middle, being that part of the carriage which moves under the headstock, exhibiting a few spindles on each side.

Fig. 82 is the frame of the opposite side of the headstock, the fellow of that seen in Fig. 77.

Figs. 83 and 84 show a few parts of the machine in double scale, which will be referred to in the sequel.

A, A, A, fig. 77, is the frame of cast iron, to which, on each side of the headstock, is fixed the roller-beam, B, shown in section. C, C′, C″, are three steam-pulleys on a horizontal shaft, *a*. The pulley, C, fixed together with the wheels, 1, upon a boss, and running loose upon the shaft. C′, is fixed on the shaft; and C″, being of a smaller breadth, is a loose pulley. There are two straps, D and D′, to move these pulleys The first drives the pulleys, C and C′, together by covering one-half of each; but it slides during a certain period of each working on the pulley, C, alone, and continues to do so till a new stretch begins. At the same time the strap, D′, which moves more slowly, and in the contrary direction, runs for a few seconds on the pulley, C′, and immediately, thereafter, goes back to its loose pulley, C″. The pulley, C, which is always kept moving with uniform velocity, drives the apparatus by which the motions are changed, and brings also back the carriage towards the roller-beam, when all other motions are stopped. The said apparatus consists of the cam-shaft, *b*, with a pulley, *c*, called the friction-pulley, which has four grooved cavities, at equal distances, in its

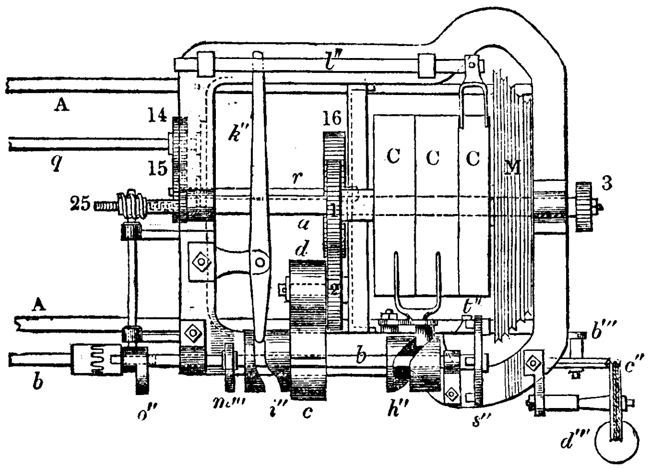


Fig. 79.—Self-actor Mule. Plan of top of Head-stock. Scale, three-fourths of an inch to the foot.

circumference, parallel to the axis, in any one of which the leather-covered pulley, *d*, fig. 72, may slide when revolving opposite to the groove. This pulley, *d*, is put in motion by wheel, 2, on its axis, driven from the wheel, 1, connected with the steam-pulley, C. When an edge of any one of the grooves of the pulley, *c*, by the action of a spring, is made to press against the leather-covered pulley, *d*, the latter will turn by friction, the pulley, *c*, through a quadrantal arc, till the shaft, *b*, is arrested by a catch, which prevents the further action of the spring, and makes the pulley, *d*, run in the concavity of the next groove. By disengaging the catch, the grooved pulley, *c*, will turn through another quadrant, and so in succession, making four different motions in one complete stretch. 3, is a pinion on the shaft, *a*, which drives by means of a carrier-wheel, 4, the wheel, 5, fixed upon the shaft, *e*; from this shaft motion is given to the shaft, *f*, connecting the front rollers of both sides of the machine by means of the bevel-wheels, 6 and 7. On this shaft is also a pinion, 8, driving the wheel, 9, on the shaft with a drum, E, which draws the carriage out by means of a rope, fig. 78. The rollers are stopped by the machine pushing the bevel-wheel, 7, out of geer with, 6, drawing the coupling ends, *h*, from the pinion, 8, making this loose on the shaft, *f*, and at the same time pushing into geer the little bevel-wheel, 10, with the wheel, 11, whence the drum, E, now derives its motion. The wheel, 10, is driven by a strap going from the little pulley, *m*, on the shaft, *e*, to the larger pulley, *l*, on the shaft, *i*, thus giving a rather slow motion to the drum, E, and to the mule-carriage. From the front roller-shaft, motion is given in the usual way to the back roller-shaft by carrier-wheels; the carrier-shaft, *n*, serving for the rollers on both sides of the machine.

F, is a twofold spiral scroll, moving with a shaft in bearings of the frame, A, seen in figs. 77 and 78. To the smaller diameters of the scrolls are attached ropes going round the spirals, and thence they go to be fixed, after a few turns, the one on the drum, E, and the other on the guide-barrel, G. Two other ropes are attached to these two barrels, E and G, having their other ends fixed to two small barrels, *o* and *p*, at the carriage, H, fig. 77, which ropes can be tightened by turning the ratchet-wheels on the axes of the barrels, which are secured by clicks. The spiral scroll, F, has nothing to do in the bringing out of the carriage, which is performed by the revolving drum, E. This, however, being disengaged by shifting the wheel, 10, out of geer with 11, the carriage stops till it is to be returned, when the pinion, 12, is thrown in geer with the bevel-wheel, 13, which acts upon the shaft of the scroll, F. This now moves the carriage, first with an increasing speed, and then with a speed decreasing, as it approaches the roller-beam, the drawing out ropes remaining equally stretched, since the scroll gives off in one direction as much rope as it takes up in another. The pinion, 12, is fixed upon the shaft, *q*, which is constantly revolving, (although not shifted in geer with 13,) being driven by the wheel, 14, which receives its motion from the carrier-wheel, 15, fig. 79, fixed with 16, upon

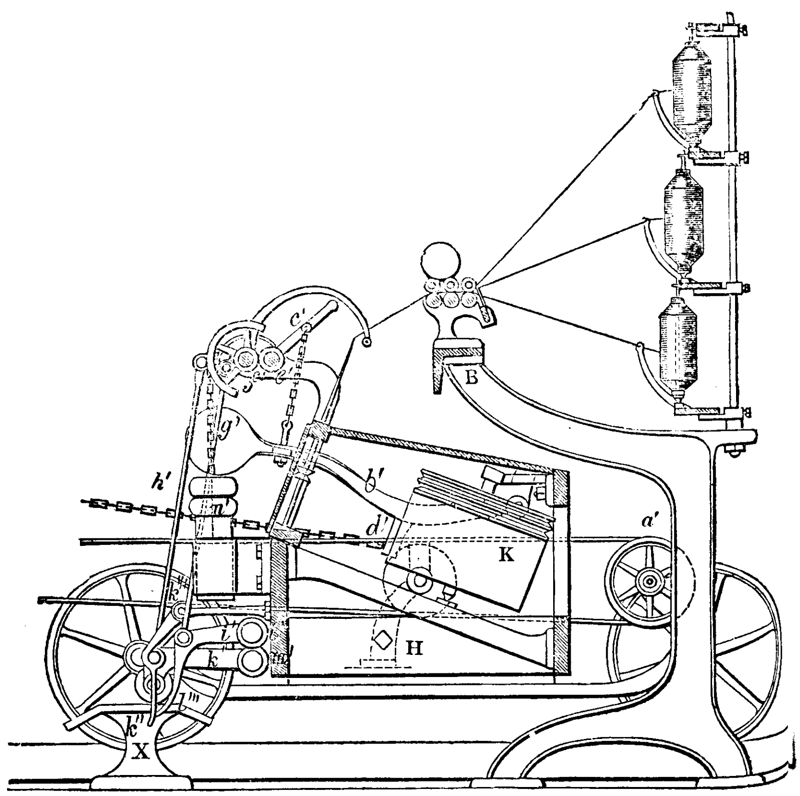


Fig. 80.—Self-actor Mule. Cross Section of the spinning parts.
Scale, three-fourths of an inch to the foot.

the shaft, *r*. The wheel, 16, gets its motion from the wheel, 1, which drives also the friction-pulley, *d*.

We shall now describe the driving parts in the carriage: *s* is an inclined shaft, standing parallel to the axis of the drums, K, fig. 80, from which the wharves of the spindles are turned by cords. On the shaft, *s*, is the double-grooved pulley, I, from which the drums, K, on the left and right-hand sides of the carriage, are driven by bands, as usual. On the under end of the shaft, *s*, is a bevel-wheel, 17, which is shifted in geer, either with the bevel-wheels 18 or 19, fig. 81. The wheel 18 is on the same shaft with a double-band pulley, L (77 and 81), which is driven by an endless band from the pulley, M, fixed on the principal shaft, *e*, and which is called the twist-pulley. The endless band comes from the twist-pulley, M, over the two guide-pulleys, *t* and *u*, seen in plan, fig. 78, and partly in 77—one end of this band going over the guide-pulley, N, and round the driving-pulley, L; then back round the guide-pulley again, and once more over the pulley, L: convolutions intended to increase the friction between the band and pulley, so as to effect the rotation of the spindles. The endless band goes thereafter round the horizontal tightening pulley, *v*, and thence back over the other guide-pulley, *t*, up to the twist-pulley, M. *See* fig. 81.

After the backing-off is performed, the shaft, *s*, is now shifted with its bevel-wheel, 17, in geer with the wheel, 19, on whose shaft is a wheel, 20, which is moved by another wheel, 21, fixed on the shaft of the barrel, O, or winding-on drum, which has grooves for receiving the convolutions of a chain attached to it. The other end of the chain is fixed to a point, *w*, of the apparatus, P, fig. 77, to be presently described. The carriage, in moving backwards to the roller-beam, causes therefore the drum, O, to revolve as the chain pulls it round, its other end being fixed at the point, *w*. Thus, the shaft, *s*, revolves slowly, being set in motion by means of the train of wheel-work, 21, 20, 19, and 17, and which, during the going in of the carriage, makes the spindles to revolve, and by the depression of the faller, to wind on the yarn. P is a toothed quadrant, turning freely on a centre, *x*. It has a grooved arm, *y*, in front of which is a screw, bearing on its central end a little bevel-wheel, 22, in geer with another, 23, turning with a little pulley, *z*, on an axis. In the groove of the said arm slides a nut, *w*, being the point to which the end of the above chain is attached, moving gradually to the end of the screw by turning the pulley, *z*, and consequently the bevel-wheels, 23 and 22, the last of which is fixed upon the screw, *y*. This qua-

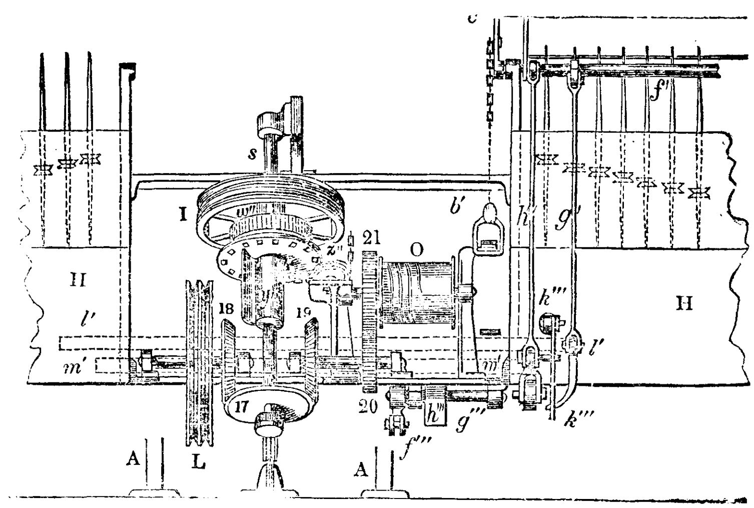


Fig. 81.—Self-actor Mule. Front View of the middle of the carriage. Scale, three-fourths of an inch to the foot.

drant moves through one-fourth of a circle during the going out of the carriage, being in geer with the pinion, 24, on the shaft of the guide-barrel G, round which the ropes pass which take out the carriage. Thereafter the scroll, F, moving back the carriage with a varying velocity, gives, by the pinion 24, a corresponding returning motion to the said quadrant, by which means the nut, *w*, is caused also to describe a quadrant of a circle of greater or less diameter, according to the point of the arm-radius, *y*, to which it has been screwed by the bevel-wheels, 22 and 23. By this action, the drum, O, does not turn in proportion to the advance of the carriage; the point, *w*, to which the end of the chain of that drum is attached following the motion of the carriage, in the proportion of the cosines of the arcs through which the quadrant, P, has turned. The turning of the drum, O, is thereby increased as the said cosines diminish, and therefore turns the spindle faster as the carriage approaches the roller-beam, the faller guiding the threads gradually upon the thinner diameter of the cop already made. In the beginning of building the cop, the nut, *w*, is nearest to the centre of the quadrant, P, and may then be considered as a fixed point for the chain, causing therefore the spindles to turn with the carriage during its going in, as represented above. During the making of the double-cone foundation of the cop, the nut, *w*, is moved gradually towards the extremity of the arm, *y*, thus describing increasing quadrantal arcs, and thereby causing the spindles to turn at each stretch more slowly at the beginning, and more quickly towards the end, of the winding-on, the faller beginning the winding-on each time at a higher point of the spindle.

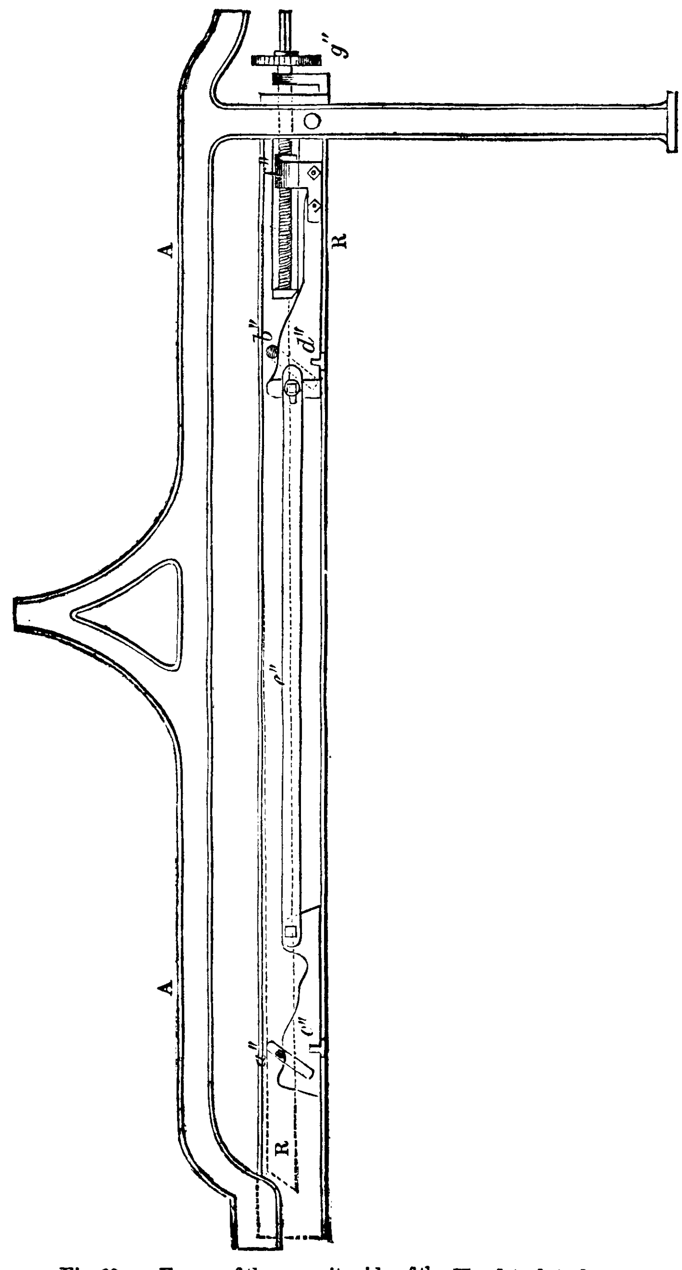


Fig. 82.—Frame of the opposite side of the Headstock to fig. 77. Scale, three-fourths of an inch to the foot.

When the double cone is made, the winding-on, guided by the quadrant, P, remains constant, as the nut, *w*, does not move any more while the faller, after each stretch, continues to lay on the winding from a higher point of the spindle. The motion to the screw, *y*, is given at each stretch in the following way :—over the little pulley, *z*, fig. 77, and over the guide-pulley, *a'*, fixed to the frame, figs. 77 and 78, is an endless

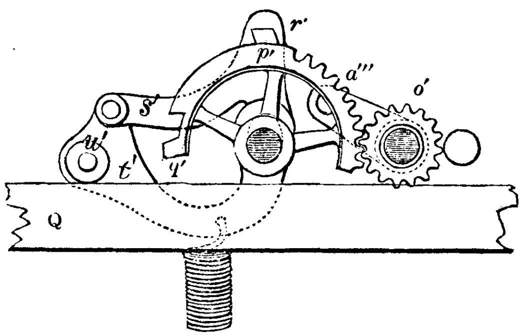


Fig. 83.—Details of the Self-actor. Scale, one inch and a half to the foot.

strap, a certain length of which is moved during the going back of the carriage in forming the double-cone foundation of the cop. *b'* is a lever, connected with the faller-arm, C', by a chain, and which when the faller sinks, presses upon the said strap, and pinches it again to the plate, *d'* (fig. 81), whereby it is fixed by the returning carriage, and drawn along with it, till the faller, *c'*, rises again, and lifts the weight of the pinching lever, *b'*, from the plate. After the double cone is made, the faller no longer descends so low as to permit the lever, *b'*, to press upon the strap, after which the nut, *w*, is no further moved outwards; and thenceforth the cop continues to be built by winding on uniform conical surfaces of yarn upon the top cone, *a*, *b*, *d*, of the foundation, as shown by dotted lines in plate V. fig. 3, the faller at each stretch descending less and less, and consequently beginning the winding-on at successively higher points.

On the carriage, figs. 80 and 81, are two shafts, e' and f', running the whole length of the carriage, the first of which is the faller shaft, and the second the counterfaller shaft, which latter is here put in front of the carriage. On either side of the carriage, both are moved by small arms attached to them, and by connecting rods joined to arms, i' and k', fixed on the ends of the horizontal shafts, l' and m'. The faller shaft, e, is always kept up by several spiral springs working on arms attached to it, unless it is depressed during the winding-on action of the machine. On the counterfaller shaft, f', are several segments, from which are suspended by chains, weights, n', which are directly proportional to the number of threads, and inversely to the fineness of the yarn—(*see* instructions, p. 202) which serve to support the threads during their winding on the spindles—a point explained with regard to the former hand-mule. The faller shafts e', e', on each side of the machine, are depressed

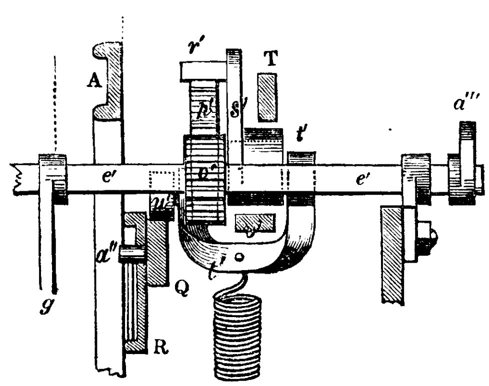


Fig. 84.—Details of the Self-actor. Scale, one inch and a half to the foot.

and raised in the following way. On the shaft belonging to the left side of the carriage is fixed a small pinion, o', which is in geer with a toothed segment, p', the shaft of which rests in bearings on the carriage, as shown in fig. 77. These parts are represented in double scale, figs. 83 and 84. It should be observed that the toothed segment, p', has one portion smooth, at whose end is a notch, q', into which, by turning the segment, which is loose on its shaft, a catch, r, may fall. This catch is fixed upon a curved arm, s', which embraces the shaft of the segment, and is thus permitted to move up and down with the catch, r'. Another curved arm, t', turns loosely round the shaft of the segment, and is connected by a link to the arm, s', and has at its end a roller, u', with which it is pressed, by a spiral spring, and slides, during the motions of the carriage, on a long rail, Q, which is fixed to the frame of the headstock, fig. 82, opposite, to that represented in fig. 77.

In fig. 82, this frame is shown with the rail, Q, in dotted lines behind. This rail has two pins, a'' and b'', going through the slots in the frame piece, R, which rest upon two plates, c'' and d'', called the *shaper*-plates, because they define the shape of the cop, and are connected with each other by the bar, e''. The shaper-plate, d'', has a nut, f'', in which a screw works, bearing on its end a ratchet-wheel, g'', one or two teeth of which are moved by a click from the carriage, at the end of each of its comings out. Thus the shaper-plates, c'' and d'', are gradually shifted, and the rail, Q, at the back of the frame piece, R, is permitted to sink a little, so as to make the roller, u, (figs. 83 and 84) run lower upon its rail, Q, during the motions of the carriage. When the faller is depressed, which is at the time when the carriage begins its going in, the segment, p' is turned, and the catch, r', falling into the notch, q', must now follow the action of the sliding-roller, u', on the rail, Q. The segment, p', now driving the pinion, o', which is attached to the faller-shaft of the left side of the carriage, will give to that shaft a regular rising motion, in proportion as the carriage approaches to the roller-beam, by being connected to the roller, u', which runs over the inclined rail, Q. The carriage having reached the end of its course, the arm, s', goes over a bar, v', seen in section in fig. 84, and is fixed to the frame, by which means the catch, r', is lifted from its notch, q' (fig. 83), and the fallers made to rise by the spiral springs attached to them. The same motion is transferred to the faller shaft, e', on the right-hand side of the carriage, by the horizontal shaft, l', to which both are connected by arms and connecting rods.

We have now to explain how all these motions are successively produced in the machine. b, fig. 77, is the shaft which, by certain disengagements, is permitted to revolve at each of four different periods, through a fourth part of a circle. On this shaft are the following guides and excentrics: h'', the guide for the fork of the strap, D, which is attached to the top end of the lever; i'', the guide for the other strap, D', which is shifted by the lever, k'', fig. 79, working in the bar, l'', on the end of which is fixed the fork for the said strap. m'' is an excentric by which the bevel-wheel, 7, and the coupling clutch, h, are shifted out of geer, whilst the wheel, 10, is brought in geer with 11. The lever which carries the bearing of the shaft, *i*, and shift-wheel, 10, into geer with 11, is connected with the lever, *n''*, fig. 77, working in the coupling, *h*, fig. 78, and is moved by the excentric, *m''*, by a hook which, being subsequently lifted, makes also the wheel, 10, to fall out of geer with 1 ; *o''* is a finger (seen best in fig. 79), by which the quantity of twist is regulated, and which keeps the shaft, *b*, from turning a fourth part of a revolution, till a notch in the plate, *p''*, allows that finger to strike through. The shaft is afterwards arrested in another way.

The plate, *p''*, is fixed on a shaft with wheel 25, which is driven by a worm at the end of the principal shaft, *a*, and may be varied in diameter, according to the quantity of twist the yarn is to have—(*see* figs. 77, 79). *q''* is another excentric by which the wheel, 12, is shifted in geer with 13, by means of the bell-crank lever, *r''*, at the end of which is the bearing of the shaft *q*.

s'' is a plate on the shaft *b*, having on one end four pins, against which a spring presses, *t''*, so as to bring the friction-pulley, *c*, in contact with the pulley, *d*, and thus to make it turn through a quadrant. On the other side of the said plate, *s''*, are three square escapement pieces, against which the end of a rod, *u''*, presses, connected with the end of the horizontal balance lever, S. By either depressing or lifting this lever, the rod, *u''*, is moved from one of the catches on the plate, *s''*, by which it revolves through a quadrant, as has been said, and is then caught by the next escapement on the plate, *s''*.

In the going out of the carriage, let us suppose the strap, D, to be driving both the pulleys, C and C', and the strap, D', to be on the loose pulley, C.'' The rollers are turned by the shaft, *e*, and the carriage moved by the drum, E, getting motion by the wheels, 8 and 9, fig. 78. The twist is given from the pulley, M, driving the pulley, L; and by means of the wheel, 18, the wheel, 17, on the shaft, *s*, which is now in geer with it. The carriage coming near the end of its course, lifts a catch from a latch (*see* dotted lines, fig. 77) of the lever, S, which sinks, therefore, a little at S, and is caught by a second catch, which is connected by a rod, v'', to a lever, T, the latter resting on the boss of the curved arm, s' (*see* figs. 83 and 84, where that lever is represented in section).

By the falling of the end, S, of the balance lever, the rod, u'', has moved from one of the escapements of the plate, s'', and after the shaft, *b*, has made a quadrantal motion, it is arrested by the finger, o'', striking against the plate, p''; by this means the excentric, m'', on the shaft, *b*, has disconnected the coupling, *h*, fig. 78. The rollers are thus set at rest, while the carriage moves a little longer, but very slowly, being driven by the shaft, *i*, which is put in geer by the wheel 10 with 11. The carriage having arrived at the end of its course, strikes against a rod, not seen in the figures, detaching the click with which, by the lever n'', the wheel 10 was shifted into 11, thus setting at rest those parts which gave motion to the carriage. The twisting motion, however, is continued till the principal shaft, a', has turned the wheel 25 so far round, that the finger, o'', can strike through the notch in the plate, p'' *see* upper part of fig. 77). The shaft, *b*, goes on to revolve through a second quadrant, and is now caught by the rod, u'', at one of the catches upon the plate, s''. By this quadrantal motion the straps are shifted; D moves to the pulley C alone, and D′, which goes much slower, and in an opposite direction, is shifted to the pulley C′, which is fixed on the shaft of the twist-pulley, M. The latter is, therefore, now turning in the contrary direction, and giving a like motion to the spindles, thus backing off the coils of the yarn from the noses of the spindles. At the same time, however, a ratchet-wheel, w'', on the slant shaft, s' (in the carriage), turns by a click, x'', a plate connected with a spiral piece, y'', to which is attached the end of a chain, which passes over the two guide-pulleys, z'', to an arm, a''' (seen above, H), fixed upon the same shaft with the pinion, o', figs. 77 and 84.

By the reverse motion of the shaft, s, therefore, the faller is depressed till a catch, r', falls in the notch, q', of the segment, p'. After which the faller follows the motion given to the roller, u', by its sliding on the rail, Q. At the time, however, that the catch falls into the notch, the lever, T, which had been resting upon the boss of the curved arm, s', falls also, and takes away the catch which had suspended the latch of the end, S′, of the balance lever, and makes this end to fall a second time, after which the rod, u'', lets another detent of plate, s'', escape, and causes the shaft, b, to revolve through the third quadrant, by which the straps, D and D′, are brought back to their former positions. Meanwhile the shaft, s, is shifted with its wheel 17 into geer with 19, as will presently be described, and the excentric, q'' (fig. 77), has shifted the wheel 12 into geer with 13, which is fixed on a shaft with the scroll, F, by which the carriage is now returned towards the roller-beam, whilst the winding-on is performed by the drum, O (fig. 81), turned by the chain attached to the nut, *w*, at the quadrant, P, fig. 77. Round the said drum there are a few coils of a rope, which passes over the two pulleys, b''' and c''' (fig. 79), and suspends a weight, d''', in order to keep the chain tight upon the drum, O.

When the carriage comes home to its place near the roller-beam, it presses down the end, S, fig. 77, of the balance-beam, and makes the rod, u'', to fall off from the third escapement of plate s'', after which the shaft *b* turns through the fourth quadrant. By this motion the excentric, q'', shifts the wheel 12, out of geer with 13, while the excentric, m'', sets the rollers in geer by the coupling-box, *h*, and of course also the drum, E, which moves out the carriage by the wheels 8 and 9. The bar, t', fitted to the frame (fig. 78) has now lifted the catch, r', out of the notch, q', in the segment, p', and thus has disengaged the faller shaft. Finally, the shaft, *s*, fig. 81. is shifted with its wheel 17, into geer with 18, to give twist again to the yarn spun during the next stretch of the carriage. It remains only to mention how this shifting of the shaft, *s*, is performed at the moment of the carriage going in and out. The step-bearing of the said shaft is fixed on the end of a bell-crank lever, e''' (bottom of fig. 77), the other end of which is connected with an arm, f''', on a shaft, g''', fig. 81, upon which shaft is a kind of a balance lever, h''', i''' (fig. 77), which slides when the carriage arrives at the two ends of its course, under rollers attached to the large radial weights U and V (fig. 77), which thus presses on that one of the arms, h''' or i''', which is just arrested by a detent or click, and keeps the wheel 17 in geer with either wheel 18 or 19. When the carriage is drawn out, and the wheel 17 is still in geer with 18, the arm, h''', is suspended, and remains so till by the falling of the lever, T, the balance-lever, S, makes its second fall, and disengages the click by which the arm h'''; was suspended, but is now depressed by the radial weight, whilst the other arm, i''', is now caught by another click. On the contrary when the carriage arrives near the roller-beam, at the same time that it depresses the balance-beam, S', and changes the motion, the click which keeps the arm, i''', suspended, is also disengaged, and the radial weight, V, presses down the arm, i''', whilst h''' is caught in its click, and keeps the wheel, 17, in geer with wheel, 18.

k''' is a detent or click, in which the arm, k', is caught. This is connected with the counter-faller shaft; when the carriage is going out, the arm, k', has on its end a roller which glides at the beginning of the course of the carriage, over an inclined plane, X, fixed on the floor, and lifts the arm, k', to be laid hold of by the catch k'''. When, however, the faller becomes depressed at the going in of the carriage, the finger, e''', attached to the arm, i', (fig. 74, near the left-hand wheel,) disengages the arm, k', from the catch, k''', and causes the counter-faller to react against the tension of the threads.

William Strutt, Esq., of Derby, F.R.S., a gentleman eminent for scientific knowledge and mechanical ingenuity, deserves to be recorded as the first contriver of a mule altogether automatic. In a memoir of the father, his enlightened son, Edward Strutt, Esq., M.P. for Derby, says, "Among his other inventions and improvements, we may mention a self-acting mule for the spinning of cotton, invented more than forty years ago (before the year 1790); but we believe the inferior workmanship of that day prevented the success of an invention, which all the skill and improvement in the construction of machinery in the present day has barely accomplished." Mr. Strutt died in 1830, and the memoir of filial piety was published soon thereafter in a periodical journal.

Sketch of the Origin, Progress, and present State of the Spinning Machine, termed " the Self-acting Mule," by an eminent Factory Engineer.

The invention of this now important machine may, in a great measure, be attributed to the injurious effects resulting from turn-outs, and other acts of insubordination of work-people, which have, from time to time, led to the invention of machinery, as a substitute for, or in reduction of, the manual labour by which various operations were performed.

In working the common, or as it is, for the sake of distinction, now termed, the "hand-mule," various persons are employed to perform different portions of the work; viz., the "spinner," who directs the general operation of the machine, gives to the yarn a suitable degree of twist during the spinning, and, when spun, winds the yarn in a certain form round the spindle to make what is termed a "cop;" one or more "piecers" to join the threads which break during the spinning, and to remove the cops, when formed, from the spindles; a "creel-filler" to place the "rovings" from which the yarn is to be spun, in a part of the machine termed the "creel;" and a "cleaner," or "scavenger," to remove the waste cotton, termed "fly," which accumulates during the spinning, and to clean the machine generally. The "spinner" being the principal person of the set thus employed, and, in most instances, an adult; the others being subordinate to him, and always young persons, or children; the set, thus arranged, working one pair of mules.

The "hand-mule" was invented about the year 1780, and from its importance in producing a peculiar kind of yarn, the use of it extended with great rapidity; and the demand thereby created for the labour of persons to work the machines, enabled the "spinner" to command a much higher rate of wages than was paid to artisans in general.

Notwithstanding this superior remuneration, the proprietors of cotton-mills were, for many years, subject to great disarrangement of business, and consequent loss, from the frequent turn-outs and other acts of insubordination of the "spinners;" by which acts, not only were their assistants thrown out of employ, but also in respect of each "spinner," three or four other persons employed upon machines required to prepare the cotton previous to being spun; all of whom, in by far the greatest number of instances, were reluctantly compelled to cease working, the product of their labour not being required whilst the "spinner" refused to work.

The injurious effects resulting from these tyrannical proceedings on the part of the "spinners," who, from their ample pecuniary resources, were able to continue them for long periods, naturally led to an anxious desire on the part of the proprietors of cotton-mills, that some means should be devised to enable them to dispense with the labour of the "spinners," who, by their refractory conduct, inflicted so much injury on the interests of their employers, and, at the same time, caused so much distress to many of their fellow workpeople.

The attention of spinners and mechanicians being thus directed to the subject during the last twenty or twenty-five years, many attempts have been made in this and other countries to invent mechanism which would dispense with the labour of the "spinner," or render the mule what is termed "self-acting," that is, by steam or other power, not manual, to cause the mule to go through the whole of its required movements to spin the yarn, retaining only the subordinate persons to piece the threads, fill the creels, clean the mule, &c. &c.

Of the various attempts made to accomplish an object of so much importance to that great branch of business, cotton spinning, the inventions of the following parties only have been put into operation beyond the purposes of experiment; viz., Messrs. Eaton, formerly of Manchester; Mr. De Jongh, formerly of Warrington; Mr. Buchanan, of the Catrine works, Scotland; Mr. Brewster, of America; Mr. Roberts, a partner in the firm of Sharp, Roberts, and Co., of Manchester; and Mr. Knowles, of Manchester.

Of the self-acting mules invented by Messrs. Eaton, ten or twelve only were put in operation in Manchester, and at Wiln, in Derbyshire, and a few in France; but from their great complexity and limited production, the whole were soon relinquished, except four at Wiln.

Mr. de Jongh obtained two patents for self-acting mules, and put twelve of them in operation in a mill at Warrington, of which he was part proprietor, but with an unsuccessful result, and they were consequently given up.

Mr. Buchanan, it is reported, has several mules, partly or entirely self-acting, at work in Scotland, but the principle of their construction has not been made public.

Of Mr. Brewster's self-acting mule nothing is known beyond the report that there are mules at work in America, of his invention, for spinning wool.

The first approximation to a successful accomplishment of the objects in view was an invention of a self-acting mule, by Mr. Roberts, one of the principal points of which was, the mode of governing the winding-on of the yarn into the form of a cop; the entire novelty and great ingenuity of which invention was universally admitted, and proved the main step to the final accomplishment of that object which had so long been a desideratum. For that invention a patent was obtained in 1825, and several headstocks upon the principle were made, which are still working successfully; but, from a combination of various causes, the invention was not extensively adopted.

In 1827, Mr. De Jongh obtained a third patent for a self-acting mule; upon which plan, with the addition of part of Mr. Roberts's invention, which was found to be essential, about thirty mules were made, part to spin cotton, and part woollen yarn. The greater part of these are continued at work, but, it is reported, with only a moderate degree of success.

In 1830, Mr. Roberts obtained a patent for the invention of certain improvements; and, by a combination of both his inventions, he produced a self-acting mule, which is generally admitted to have exceeded the most sanguine expectations, and which has been extensively adopted.

In 1831, Mr. Knowles, of Manchester, supported by the Oxford Road Twist Company, to whom he was manager, obtained a patent for a self-acting mule. On the enrolment of his specification, however, it was discovered that he had infringed both of Mr. Roberts's patents. Application was consequently made to the Court of Chancery for an injunction, which was immediately granted; and on a motion to dissolve the injunction, it was refused. Subsequently, in order to avoid an action at law, Mr. Knowles and the Oxford Road Twist Company consented to the injunction being perpetuated, with costs; when permission was granted by Messrs. Sharp, Roberts, and Co., for Mr. Knowles's mule to be used in the mills of the Oxford Road Twist Company *only*, on condition of their paying a consideration for using any part of Mr. Roberts's invention, should they do so.

Such is a short sketch of the origin and progress of self-acting mules, up to the year 1830; since that time, the patent mule of Messrs. Sharp, Roberts, and Co. has been extensively adopted, there being at the present time (Dec. 1834) in operation, in upwards of 60 mills, between 300,000 and 400,000 spindles, besides extensive orders in course of execution. It may be proper to observe, the adoption of the mechanism to render mules self-acting does not involve a sacrifice of the whole of the hand-mule, but merely that part of it termed the headstock, being in value about one-fifth of the entire mule, the self-acting mechanism being contained in the headstock, which is adapted to be applied to the other parts of a mule, as the roller-carriage spindles are termed the body of the mule.

In considering the advantages resulting to the proprietors of cotton-mills from the use of self-acting mules, it may be stated that, although the only, or at any rate the principal benefit anticipated, was the saving of the high wages paid to the hand "spinner," and a release from the domination which he had for so long a period exercised over his employers and his fellow work-people, it soon became manifest that other and very important advantages were connected with the use of the machine.

The various advantages attending the use of self-acting mule headstocks, were enumerated in a statement submitted by Messrs. Sharp, Roberts, and Co. to the proprietors of cotton-mills, of the principal points in which the following is a copy:—

"First, the advantages connected with spinning.

"The saving of a 'spinner's' wages to each pair of mules, piecers only being required, one overlooker being sufficient to manage six or eight pair of mules or upwards.

"The production of a greater quantity of yarn, in the ratio of 15 to 20 per cent., or upwards.

"The yarn possesses a more uniform degree of twist, and is not liable to be strained during the spinning, or in winding-on, to form the cop; consequently fewer threads are broken in those processes, and the yarn, from having fewer piecings, is more regular.

"The cops are made firmer, of better shape, and with undeviating uniformity; and from being more regularly and firmly wound, contain from one-third to one-half more yarn than cops of equal bulk wound by hand; they are consequently less liable to injury in packing or in carriage, and the expense of packages and freight (when charged by measurement), is considerably reduced.

"From the cops being more regularly and firmly wound, combined with their superior formation, the yarn intended for warps less frequently breaks in winding or reeling, consequently there is a considerable saving of waste in those processes.

"Secondly, the advantages connected with weaving.

"The cops being more regularly and firmly wound, the yarn, when used as weft, seldom breaks in weaving; and as the cops also contain a greater quantity of weft, there are fewer bottoms, consequently there is a very material saving of waste in the process of weaving.

From those combined circumstances, the quality of the cloth is improved, by being more free from defects, caused by the breakage of the warp or weft, as well as the selvages being more regular.

"The looms can also be worked at greater speed, and, from there being fewer stoppages, a greater quantity of cloth may be produced.

"That the advantages thus enumerated, as derivable from the use of self-acting mules, have not been over-rated, but in many instances have been considerably exceeded, the author, by extensive personal inquiry and observation, has had ample opportunity of proving, &c. &c.

"Statement of the quantity of yarn produced on Messrs. Sharp, Roberts, and Co.'s self-acting mules in twelve working hours, including the usual stoppages connected with spinning, estimated on the average of upwards of twenty mills:—

No. of Yarn.		No. of Twist.		No. of Weft.
16	.	$4\frac{1}{2}$ hanks	.	$4\frac{7}{8}$ hanks per spindle.
24	.	$4\frac{1}{4}$,,	.	$4\frac{5}{8}$,,
32	.	4 ,,	.	$4\frac{3}{8}$,,
40	.	$3\frac{3}{4}$,,	.	$4\frac{1}{8}$,,

"Of the intermediate numbers the quantities are proportionate.

"Dec. 23, 1834."

Results of trials made by Messrs. Sharp, Roberts, and Co., at various mills, to ascertain the comparative power required to work self-acting mules, in reference to hand-mules, during the spinning up to the period of backing off.

The mode adopted to make the trials was as follows, viz.:—

A force, indicated by weight in pounds, was applied to the strap working upon the driving-pulley of the respective mules, sufficient to maintain the motion of the mule whilst spinning, which weight, being multiplied by the length of strap delivered by each revolution of the pulley, and again by the number of revolutions made by the pulley whilst spinning, gave the total force in pounds, applied to the respective mules whilst spinning; for instance, suppose a mule to be driven by a pulley 12 inches diameter (3·14 ft. in circumference), such pulley making 58 revolutions during the spinning as above, and that it required a force equal to 30 lbs. weight to maintain the motion of the mule; then 30 lbs. × 3·14 feet circumference of pulley × 58 revolutions in spinning = 5,463 lbs. of force employed during the spinning to the period of backing off.

Particulars of the trials referred to, and their results :—

At what Mill, and the description of Mule.	No. and kind of Yarn.	Diameter of Pulley or Rim-wheel.	Revolutions of Pulley or Rim-wheel.	Required Force for Motion.	Total Force employed in Spinning.
Messrs. Birley & Kirk.	Weft.	Ins.		lbs.	lbs.
Self-acting Mule, 360 sps.	30 to 34	12	58	30	5,463
*Hand-Mule, 180 sps. . .	do.	15	36	26	3,669 } × 2 = 7,338
Messrs. Leech and Vandrey	Twist.				
†Self-acting Mule, 324 sps.	36	12	70	36	7,912
Hand-Mules, 324 sps. . .	36	29	58	16½	7,273
Messrs. Duckworth & Co.	Twist.				
Self-acting Mule, 324 sps.	40	12	62	33	6,421
Hand-Mule, 324 sps. . .	40	47	36	15½	6,646

* The trial was disadvantageous for the hand-mules, being two for 360 spindles.

† The trial was disadvantageous for the self-acting mules, being driven by a very short and tight vertical strap, the hand-mule having a long, horizontal strap.

Tables and Instructions referring to Sharp, Roberts, and Co.'s Self-Acting Mule, showing the Speed to be given to the Twist-pulley for different counts of Yarn; the Wheels and Pulleys requiring to be changed in varying the count; the mode of calculating such changes, &c.

Note.—The figures placed between parentheses, after the name of any part of the machine, refer to the sketch of such part, in the set of plates supplied to parties using the self-acting headstock. The letters P. L. signify the pitch line of the part referred to.

Twist-Pulley (No. 4.) M, figs. 77, 79.

In the twist-pulley are five grooves, of different diameters, by which the speed of the spindles may be varied to a certain extent, without changing the strap-pulleys in the driving apparatus over the headstock.

The dimensions of the intermediate double-grooved pulleys (No. 220 and 223), I and L, fig. 81, which carry the band to communicate motion from the twist-pulley to the drums, are so arranged as to cause the revolutions of the twist-pulley and the spindles to be nearly in the ratio of the pitch-line diameters of the twist-pulley (taken at $\frac{1}{2}$ inch more than the bottom of the groove,) to the pitch-line diameter of the warves of the spindles (taken at $\frac{1}{16}$ inch more than the bottom of the groove,) assuming that the face of the drum, and the bottom of the grooves for its band, are of equal diameters, or nearly so, as is generally the case; but for the sake of accuracy in calculating the speed of the spindles, it is desirable to ascertain, by actual experiment, their relative speed with each of the five grooves of the twist-pulley.

Although the speed at which it is advisable that the spindles of mules should revolve, depends upon, and is regulated by, a variety of circumstances, yet the following is submitted as a table of speeds, for various counts of yarn, at which self-acting mules, of moderate size, and in good condition, have been proved to work effectively, when spinning from rovings of medium or fair quality. The table also exhibits the speeds at which the twist-pulley should revolve, so as to admit of all the various speeds of the spindles being produced, by placing the band in a suitable groove of the pulley. The speeds in the table being arranged for mules of not exceeding 300 to 340 twist, or 350 to 400 weft spindles, for larger mules the twist-pulley should be speeded about 5 revolutions per minute slower, for about every 30 additional twist, or 40 weft spindles.

NOTE.—When it becomes requisite to increase or decrease the speed of the twist-pulley, the change is, in general, most easily effected in the fast and loose pulleys in the driving apparatus; and as the speeds stated in the table are intended for the *actual* speeds, in calculating, an allowance should be made for the slipping of straps, ranging from 5 to 7½ per cent.

TABLE of Speeds of Spindles, for spinning various counts of Yarn, Twist, and Weft; and the Speeds at which the Twist-pulley should revolve, to produce such Speeds of the Spindles.

No. of Yarn.	Speed for Twist.	Revolutions of Pulley.	Speed for Weft.	Revolutions of Pulley.
8	3,800	210 to 220	2,800	160 to 170
10	3,875	,,	2,900	,,
12	3,950	,,	3,000	,,
14	4,025	,,	3,100	,,
16	4,100	,,	3,200	,,
18	4,175	230 to 240	3,300	190 to 200
20	4,250	,,	3,400	,,
22	4,325	,,	3,500	,,
24	4,400	,,	3,600	,,
26	4,475	,,	3,700	,,
28	4,550	,,	3,800	,,
30	4,625	,,	3,900	,,
32	4,700	250 to 260	4,000	220 to 230
34	4,775	,,	4,100	,,
36	4,850	,,	4,200	,,
38	4,925	,,	4,300	,,
40	5,000	,,	4,400	,,
42	,,	,,	,,	,,
44	,,	,,	,,	,,
46	,,	,,	,,	,,
48	,,	,,	,,	,,
50	,,	,,	,,	,,
52	,,	,,	,,	,,
54	,,	,,	,,	,,

The foregoing table, as stated, refers to yarn of *medium* quality, and is intended only as a general guide, subject to certain modifications: for instance, for yarn spun from rovings of a *low* quality the speed of the twist-pulley may be decreased, or the band may be placed one or two grooves *lower* on the pulley than for rovings of *medium* quality; and for yarn spun from *superior* rovings, the band may be placed one groove higher than for rovings of *medium* quality; in either case, a suitable twist-wheel must be used to give the proper quantity of twist to the yarn. In equal cases, as to *count* and *quality* of yarn, when a variation in *quantity* of *twist* only is required, it is better to change the twist-wheel than to remove the band from the groove which gives the speed best suited to the quality of yarn.

The going-in, or putting-up of the carriage.

The going-in speed of the carriage should be adapted to the speed of the twist-pulley, and the size of the mule, which may be effected by varying the spur-wheels (No. 65 and 67.) *See* 15, and 14, fig. 51, p. 182.

TABLE of the relative Number of Teeth in the two going-in Spur-wheels (the total number being 57 teeth), to effect the putting-up of the carriage at a suitable Speed.

No. of Spindles in Mule.	Speeds of the Twist Pulley.							
	Not exceedg. 200 Revs.		Above 200, Not ex. 230		Above 230, Not ex. 260		Above 260 Revoltns.	
	Wheel. 65	Wheel. 67	Wheel. 65	Wheel. 67	Wheel. 65	Wheel. 67	Wheel. 65	Wheel. 67
	Teeth.	Teeth.	Teeth.	Teeth.	Teeth.	Teeth.	Teeth.	Teeth.
Not exceeding 360 twist, or 420 weft spindles.	29	28	28	29	27	30	26	31
Above 360 twist, or 420 weft spindles . .	28	29	27	30	26	31	25	32
Above 420 twist, or 480 weft spindles . .	27	30	26	31	25	32	24	33

For a variation of 20 revolutions per minute in the speed of the twist-pulley, a corresponding variation may be made in the putting-up of the carriage by an alteration of one tooth in each of the spur-wheels (No. 65 and 67.) 15 and 14, fig. 51.

Information required as data for calculating the changes which may be required in the following parts of a self-acting mule; viz.,—

The twist-wheel, (No. 34.) *See* 25, fig. 77.
The back-change wheel, (No. 26.)
The rack-pinion pulley, (No. 239.)
The shaper-wheel, (No. 159.)

1st.—The number of yarn to be spun, and whether twist or weft; and the desired diameter of the cop?

2d.—The number of turns of twist per inch, which the yarn should have, specifying the proportion of twist to be given during the draw, and at the head?

3d.—How much the carriage should gain on the rollers during the draw?

4th.—The diameter of the front roller?

5th.—The number of revolutions of the spindles for one of the twist-pulley, ascertained by experiment, with the band in the middle groove?

6th.—The number of teeth in the rack-pinion (No. 237?)

7th.—The number of teeth in the pinion (No. 23) on the twist-pulley shaft?

Tables connected with parts of the self-acting mule headstock, to facilitate the calculation of change-wheels, pulleys, &c.

TABLE of the Number of Revolutions made by Front Rollers of various diameters, in delivering various lengths of Yarn.

Delivery of Yarn. Inches.	Diameter and Circumference of Rollers.					
	7-8th Dia. 2·74 Circ.	15-16th Dia. 2·94 Circ.	1 Dia. 3·14 Circ.	1 1-16th Dia. 3·33 Circ.	1 1-8th Dia. 3·53 Circ.	1 1-4th Dia. 3·92 Circ.
50	18·24	17·	15·92	15·01	14·16	12·75
50½	18·43	17·17	16·08	15·16	14·30	12·88
51	18·61	17·34	16·24	15·31	14·44	13·01
51½	18·79	17·51	16·40	15·46	14.58	13·13
52	18·97	17·68	16·56	15·61	14·73	13·26
52½	19·16	17·85	16·71	15·76	14·87	13.39
53	19·34	18·02	16·87	15·91	15·01	13·52
53½	19·52	18·09	17·03	16·06	15·15	13·64
54	19·70	18·36	17·19	16·21	15·29	13·77
54½	19·89	18·53	17·35	16·36	15·43	13·90
55	20·07	18·70	17·51	16·51	15·58	14.03
55½	20·25	18·87	17·67	16·66	15·72	14·15
56	20·43	19·04	17·83	16·81	15·86	14·28
56½	20·62	19·21	17·99	16·96	16·	14·41
57	20·80	19·38	18·15	17·11	16·14	14·54
57½	20·98	19·55	18·31	17·26	16·28	14·66
58	21·16	19·72	18·47	17·41	16·43	14·79
58½	21·35	19·89	18·63	17·56	16·57	14·92
59	21·53	20·06	18·78	17·71	16·71	15·05
59½	21·71	20·23	18·94	17·86	16·85	15·17
60	21·89	20·40	19·10	18·01	16·99	15·30

TABLE of the Number of Revolutions made by Rack Pinions, of various Numbers of Teeth, in Stretches of various length.

Stretch. Inches.	16 Teeth. 1 rev. 3·30in.	17 Teeth. 1 rev. 3·51in.	18 Teeth. 1 rev. 3·72in.	19 Teeth. 1 rev. 3·93in.	20 Teeth. 1 rev. 4·14in.	21 Teeth. 1 rev. 4·35in.
55	16·66	15·66	14·78	13·99	13·28	12·64
57½	17·42	16·38	15·45	14·63	13·88	13·21
60	18·18	17·09	16·12	15·26	14·49	13·79

Front roller-shaft pulley (No. 82), whether for band or strap.
Pulley for band, P. L. diameter 5½ inches—P. L. circumference 17·27 in.
Pulley for strap, P. L. diameter 5¼ inches—P. L. circumference 16·48 in.

Rules for calculating the Wheels and Pulleys of the Headstock which require to be changed, in varying the count and quality of the Yarn.

1*st.*—*Twist-Wheel* (No. 34).

To find the proper twist-wheel to give to the yarn any required number of turns of twist per inch.

Multiply the number of inches in the total stretch or draw of the carriage by the required number of turns of twist per inch in the yarn; divide the product by the number of revolutions given to the spindles in one revolution of the twist-pulley, and the quotient will give the number of teeth for the twist-wheel.

Example: suppose,

The total stretch or draw of the carriage, $57\frac{1}{2}$ inches,

The required number of turns of twist per inch, 21,

The ratio of the spindles to the twist-pulley 17·6 to 1,

Then, 57·5 inches $\times$ 21 twist $\div$ 17·6 ratio $=$ 68 teeth in the twist-wheel.

N.B.—The number of turns of twist per inch may be increased or reduced, either by varying the number of teeth in the twist-wheel, or by placing the band in a different groove of the twist-pulley, or by a union of the two modes, as the case may require.

The general pitch of the twist-wheel and the worm (No. 8), prepared for the headstock, will suffice for all counts of yarn from No. 10 to No. 50; but for higher counts than No. 50, a finer pitch will be required, the diameter of the twist-wheel being limited. For lower counts than No. 10, a double worm will be required.

2d.—Back Change-Wheel (No. 26).

To find the back change-wheel, that will admit of the required proportion of the total twist being given during the coming out of the carriage, and at the head.

Multiply the number of teeth in the pinion (No. 23), on the twist-pulley shaft, by the number of revolutions of that shaft required to give the proportion of twist during the coming out of the carriage;—divide the product by the number of revolutions of the front roller in delivering the yarn, and the quotient will give the number of teeth for the back change-wheel.

Example: suppose,

1st.—The total number of turns of twist per inch, 21; proportion in the coming out of the carriage, 16, at the head, 5.

2d.—The number of teeth in the pinion on the twist-pulley shaft, 18.

3d.—The revolutions of the twist-pulley shaft during the coming out of the carriage, 52; viz., the total revolutions of the shaft equal the number of teeth in the twist-wheel, say 58; and as 21 total twist : 16 required in coming out : : 68 total revolutions : 52 revolutions of the shaft in coming out.

4th.—The delivery of yarn 54 inches; the diameter of the front rollers 1 inch = circumference 3·14 inches; 54 inches ÷ 3·14 = 17·22 revolutions of rollers in delivery.

Then, 18 back pinion × 52 revolutions of twist-pulley shaft ÷ 17·22 revolutions of rollers = 54 teeth in the back change-wheel.

N.B.—By increasing or reducing the number of teeth in the back change-wheel, a greater or less proportion of the total twist is given during the coming out of the carriage.

3d.—*Rack-Pinion Pulley* (No. 239).

To find the diameter of the rack-pinion pulley which will produce the required gain of the carriage upon the rollers during the coming out of the carriage.

Multiply the P. L. circumference of the front roller-shaft pulley (No. 82) by the number of revolutions of that pulley during the delivery of the rollers; to the product add the length, in inches, of the total stretch; then divide the sum by the number of revolutions of the rack-pinion during the total stretch, and the quotient will give the P. L. circumference of the rack-pinion pulley, from which the P. L. diameter may be found.

Example: suppose,

The total stretch $57\frac{1}{2}$ inches.

The gain of the carriage $3\frac{1}{2}$ inches.

The diameter of the front roller 1 inch = circumference 3·14 inches.

The P. L. diameter of the front roller-shaft pulley $5\frac{1}{2}$ inches = P. L. circumference 17·27 inches.

The number of teeth in the rack-pinion 18; advance on the rack in one revolution 3·72 inches.

1st.—57·5 inches stretch $-$ $3\frac{1}{2}$ inches gain of carriage = 54 inches delivery of rollers $\div$ 3·14 inches circumference of rollers = 17·22 revolutions of front roller-shaft pulley.

2d.—57·5 inches stretch $\div$ 3·72 inches advance of rack-pinion in one revolution = 15·45 revolutions of pinion in stretch.

Then 17·27 P. L. circumference of pulley $\times$ 17.22

its revolutions + 57·5 inches stretch = 354·88 inches ÷ 15·45 revolutions of pinion = 22·96 inches P. L. circumference ÷ 3·14 = 7·3 inches P. L. diameter of rack-pinion pulley.

N.B.—In order that the diameter of the rack-pinion pulleys should not vary more than 1 inch, viz., from $6\frac{1}{2}$ to $7\frac{1}{2}$ inches, the number of teeth in the rack-pinion requires to be varied, according to the diameter of the front roller. The following scale will be a suitable one to produce any gain of the carriage upon the rollers, not exceeding 6 inches, viz.:—

For Rollers	$\frac{7}{8}$ *or* $\frac{15}{16}$ *in. diameter,*	*a Pinion of*	17	*Teeth.*
,,	1 or $1\frac{1}{16}$,,	,,	18	,,
,,	$1\frac{1}{8}$ or $1\frac{3}{16}$,,	,,	19	,,
,,	$1\frac{1}{4}$,,	,,	20	,,

It may occasionally save calculation to note, that a reduction of $\frac{1}{8}$ inch in the diameter of the rack-pinion pulley, increases the gain of the carriage about 1 inch; and an increase of $\frac{1}{8}$ inch decreases the gain in a similar degree.

4th.—*Shaper-Wheel* (No. 159).

The number of teeth in the shaper-wheel will nearly correspond with the count of the yarn, to make a twist-cop of $1\frac{1}{4}$ inch diameter, or a weft-cop of 1 inch diameter (care being taken to use the proper copping-plates.)

To make a cop of greater diameter, use a wheel with a greater number of teeth; and to make one of less diameter, use a wheel with a less number of teeth. It may also be observed, that in counts of yarn below No. 24, it will be convenient to have a wheel which will admit of two, and in some cases three teeth being taken at once, by which means a more minute increase or decrease in the diameter of the cop may be effected, than by one tooth only being taken.

5th.—Counter-Faller Weight (No. 272).

The quantum of weight to be applied to the counter-faller will depend on the number of spindles in the mule, the count and description of the yarn, and the degree of hardness of cop which the yarn will admit of, without injury to the quality.

As a general guide, however, faller weights may be used as follows, viz.:

On twist-mules, for every 100 spindles, 12 to 16 lbs.

On weft-mules, for every 100 spindles, 9 to 12 „

Low counts, of course, admitting of greater weight than fine counts. In cases where the relieving lever-weight (No. 285) is introduced, which, whilst the yarn is backed off, and the faller depressed, is caused not to act upon the counter-faller, but when those motions are performed, is caused to act upon it, during the winding-on of the yarn, by resting on a catch (No. 288) connected with one of the counter-faller coupling-links (No. 256) and the counter-faller arm (No. 271);—the proportion of weight so applied, should be from two-fifths to three-sevenths of the total weight acting upon the counter-faller; the remaining three-fifths, or four-sevenths, being suspended from the arm (No. 273) on the counter-faller shaft.

NOTE.—In the foregoing calculations with which a V grooved pulley is connected, the *pitch line* diameter is assumed at $\frac{1}{2}$ inch more than the diameter at the *bottom of the groove*. In cases, therefore, where a band of such size may be used, as to cause the *pitch line* diameter to be greater or less than is assumed, there will be a corresponding variation between the *calculated* and the *actual* result, which must be allowed for.

The grinding of mule-spindles is performed upon an ordinary large grindstone, turning into a vertical plane, against the edge of which the spindle is pressed by a long cross-lever, carrying a wooden roller on its middle, which is made to bear against the side of the spindle, held tangentially to the face of the grindstone.

After having been forged at the anvil, the mule-spindles are hammered straight on a flat table of iron, and proved by suspending each horizontally between two points, and turning them round at a small distance from the table. The spindles are then ground and polished. They are finally pointed upon another grindstone.

For mule-spindles, both a coarse and a polishing grindstone are employed.

The spindles of bobbin-and-fly frames are turned on a lathe at the ends, and afterwards fixed to their flyers by a cross-pin.

The throstle-spindles, however, are screwed to the fly by a few threads formed at their points.

The flys of the throstles are polished by mutual attrition in a revolving barrel, containing shreds of leather—a process which occupies two or three days.

Spindles are tempered by being heated red hot in bundles of 6 dozen, or thereby, and then dipped perpendicularly into a stratum of water, only half an inch deep; the object being to harden merely their tips.

Mr. Whitworth, an eminent machine maker, in Manchester, obtained a patent in April, 1835, for certain modifications of the self-actor mule, in which he specifies several ingenious devices. The mechanism is designed, first, to traverse the carriage in and out by means of screws or worm-shafts, which are placed so as to keep the carriage parallel to the drawing-rollers, and supersede squaring bands; secondly, to afford an improved manner of working the drums of a self-acting mule by geer; thirdly, better means of effecting the backing off; fourthly, a new mechanism for working the faller-wire in building the cops; and fifthly, an apparatus for winding the yarn on to the spindles. His mule is constructed upon the box-organ principle represented in plate V. For further details of this ingenious machine, we must refer our readers to the specification in "Newton's London Journal," for March, 1836, page 1.

SECTION IV.

Reeling into Hanks and Counting.

THE automatic reel employed for winding the yarn into measured lengths, called hanks, from the bobbins of the throstle or the cops of the mule, in order to prepare it for the general market, is a beautiful mechanism, as constructed in a modern cotton-mill.

The cops made on the mule being light and easily transported are not always reeled off, if they be destined for the shuttle, or the doubling-mill. But if their yarn be of the warp quality, it must be wound upon large bobbins suited to the warping-mill. These bobbins are filled with cop or throstle yarn, by being laid horizontally upon revolving carrier-pulleys or barrels, so that they may turn by mere friction, and wind on the thread from the cops or small bobbins set upright on skewers in an adjoining shelf or creel.

The machine represented in figs. 79 and 80 is employed for winding yarn or threads from bobbins into regular hanks, 840 yards in length. It consists—1st, of a hexagon reel, one yard and a half in circumference; 2d, of a carriage, upon which the spindles or skewers are mounted that bear the bobbins. This carriage has a slow traverse motion parallel to the axis of the reel, for the proper distribution of the thread upon its surface. 3d, of the frame-work upon which the carriage traverses; and 4th, of the driving-geer or mechanism.

Fig. 79 is an end view, and fig. 80 a front view; the middle portion of the machine having been left out in the drawing, as being merely a repetition of the same parts. A A are two end iron framings, connected by two wooden cross-rails, *a*. B is the reel, consisting of six horizontal lathes or spars, made fast to arms which

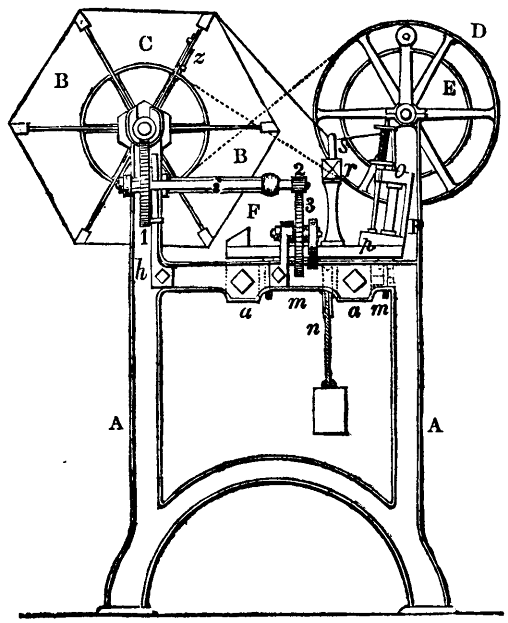


Fig. 79.—Automatic Reel, for winding and counting hanks. End view. Scale, three-fourths of an inch to the foot.

pass through the central wooden shaft *b*, fig. 80. The arm *z* of one of the six lathes is made of two pieces connected by a hinge-joint, round which this lath may be turned, to loosen the hank-coils, in order to remove them from the reel. During the winding, the arm is kept extended in a straight line by wire-hooks catching in eyes.

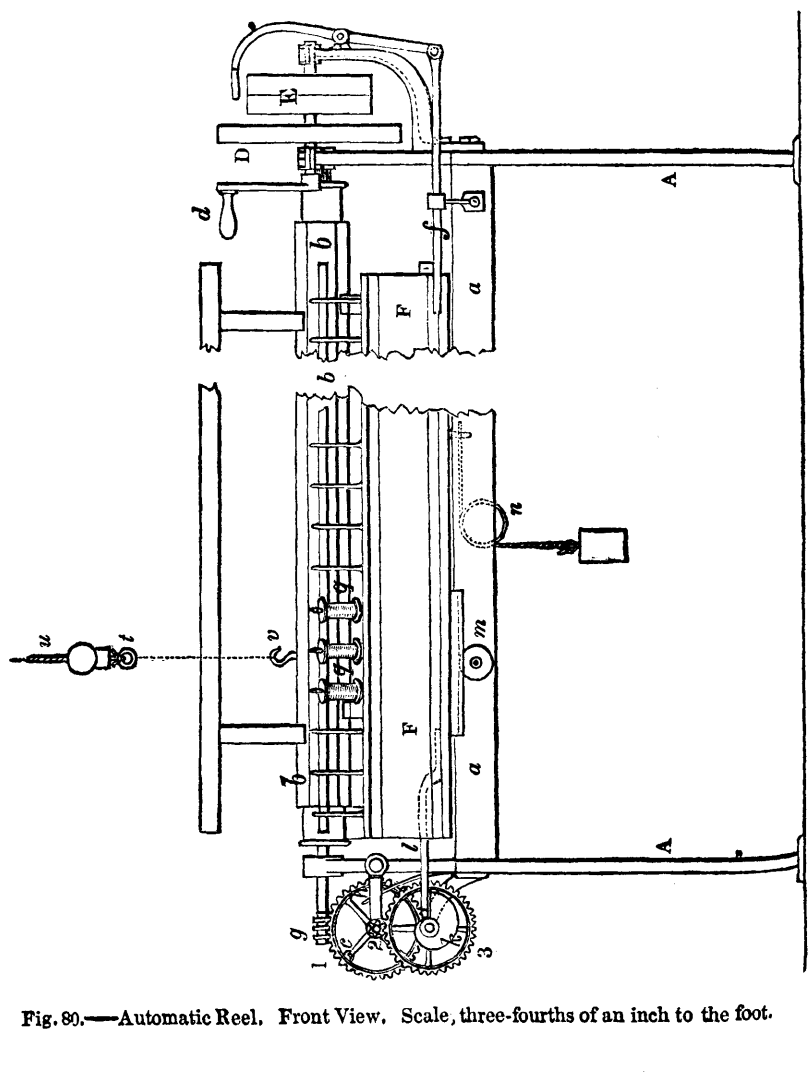


Fig. 80.—Automatic Reel. Front View. Scale, three-fourths of an inch to the foot.

Upon the other end of the machine, to that represented in fig. 79, a pulley, C, is fixed, upon the prolonged axis of the wooden shaft, *b*, exterior to the frame. This pulley is driven by a strap from the pulley D, upon a short iron shaft, which is either moved by the hand applied to the winch-handle *d* (fig. 80), or by a strap from the mill-shaft, passing over the usual outrigger fast and loose pulleys at E. *e* is the forked bar to serve as a guide to the strap. The attendant may move it when he pleases, by means of a horizontal geering-rod, *f*, which extends along the front of the machine, to give him the facility of acting on the straps at whatever point he may happen to be. If a thread chance to break, he shifts his rod to the left hand and stops the machine, by throwing the strap outwards upon the loose pulley.

Upon the other end of the central iron axis of the wooden shaft, *b*, there is a worm-screw, *g*, which drives the wheel, 1. In the circumference of this wheel there is a stud or pin, *c*, which, after each revolution of the reel, strikes against a bell-spring, *h*, and produces a jarring sound, announcing to the tenter that a certain measure of yarn is completed in the winding. At the right-hand end of the shaft, *i*, of the wheel, 1, is a small pinion, 2, driving the wheel, 3, to which a spiral plate, *k*, is fixed, which works against an iron bar, *l*, attached to the carriage that bears the bobbins. F F is the carriage which traverses upon rollers *m*, attached to the wooden-stretcher rails, *a*, *a*. Another roller, *n*, serves for putting a band over, which is fixed to the carriage, and suspends a weight for keeping the carriage in contact with the spiral plate, *k*.

o represents (fig. 79) the top bearing, and *p* the under or step-bearing of the spindles. These are generally old ones removed from the mules. *q* are the bobbins made fast by pressure upon their respective spindles with which they revolve. In fig. 80, three bobbins are seen in their places, the other spindles are bare. *r*, is a wooden bar fixed upon the carriage, bearing glass hooks, *s*, at its top, for guiding the thread from the bobbins to the reel.

t is a ring at the end of a cord, *u* (fig. 80), suspended from a pulley at the ceiling; the other end of the cord goes over a second pulley, at a convenient place in the apartment for hanging on a counter-weight.

As soon as the winding on of the hanks is completed, and they have been separately tied round with a string to separate and distinguish them, the hooks which keep the arm *z*, of the reel extended are loosened, the lathe, or rod, is turned inwards, all the hanks are slid by hand towards the worm-screw end of the reel, which is then lifted up out of its bearings. The tenter (a young woman) pulls down the rope, *u*, and slips the ring *t*, upon the hook, *v*, attached to the wooden shaft of the reel, which will thus continue suspended above its bearing at the full end, till the hanks are taken off it. The reel is now lowered, the ring, *t*, is unhooked, while the counter-weight at the other end of the cord lifts it to a suitable height out of the way of the machine, as shown in the figure. The arms, *z*, at each end of the reel are then made straight, and secured in that position by their hooks. The winding of a fresh series of hanks once more begins, and the spiral plate, *k*, by the rod, *l*, again makes the carriage traverse gradually in a direction parallel to the axis of the reel.

The reel strikes a check after every 80 revolutions. These 80 revolutions form a ley or rap 120 yards long; and seven of them make up a hank, equal to 840 yards, or a little less than half a mile. The size of yarn is ascertained by weighing the hanks in a kind of balance, called a quadrant, and each size is put up separately in bundles of five or ten pounds weight. The cubical packages formed in the bundling-press, are wrapped neatly in paper, and thus sent into the market.

SECTION V.

The Singeing or Gassing of Yarn.

The fine cotton yarns which are used for making bobbin-net lace-thread, and for the hosiery trade, are generally subjected, first of all, to a singeing process by the flame of coal-gas, in a peculiar machine, to free them from their loose, divergent fibres, whereby they not only acquire a more level or compact appearance, but are raised to a higher number by the diminution of their weight per hank. In this way yarn of No. 90 will become No. 95.

The machine for this purpose may be said to consist of a series of gas jet-flames, through every one of which a thread is made to traverse several times, with a velocity corresponding to the quality of the yarn. The motion is given by the revolutions of winding and unwinding bobbins, turning from 2,500 to 3,500 times per minute. After singeing, the yarn is either reeled into hanks from the bobbins, or sent to the doubling-mill.

The winding process in the gassing machine will serve to illustrate the manner in which yarn is wound from the smaller bobbins of a throstle-frame upon the larger bobbins of a warping-mill, with the addition of a contrivance for arresting the mechanism whenever a knot or foul point occurs in the thread. This modification is introduced in the gassing apparatus to prevent the flame from burning the thread when its rapid movement is thus stopped. The gas flame is, by this curious contrivance, suddenly turned aside, while the bobbin is at the same time lifted off the rotating barrel which turns it by friction, and is left at rest till the tenter female has had leisure to draw the knot through the slit, or to mend the defect. She now presses the bobbin down upon the carrier-barrel again, and restores the gas flame to its proper position under the running line of the yarn.

Fig. 81, presents an end view of an excellent

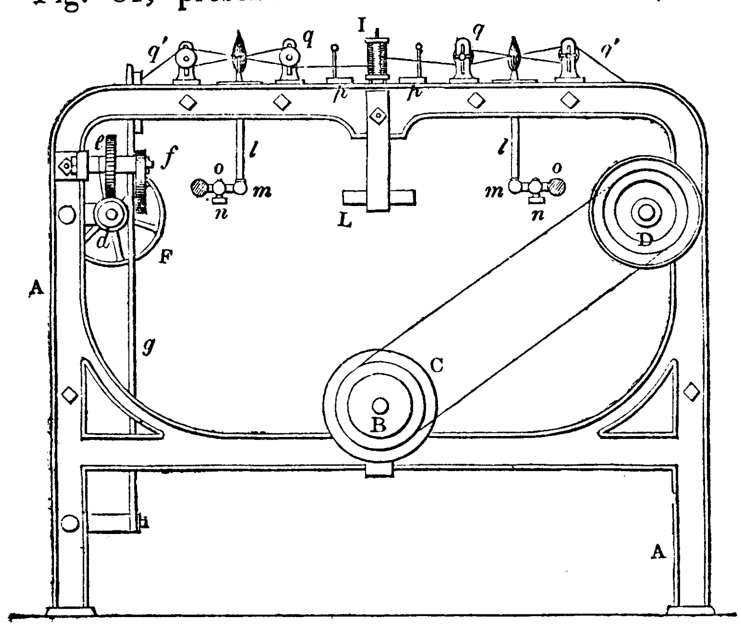


Fig. 81.—Thread Singeing or Gassing Machine. End view.
Scale, three-fourths of an inch to the foot.

gassing machine, from which it will be seen to consist of two similar sides, or to be double.

Fig. 82 is a front view, showing a portion of the machine towards both ends; the middle, being a mere repetition of the parts here represented, has been left out.

Fig. 83 is a cross section of one-half of the machine, or of one of the two working sides, drawn to a double scale, in order to exhibit more clearly the mechanism for unwinding and winding one bobbin.

The gassing machine consists of two end frames, A, A, figs. 81 and 82, and if very long, it has a similar sustaining frame in the middle also. These frames are connected by four wooden rails stretching across the top, shown in section at *a* and *b*, fig. 83; and two other beams, *c*, lower down upon the sides of the

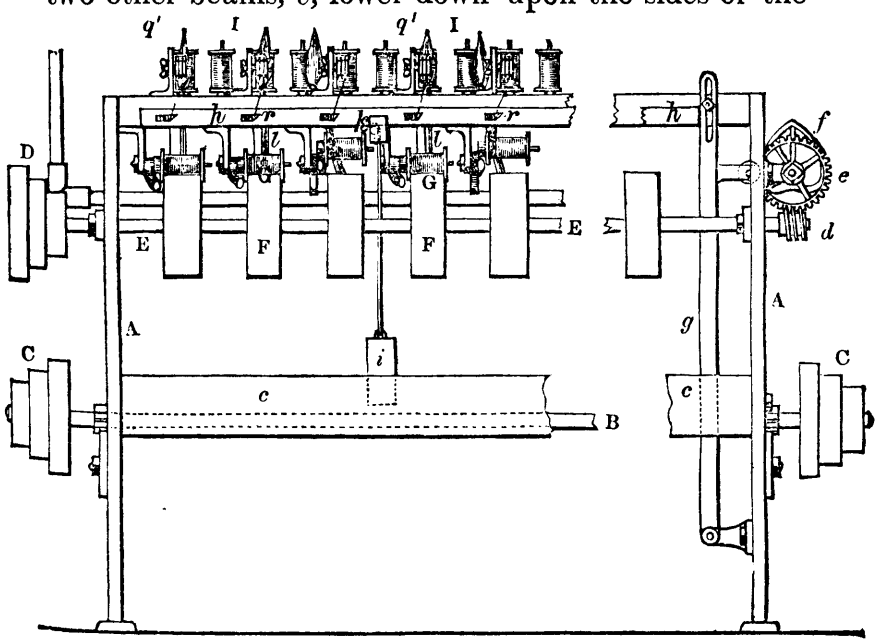


Fig. 82.——Thread Singeing or Gassing Machine. Front View.
Scale, three-fourths of an inch to the foot.

frame, fig. 82. B is a horizontal shaft driven from the mill-shafts under the ceiling of the apartment by the usual strap going over the outrigger fast and loose pulleys (not shown here). Upon each end of that shaft, B, is a threefold pulley, C, each connected by a strap with a similar pulley, D, fixed upon one of the horizontal shafts, E, E, which extends the whole length of the machine. Upon these shafts, on each side of the machine, sets of cylinders or pulleys, F, F, are made fast, which drive the winding-on bobbins laid upon them by the friction of contact with their surfaces. To these bobbins a different velocity may be imparted, according to the diameter of the pulley-groove in C and D, to which the cord or strap is applied.

G G are the bobbins; some of them resting upon their carrier-cylinders, F, in fig. 82, and some of them

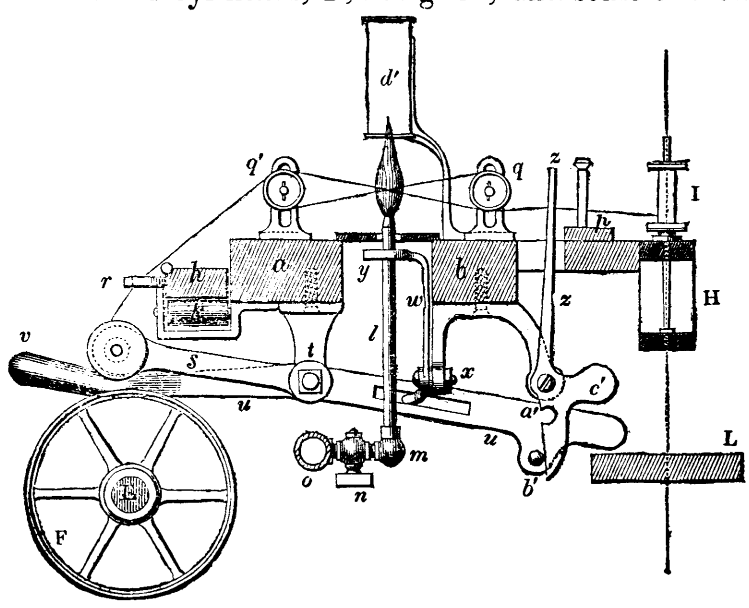


Fig. 83.—Thread Singeing Machine. Cleaning and Tricker Mechanism. Scale, one inch and a half to the foot.

suspended by being thrown out of geer, as when a knot arrests the motion of the thread.

Upon the end of the shafts, E, opposite to that where their driving-pulley, D, is fixed, is a worm-screw, *d*, fig. 82, which works into a wheel, *e*. With this wheel a heart-wheel, *f*, is connected, which revolves with the other upon the same stud, projecting from the frame. The heart-wheel presses against a roller attached to the lever, *g*, whose upper end is connected with the guide bar, *h*, figs. 82 and 83. A weight, *i*, appended to a band hanging over a little roller, *k*, fig. 82, serves to keep the bar, *h*, in contact with the heart-wheel, while the bar is shifted by the motion of the wheel, with the effect of guiding the thread from one end of the bobbins, G, G, to the other, during their rotation upon their carrier-cylinders, F, F.

The proper singeing mechanism is best seen in fig. 83. *a* and *b* are the stretcher-rails connecting the two end-frames of the machine, and forming a kind of a table; the space between them being filled with a piece of sheet-iron perforated with slits, for the passage of the gas tubes, *l*. These several upright tubes are connected by joints, *m*, with a small stop-cock, *n*, screwed into the two horizontal main gas-pipes, *o*, *o*, which extend through the whole length of the machine, and terminate in the larger gas-pipe of the factory. H is a small frame, in which are fixed top and under step-bearings of a line of spindles, equal in number to that of the winding-on bobbins of both sides of the machine. Upon these spindles the bobbins, I, are set. From these the yarn is wound off. *p* is a bar furnished with glass pegs or pins, for the purpose of guiding the threads from one-half the number of spindles to each side of the machine. *q* and *q′* are two small rollers, over which the yarn is guided to and fro in its passage through the flame of the gas jets from *l*; and they may be fixed higher or lower in their respective slot bearings, so as to place the yarn in the most suitable part of the flame.

The yarn unwound from the bobbin, I, is guided round the glass pin of the bar, *p*, it passes through a narrow slit, or cleaner in the lever, *z*, (to be presently described,) under the one roller, *q*, over the other roller, *q′*, down to the guide aperture, *r*, of the guide bar. A glass rod which is fixed to the edge of this bar, prevents its friction upon the wood.

The yarn which passes through the aperture, *r*, is thereby guided in the proper direction for distributing itself equably over the winding-on bobbins. These bobbins revolve upon a stud projecting from the end of a single armed lever, *s*, which moves freely upon the fulcrum, *t*. When the end, *v*, of the lever, *u*, *u*, is depressed, the bobbins, G, come to bear upon the rotating carrier-pulleys, F. But when the end, *v*, is raised, it lifts the bobbins, as if by a hand, out of contact with the said driving-cylinders. The long lever, *u*, *u*, moves about the same fulcrum, *t*, with the bobbin lever-arm, *s*, being bent in such a way that when its handle, *v*, is lifted, it catches under, *s*, and lifts it also. In a slot of the lever, *u*, one arm of the bell-crank lever, *w*, plays. This bent lever has its fulcrum at *x*, its other arm is upright, and embraces with its fork end, *y*, the gas-tube, *l*. *z z* is an upright very light lever, having at its upper end a fine slit, through which the thread passes, and at its under end a notch, a', for laying hold (upon occasion) of the stud-point, b'. This stud projects from the bent lever, u, near to its end.

L is a board or bench, extending the whole length of the machine; and upon it the stud-end of the lever, u, rests, unless when the stud b, is laid hold of and lifted by the notch, a', of the lever, z, z.

d' is a tube of sheet-iron, serving as a chimney over the gas flame, to prevent its flickering by cross draughts of air.

Suppose now the yarn of the bobbins, I, to be attached to the barrels of the bobbins, G, as shown in fig. 83. The attendant female depresses with her finger the handle, v, of the lever, u, and thereby raises its other and heavier end till its stud, b', entering into the notch, a', keeps it suspended in that position; whereby the bobbin, G, is allowed to press upon the rotating pulley, F, by its own weight and that of its lever, s. The bobbin immediately begins to revolve, and to wind on yarn, whilst the bell-crank, w, moved by the oblong slot of the lever, u, sets the gas-tube in the position proper for applying the flame to the thread in its passage between the rollers, q and q', figs. 81, and 83. Should a knot or rough point of the thread present itself, too large to pass through the cleaner-slit in the top of the lever, z, it will give by its swift motion a twitch to the lever, and turn it so as to release or unlock the notch in its under arm, from the stud, b, of the lever, u, u, and thus let the heavy end of this lever fall down upon the bench, L. By this movement the under short arm of the bell-crank, w, gets also a twitch from the slot in u, and this in its turn shifts the gas-tube, l, aside by the simultaneous motion of the forked end, *y* of *w*. Meanwhile the arm, *v*, of lever, *u*, being raised, lifts the lever, *s*, along with the bobbin, G, supported by the horizontal studs at its end. By these combined actions (all proceeding from the trigger jerk given to *z*, by the knot in the thread) the whole mechanism for singeing and winding that thread is thrown out of geer, or rendered inoperative.

The tenter, who is paid according to the quantity and goodness of her work, in casting her eye over the machine, sees at a glance the bobbins which are reposing above the line of their star-pulleys, F′, and having corrected the defects in the threads, sets them immediately in train with the machinery, merely by depressing the handle, *v*, which once more puts the trigger apparatus at the other end of the lever, *u*, in geer with the general driving-shaft, as above described.

SECTION VI.

Doubling and Twisting of Yarn; or the Thread Manufacture.

Cotton yarns are formed into different kinds of thread, according to the purpose which it is to serve. Thus we have, bobbin-net, lace-thread, stocking-thread, sewing-thread, &c. Two or more single yarns laid parallel and twisted together, constitute thread. Lace-thread is made always from the finest numbers of yarn, from No. 140 to No. 350. It consists of two threads twisted together by means of an appropriate machine, presently to be described. The manufacture of sewing-thread differs in nothing from the preceding, except that usually three or more single yarns are here twisted together into one. Stocking-thread is made of more or fewer yarns, according to the object of the manufacturer. All good thread should be gassed before it is taken to the doubling and twisting-mill.

This operation is improved by passing the yarns, immediately before being doubled and twisted, through a trough containing a weak solution of starch, which promotes the compactness, strength and smoothness of the thread. The twist is usually given to the doubled yarns in an opposite direction to the twist of the individual yarns in the spinning machines. It is effected by spindles and flys, like those of the common throstle. The doubling-machine is provided with one pair of rollers, similar to the drawing-rollers of the throstle, but larger in dimension, for the purpose of delivering the yarns at a measured rate to the twisting-spindles, to ensure sufficient tension and time for equable and proper torsion.

The thread is wound upon bobbins, revolving round spindles, upon the friction principle of the throstle-frame.

The bobbins rub by their under disc-end upon the copping-rail, and receive from it, by means of a heart-wheel, the usual traverse motion, up and down, for the equable distribution of the thread over their barrels.

The machine represented in the figs. 84, 85, and 86, is constructed for doubling fine yarn into lace-thread from the mule-spindle cops.

To adapt it for doubling the yarn from throstle-bobbins, nothing is necessary but to erect a frame for carrying the spindles upon which these bobbins would be set, in the place of the creel and skewers of the present machine.

Fig. 84 is the view of that end of the machine to which the motion is communicated from the mill-shaft.

Fig. 85 is one of the front views, which are similar on both faces, the machine being double, like the throstle-frame.

Fig. 86 exhibits a part of a transverse section, being an analysis of the apparatus subservient to one spindle. It is drawn upon double the scale of the other two figures.

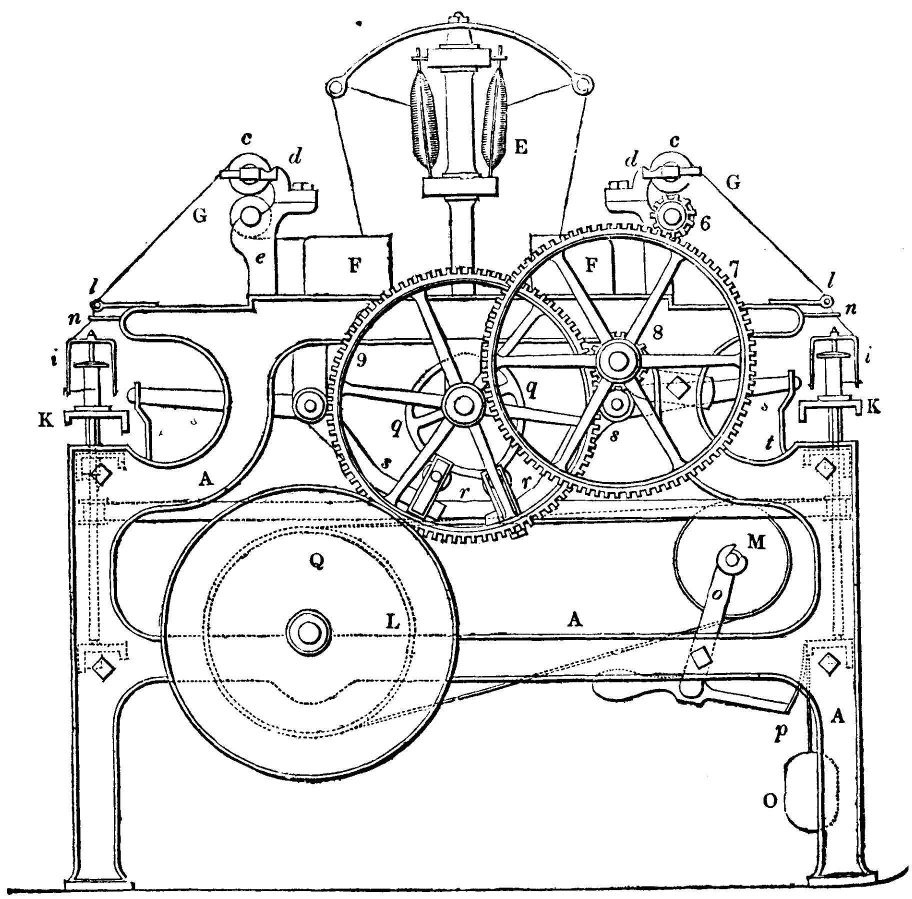


Fig. 84.—Doubling and Twisting Frame. End view. Scale, one inch to the foot.

A A are the two cast-iron end frames, connected at their tops by two beams, B, B; and upon each side by two other beams, C and D, for the purpose of carrying the bearings of the spindles.

E is the creel upon which the cops are set up in two parallel rows, one upon each side or face of the machine, the number of which cops (or bobbins) must be double, triple, &c., the number of the twisting spindles, *i*, *i*.

F F are two troughs filled with water, or very thin starch paste, through which the yarns are made to pass under a glass rod, *a*, in which are concentric grooves, to keep the yarns in one line of traction. G G are two sets of rollers, consisting of smooth iron under rollers, *b*, and light wooden top rollers, *c*; each set revolving by its iron axis in slot bearings, *d*, which are screwed upon the bearings, *e*, of the under roller. The upper rollers traverse, and consist of as many different ones as there are threads; each of them being held upon the under roller by tops sliding in vertical slots.

This pair of rollers serves, as we have said, to draw the yarn from the cops (or throstle bobbins) through the trough F, and over its rounded edge, *f*, which is covered with flannel for the purpose of wiping the superfluous moisture from the yarn, and delivering it in two parallel lines to the spindles, which twist them together as they proceed from the roller, G.

Figure 85 shows the thread first passing beneath the under-roller, *b*, then round about it, and over the roller, *c*, down to the fly of the spindle, *i*, *i*.

H H are the spindle-stems, having their upper brasses or collars, *g*, fixed in the beam, C, and their under step-bushes, *h*, in the beam D. *i i* are the flies,

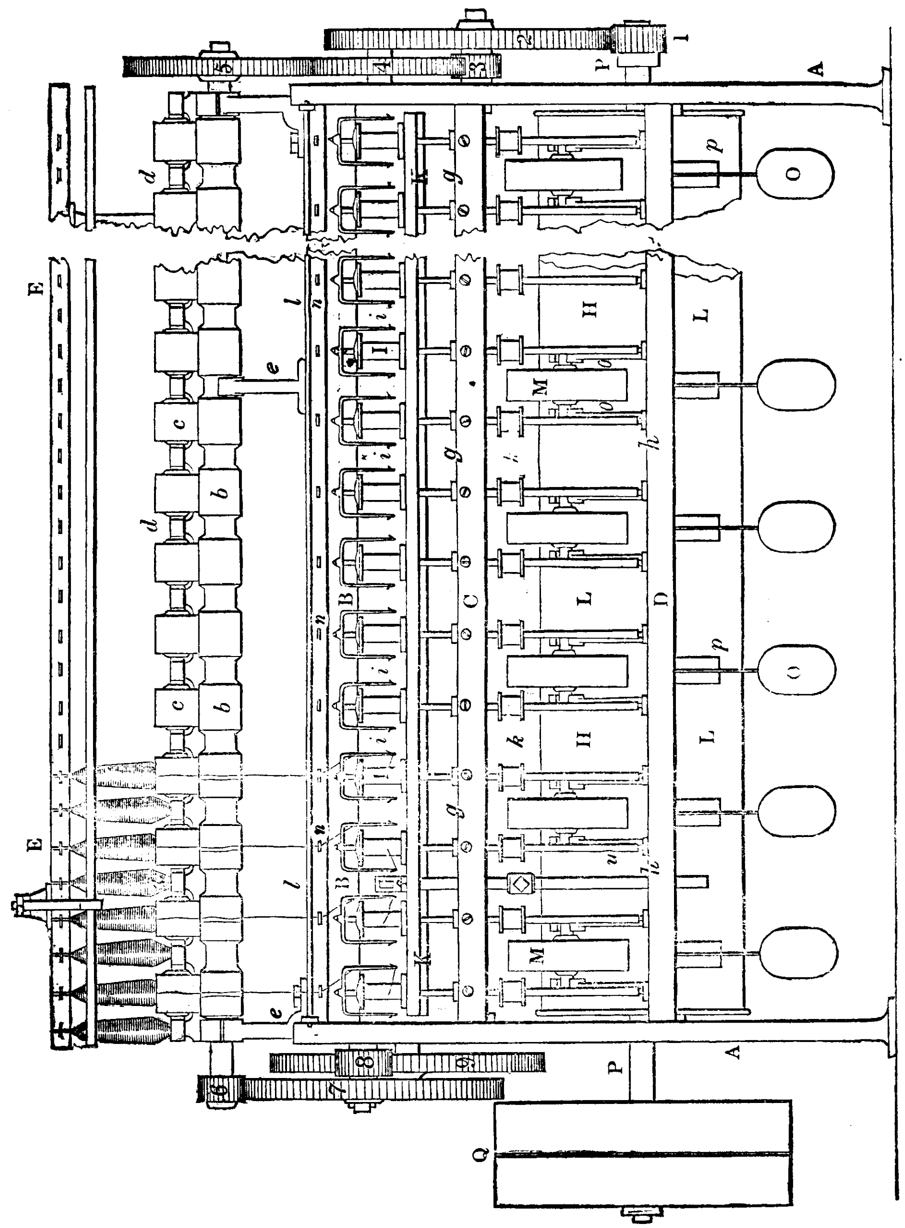


Fig. 85.—Doubling and Twisting Frame. Front view. Scale, one inch to the foot.

and *k* the wharves or pulleys upon the spindles, for making these revolve by straps. I I are the bobbins, which rest upon the copping-rail, K, K, and are moved up and down with it. *l* is a smooth wire, for the yarn to glide over. It is fixed to a rail or board, *m*, extending the whole length of the machine. *n n* are wire eyelets, through which the yarn passes in its way to get twisted underneath by the spindles.

L, fig. 84, is a large tin drum, which imparts motion to the spindles by bands or straps; one band passing round the wharves of four spindles, two upon each side of the machine. These bands are kept in proper tension by the tightening pulleys, M, M. These pulleys rest with their axes upon the extremities of the arms *o*, of bell-crank levers, whose other extremities (figs. 84 and 85 at bottom) suspend weights, O, attached to a curved plate, *p*, fixed to their points. The straps of the tin-plate drum, or cylinder, L, go first round the wharves of two spindles upon the right-hand side, thence round two upon the left-hand side, and thereafter over the tightening pulley, M, to the drum, L, as plainly shown by dotted lines in fig. 84.

The train of motions in this machine may be easily traced upon the shaft, P, of the tin-plate drum, L. Exterior to the frame-work at the end, are the usual outrigger fast and loose pulleys, Q, for driving the machine. The other end of the shaft, P, (fig. 85), bears the pinion, 1, which drives the wheel, 2, and thereby a pinion, 3, turning loose with the latter upon a stud. The pinion, 3, drives a carrier-wheel, 4, whence the motion is given to the wheel, 5, upon the iron roller-shaft. The wheel, 4, by another similar carrier-wheel, drives a similar wheel upon the iron

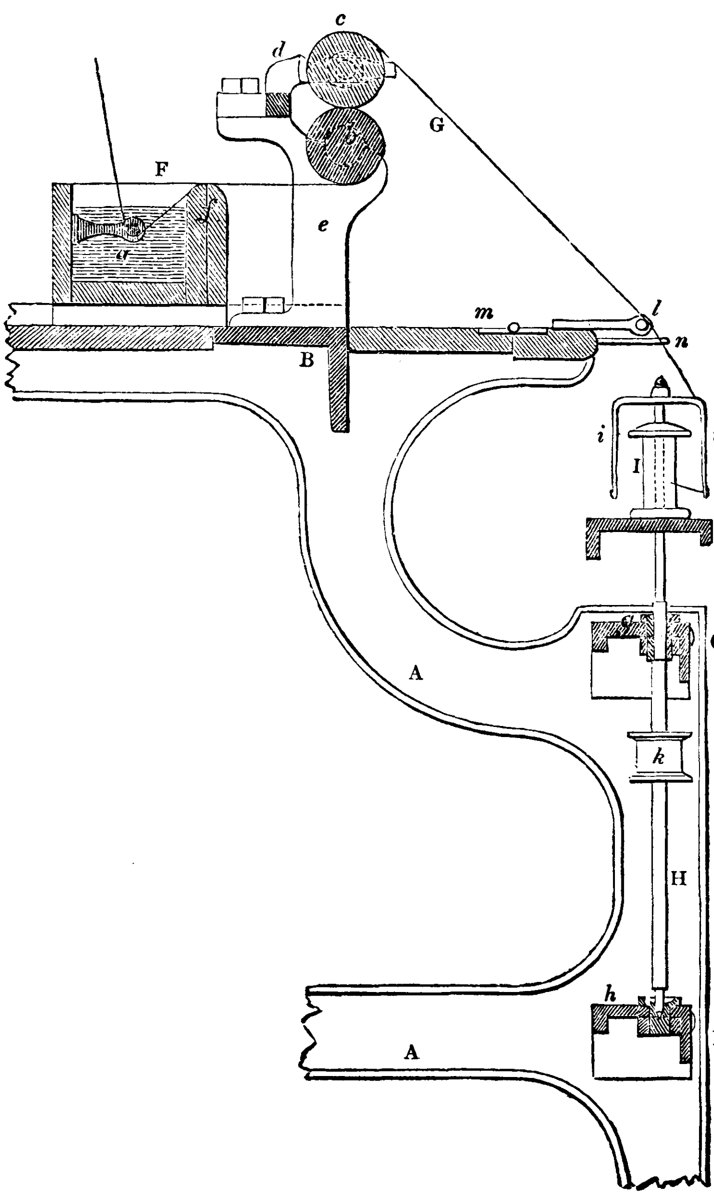


Fig. 86.—Doubling and Twisting Frame. Details of Spindle Mechanism. Scale, two inches to the foot.

roller-shaft of the other side (the latter cannot be seen in the view, fig. 85.)

Upon the end of the machine represented in fig. 84, a pinion, 6, is attached to the one roller, which drives the wheel, 7, and by a pinion, 8, on the same axis, also the wheel, 9, fixed upon the horizontal shaft that extends the whole length of the machine, for carrying several equal heart-wheels, such as *q, q*. Each of these wheels acts upon two rollers, *r, r*, attached to the ends of the one set of arms of the curved levers, *s, s*. The other arms of these levers are connected with the copping-rails, K, K, by the links, *t, t*, on each side of the machine, fixed to the rods *u*, which are screwed into the said copping-rail, and slide in the beams, C and D, fig. 85. In this way the copping-rail is made to rise and fall alternately, as the revolving heart-wheels, *q, q*, depress or elevate the arms of the levers *s, s*.

In the thread machine there are three distinct simultaneous movements; 1. That of the rollers, or, more properly speaking, the under rollers, for the upper are carried round merely by the friction of the former; 2. That of the spindles; and 3. The traverse or up-and-down motion of the bobbins.

The twist of the thread ought to be proportional to its fineness; with which view the machine is so constructed as to permit of its wheels and pinions being exchanged for others with different numbers of teeth.

It is obvious that the motion communicated to the under rollers from the main shaft, P, is retarded; while that communicated to the spindles is accelerated. Thus, for one turn of the shaft, P, or the pinion, 1, upon its remote end, the wheel, 2, will make $\frac{1}{5 \cdot 5}$ of a turn; and for one of the pinion, 3, upon the axis of 2, the wheel, 4, will make $\frac{1}{3}$ of a turn; hence the wheel, 5, of the same size as the carrier-wheel, 4, makes one turn for 16·5 turns of the steam-shaft, P. The surface of the under rollers turned at this rate by wheel, 5, is $75\frac{43}{100}$ twelfths of an inch, being 24 twelfths, or 2 inches in diameter; and therefore these rollers will deliver $\frac{75{\cdot}43}{16{\cdot}5} = 4{\cdot}57$ twelfths of an inch of thread for each revolution of P.

The drum, L, L, having ten times the diameter of the wharves of the spindles, each turn of it will give ten revolutions to the spindles. Hence while 4·57 twelfths of an inch are delivered, the spindles turn ten times round, or give ten twists to that portion, being fully 26 twists per inch.

Whatever be the number of the yarn, the traverse motion of the bobbins remains unchanged.

SECTION VII.

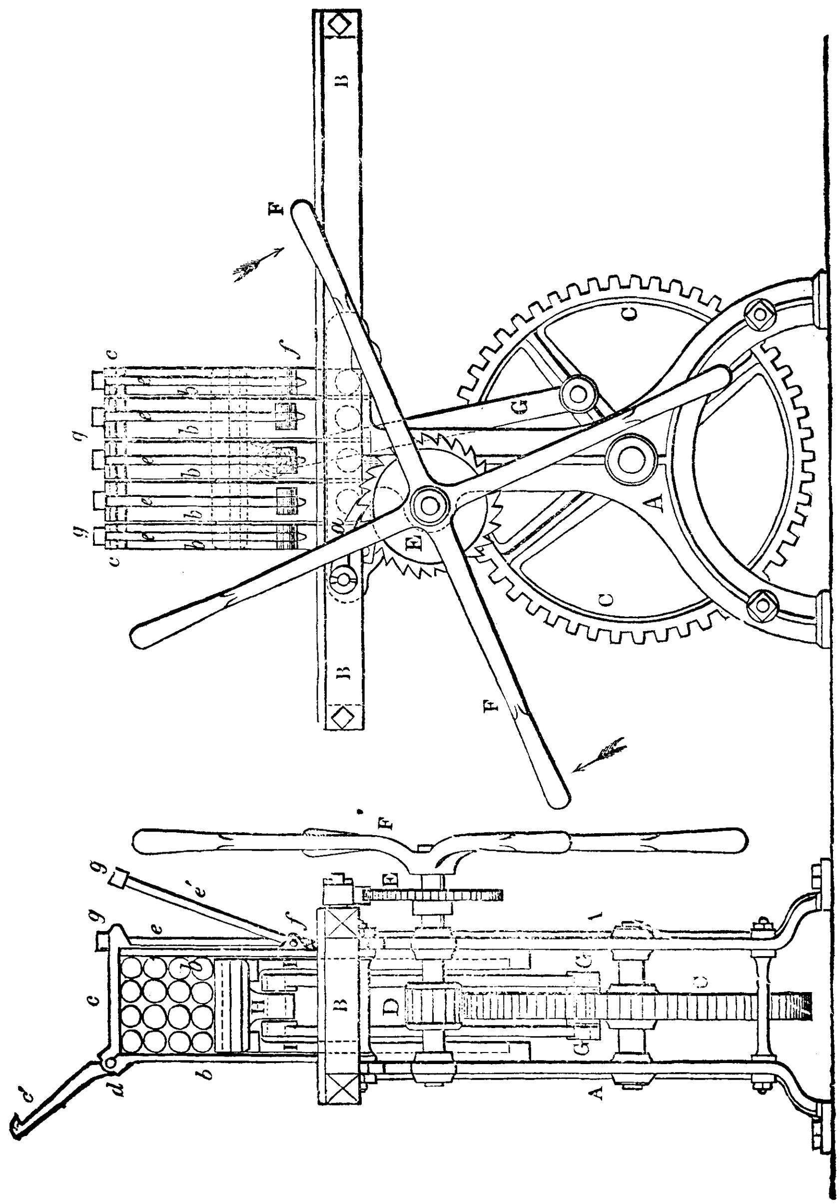
The Bundle-Press.

The object of this machine is to pack up the hanks in bundles of a few pounds weight each, and to compress them into such a moderate compass as may allow them to be transported to a distant market with little cost or risk of injury. Though small in size, the bundle-press is characterized by the same ingenuity and mechanical soundness of construction which distinguish the Manchester workmanship in general.

Fig. 87 shows the front view, or the face opposite to the station of the packer. Fig. 88 is an end view.

A A is the strong frame of cast iron.

B B is a wooden table fixed to the frame. Its



Yarn Bundle or Packing Press. Scale, three-fourths of an inch to the foot.
Fig. 87. Front view. Fig. 88. End view.

right-hand end serves for holding a quantity of yarn ready to the packer's hand. Upon the left-hand side of the table are laid the papers and twine used in making up the bundles.

C, is a wheel which is moved by the pinion, D. The pinion is fixed upon a shaft which is turned round by the arms of the cross, F. Upon the same shaft is a ratchet-wheel, E, furnished with the usual click, *a*, to arrest the shaft at the point last arrived at, by its revolution in the direction of the arrows.

Upon one of the radial arms of the wheel, C, is cast a boss, on which the two connecting rods, G, G, are fixed. The upper ends of these rods are joined by the press plate, H, which must, therefore, move upwards when the wheel, C, is turned round. In order to make the plate, H, ascend in a vertical direction, it carries two guide-bars, I, I, which move between flanges cast upon the inside of the frames, A, A.

The part of the machine by which the pressing is performed, consists of two sets of flat bars or rulers, *b, b*, &c., between which the press-plate moves up and down. Each set consists of five bars, which are screwed against the top of the frame A, but leave sufficient space between them for receiving the binding packthread or twine.

The top of the press consists of five rails, *c, c, c, c, c*, which fit the five bars of the sides. They are connected with one of these sets by joints, *d, d, d*, and are raised up to let in the yarn, and to take out the bundle. The other ends of these rails *c, c, c*, are laid upon the five front bars, and are secured in their places by rods, *e, e, e*, which turn round the joints, *f, f, f*, and are let into slits of the rails, *e, e, e*, the projecting heads, *g, g, g* of these rods preventing the rails from rising. When the pressing has been performed, the rods are pushed from the slits into the inclined position, *g, e, f,* seen in fig. 87, which they retain by means of the little tails at their bottom, which bear against the bars, *b, b.* The packer then raises the top rails into the oblique position represented in the same figure at *c′*.

The iron press-plate is covered with a smooth piece of hard wood, in which are cut grooves for laying the packthread or twine in correspondence with the spaces between the side bars, *b, b.* He lays these threads in their places, when the press-plate is at its lowest level; he then fills the space between the bars *b b* with hanks previously twisted slightly, and neatly folded together, and lowering the top rails *c, c, c,* pushes the key-rods *e, e, e* into the slits of the rails, and begins to turn the cross F so as to drive the wheel C by the pinion D, and move the plate H upwards. After having given sufficient compression to the bundle, he binds the threads together round it, after which he pushes the click out of the ratchet-tooth, when the elastic rebound of the cotton drives down the press plate to its lowest level. He now takes out the bundle, and repeats the same operations.

From the increasing magnitude of the angle formed by the acting spoke of the wheel, and the pushing rods G, G, the mechanical advantage becomes exceedingly great towards the conclusion of the pressure, and thus enables a feeble arm to form a very compact bundle.

CHAPTER V.

WEAVING.

SECTION I.—Warping-Mill.

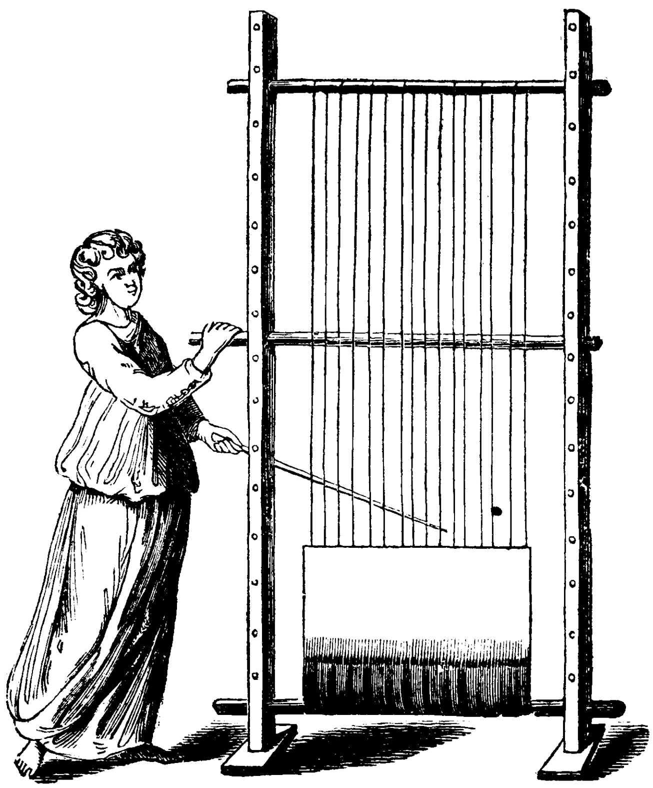


Fig. 89.——Ancient Warping Frames, from Montfaucon.

THE preparatory step to weaving is arranging the warp-yarn in truly parallel layers upon a wooden beam. This operation is effected by the aid of an ingenious machine, called the warping-mill.

The warp-yarn, as spun either in the throstle or the mule, must be wound from the small bobbins or cops, upon bobbins of a much larger size, suited to the adjustments of the warping-mill. This transfer is made by a winding-frame, very similar to that described for gassing yarn, but greatly more simple, from the absence of the singeing apparatus. In the present case, the large bobbins are laid horizontally upon rotating-pulleys, and revolve by surface friction, so as to wind-on the yarn from the smaller bobbins or cops set upright or horizontally upon skewers in an adjoining frame or creel. The threads are made to pass through glass hooks fixed upon a guide-bar, which traverses to the right and left, through a space equal to the barrel of the large bobbin, so as to distribute the yarn evenly over its surface. (See this apparatus described under the gassing machine.)

From these bobbins the yarn is next transferred to another machine called the warping-mill. Here the yarn intended to form the warp of one long web or *cut* in the power-loom is generally wound in eight portions upon eight separate rollers; from which it is united upon one roller or warp-beam in the power-loom dressing machine. By the above plan, the attendant on the warping-mill has only to watch one-eighth part of the whole yarns, from two to four thousand in number, which may go to form the entire breadth of the web; and she can, therefore, more readily recognize the particular thread which breaks, and mend it immediately, so as to preserve all the yarns of the same length.

A warping-mill of the latest and most approved construction, is represented in plate VII., figs. 1 and 2. Fig. 1 shows an end view of the machine; and fig. 2 a view seen from above, or a ground-plan. In both figures the bobbin-frame is shown only in part; the rest, being a repetition, may be supposed extended to suit any number of threads or breadth of web.

B B is the iron frame-work of the machine, upon which the three wooden rollers C, C′, and C″, rest, which guide the yarns given off by the bobbins, after they pass between the brass wires, *a*, fixed upon the wooden bar, *b*. To prevent the threads of the bobbins nearest the frame, B, from rubbing upon the bar, *b*, its edge is rounded off with a smooth wire, *c*. D, are six prismatic bars placed horizontally upon the top of the frames B, and extending right across the machine.

E are plates cast on the frame-work, having upon their inner surfaces six upright ribs corresponding with the bars, D; the breadths of the latter being equal to the intervals or square channels between the said ribs. *d* is another guide for conducting the yarn, consisting also of upright wires, like a comb, between which the threads pass.

F is a small roller to support the weight of the yarn, and to prevent its rubbing upon the bars, D and *d*, in its rapid motion to the winding-beam, or yarn-roller, G, shown by dotted lines in plan (fig. 2). Upon its ends, at a distance asunder suited to the breadth of the yarn-roll, are two light cast-iron plates, *e*, *e*, which are furnished with a projection that fits into a longitudinal groove in the wooden roller, and may be thus shifted farther in upon the roller, according to the breadth of the spread yarn. The tooth or feather of the end plate, by entering the groove cut in the roller, is prevented from slipping round upon it.

The warp-beam, G, lies with its iron axis in two slots of the brackets, *f*, *f*, made fast to the cross-frame piece of the frame, B, and presses upon the roller, H, with its whole weight. This roller is made of wooden spars, screwed upon the circumference of several iron rings wedged upon a shaft, so as to form a hollow cylinder. The wood is then covered with flannel, upon which the warp-roller is laid.

This roller, H, lies with its axis in bearings attached to the frame B, and carries at the one end the usual fast and loose pulleys I, by which it receives motion through a strap, from a pulley on the mill-shaft, and imparts that motion to the roller G by surface friction.

Upon the shaft of the roller H there are two wheels, K, K, which enable the attendant to turn backwards the roller H, and thence also the yarn-roller G, in case a thread should break and its end should run on. It is necessary, however, first of all, to detach the warping-mill from the driving-shaft of the factory, by shifting the strap upon the outrigger loose pulley at I. To facilitate the throwing the machine out of geer in a moment, there is a fork, *g*, at the bent end of a bar, which extends across the frame, and presents a handle at *h*, for shifting the strap and arresting the movement.

The working of this machine will hardly need any minute elucidation. The yarns proceeding from the bobbins at A go over the roller C, under the roller C′, and over the roller C″, thereby bringing the threads of all the bobbins into one horizontal plane. They pass thence over the bars D, through between the guide wires *d*, *d*, wind over the roller G′, as it revolves by friction of contact with the rotatory roller H, its axis being at liberty to rise in the slots of *f*, *f*, in proportion as the diameter of the barrel increases. For the purpose of showing the threads more plainly, the whole of the machine is painted black, so that the warper sees at once if there be a deficient white thread upon the dark ground. She immediately stops the mechanism, takes up one of the six smooth prismatic rods out of the grooves in the brackets *i*, *i*, and lays it down across the yarn in the interval between the two farthest bars D, so that the ends of the rods lie between the ribs of the side plate E. She then turns the roller G back, by acting with her hand upon one of the wheels K, K, and thereby causes the yarn to wind off, the slack of which immediately falls down in doubled threads under the weight of the iron rod between two contiguous ribs of the side plate E, like a window casement sliding down in its side grooves.

If still she cannot recover or reach the broken end of the thread, she places another of the smooth rods in the next partition of the bars D; which, descending in the cell, carries before it another double length of the yarns, as they are uncoiled, by the retrograde motion given to the roller G. The warper goes on to recal the wound-up yarns in this manner, without any possibility of ravelling them, or affecting their parallelism, till she finds and repairs the broken ends. The roller G must now be turned slowly forwards till all the prismatic rods be lifted from the ground, and disengaged from the travelling warp, when they are restored to their grooves in the brackets *i*, *i*. The strap is next shifted upon the fast pulley at I, and all moves smoothly once more, till another thread chances to break. As the bringing back of the broken ends is an irksome process, which loses time, and impairs her wages, it is a lesson which inculcates vigilance in no common degree.

The warp is now ready to be transferred to the dressing machine.

SECTION II.

The Dressing Machine.

Consists of the following principal parts, 1. The frames for carrying the rollers which have been filled with yarn upon the warping machine. Generally eight rollers are used to compose a warp, and they are arranged in two sets at the opposite ends of the machine.

2. The sizing apparatus in which the warp-yarn of four of the said rollers passes between two cylinders, one of which is immersed in a trough with size. Whilst, therefore, the lower cylinder gives size to the yarn, the upper one squeezes out the superfluous quantity of the paste.

3. The part of the machine where the paste is rubbed into the fibres of the yarn, and smoothed over by means of brushes. In this part the machines differ from each other, according to the kind of brushes that are used. In some dressing machines, two cylinders covered with brushes, one over, and one under the warp, revolve in a contrary direction to that of the yarns. In another sort of dressing machines, two flat brushes, one over and one under the warp, are moved to and fro in such a way that they touch the yarn only in one direction of their movement. It is obvious that, in the latter kind of machines, the yarn can be damaged only upon the first entering of the brushes (which, however, is performed very gradually), whilst in the cylindrical, the revolving bristles are constantly apt to rub and tear the delicate threads.

4. The drying of the size in the warp is performed by passing it over a box or chest filled with steam. In addition to the steam-chest, a fan is used for changing the air, and thus promoting a quick evaporation.

5. The last operation which is done in this machine is the winding of the warp upon the main yarn-beam, which is to be put into the loom. The two parts of the warp which have till that time been worked separately on either end of the machine are united here, and carried through a reed to produce a regular winding upon the yarn-beam. The revolving of the latter is the cause of the warp's travelling from the eight yarn-beams through the five operations just mentioned.

The dressing-machine is shown in a longitudinal view in figs. 1, 2, 3, and 4, plate VIII. The drawing contains one end of the machine, in which one half of the warp is prepared, and the middle part of it, where both parts of the warp are united and wound up together. The other end of the machine is exactly the same as that represented, and therefore is left out to reduce the size of the engraving. Figs. 1, 2, 3, and 4 represent all the essential parts of the machine which will be mentioned in the following description.

A, A is one of the frames which carry the yarn rollers B, B, B, B, as prepared at the warping mill. The rollers can be fixed at successive heights in order to make the yarn from the rearmost rollers clear the front ones.

The yarn of all the four rollers (which contain different numbers of threads according to the various breadths and fineness of the cloth to be woven,) is carried through a warp reed, *a*. This reed is formed, as in general, (see fig. 2,) of brass wires, but much stronger, and with wider intervals than those commonly used in weaving. Behind the reed *a* is a small roller, *b*, which revolves by the friction of the travelling warp, and serves to collect the yarn of all the beams in one horizontal plane.

C is a large wooden cylinder immersed in a wooden trough, D, which is filled with glue, paste, or starch. This cylinder is pressed by another smaller one, E, of iron, which is covered with cloth; by drawing the warp forward, and thereby turning the cylinders C and E, the latter squeeze out the superfluous part of the size which had previously been raised from the trough by the surface of the former roller. As the weight of the cylinder C is very considerable, and would therefore produce too much friction to be safely turned by the travelling warp, its shaft, instead of lying in bearings, turns upon friction-rollers, *c, c*. From the sizing cylinder C the warp travels in the direction marked *d, d, d*, thus passing through the reeds *e, e, e*, under the lathe roller F, through what are called the heddles G, and through the large reed H to the yarn-beam I. The other half of the warp on the other end of the machine, comes in the direction *d′, d′, d′*, passes under the roller F′, through the same heddles *g*, and reed H, to the said yarn-beam I, which is similar to those used on the warping machine. To prevent the threads from sticking together, and to make it easier for the dresser to mend any broken ones, the warp is separated by the wooden rods *f, f, f*, (called lease-rods.)

K is a box constructed either of deals or sheet iron, and screwed to the frame L of the central part of the machine. In this box, and upon two slender beams, Z, which connect the frames L and A, are sheet-iron cases, M and M′, (see the dotted lines in the figure,) which are supplied with steam from a main pipe, which serves, at the same time, to heat the room.

N is the main shaft which goes across the machine; on the end of which are three pulleys, a fixed and a loose one, O, to give motion to the machine from the shafts, and a third pulley, P, to drive the fan Q.

The said shaft N has two cranks in the centre of the machine, which stand at right angles to one another, the use of which will be explained hereafter. On the shaft N there is also a conical pulley R, which corresponds with a similar one, S, set in the reverse direction of the former. Hence, by moving a strap from the small diameter of the pulley R to its larger diameter, and at the same time, from the larger diameter to the smaller of the pulley S, the velocity of the cone S will be gradually increased, and by moving the strap in the contrary way it will be decreased, whilst the shaft N continues to revolve with equal velocity. The movement of the said strap is effected by turning a handle, *g*, on the other side of the machine, and shifting, by means of a screw, the guide *h*, which keeps the strap at the place deemed proper by the dresser. On the short shaft where the cone S is fixed, there is also a small pinion (not seen in this view of the machine), which works in the wheel *i*. Fixed to *i* is a bevel-wheel, *k*, which drives another such wheel, *l*, fixed upon a shaft sloping upwards, *m*, seen only in dotted lines, as those parts last mentioned are attached to the other side of the machine. This shaft *m*, by means of two bevel-wheels, *n* and *o*, drives the yarn-beam I, as is represented in fig. 4. The wheel *o* moves between two bearings, with its shaft *p*, which can be shifted through the boss of the wheel, according to the length of the yarn-beam which is to be put into the machine. When the yarn-beam which lies with its other end in the bearing *q* has been put in a hole made for that purpose in the shaft *p*, fig. 4, the wheel *o* is screwed fast upon the shaft, and is now able to turn the beam by means of *r* and *s*.

By the revolving of the yarn-beam I, as just described, the warp is drawn from the rollers B, B, B, B, in the directions *d, d, d,* and *d′, d′, d′*, and wound upon its surface so as to increase its diameter, and, of course, the velocity with which the yarn is drawn in through the operation, and thereby it would prevent its getting dried before it is wound on the beam. The cones R and S are contrived so as to obviate this inconvenience. From them the motion is given to the wheels and shafts already described, and to the yarn-beam I. As soon as the dresser observes that the warp is not perfectly dried, he decreases the velocity of the machinery by turning the handle *g*, and moving the strap which turns the cone S towards the smaller diameter of the cone R. If he finds that he could work the machine a little quicker, he turns the handle the other way.

Q is a fan of three wings, working between the two halves of the warp which come up from the two ends of the machine.

By drawing the hot air from underneath the steam-boxes M, M′, and blowing it against the expanded warp, it serves very powerfully to dry it. This is an arrangement which has been lately adopted.

The fan Q is put in motion by a strap which comes from the pulley *t* to the pulley seen under the letter *u*.

With the first one is connected another pulley *v* (seen in the figure only in dotted lines), which is put in motion by a strap from the large pulley P, P, on the shaft N. On the shaft of one of the rollers F′, which are made of single lathes to prevent the sized yarn from sticking to them, is a worm working in the wheel *w*, which strikes, after each revolution, against a bell, in order to indicate the quantity of warp wound upon the beam I. This point is marked by the dresser with a line of coloured paste.

In order to wind on the yarn evenly between the two side plates of the yarn-beam, the reed-frame (that is, the frame into which a very broad reed, made with long wire, is put), and through which the yarn passes just before it is wound upon the yarn-beam, can be moved a little to the right or left by means of a handle, *y*, which moves a screw working in a nut attached to the said frame. This lies upon two pieces of wood screwed against the frame, L, of the machine. The heddle-frame *g*, which also lies loose upon two such pieces of wood, is adjusted to the former, in order to give as little friction to the yarn as possible. *See* fig. 4.

It remains now for us to give a description of the brushing apparatus, which has not hitherto been mentioned, because it is an addition not absolutely necessary, but a good assistance in producing a well-dressed warp. In the machine here represented, the rectilinear system of brushing has been adopted.

A′ and B′ are brushes like that represented in fig. 3, the one working on the top, the other from beneath, against the warp; both are fixed with the ends upon iron bars, C′, which work in joints, *a*′ and *b*′, upon the levers E′ and D′. The lever D′ moves round a bearing, c', fixed to the floor. The other lever E', however, has its bearing on the end of an arm, H', which is fixed to the end of a shaft, e'. Upon the centre of the shaft is fitted another lever, G', the end of which is connected by a long rod, I', with the first crank in the shaft N mentioned before. The other crank of this shaft, which moves ninety degrees from the former, is connected by a similar rod, H', with a bearing attached to pieces connecting the levers E' of the two sides of the machine.

f' is a counter-weight working upon the shaft e' to balance the weight of the brushes. It will now be perceived that by moving the crank-shaft N from the position the drawing shows it in, the first crank will move the lever G', depress E', and of course also gradually depress the brush A' upon the warp, whilst the other one B' is gradually lifted up against it (the bar C' turning upon the joint b').

At the same time, however, the second crank is drawing the frame E' and also the bar C' forward, in the same way as a weaver used to apply the dressing by hand upon the warp in the loom. When the cranks have moved through 180 degrees, the brushes will have left the warp, and will move backwards at som distance above and beneath the warp, without touching it.

SECTION III.

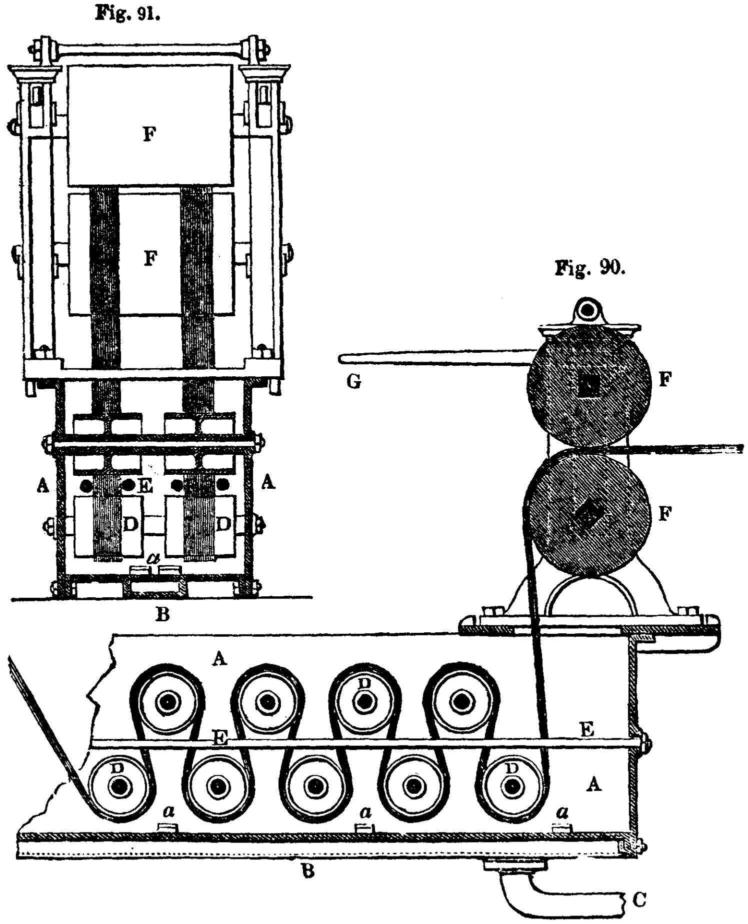
The Sizing Machine.

Instead of the dressing machine, in which a small quantity of paste is applied to the surface of the yarn, and is rubbed in between the fibres by means of brushes, there is now sometimes used a very simple apparatus to impregnate the yarn with size.

It is a fact well known, particularly to dyers, that stuffs are not well penetrated by a fluid, &c., if they are not alternately immersed in the fluid, and then squeezed out again, for the purpose of expelling the air contained in the fibrous matter. With this view, the sizing machine has been constructed, which consists of a large trough filled with size through which

Fig. 91.

Fig. 90.



Lillie's Sizing Machine.—Scale, half an inch to the foot.

the warp is drawn, but, instead of passing it simply through the fluid, it passes over a set of rollers which turn by the friction of the travelling warp. This motion, by which the warp is pressed tight upon the rollers, and left loose again in the space between every two of them, effects a complete impregnation of the fibres of the yarn.

The sizing machine is represented in the annexed figures. Fig. 90 is a longitudinal section, in which there are represented only nine of the rollers, instead of twenty and more as are generally used.

Fig. 91 shows a cross section of the same machine by which it will be perceived that two different warps are managed in the machine at the same time.

A, A, is a trough of cast-iron plates screwed together, having the joints secured with cement. To the bottom plate is cast, in the direction of its length, a channel, B, which serves as a steam case, and which communicates with the inner trough by the openings *a, a, a.* These openings are covered with small valves, which are lifted by the steam coming from the pipe C in the channel B, which, however, prevent the fluid contained in the trough from entering the steam pipe, if this should be empty of steam. D, D are very light cast-iron pulleys or rollers, which revolve upon rods, screwed across the trough. They are arranged in two rows one over another, to make the warp travel up and down. Between these two sets of rollers, and through the length of the trough, are fixed two rods E, E, for either of the warps, as will be seen in the section, fig. 91. They are about four inches apart, and serve to keep the warp in the centre of the rollers D, D, whilst it is travelling from one end of the machine to the other, and remaining constantly immersed in the fluid which fills the trough to about two inches under the upper edge.

After having passed all the rollers D, D, as is seen in fig. 90, the warp is squeezed between two large wooden rollers F, F, which are pressed together by weights suspended at the levers G.

The superfluous moisture is here expelled, and runs back into the trough, whilst the warp is led either over the cylinders of a drying machine, like those used for the drying of dyed or printed goods, or it is wound up in a bundle, and carried into a hot room. The better plan would be to let it pass over the rollers of a hot flue, winding the end of the warp direct upon the yarn-roller, after the threads have been first drawn through a reed.

An eminent manufacturer at Hyde makes the paste for dressing his warps in the following way.

Of Calcutta flour, at 14*s*. per cwt., 140 pounds are put into each paste-tub, whose average depth is 20 inches, and width 30 inches. The tub is filled up to nearly the brim with cold water, and the materials being well mixed, are left alone for three days. The glutinous matter which collects at top is skimmed off; the mixture is now run down into a cylindric vessel of cast iron, in which vanes are made to revolve by a vertical spindle, so as to triturate the whole well together, while steam is admitted from a pipe which dips down near to the bottom. The paste being boiled in this way for an hour, is then run off into casks, in which it is left during three weeks; at the end of this time, it is smoothed or levigated by being forced hrough between two rollers revolving almost in contact with each other, at the bottom of a pyramidal hopper, into whose wide mouth the paste is ladled.

Mr. Lillie's sizing machines will dress a length of warp of upwards of one mile in the course of an hour. Each drying cylinder in the steam range makes 20 turns in the minute, with a diameter of 18 inches, or a circumference of $4\frac{1}{2}$ feet; but $4\frac{1}{2} \times 20 = 90$ feet per minute $= 5{,}400$ per hour $= 1{,}800$ yards. A common dressing machine does 10 pieces or cuts of 60 yards each in a day; which is at the rate of 3,600 yards in a week.

One of these machines made by Mr. Lillie for Mr. Waterhouse, an eminent manufacturer near Manchester, dresses, in 12 hours, 100 warps, each 370 yards long, which is no less than 37,000 in that time, being at the rate of 3,083 yards per hour, or $1\frac{3}{4}$ mile.

CHAPTER V.

Weaving.

Weaving is the art of making cloth by the rectangular decussation of flexible fibres, of which the longitudinal are called the warp or chain, and the transverse the woof or weft. The former extends through the whole length of the web, the latter only over its breadth. The outside thread on each side of the warp, round which the woof-thread returns in the act of decussation, is called the selvage or list.

In the earliest records of man we find this indispensable, though now vulgar, art, mentioned with the highest honour; thus, in the book of Exodus, we read,—"With wisdom to work the work of a weaver;" and in the most ancient of books, one of its implements is elegantly used to illustrate a moral apothegm,—"My days are swifter than a weaver's shuttle."—*Job.*

The art of weaving is more ancient than that of spinning, for the first cloth was, no doubt, akin to what we call matting,—a texture formed by the interlacement of woody fibres, and of grasses of various kinds, as is still executed by several of the South Sea islanders. At the period of Captain Cook's voyages, most of them were strangers even to that rude art, for they made their cloth by cementing or stitching shreds together, rather than by any kind of decussation.

It was the art of spinning, however, which first gave value to the art of weaving, properly so called, by supplying it with threads of any desired length, strength, and flexibility, to be worked up into a cohesive and durable web. The cultivation of flax, and the conversion of its tough fibres into clothing, were known at a very remote period in Egypt; and we perceive, from the story of Penelope's web, how highly the art of weaving was esteemed in the heroic ages of Greece. It was long, however, before it spread into western Europe; for when Julius Cæsar invaded Great Britain, he found our ancestors unacquainted with the loom. The Romans introduced this implement along with the other arts of civilization, and soon succeeded in establishing its use extensively among their English subjects; for the "Notitia Imperii" makes mention of an imperial manufactory of woollen and linen cloth at Winchester, for the use of the Roman army. The art of weaving, however, must have advanced much more rapidly among our neighbours on the Continent than in this kingdom; for a great part of the British wool was for a long time exported in the raw state, and brought back from the Low Countries in the form of cloth.

There is a curious allusion to fancy weaving in Bishop Aldhelm's book concerning "Virginity," written about the year 680. "It is not a web of one uniform colour and texture, without any variety of

Fig. 92.—Representation of ancient Distaff Spinsters, from Montfaucon.

figures, that pleaseth the eye, and appeareth beautiful, but one that is woven by shuttles, filled with threads of purple, and many other colours flying from side to side, and forming a variety of figures and images in different compartments, with admirable art." One of the most curious specimens of this ancient figure-weaving and embroidery now extant, is that preserved in the cathedral of Bayeux. It is a piece of linen nineteen inches in breadth, by sixty-

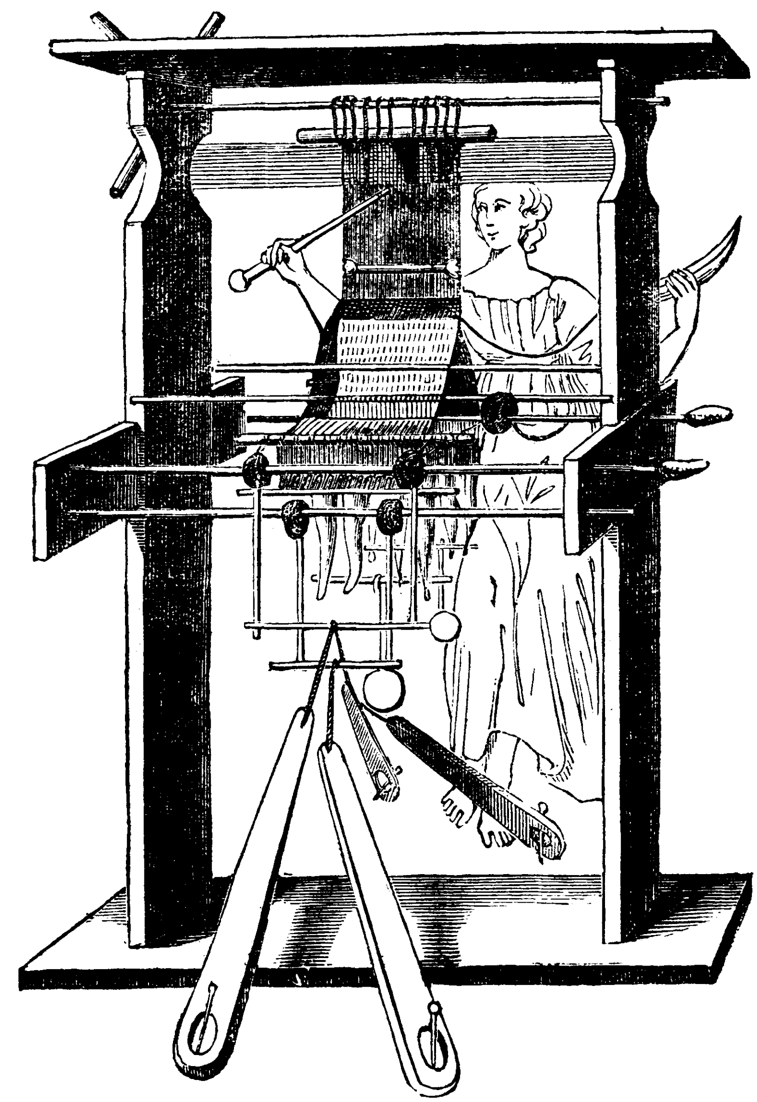


Fig. 93.—Ancient Loom, from Montfaucon.

seven yards in length, and contains the history of the "Conquest of England by William of Normandy;" beginning with Harold's embassy in 1065, and ending with his death at the battle of Hastings in 1066. This extraordinary piece of work is supposed to have been woven by Matilda, Queen of William the Conqueror, and the ladies of her court; but it is indebted for what beauty it possesses, much more to the labours of the needle, than of the loom.

From the few monuments which exist of ancient weavers, it is not easy to form a distinct idea of the manner in which they formed their woollen and linen cloths. If we judge from the figures still extant of the fourth and fifth centuries, this art was one of extreme simplicity. We there see some women spinning, others smoothing out the web. Those who weave the tissue are represented standing.

"In the ancient "Virgil of the Vatican," supposed to be a manuscript of the fourth century, and which formerly belonged to the monastery of St. Denys, in France, a woman is exhibited at work on a piece of cloth; she is in an upright position, and makes use of a long rod for a shuttle, fig. 93. I leave it to the skilful in weaving to explain this mode of proceeding. Another manuscript of the "Bibliothèque du Roi," which is a commentary on the book of Job, has a figure of a weaver at work on his web; and he also is standing. Although this manuscript be only of the tenth century, the figures are copied from more ancient manuscripts; for, according to an ancient commentator, the oldest copies of the book of Job possessed these painted images, which have been transmitted in the later copies."—*Montfaucon*, iii. p. 358.

At so late a period as the year 1331, weaving was so little understood in England, that the arrival of two weavers from Brabant is recorded in the chronicles among the important events of the time. But it was the religious persecutions of the Duke of Alva which first gave importance to our cloth manufacture, by driving crowds of Flemish weavers to seek a home in this country. What one bigot had begun, another completed. Louis XIV., by his revocation of the Edict of Nantz, in 1686, caused the expulsion from France into England of about 50,000 of the best French manufacturers, many of them eminently skilled in the weaving of silk and other fine fabrics.

Fig. 94.—The Weaver, with his Wife fetching Woof, as figured in Schopfer's Panoplia—Frankfort on the Maine, 1568.

The process of *warping* always precedes weaving. Its object is to extend the whole number of threads, which are to form the chain of the web, alongside of each other in a parallel plane. As many bobbins are taken as will furnish the quantity of thread required for the length of the piece of cloth. The bobbins are usually one-sixth the number of all the threads, and are mounted loosely on spindles in a frame, so that they may revolve, and give off the yarn freely. The warper sits at A, fig. 95, and turns round the reel B, by the wheel C, and rope D. The yarn on the bobbins is seen at E. The slide F rises and falls by the coiling and uncoiling of the cord G, on the shaft of the reel H. By this simple contrivance, the band of warp-yarns is wound from top to bottom,

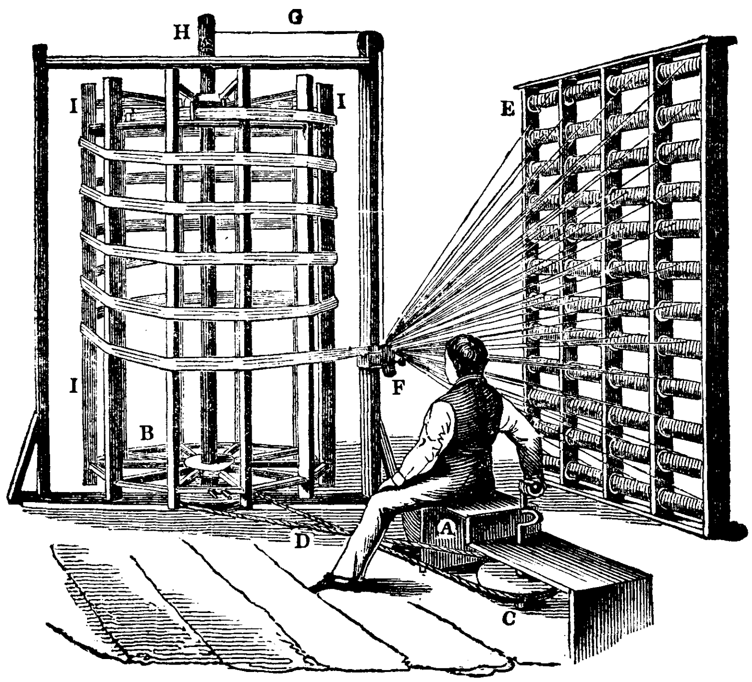


Fig. 95.——Hand-warping for the Muslin-weaver.

spirally, round the reel. I, I, I, represent wooden pins, similar to those used in peg-warping.

Most warping-mills are of a prismatic form; and have twelve, eighteen, or more sides. The reel is usually about six feet in diameter, and seven feet high, and serves to measure accurately, on its circumference, the length of the warp. It may be turned either way by a rope moved by the trundle C, which is actuated by the warper's hand. At E, is the frame to contain the bobbins, the threads from which pass through the heck placed at F. This now consists of a number of finely polished and hard tempered steel pins, with a small hole at the upper part of each to receive and guide one thread. The modern heck contains two parts, either of which may be lifted by a small handle below, and the eyes of each are alternately placed. Thus, when one is raised, a vacancy is formed between the threads, and when the other is raised the vacancy is reversed. By this the lease is formed at each end of the warp, and this is preserved by appropriate pegs. These being carefully tied up, give the rule for the weaver to insert his rods. The warping-mill is turned each way successively, until a sufficient number of threads are accumulated to form the breadth wanted. The warper's principal care is to tie immediately every thread as it breaks, otherwise deficiencies in the chain would exist, highly detrimental to the web, or productive of great inconvenience to the weaver. The box which contains the heck slides on an upright rod, as shown in the figure.

The simplest, and probably the most ancient, loom is the Indian. It consists of two bamboo rollers,—one for the warp, and another for the woven cloth, and a pair of heddles for parting the warp in the decussation of the woof. The shuttle performs the double office of shuttle and lay for driving home the parallel yarns. It is made like a large netting-needle, and rather longer than the intended breadth of the cloth. The Tanty carries this rude apparatus to any tree

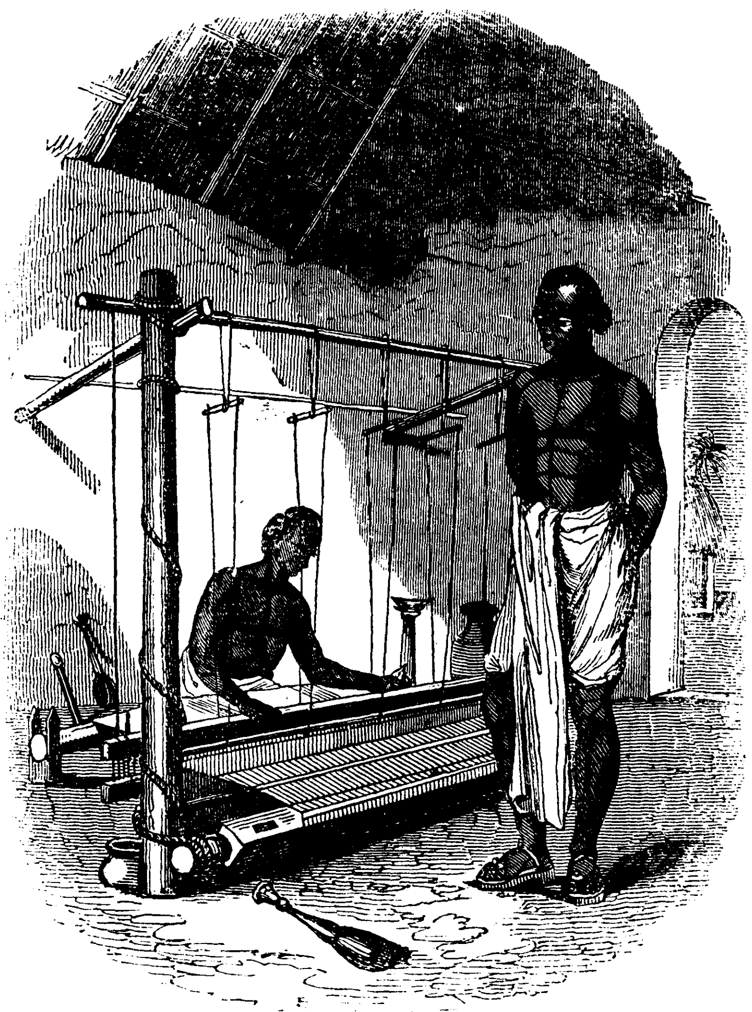


Fig. 93.—Indian Tanty, from a Plate in Solvyn's "Hindoos."

which may afford a comfortable shade: here he digs a hole large enough to receive his legs and the lower part of the geer or treddles; he then stretches his warp by fastening his two bamboo rollers, at a proper distance from each other, with pins into the turf; the heddles he fastens to some convenient branch of the tree overhead; he inserts his great toes into two loops under the geer to serve him for treadles; he finally, sheds the warp, draws the weft, and afterwards strikes it up close to the web with his long shuttle, which thus performs the office of a batten.

Fig. 97 exhibits our loom in its plainest state. The

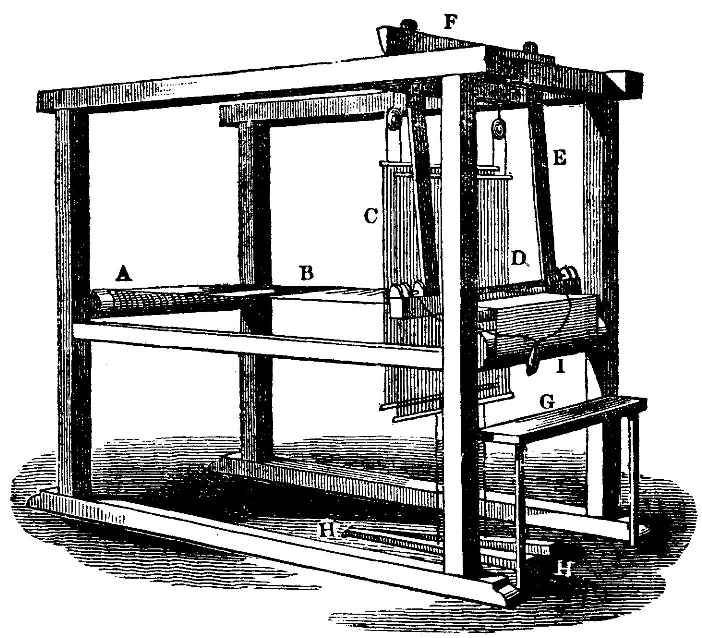


Fig. 97.—Common Fly-shuttle Loom.

warp is wound about the beam A; the lease is preserved by the rods at B; and the two heddles or healds at C, consist of twines looped in the middle, through which loops the warp-yarns are drawn, one-half through the front heddle, and the other through the back one. The yarns then pass through the reed under D, fixed in a movable swinging frame E, called the batten, lay, or lathe. This lay is suspended to a cross-bar F, attached to the upper part of the side uprights, so as to vibrate upon it. The weaver sits on the board G, presses down one of the treddles at H with his foot, which raising one of the heddles and sinking the other, sheds the warp by lifting and depressing each alternate thread a little way: a pathway is thus opened for the shuttle to traverse the warp. The weaver holds the picking-peg I, in his right hand, and by a smart jerking motion drives the shuttle swiftly from one side of the loom to the other, between the warp-yarns. The shuttle having left behind it a shoot of weft, between the reed and the weaver, he now pulls the lay, with its reed, towards him with his left hand, so as to drive home the weft-yarn to the web, made by the preceding casts of the shuttle. The cloth is wound upon the cloth-beam over I, in proportion as it is wove.

An accurate representation of the most improved kind of shuttle, furnished with friction wires, is given under power-loom weaving, page 296. As the shuttle darts across the warp, the weft-yarn uncoils from its cop or pirn, and runs through a small hole in the side of the shuttle.

The mode of throwing the shuttle by the jerk of a picking-peg and cord is a great improvement on the old way of throwing it from the hand. It was invented in the year 1738 by Mr. John Kay, a native of Bury in Lancashire, who was at that time resident in Colchester. It enabled the weaver to make nearly double the quantity of cloth in the same time, and of any requisite width.

One might imagine that the author of this elegant invention, so well calculated to lighten the drudgery, and facilitate the gains of his fellow operatives, would have obtained favour in their eyes, at least, if not some recompense; but, alas! Kay shared the too-common fate of the real benefactors of his race. He was persecuted as a dangerous innovator, who, in showing how brute labour could be spared, might possibly diminish the demand for workmen. He was driven by cabals and mobs from his native land,—forced to live and die a sad exile in Paris.

John Kay brought this contrivance to his native town in the above year. It was adopted by the woollen weavers immediately, but was little used by the weavers of cotton goods before the year 1760. In that year Mr. Robert Kay, of Bury, son of the preceding, invented the drop-box, by means of which the weaver can, at pleasure, use any one of three shuttles, each containing a different coloured weft, without the trouble of removing them from the lay.* *See* fig. 98.

As soon as a few inches of cloth are woven they are wound upon the cloth-roll, by putting a short lever into a hole in the end of that roll, and turning it round, while a click, resting in the teeth of a ratchet-wheel on the cylinder, prevents its return. The cross-sticks at B are smooth, and usually three in number. Being put between the warp-yarns, they preserve the lease and keep the threads from entangling. They are maintained at a uniform distance from

* Mr. Guest's compendious History of the Cotton Manufacture, p. 8.

the heddles, either by tying them together, or by a small cord with a hook at one end which lays hold of the front rod, and a weight at the other which hangs over the yarn-beam. The cloth is kept extended during the operation of weaving by means of two pieces of hard wood, called a templet, furnished with sharp iron points in their ends, which take hold of the opposite edges or selvages of the web. These two pieces are bound together by a cord, which passes obliquely through holes or notches in each piece. By this mode of connexion the templet can be lengthened or shortened according to the width of the cloth. After the proper degree of extension is given, the two parallel bars of wood are kept flat on the cloth by a small cross bar, which turns on a peg fixed in one of the bars, (*see* power-weaving, p. 287.)

The perfection of weaving depends very much upon the warp being extended in the loom in a parallel plane, with an equal tension. In setting the lease-rods, care must be taken that all the threads which are to go through one of the heddles be separated by these rods from the threads belonging to the other heddle. This separation is originally made in the warping-mill by means of the heck.

The operation of *beaming* the warp requires particular care to insure good cloth. When the weaver receives his warp in a large ball or bundle, he proceeds to roll it regularly upon the yarn-roller of his loom. In this process he employs an instrument called a separator or ravel, composed of a number of shreds of cane, fastened together by means of a rail of wood, like the teeth of a long comb. The threads are to be inserted into the spaces between these teeth, so as to spread the warp to its proper breadth. Ravels resemble reeds, but they are coarser, and of different dimensions. A ravel proper for the purpose being chosen, one of the small divisions of the warp is placed in every interval between two of the teeth. The upper part of the ravel, called the cape, is then put on to secure the threads from getting out between the teeth, and the operation of winding the warp on the beam now commences. After the warp is wound upon the beam, the operation of drawing is performed, which consists in passing every thread through its appropriate eye or loop in the heddles. Two rods are first inserted into the lease formed by the pins in the warping-mill; and these rods being tied together at the ends, the twine by which the lease was secured is cut away, and the warp is stretched to its proper breadth. The yarn-beam is suspended by cords behind the heddles, somewhat higher, so that the warp hangs down perpendicularly. The weaver places himself in front of the heddles, and opens the eye of each heddle in succession, while an assistant, placed behind the heddles, selects every thread in its order, and presents it to be drawn through the open eyes of the heddles. The succession in which the yarns are to be delivered is easily determined by the lease-rods, as every thread crosses that next to it. The warp, after passing through the heddles, is drawn through the reed by an instrument called a sley, or reed-hook, and two threads are taken through every interval in the reed.

The lease-rods being passed through the intervals which form the lease, every thread will be found to pass over the first rod, and under the second; the next thread passes under the first, and over the second; and so on, alternately. By this method every thread is kept distinct from the one on either side of it, so that, if broken, its true situation in the warp may be found at once. There is likewise a third rod which divides the warp into what is called *split-fuls,* for two threads pass alternately over and under it; and these two threads also pass through the same interval betwixt the splits of the thread.

The cords or mounting which move the heddles are now applied; the reed being placed in the lay or batten, the beginning of the warp is knotted together into small portions, which are tied to a shaft and connected by cords with the cloth-beam; and the yarns are finally stretched in order to begin weaving.

The operations of common weaving are simple, and soon learned, but require much practice to be performed with dexterity. In pressing down the treadles of a loom, most beginners are apt to apply the weight or force of the foot much too suddenly. The ill effects of this sudden pressure are particularly obvious in weaving fine or weak cotton yarns; for the body of the warp must thereby sustain a stress nearly equal to the force with which the foot is applied to the treadle. Moreover, every thread is subjected to all the friction occasioned by the heddles and splits of the reed, between which it passes, and with which it is brought in contact when rising and sinking. As it is difficult to make yarns equally strong and tight, some will be more affected than others by undue or sudden pressure, and be occasionally broken. Even with the greatest care, more time is lost in tying or replacing these warp-yarns, than would have been sufficient for weaving a considerable piece of cloth.

Should the weaver, from negligence, continue the operation after one or more warp-threads are broken, the cloth will be seriously damaged. The broken thread does not retain its parallelism to the rest, but crossing over or between those nearest to it, either causes them also to break, or interrupts the passage of the shuttle. In every kind of weaving, also, but especially in thin wiry fabrics, such as book-muslins, much of the beauty of the goods depends upon the weft being in a proper state of tension. If the motion given to the shuttle be too rapid, it is very apt to recoil, and to slacken the thread. It has also a greater tendency either to break the weft altogether, or to unwind it from the pin of the shuttle in doubles, which, if not picked out, would disfigure the fabric. The weft of thin cotton goods is sometimes woven wet into the cloth, the moisture tending to lay the ends of the cotton filaments smooth or parallel.

In the common operation of weaving, the proper force of stroke for beating up the weft-yarn must be learned by practice. The weaver ought, however, to mount his loom in such a manner that the swing or vibration of the lay may be proportional to the thickness of the cloth. As the lay oscillates backwards and forwards upon centres placed above, its motion is similar to that of a pendulum. The greater, therefore, the arc through which the lay moves, the greater effect will it have in driving home the weft, and the thicker the fabric will be, as far as the weft is concerned. Hence in weaving coarse and heavy goods, the heddles ought to be hung at a greater distance from the place where the weft is struck up, and consequently where the cloth begins to be formed, than it should be for light goods. The line of the last wrought shot of weft is called by weavers the *fell.* The pivots on which the lay swings ought in general to be so placed that the reed will be exactly in the middle between the fell and the heddles, when the lay hangs perpendicularly. As the fell constantly varies its position, the medium distance should be taken, or the place where the fell will be when half as much is woven as can be done without winding it on the cloth-roll, and drawing more warp from its cylinder.

The intervals for taking up the cloth should always be short in weaving light goods, for the less the fell varies from the medium, the more regular will be the impulsion of the lay. Mr. Hall obtained a patent, in 1803, for a method of continually turning round the cloth-beam, so as to wind up the cloth as fast as it was woven, or even shot by shot. This was effected by a ratchet-wheel fixed on the end of the cloth-beam, and a catch or detent to move it round one tooth at a time. This catch was actuated by the impulsion of the lay. Similar contrivances are now universally adopted in power-loom weaving.

Dressing a web, is the application of flour paste to the warp with a brush, in order to smooth down all the loose filaments of the yarn, as well as to increase its stiffness and tenacity. In applying the dressing, the weaver suspends the labour of the shuttle whenever he has worked up the portion of warp already dressed, applies the comb to clear away knots and burs, then pushes back the lease rods towards the yarn beam, and, lastly, brushes the yarn with the paste by two brushes, holding one in each hand. The superfluous humidity is afterwards removed by winnowing the warp with a large fan. A small quantity of grease is occasionally brushed over the yarn, the lease-rods are restored to their proper places, and the loom is put in action. The preparation of paste or size for weavers' dressing has been the subject of several patents. Mr. Foden recommends a quantity of calcined gypsum to be reduced to a fine powder, mixed with alum, sugar, and the farina of starch or potatoes, the whole to be made into a thin paste with cold water, and the mixture afterwards boiled to a gelatinous consistence.

Peter Marsland, Esq., of Stockport, obtained a patent in 1805 for an ingenious method of starching cotton yarn in the cop, so that it might be ready for weaving whenever it was warped. He placed the cops in a tight vessel, exhausted the air, and then admitted the hot paste in a liquid state. By this elegant physical device, he caused the cotton fibres to be thoroughly impregnated into the very heart of the cops. It was found, however, difficult to dry the cops thereafter, and to transfer their yarns to the warp-mill bobbins.

In the specifications of some throstle-spinning patents, it is proposed to give the yarn a dressing before it is wound upon the bobbin by making it pass between a pair of rollers immersed in a trough filled with paste. Cop-yarn is sometimes passed over a cylinder revolving in a paste-box during the process of reeling it on the bobbins of the warping-mill.

For the insertion of wefts of different fineness, or of different colours, into one web, different shuttles must be in readiness for alternate use. With this view, an apparatus of movable shuttle boxes is attached to each end of the lay, as is represented at D in fig. 98. Here are seen three boxes so constructed as to slide up and down in a vertical plane. They are suspended by a cord from the cross levers G, G, which turn upon centres in the suspending bars or swords of the lay, marked B, B. A represents the cross spar of wood on which the lay oscillates upon iron gudgeons or

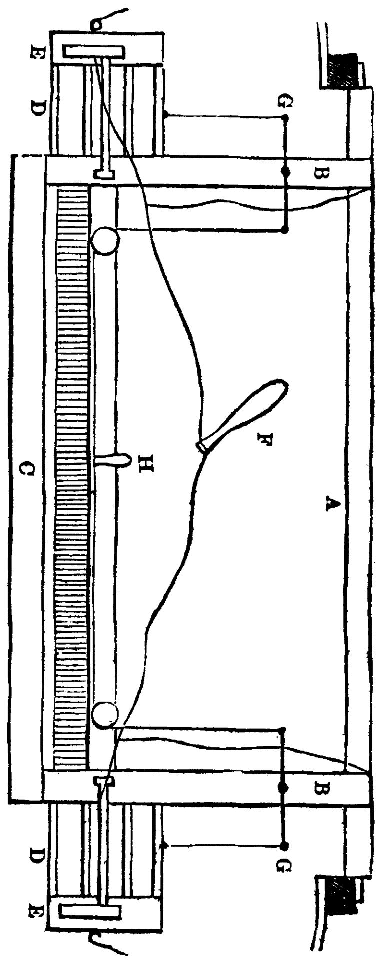


Fig. 98.—Movable Shuttle-box Apparatus.

pivots driven into each of its ends, and resting upon the upper rails of the loom, as shown in section. The under part of the lay appears at C, and the upper bar or lay-cap H, which the weaver seizes in his hand in driving home the weft. Above E, E are seen the two pieces of wood called drivers or peckers, which traverse horizontally upon smoothly polished iron rods, and which give motion to the shuttle. These drivers are impelled by the jerk of the weaver's hand, and the impulse must be so smartly given as to communicate adequate velocity to lodge the shuttle in the opposite box, overcoming the friction of the shuttle along the warp-race.

The pin H is made to slide freely from right to left on the upper bar of the lay, whereby the levers G are moved at pleasure, and any one of the three boxes brought opposite the driver. F is the pecker handle.

When the pattern of the cloth is to be diversified, a single pair of alternate heddles and levers becomes inadequate to the work, and several heddle-leaves must be introduced into the loom. Every leaf is suspended from a particular lever above, connected by a cord with the march-bars below, and thence with a corresponding series of treadles. Such an apparatus will afford a comprehensive range of patterns; but the draw-loom must be had recourse to for fancy work in general.

Fig. 99. This wood-cut exhibits the outline of a loom mounted with several heddle-leaves. Instead of the jacks which lift the heddle-frames in the plain loom, levers, such as are shown at A, A, are used, one of which suspends every leaf of the heddles. From the ends of these levers a connexion is formed by a cord with the marches at B, of which there are two sets, diverg-

ing from the centre of the loom to either extremity. In order that every treadle may operate equally on both sides, the spring staves C, C, are used, from which the connexion is established with the treadles at D. When a heddle is depressed, this part of the apparatus will raise the leaf or leaves with which it is connected,

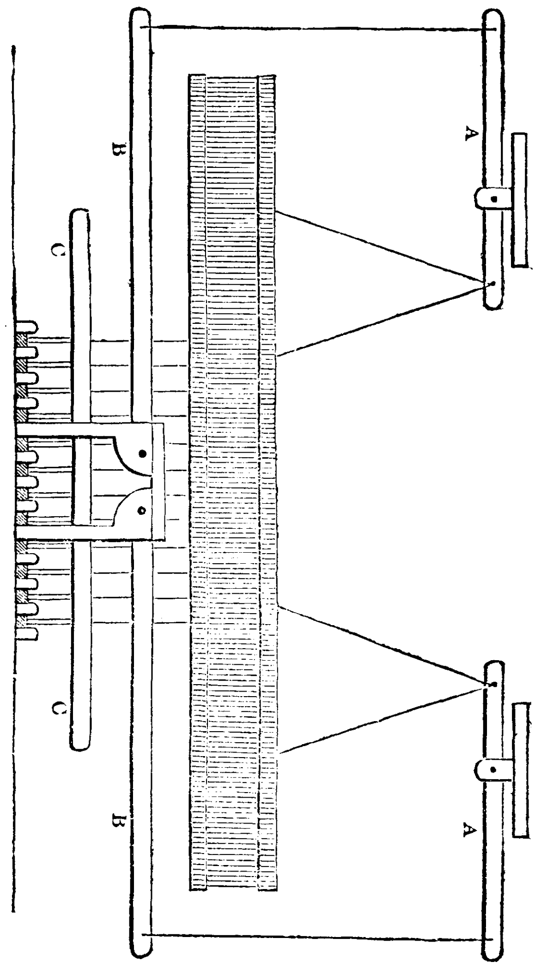


Fig. 99.—Loom with several Heddle-leaves.

and, by direct communication from the heddles, the sinking is produced.

Figures or patterns are produced in cloth by employing threads either of different colours, or of different texture, in the warp or weft. In weaving, the threads must be so disposed that some colours will be concealed and kept at the back, whilst others are placed in front; and they must occasionally change places, so as to show as much of each colour or texture as is requisite to make out the figure or pattern. The weaver has three means of effecting such changes of colour or appearance.

First, by using differently coloured threads in the warp, or threads of different sizes and substances; these are arranged in the warping, and require no change in the manner of weaving. This style is confined to patterns, with stripes in the direction of the length of the piece. Secondly, by employing several shuttles charged with threads of different colours or substances, and changing one for another every time that a change of colour or appearance is required. This plan makes stripes across the piece; or if combined with a coloured warp, it makes chequered and spotted patterns of great variety. Thirdly, by employing a variety of heddle-leaves, instead of two, each heddle having a certain portion of the warp allotted to it, and provided with a treadle. When this treadle is pressed down, only a certain portion of yarns which belong to its heddle will be drawn up, and the rest will be depressed; consequently, when the weft is thrown, all those yarns which are drawn up will appear on the front or top of the cloth; but in the intervals between them, the weft must appear over those warp threads which are depressed. The number of threads which are thus brought up may be varied as often as the weaver chooses to press his foot upon a different treadle, and thereby he produces his pattern. When all these three means are combined together, they afford the weaver ample resources for representing the most complicated patterns.

Tweeled and figured cloths are so various in their textures, and so complex in their formation, that it is difficult to convey an adequate idea of the modes of constructing them without entering into lengthened descriptions incompatible with the limits of this work. In examining any piece of *plain* cloth, it will be observed that every thread of the weft crosses alternately over and under every thread of the warp in its decussation; and the same may be said of the warp. In short, the warp and weft-yarns are thus interwoven and tacked at every individual thread. In *tweeled* cloth only the third, fourth, fifth, sixth, &c., threads interlace each other to form that peculiar texture.

Figure 100 represents a section of tweeled fabric. The warp is shown by the round dots. Here four of the successive threads of the warp will be found to pass over or under the same thread of the weft; or, in other words, by tracing any thread of the weft, it will be found to pass over four threads of the warp. Then it crosses and passes between the threads of the warp, and proceeds beneath four more threads, before it makes another intersection between the threads of the warp. By this means the warp-yarns get con-

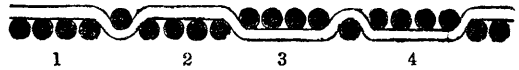


Fig. 100.—Dimity, Diaper, Kerseymere.

densed so as to thicken the fabric. The tweeled fabric is also ornamental, from the figure being capable of inversion at pleasure. Thus there are four threads passed over in this pattern, and one only intersected; of these four threads, the series marked 1 and 2 are under the weft-line, while those marked 3 and 4 are above it. This does not affect the solidity or strength of the texture, but is merely subservient to ornament. At all the intersecting points where the threads actually cross or interweave, both threads of warp and weft are seen together, and these points are therefore more marked to the eye, even if the warp and the weft are of the same colour. In plain tweels these points form parallel lines extending diagonally across the cloth, with different degrees of obliquity, according to the number of weft-threads over or under which the warp-threads run before an intersection takes place. In the coarsest kinds every third thread is crossed; in finer fabrics, each sixth, seventh, or eight thread is crossed. In some fine tweeled silks the crossing does not take place until the sixteenth interval.

The art of adapting those parts of a loom which move the warp to the formation of various kinds of ornamental figures upon cloth is called by weavers *draught and cording*. In every species of weaving, whether direct or cross, the whole difference of pattern or effect is produced either by the succession in which the threads of warp are inserted into the heddles, or by the succession in which those heddles are moved in the working. The heddles being stretched between two shafts of wood, all the heddles connected by the same shafts are called a leaf, and as the operation of introducing the warp into any number of leaves is called *drawing a warp*, the plan of succession is called the *draught*. When this operation has been performed correctly, the next part of the weaver's business is to connect the different leaves with the levers or treadles by which they are to be moved, so that one or more may be raised or sunk by every treadle successively, in the order suitable to the particular pattern.

As these connexions are made by coupling the different parts of the apparatus with cords, the name of *cording* is given to this operation. In order to direct the operator in this part of his business, especially if previously unacquainted with the particular pattern upon which he is to be employed, plans are drawn upon paper similar to that represented in the wood-cut.

Fig. 101 is the horizontal section of a loom, the heddles being represented across the paper at A, A, and the treadles under them, and crossing them at right angles as at B, B. They are represented as distinct pieces of wood, those across being the under shaft of each leaf of heddles, and those at the left hand the treadles. In the actual loom the treadles are placed at right angles to the heddles, the sinking cords descending perpendicularly, as nearly as possible to the

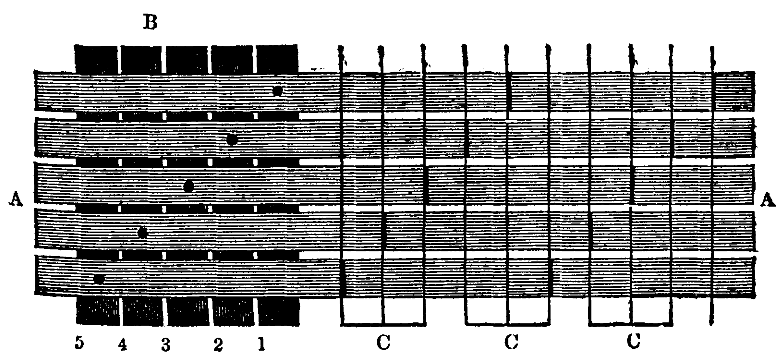


Fig. 101.—Five-leave Tweel.

centre of the latter. Placing them at the left in the plan, therefore, is only for ready inspection and practical convenience. At C a few threads of warp are shewn as they pass through the heddles, and the thickened marks denote the leaf with which each thread is connected. Thus the right-hand thread next to A, passes through the eye of a heddle upon the back leaf, and is unconnected with all the other leaves; the next thread passes through a heddle on the second leaf; the third through the third leaf; the fourth through the fourth leaf, and the fifth through the fifth, or front leaf. One set of the draught being now completed, the weaver begins again with the back leaf, and proceeds in the same succession to the front one.

Two sets of the draught are represented in the figure, and the same succession must be repeated till all the warp is included. Weavers understand this, and seldom delineate more than one set. When they proceed to apply the cords, the left-hand part of the plan at B serves as a guide. A connexion must be formed by cording, between every leaf of heddles and every treadle, for all the leaves must either rise or sink. The rising motion is effected by joining the leaf to one end of its correspondent top-lever; the other end of this lever is tied to the long march (*step*) below, and this to the treadle, fig. 99. The sinking connexion is carried directly from under the leaf to the treadle. In order to direct the weaver which of these connexions is to be formed with each treadle, a black dot is placed when a leaf is to be raised, where the leaf and treadle intersect each other upon the plan; and the sinking connexions are left blank. For example, to cord the treadle 1, put a raising-cord to the back leaf, and four sinking cords to each of the other. For the treadle 2, raise the second leaf and sink the remaining four, and so of the rest, the dot always denoting the leaf or leaves to be raised. The figure is drawn for the purpose of rendering the general principle of this kind of plans familiar to those who have not been previously acquainted with them; but those who have been accustomed to manufacture or weave ornamented goods never take the trouble of representing either heddles or treadles as solid or distinct bodies. They content themselves with ruling a number of lines across a piece of paper, sufficient to make the intervals between these lines represent the number of leaves required. Upon these intervals they merely mark the succession of the draught, without producing every line to resemble a thread of warp. At the left hand they draw as many lines across the former as will afford an interval for each treadle, and in the squares formed by the intersections of these lines they place the dots, spots, or cyphers, which denote the rising cords. It is also common to continue the cross lines which denote the treadles a considerable length beyond the intersections, and to mark by dots placed diagonally in the intervals the order, or succession, in which the treadles are to be pressed down in weaving.

Figure 100 represents the regular, or run-tweel, which, as every leaf rises in regular succession while the rest are sunk, interweaves the warp and woof only at every fifth interval; and, as the succession is uniform, the cloth when woven presents the appearance of parallel diagonal lines at an angle of about 45° over all the surface. When there is no other figure upon the cloth and the fabric is fine, this produces a very pleasing effect, and is much used. The wood-cut, figure 101, represents the draught and cording of striped dimity of a tweel of five leaves. This is the most simple species of fanciful tweeling. It consists of ten leaves, or double the number of the common tweel. These ten leaves are moved by only five treadles, in the same manner as a common tweel. The design is formed by one set of the leaves flushing the warp, and the other set the weft.

Here the stripe is formed by ten threads, alternately drawn through each of the two sets of leaves. In this case the stripe and the intervals will be equally broad, and what is the stripe upon one side of the cloth will be the interval on the other, and conversely. Great varieties of patterns may be introduced by drawing the warp in greater or smaller portions through either set. The tweel is of the regular kind, but may be broken by placing the cording spots alternately. The cording marks of the lower, or front leaves, are exactly the converse of the other set, for where a raising mark is placed upon one, it is marked for sinking in the other; that is to say, the mark is omitted, and all leaves which sink in the one are marked for raising in the other; thus, in the back set one thread rises in succession and four sink; but in the front set four rise and only one sinks. The weft passing over the four sunk threads and under the raised one, in the first case is flushed above, but in the second the reverse occurs, or it is flushed below, and thus the appearance of a stripe is given.

Among the varieties of texture produced by the loom that of common gauze, or *linau*, a substance much used for various light purposes, deserves to be explained. A section of its web is represented in fig. 102. The essential difference between this fabric and those hitherto described consists in the warp being twined or twisted like a rope during the operation of weaving, whereby the cloth acquires a considerable resemblance to lace. The twisting of the warp by the

Fig. 102.—Common Gauze.

working of the heddles is not continued in the same direction, but is effected alternately from right to left and from left to right, between every intersection of the weft. The texture of gauze is always open, flimsy, and transparent, but from the twining of the warp it possesses an uncommon degree of strength and tenacity, in proportion to the quantity of materials which it contains. This quality, together with its transparency, fits it for ornamental purposes of various kinds, particularly for flowering or figuring either with the needle or in the loom. In the warp of gauze a much greater degree of contraction takes place during the weaving than in plain or tweeled goods, where no such twist is given to the warp yarns. By inspecting the figure it will be seen that the twisting between every intersection of weft amounts to one complete revolution of two contiguous threads. Hence *linau* possesses this peculiarity, that the same thread of warp is always above the weft in the loom, and the adjoining thread is always below it.

The draw-loom is one of the most complete and intricate machines used in the weaving of ornamental cloth. There is no variety of pattern or figure, however extensive, which can be brought within the range of cloth of the largest dimensions but may be produced by this multiform, though costly apparatus. Draw-looms are used for three purposes in this country—for weaving spotted muslins, damasks, and carpets. The general principles of the construction are in all cases the same, but they are modified according to the specific application. When patterns become so diversified that the number of heddles necessary for moving the warp in its configurations could neither be included within any moderate bounds, nor worked by any ordinary power, recourse must be had to the draw-loom. Of all the machines of this kind, that for weaving damasks is the most complicated; in some cases it contains 120 designs of ten spaces each, a number equivalent to 1,200 leaves of the diaper-heddle harness, or 6,000 of the leaves such as are used for dimity or common tweeling. The general principle of the draw-loom harness, and the mode by which the flushing is reversed, is in every respect the same as that of the diaper, the difference consisting solely in the greater capabilities of the draw-loom, and the method of mounting and working it.

The wood-cut, fig. 103, shows a perspective view of the harness part of a draw-loom, and of the apparatus for working it. The harness cords of a draw-loom are of necessity so numerous and so closely crowded together, that any representation of the whole, even upon a very large scale, must convey an inadequate idea of their structure and operation. A few, therefore, only, are here exhibited at intervals to illustrate the mode of constructing them; and the principle being once well understood, may be extended to any number that convenience will admit. The harness of the draw-loom is not confined by leaves, but every cord carries a mail or loop for the warp, and is kept stretched by a weight. The weights attached to the harness are represented at L. A horizontal board or frame, C, is fixed across the loom, and is either perforated with a number of small holes, or is divided by wires or pins, to serve as guides to the cords of the harness that pass

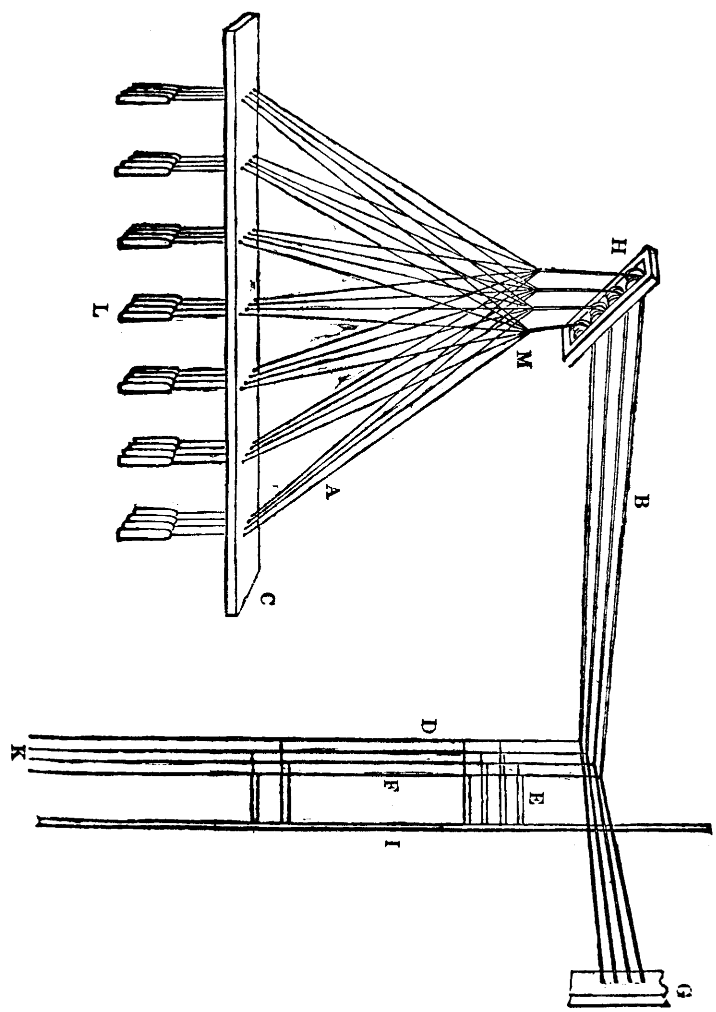


Fig. 103.——Draw-Loom.

through them. When the range or extent of the design has been ascertained, by counting on the design-paper the greatest number of squares contained in it from right to left, the harness must be made to correspond with this range. Let the range be supposed to extend to 500 squares, and the whole breadth of the warp to contain 10,000 threads. If five threads are to be drawn through each mail, the number of mails composing the harness will be 2,000, and four ranges of the pattern will comprehend the whole breadth. The divisions in the board C, and the number of pulleys in the box or case H, being adapted to this, the operator may proceed to put up his harness, which is done as follows:—The 1st, 501st, 1,001st, and 1,501st harness-twines, after being passed through their respective intervals in the board or frame C, are to be knotted together at M. A cord being attached to these, is carried over the first pulley in the case H, and is made fast to the piece of wood G, which is commonly called the *table*. The 2d, 502d, 1,002d, and 1,502d are next connected in the same way, and the cord attached to them, passing over the second pulley, is fastened to the table as before. The same operation is successively carried on until the whole 500 connexions are completed. The cords at B passing over the pulleys and fastened to the table are called the *tail* of the harness. From each cord in the tail a vertical cord descends, and is made fast to a piece of wood, K, which is lashed to a fixture in the floor. These cords, represented at D, are called *simples*. The draught of the warp through the mails of the harness is regularly progressive from right to left as in common tweeling, and the draught cording and mounting of the front leaves are exactly the same as in diaper. A stout cord is now stretched perpendicularly from the roof to the floor, and made fast at both ends. This cord is seen at I. The loom is now ready to be adapted to work to any pattern of the range of 500 squares or mails.

The next operation, therefore, is to apply a certain number of small cords, called *lashes,* as shewn at E, in order to form the particular pattern required. This is called reading on the design, and from its complexity, and the injurious consequences of a slight error, it is performed by two persons in concert. The first individual selects from the design-paper the simples to which lashes are to be applied in succession, and the second applies these lashes according to the instructions communicated by the first. In reading or selecting the lashes in their proper rotation they should bear in mind that the whole range of squares from right to left, between the extreme points of the pattern, is equal to the number of simples, and the whole range from top to bottom is equal to the number of operations which those simples are to undergo. The person who is to select takes, therefore, the design-paper, begins at the lowest square, and, counting from the right hand, instructs the other to pass as many simples as there are blank squares upon the paper, to put lashes to as many as are coloured, again to pass over the blanks, to take the coloured squares, and so on till he has reached the left side of the pattern. When these lashes have been applied, which is done by passing each loosely round the simples which it is to work, they are knotted together, and attached to the cord I, by a loop, so that they may slide up and down freely, both upon the cord and the simples. Proceeding to the second square from the bottom, the selection is made in the same way, and thus they continue until they have reached the top. The lashes being now in clusters upon the cord I, these clusters are connected at convenient distances from each other by small cords represented at F, the first applied cluster being the lowest upon the cord I.

The draw-loom being now ready for work, the operators may begin to weave; two persons being required to work the machine. One of them pulls down the first set of lashes, the whole of which are placed high upon the cord I, and, by pulling them tight, he draws the simples with which they are connected clear of all the rest. Then by grasping these simples firmly in his hand, and pulling them down, he tightens the tail-cords at B by making them diverge more from a straight line, and of course raises the mails which are attached to them by the harness-twines at M. The weaver then works over his front mounting, as in common tweeling, once or oftener, if more squares than one upon the design-paper are included between the same parallel straight lines from top to bottom. When a change of the harness becomes necessary, the connecting cord F pulls down the second cluster of lashes, upon which the same operation is performed as before. By these means, the simples, however numerous (and in the case we have supposed, they would amount to 500) are selected from each other with the greatest accuracy and ease. The successive performance of the same operation completes the pattern; when it is necessary merely to push the lashes up again and begin a new one.

In the harness of the spot draw-loom for muslins, as the warp is slender, short eyes of twine are substituted for the mails of wire. In the front mounting also, four leaves of heddles are used; but they are so mounted, that two leaves will go together either up or down, or in opposite directions. The heddles are constructed like those for weaving plain cloth, and every thread is drawn through two heddles, being taken through the upper cleft or link of the one, and through the under link of the other. When the two leaves move in the same direction, the threads of warp are confined as in the clasp of a common heddle; but when they move in a contrary direction, they present all the facility of the long eye in allowing the thread to rise without interruption.

Power-Loom or Automatic Weaving.

Without tracing minutely the first rude steps of this factory child, we shall proceed to describe the grandeur of its present state. Continuity of action is an essential principle of all mechanisms impelled by the force of steam or running water; while alternate effort and repose are the characters of human labour. Hence the interruptions in the movements of the shuttle which take place while the weaver is dressing a certain portion of the web, and which serve to diversify his labour, would be intolerable in a factory where power and time must be economized to the utmost. It became, therefore, a matter of primary importance to combine with the automatic loom an automatic dressing machine. By the commencement of this century, the mechanism of the power-loom had been so far perfected by rival inventors as to demonstrate its practical value, provided a good system of dressing the chain or warp could be devised. This want was not long of being supplied. In the year 1804, Mr. Johnson, of Stockport, obtained a patent for a method of dressing a whole web at once by a self-acting machine. An improvement was made upon it by Mr. MacAdam in 1806, which was immediately realized on a considerable scale in Mr. Monteith's weaving factory at Pollockshaws, near Glasgow. This was probably the first web-dressing mechanism which continued to give satisfaction to the manufacturer during a series of years.

Certain defects in this apparatus were, after a little while, removed by the warp-dressing machine of Messrs. Ross and Radcliffe, of Stockport. The Chamber of Commerce, of Manchester, were so much convinced of the value of the improvements introduced by these gentlemen, that they forwarded a memorial to the Lords of the Treasury soliciting a reward to the ingenious inventors. They here state "that the effects of the new method have been to bring the whole process of the manufacture (of cotton) from the raw material to the cloth into one connected series of operations, by means of which a cheaper, more uniform, and better fabric has been produced. That for introducing this greatly improved system the public is indebted to the persevering efforts of Messrs. Radcliffe and Ross, of Stockport, who, it appears, had expended their whole capital in bringing it to maturity, and were, in consequence, unable to remunerate themselves by the use and application of their own plans. That Messrs. Radcliffe and Ross are, therefore, in the opinion of your memorialists, justly entitled to be recompensed by the public for the advantage derived from the adoption of this system." From a letter addressed to he Lords of the Treasury by Mr. Radcliffe, in June, 1825, it would appear that the prayer of the above memorial was unsuccessful.

We now proceed to describe the power-loom in its most practicable state, as constructed by the celebrated mechanicians, Messrs. Sharp and Roberts, of Manchester. It has taken no less than a century and a half to mature this admirable substitute for one of the most irksome but indispensable labours of man. Desgennes announced in the "Philosophical Transactions," so long ago as the year 1678, that he had contrived an automatic loom, possessing, as he thought, all the qualities only now realized; so great is the interval often between the speculative idea of a machine, and its effective execution, in consequence of the delicate compensations and adjustments which experience alone can discover. It was not till Horrocks, of Stockport, in 1813, after a long, laborious, and most costly career of experiment*, introduced some very important modifications into the power-loom, that it began to act any considerable part in our cotton manufacture. Horrocks, however, did not reap the reward due to his ingenuity, having omitted certain minutiæ in the construction of his machine, which interfered with its uniformity of performance, and thus allowed the prize of excellence to be won by his successors. His power-loom is described with figures in the Repertory of Arts and Manufactures for the year 1814. On that basis

* He had obtained one patent for a power-loom in 1803, and another in 1805.

Messrs. Sharp and Roberts have made their accomplished mechanism.

Towards the end of the year 1829, M. Emile Dollfus, as chairman of their committee of mechanics, made to the Société Industrielle of Mulhausen an interesting report, replete with new and valuable experimental facts, upon the different power-looms then employed in the cotton factories of Alsace. This report was published in the bulletin of the society for the year 1830, accompanied with several plates representing the ingenious power-looms of M. Josué Heilmann, M. Jourdain, MM. Risler and Dixon, and finally that of Messrs. Sharp and Roberts, as constructed in the great workshops of MM. André Kœchlin and Company, at Mulhausen.

One new feature of Mr. Horrocks' loom was the lathe being made by compound levers to advance quickly so as to give an effective stroke to the weft, and then to retire quickly to a stationary position. By this means, the shuttle was allowed to pass through the shed while the lathe was standing still; a larger shuttle might be used, capable of holding a full-sized cop; the waste of weft from the bottoms in the cops became less; from the smartness of the stroke, less weight for tension was required upon the yarn-beam, and therefore less power was required to move the healds or heddles from the smaller tension of the warp. From this cause, also, less moving force would be expended, fewer threads would break in the working, and more threads of the weft could be condensed into the inch, making a stronger and more uniform fabric.

Description of Sharp and Roberts' improved Power-Loom.

Figs. 104 and 106 are two side elevations; and fig. 105 is a front view.

Those parts in the engravings marked with the letter A, compose the frame-work of the loom. B is the usual outrigger, or fast and loose pulleys, upon the principal or crank shaft. C is a small fly-wheel for equalizing any casual irregularities of motion in the machine.

Upon the other end of the main shaft is a wheel, D, figs. 105 and 106, driving another wheel, D′, with double the number of teeth, upon the shaft, E, which makes, therefore, only half as many revolutions as the main or crank shaft, B. The shaft, E, is called the tappet or wiper-shaft: it raises and lowers the treadles, and throws the shuttle, while the shaft, B, by means of its cranks, F, figs. 104 and 106, drives home the weft towards the finished cloth, or works the batten.

The cranks, F, are connected with the two levers, G, G, called the swords of the lay, to which the batten H is made fast, which carries the reed in its middle, and the shuttle-boxes, *h, h,* at its ends, see fig. 105.

I is the warp-beam. The warp-yarns pass from it over the roller, K, through the heddles L, through the reed *l*′, over the breast beam M (having been now changed into cloth). This is finally wound upon the roller, N, or cloth-beam. This roller bears at one end a toothed wheel, *a,* which is moved slowly by a small pinion, *u,* (fig. 104) upon the axis of the ratchet-wheel, *b.* This latter wheel is turned round a little after every throw of the shuttle, or shoot of the weft, by means of a stud, *c*, (figs. 105 and 106), fixed upon the side of the lever, G, and pressing against the other lever *d*, with which a click is connected. The degree of motion of the ratchet is regulated according to the quality of the cloth, by fixing the click in different holes of the (dotted) lever, *d*. The lifting of the heddle, L, is performed by two

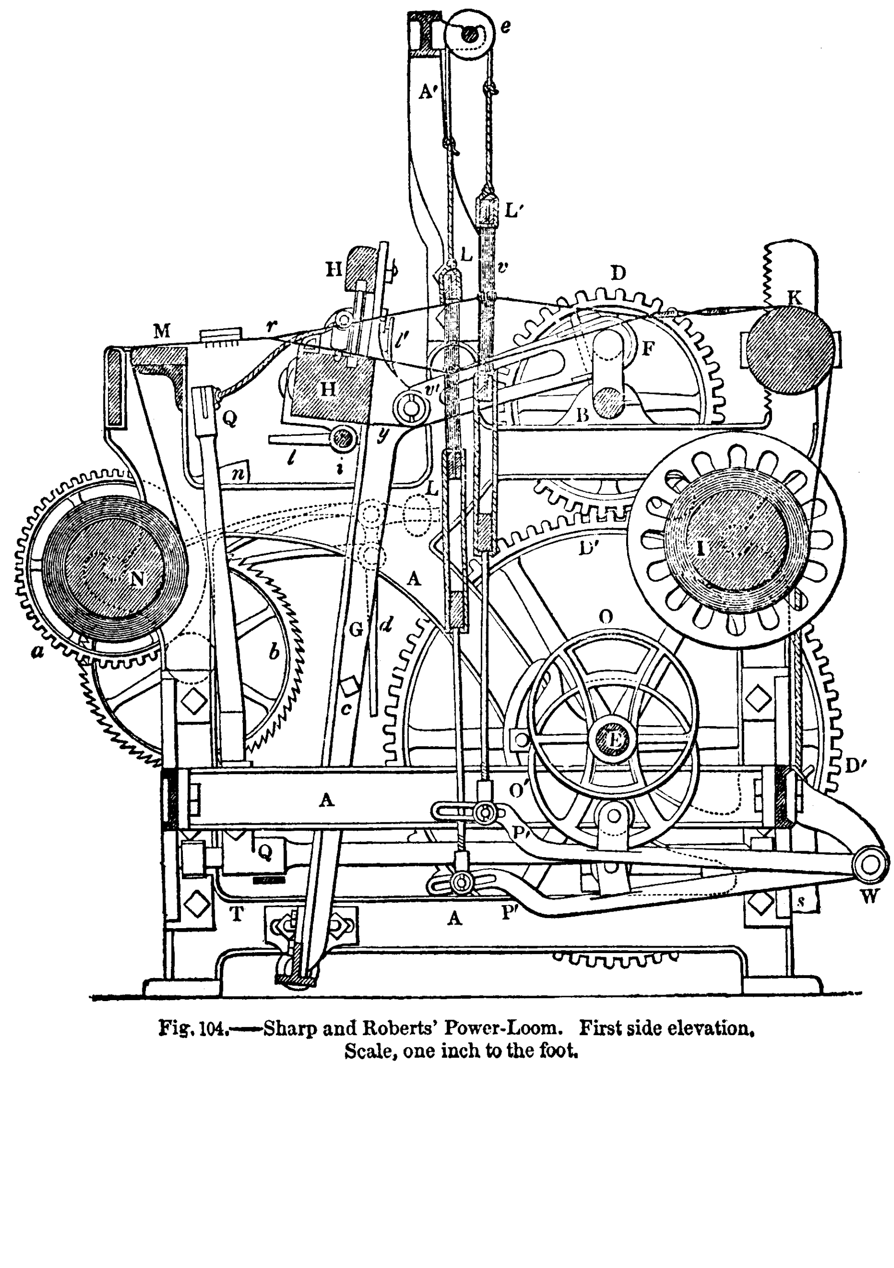


Fig. 104.—Sharp and Roberts' Power-Loom. First side elevation. Scale, one inch to the foot.

eccentric tappets or wipers, O, O′, upon the shaft, E, which press the treadle-levers, P, P′, alternately up and down. These levers are connected by strings or wires with their respective heddles, which are in their turn placed in communication by straps which play over the small rollers, *e*, *e* at the top of the loom.

In fig. 105, the levers, P, P′, have been shown in section, in order to explain the way in which the eccentrics, tappets, or cams, work through the intervention of two small friction-rollers, made fast to the levers.

The shuttle is thrown by the two levers, Q, Q, which are alternately moved with a jerk by the rollers, R, fixed by arms on the shaft, E, and working upon cams S, connected with the shafts of the arms, Q, Q. These arms, which represent the right arm of the hand-loom weaver, are united by the pecking-cord, T, which is mounted with a spring of spiral wire, so that either arm may be brought to its proper relative position.

The shuttle is lodged in one of the boxes, *f*, *f*, of the batten, H, and is driven across along its shed-way by one of the pickers, *g*, *g*, which run on the two parallel guide-wires, *h*, *h*, and are connected with the peg-arms, Q, by strong cords. *See* fig. 105.

If by any accident the shuttle should stick in the shed-way, the blows of the lay, or batten, H, against it, would very soon cause the warp to be torn to pieces. In order to guard against this misfortune a contrivance has been introduced for stopping the loom immediately, in case the shuttle should not come home into its cell. Under the batten H, fig. 106, there is a small shaft, *i*, figs. 104 and 106, on each side of which a lever, *l*, *l′*, fig. 104, is fixed. These two levers are pressed by springs against other levers, *m, m,* which enter partly into the shuttle-boxes. They act there as brakes to soften the impulse of the shuttle, and allow, also, the point of the lever, *l,* to fall downwards into a line with the prominence at *n,* provided the shuttles do not enter in and press the spring-point, *m,* backwards, and

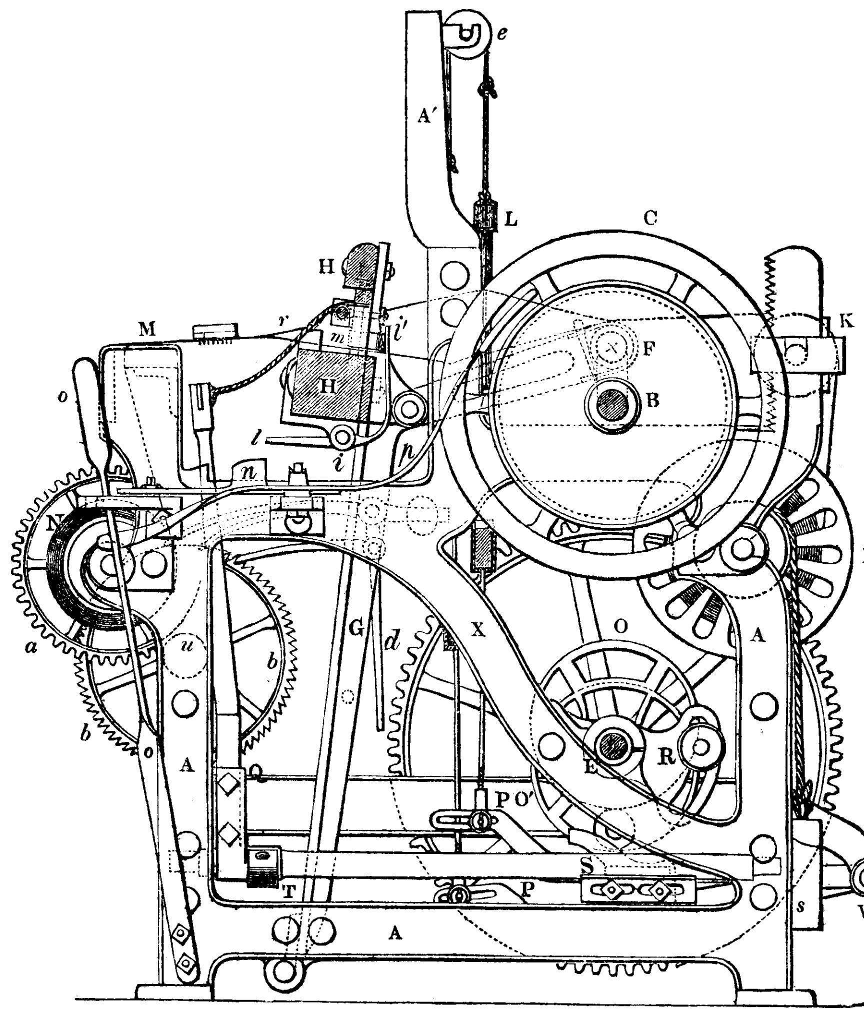


Fig. 106.—Sharp and Roberts' Power-Loom, Second side elevation. Scale, one inch to the foot.

thereby the upright arm of the bent lever, *l'*, onwards, so as to raise its horizontal arm, *l*, above *n*. When this does not take place, that is, when the shuttle has not gone fairly home, the lever, *l*, hangs down, strikes against the obstacle *n*, moves this piece forwards, so as to press against the spring lever or trigger *o*, *o*, which leaps from its catch or detent, shifts the fork, *p*, *p*, with its strap, from the fast to the loose pulley at B, fig. 105, and thus in a twinkling, arrests every motion of the machine. *See* figs. 104 and 105 at the right-hand sides.

The shuttle is represented (fig. 107) in a top view, and fig. 108 in a side view. It is made of a piece of box wood, excavated by a mortise in the middle, and tapered off at its ends, the tips being shod with iron-points to protect them from injury by blows against the guides and the bottoms of the boxes.

In the hollow part, *a*, *b*, there is a skewer or spindle, *c*, seen in dotted lines. One end of this skewer turns round about the axis, *d*, to allow it to come out of the mortise when the cop is to be put on.

e (see the dotted lines in fig. 108) is the spring which keeps the spindle, *c*, in its place by pressing against one of the sides of the square ends of the spindle. *f* is a projecting pin, or little stud, agains which the spindle, *c*, bears, when laid in its place. *g* is a hole in one side of the shuttle, bushed with ivory, through which the thread passes, after being drawn through a slit in the centre of a brass plate, *h*. In that side of the shuttle which is furnished with the eye-hole, there is a groove extending its whole length for receiving the thread in its unwinding from the cop. The under surface of the shuttle, which slides over the warp-shed, is made smooth from end to end by means of two wires, which abate the friction.

Thus we see that in the power-loom, there are eight points to be considered :—

1. The framework of the machine.

2. The mechanism connected with the warp.

3. The movement of the healds or heddles.

4. The movement of the lathe or batten.

5. The movement of the shuttle.

6. The mechanical arrangements of the whole machine.

7. The mode of action, or working of the several parts.

8. The methods of throwing the loom out of geer.

1. The *frame-work* is of cast iron, and is composed of two sides, each being cast in a single piece marked **A** in the three figures, in which are seen an upright at each

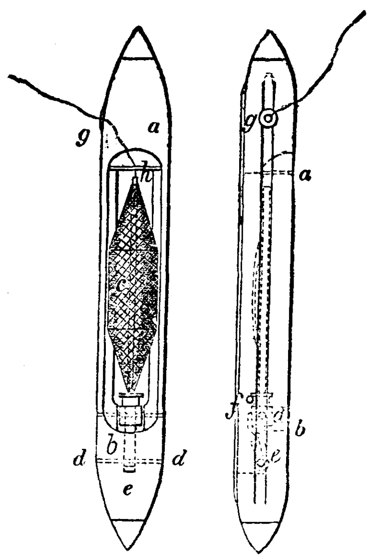


Fig. 107. Fig. 108.
Sharp and Roberts' Power-Loom Shuttle. Scale, two inches to the foot.

end, a cross-bar at top and bottom, with a curved bar diagonally placed. Upon the front of the uprights in fig. 105, immediately above the letter A, there are notched brackets for supporting the iron axes of the cloth-beam, N. On the back uprights of the loom, there is a slot-bar for supporting the axes of the warp-beam, I, see fig. 104. Towards the middle of the top rails of each side the vertical prolongation terminates in the arch A′.

The cross binding rails which unite the two faces and the two ends of the loom are,—

1. The great arched rail, A′, fig. 105, shaped like a basket-handle, which is made fast by screw-bolts and nuts, of which the heads are seen under A′ in fig. 104. This arc is destined to support the heddles, *e, e*.

2. The front cross-rail, A′, fig. 105, bifurcated at the ends to afford a greater extent of binding surface with the uprights.

3. The back cross-rail (not seen in these views), perfectly similar to the front one, A′.

The frame-work is exceedingly substantial, and stands steadily upon four large feet. The floor which bears it should be free from tremor, a stone or brick floor, on the ground story, being the best.

2. *Arrangement of the Warp.*

The warp is wound, as we have said, upon the cylindric wooden beam, I, figs. 104 and 106, from which it passes over the guide-friction roller, K, whereby it is brought into a horizontal plane suited to the play of the shuttle and the lathe. The cloth being formed at *r*, figs. 104 and 106, progressively slides over the strong breast-beam, M, and is wound upon the cloth-beam, N.

It is essential to good work in the power-loom, that the warp and the cloth be uniformly stretched to the proper tension during the whole process of weaving; for if it become at any time greater, more force will be required to move the heddles in opening the shed, the yarns will get broken, and one shoot cannot be driven so close home upon another as when the tension is less. On the other hand, if the web be left too slack, the shoot of weft will be driven too far into the shed, and will thereby ride, in some measure, over the warp. It would not be difficult to give the chain the requisite degree of tension for the particular style of goods, were it not necessary to maintain it at the same pitch all the time that the cloth is winding, and the warp unwinding about their respective rollers. The warp-beam, I, has, at each of its ends, a large wooden pulley (one is seen in fig. 104,) which are fixed by screws upon the disc iron plate; round that pulley a cord makes two or more turns, and then hangs down with the tension weight at its end (see fig. 104); a lighter counter-weight, not seen in this view, hangs interiorly from the other end of the cord. The weight, *s*, consists of round plates of cast-iron, and it may, therefore, be modified at pleasure by increasing or diminishing their number.

The roller, K, may be raised or lowered upon its rack-work upright, as shown in fig. 104.

The surface of the breast-beam, M, slopes slightly, and is made very smooth to facilitate the sliding motion of the cloth in its way to be wound upon N.

The cloth-roller, N, bears upon one of its iron axes prolonged the toothed wheel, *a*, which works into a pinion (seen in dotted lines, *u*, in fig. 104,) upon the axis of the ratchet-wheel, *b*. Hence if the ratchet-wheel be turned round, it will turn the pinion, *u*, and the wheel, *a*, on the shaft of the cylinder, N, so as to wind up the cloth as it is made. The click-lever on the top of the ratchet-wheel makes it hold whatever it has got, and thereby prevents the cloth from unrolling.

3. *Movement of the Heddles.*

These are of the usual construction in this power-loom; they are shown in section at L, L′, fig. 106, and in front view in fig. 105. The loops or eyes, *v*, fig. 106, through which one-half of the threads of the warp passes, lie in two ranges; as also the loops, *v*′, of the other heddles, which transmit the other half of the threads. The loops are arranged in two ranks, and in different planes (on different levels,) in order that the warp-yarns in passing may be brought closer together. Thus the even numbers of threads, 2, 6, 10, &c., which belong to the heddle, L, pass in the loops of the first or upper range, and the numbers, 4, 8, 12, &c., in those of the second range; and the odd numbers of threads, 1, 5, 9, &c., which belong to treadle, L′, pass in those of its upper range, and the numbers, 3, 7, 11, &c., in those of the second.

With the same view there are two heddle-sticks at L, L′, so that the threads which belong to the first range of loops may be received over the two front rods above and below, and the threads which belong to the second range may be received over the two back rods. In fig. 106 the line of division is shown in the middle of the section of the heddle-rods at L. The same takes place with the other heddle, L′.

The rods of the first heddle-leaf are each attached above to two cords terminating in leather straps, *e, e,* (fig. 105) the ends of which are nailed to the wooden pulleys, as shown in section at *e,* figs. 104 and 106. The rods of the second heddle-leaf are in like manner attached by two cords, with two leather straps nailed to similar pulleys. The last two pulleys have a smaller diameter than the first. Both systems of pulleys are fixed upon an iron shaft, which turns in the notch-bearings of the bracket projecting from the point, A′, of the basket-handle rail (as shown at *e,* fig. 104).

At their under part, the heddle-leaves are also attached by two cords to two strong wooden bars, U, V, to the middle of which are fixed the iron rods, O, O, which are jointed to the treadle-marches, or steps, P, P′. These are connected by screw-joints (fig. 105), so that the point of attachment may be varied according to circumstances.

We must now show how the treadles or marches, P, P, (figs. 104 and 106) are raised and lowered, and how they effect, at the same time, the elevation and depression of the heddles

In figs. 104 and 106 are seen the two bent lever-bars, P, P′, which turn upon a fulcrum at W, and which are prevented from deviating sidewise by the upright fixed bars, which pass through slits in their middle, as shown in fig. 106. When the march or lever, P, is pushed down, depressing the front heddles, the lever, P′, necessarily rises, because the one leather strap cannot roll round the pulley, *e,* without unrolling the other, and reciprocally. In order to shed the warp alternately, first in one direction and then in another, nothing is required but to depress, in succession, each of the treadles or levers, P, P′, taking care not to obstruct the motion of the rising one.

The movements, 4 of the batten, and 5 which throws the shuttle, are essentially a little complicated, not so much from any difficulty of giving them the requisite velocity, as from the necessity of making them start precisely at an instant, dependent not merely on the position of the heddles, but on that also of the batten.—*See* pages 302, 303.

6, 7. *The Communication of Motion, or the Train of the Working Parts.*

The driving-shaft, which puts the whole machine in motion, is represented by B, figs. 104 and 106. It is supported by the upper cross-rails, which extend beyond the side-frames, to carry upon the right hand the toothed wheel, D, fig. 106, and to the left the pulleys or outriggers, C, fig. 104, upon which the steam-belt runs. Inside of the frame, opposite each of the swords, G, of the batten, there is a crank mechanism, B, F, upon the driving-shaft, to which the links, F, *y*, are adjusted which move the batten. It is therefore evident that, for every turn of the fly-wheel, C, or the steam pulley-shaft, the batten must make a complete vibration to and fro, advancing each time so as to beat up the shoot of weft at exactly the same point. Hence if the main-shaft make 120 revolutions in the minute, the shuttle must pass 120 times along the shuttle-rail.

The toothed wheel, D, figs. 105 and 106, making as many turns as the fly-wheel, works in the toothed wheel, D′, of double diameter, and therefore communicates to it half its own velocity. This wheel, D′, is made fast to one of the extremities of the tappet, or wiper-shaft, E, (figs. 104, 105, and 106,) whose two bearings are in the curved diagonal rails, X, fig. 104. This shaft, E, is moreover supported in the middle by a clamp-collar, between O and O, fig. 105, in order to guard it against the least flexure, in consequence of the heavy strains it is exposed to in moving the treadles.

The eccentrics, O, O′, are mounted upon the shaft, E, and turning with it, impart alternate pressure to the marches or treadles, P, P, as well as to the pecking arms, Q, Q′. The effect of these eccentrics may be readily conceived from their being of a spiral form, but with their curves placed in opposite positions. Hence if from the common centre of the two eccentrics any radius be drawn to the two circumferences, the sum of the two portions of it, intercepted by the centre and each circumference will be a constant quantity, which is the essential condition to be fulfilled by these eccentrics, to give equal alternate impulsions.

The ratio between the greater and smaller curvature of these eccentrics, depends upon the extent of the opening or shedding of the warp, for the shuttle-race. In the figures here engraved, the measurements are $\frac{1}{4}$ and $\frac{1}{2}$ inch, which, by the scale of 1 inch to the foot, gives 3 inches and 6 inches; and as the bottoms of the upright rods, which move the heddles, work in the levers, P, at a distance from the fulcrum, W, one-half greater than the eccentrics, O, or as the fraction $\frac{3}{2}$; the movement of the heddles will be $\frac{3}{2} \times 3$ inches $= 4\frac{1}{2}$ inches. In order to open the shed still more, the lower ends of the heddle-rods would need merely to be removed by the slots and nuts farther from the fulcrum, W, that is, nearer to the points of the treadles, or tappet-wheels, O, O, of a greater eccentricity may be used.

It is obvious that there should be a certain relation between the position of the crank elbows, B, F, figs. 104, 106, and the position of the eccentrics, O. Thus, in figs. 104 and 105, the main-shaft must make one-quarter of a turn before the crank, F, with its link, F *y*, can strike the batten, H, against the shoot of weft. During this quarter of a turn, the tappet shaft, E, moving with one-half the speed, will make only one-eighth of a turn. The position of the eccentrics must be nicely adjusted upon their shaft, to that of the crank, and firmly fixed in that position, so that the batten may strike home the shoot upon the closed warp, or upon the warp still partly shed, as may be thought preferable. In the position shown by the figures, the lay will strike somewhat before the closing of the shed; for the eccentric or tappet-shaft, E, will make one-eighth of a turn, equivalent to one-quarter of a heddle-stroke, while the crank-shaft, B, will make the quarter of a revolution requisite to drive home the lay upon the shoot.

We may now readily apprehend in what manner the double arm throws the shuttle at the proper moment. The two levers, (figs. 104 and 105), which produce the pecking motion, are actuated by two friction-rollers, (one of which is seen to the right of R, fig. 104,) attached to the eccentrics or tappets, and diametrically opposite the one to the other. By shifting the position of these projecting rollers in the curved slot of the eccentric, R, the throwing of the shuttle, effected by their striking down the pecking lever, may be adjusted to any point in the revolution of the tappet-shaft, which moves the heddles. As the shuttle can be thrown, however, only when the warp is open in a considerable degree, the screw-bolts which carry the wiper-rollers cannot be moved beyond the space included within the extremities of the great arcs of the eccentrics. And since there are two rollers diametrically opposite, it is obvious that in each complete revolution of the eccentrics, the shuttle must be thrown twice; and as each of these revolutions corresponds to two revolutions of the crank-shaft, or two strokes of the batten, there will result, as there ought to do, one stroke of the battens for every passage of the shuttle.—For point 8, *see* page 295.

I have seen this power-loom weaving at very various speeds, from one hundred pecks or shoots in the minute, up to one hundred and eighty. The average number in the most improved loom-shops for weaving calico, may be reckoned one hundred and twenty.

Near to each of its ends the warp-beam has two square-grooved large wooden pulleys, which are fixed by screws upon the cast-iron discs. These discs have a hollow socket in their centres for receiving the ends of the beam; and they also are fixed by four screws, which pass down through this socket into the wood. To give them a firmer hold, the sockets have a projecting feather or wedge within, which fits into a square groove or mortise cut in the side of the roller. Round the smaller pulley a cord makes two turns, carrying upon its inner extremity a light weight and upon its outer one a much heavier weight. Round the larger pulley, at the other end of the warp-beam,