THE COTTON MANUFACTURE

OF

GREAT BRITAIN

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COTTON MANUFACTURE

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SYSTEMATICALLY INVESTIGATED,

AND ILLUSTRATED BY 150 ORIGINAL FIGURES,

ENGRAVED ON WOOD AND STEEL;

WITH AN INTRODUCTORY VIEW OF ITS COMPARATIVE STATE
IN FOREIGN COUNTRIES,

DRAWN CHIEFLY FROM PERSONAL SURVEY.

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THE

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BOOK III.

CHAPTER III.

Description of the Preparation Processes of a Cotton Mill.

SECTION I.

Cleaning, Picking, Scutching, Blowing, and Lapping Machines.

WERE cotton wool delivered to the spinner in the same state as it exists in the pods of the plant, it would be found sufficiently open and clean to undergo immediately the carding operation; but, as we have shown in treating of the husbandry of cotton, the wool has to be compressed so strongly in bags, in order to facilitate its transport from the place of its growth to that of its manufacture, as to cause a matting together and entanglement of its filaments in tufts, which must be carefully undone before it is presented to the teeth of the cards, which would tear the matted filaments asunder, and ruin the staple.

The first operation of a cotton-mill therefore is to open up the cotton into its original spongy state, and at the same time to shake out any earthy or vegetable matters which may have been accidentally mixed with it. As perfect uniformity is a prime quality in yarn, and as this will depend not a little upon the uniformity of the wool, this object is promoted by mixing together the contents of several bales of the same kind of cotton into one heap, commonly called a *bing*. The wool from every bag should be evenly spread in a stratum on a clean mat, so that, when several such strata are piled over each other, a section of them from top to bottom will afford an average of the whole stock. A tool like a hay-rake is sometimes employed to draw down and teaze asunder the agglomerated mass of cotton as it is wanted for the picking and other cleaning processes. Much skill may be shown in the suitable intermixture of different kinds of cotton, in order to improve a weak-stapled quality, and make it work into good yarn. Soft, short, riband-like filaments are best adapted for spinning into wefts; firm, long, and cylindrical ones are best adapted for making the wiry warps and lace-thread yarns. Cottons which differ much in the length of their staple and form of their fibres do not draw, rove, or spin well together. To make this choice with final precision, the tact of the fingers should be aided by the power of the microscope. Coarse wefts are made from Surats, Bengals, and the inferior Uplands, with waste tops from the blowing machine ; but the better wefts for muslins require the finer staples of Bahia, Demerara, New Orleans, and the inferior Sea-islands. Warps are spun from New Orleans, Egyptian, Maranham, Pernambuco, and Sea-island, &c. The mixture of cottons of different qualities is very conveniently done by an apparatus attached to the lapping machine, as will be explained in its place.

Fine cotton, such as the best Sea-island, is generally cleaned and opened at first by the hand-labour of women and children. For this purpose it is spread in small quantities at a time on an elastic table of tesselated cords, called a *flake,* through the meshes of which the seeds and dust are made to fall, by beating it with slender rods or wands, while the spring of the table helps to open out the knots. Such impurities as resist this separating process are removed by the fingers.

Various machines for accomplishing the same object have been contrived. One of the earliest and most ingenious was that of Bowden, in which a parallel series of rods was made to strike upon a flake-table of cords, in imitation of beating by a number of hands. It was patented in 1801; but, being somewhat complicated and violent in its action, it did not keep its ground in the factories, though it was a powerful automaton. Each rod, after inflicting a flat blow, was drawn horizontally backwards by a sliding motion, and then raised vertically to discharge another blow by the power of a spring suddenly disengaged.

The *Willow* is the first machine in general use at present for opening out the entangled flocks of cotton wool. Its object is to clean the cotton slightly, by a sort of winnowing action, which led me to suppose that the name of the machine had been originally *winnow.* But M. Bourcart, an eminent cotton manufacturer at Guebwiller, in Alsace, informed me, that a cylindrical cage, made of *willows,* with a rotatory axis and cross arms, had been employed of old in Normandy for cleaning cotton, and probably sheep's wool, under the name of *le panier de Normandie.*

This simple mechanism, as obligingly sketched for me by him, is represented in fig. 22. It is undoubtedly the original of the English *willow*, both in form and denomination. The cotton is put in at the hopper, A, near the upper end, and on turning round the axis by a handle, or the pulley, B, by a band, it tumbles down the inclined plane, and falls out at the bottom, C, discharging through the interstices of the willow wands the earthy impurities in its progress.

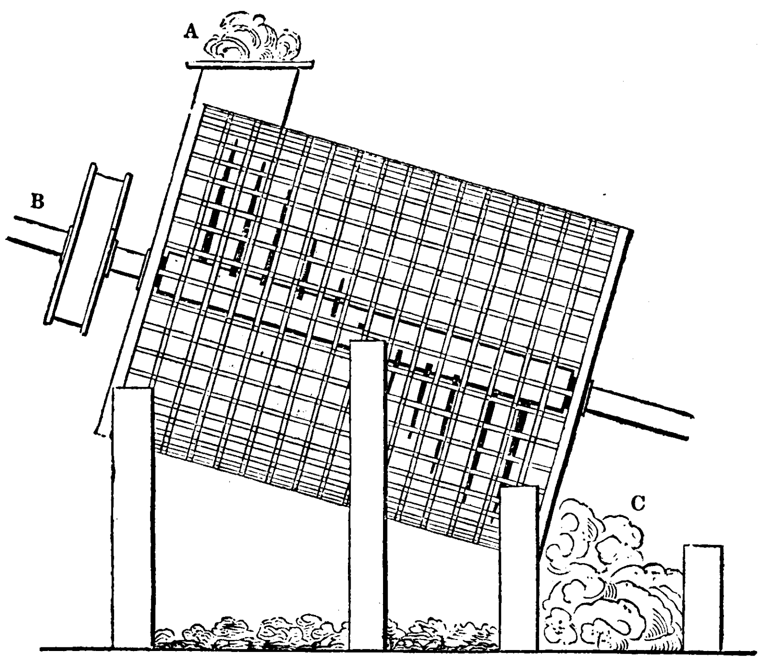


Fig. 22.—The primitive Willow of Normandy.

The willow, as now used in the English cotton factories, is shown in figs. 23, and 24. Fig. 23 represents the front view, or working face; fig. 24 shows the cross section. The machine consists of a rectangular frame, A, fig. 24, revolving in the direction of the arrow, upon its axis, B, which turns in bearings fixed to the frame, C, C, fig. 23. Upon the shaft or axis, exterior to the frame, are two pulleys, D, D, the first fast and the second loose—the former of which is called the steam-pulley in the factories, being that which puts the machine in gear or connexion with the steam power. This pulley derives motion from a strap in communication with the general shafting of the mill, as has been explained in the preceding chapter. Upon the four edges of the square revolving frame, A, are fixed a series of iron pins or pegs, which in the rotation pass

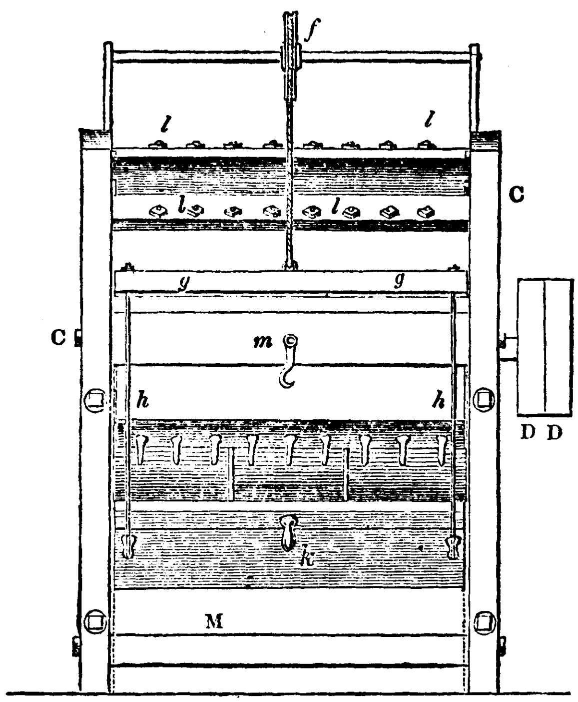


Fig. 23.—Square-framed Willow. Front View.
Scale, three-fourths of an inch to the foot.

between other similar pins, fixed to the inner surface of them antle, or case, E, of the willow. The inner face is not concentric with the motion of the pins round the axis; but the fixed pins project on the inside to different distances, relatively to the centre, in order to effect the progressive opening out of the cotton by the successive teazing motion of the rows of pins, *a, b, c,* of progressively increasing lengths.

The bottom of the willow is formed of a semi-cylindrical wire grid, F, F′ (cage-like), one half of which,

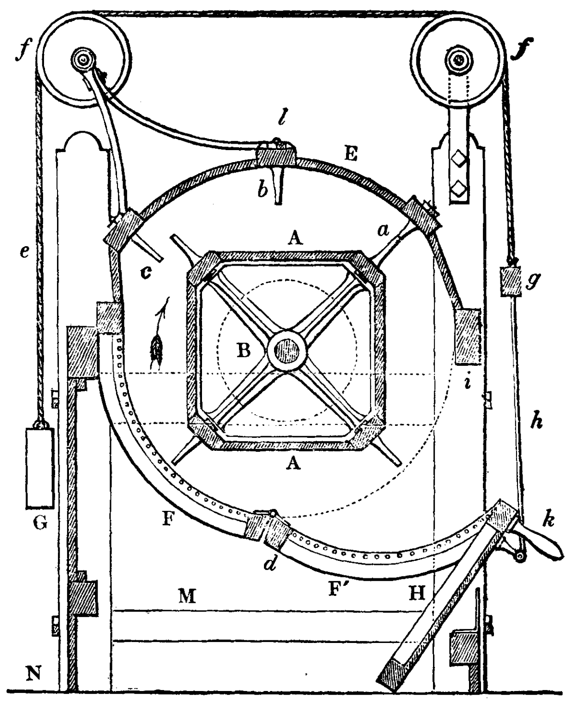


Fig. 24.—Square-framed Willow. Side View.
Scale three-fourths of an inch to the foot.

F, is fixed, and the other, F′, is movable round the hinge at *d*. This movable part is counterpoised by a weight, G, from which a rope, *e*, proceeds, passing over the pulleys, *f, f,* and is fixed to a bar of wood, *g, g,* fig. 23, to whose ends are attached the two slender rods, *h, h,* which suspend the movable part of the grid. To this part a door, H, fig. 23, is connected, which serves to shut the front opening of the willow-case when the grid, F′, is raised by the hand of the workman to the level of the dotted line, *i.* The handle, *k,* is used for lifting the door, and for fixing it in a closed state by means of the hook, *m,* fig. 23, attached to the frame.

In working this instrument, the boy who tends it lets down the door, throws in an armful of cotton upon the folded-down face of the grid, F′, and instantly shuts the door, which brings up the grid into the circle of the willow, *d, i.* The revolving frame, A, now agitates the cotton between its own pins and those of the case, whereby it is opened up, and discharges its dust through the grid, F, F′, into the subjacent space, M, which is cleared out from time to time through a door, N, in the back part of the willow. In some factories this chamber is put in communication with a fan, which serves to suck out the lighter dust as it is separated from the cotton wool. After the cotton has been wafted about for a few seconds, the tenter-boy lets down the door, H, and dexterously lifts the cotton from the folded-down grid, F′, where the machine always throws it. He then introduces a fresh quantity.

The proper speed of the steam-pulley axis, and of course of the revolving frame, A, is considered to be 600 revolutions per minute. A machine armed with such strong iron pins, and turning with such velocity, has a dangerous aspect, and must undoubtedly be managed with discretion. I inquired particularly concerning the chance or frequency of accidents with the willow, in my tour through the factory districts, and found that they were very rare. I saw that the cotton was all deposited upon the depressed grid, F′, quite out of the limits of the revolving spikes. In fig. 23, the series of iron nuts, *l*, *l*, *l*, corresponds to the series of iron pins, *a*, *b*, *c*, in fig. 24, which project from the inner surface of the case.

A skilful spinner of Stayley Bridge assured me that spiked willows should be used in all cases with extreme tenderness and circumspection, especially on long-stapled cotton wool, as they were apt to draw it into knots; for the inferior, foul cotton wools—such as the Surats, Bengals, and some of the Upland Georgia, the following machine, the Conical Willow, as made by Mr. Lillie, is of remarkable power. It cleans and opens from 12,000 to 15,000 pounds of cotton, without injuring the staple, every week at Messrs. Marshall's factory, at Portwood, Stockport; in another establishment it winnowed the surprising quantity of twenty-four bags, equal to 7,200 pounds, in one day, for coarse spinning.

New Conical Self-acting Willow.

To obviate the danger and interruptions of work to which the preceding machine is liable, the following modification, borrowed in some respects from the wool willow, has been lately introduced into the cotton factories. Here the cotton wool is continually fed in at the one end, and given out at the other, without any manual intervention, strictly speaking—an effect due to the centrifugal motion imparted to the filamentous flocks by the rapid revolution of a cone within a concentric case, furnished with iron pins or spikes, as in the square-framed willow. The cotton is drawn in at the smaller end or summit of the cone, and is whisked onwards to the larger end or the base, where it falls

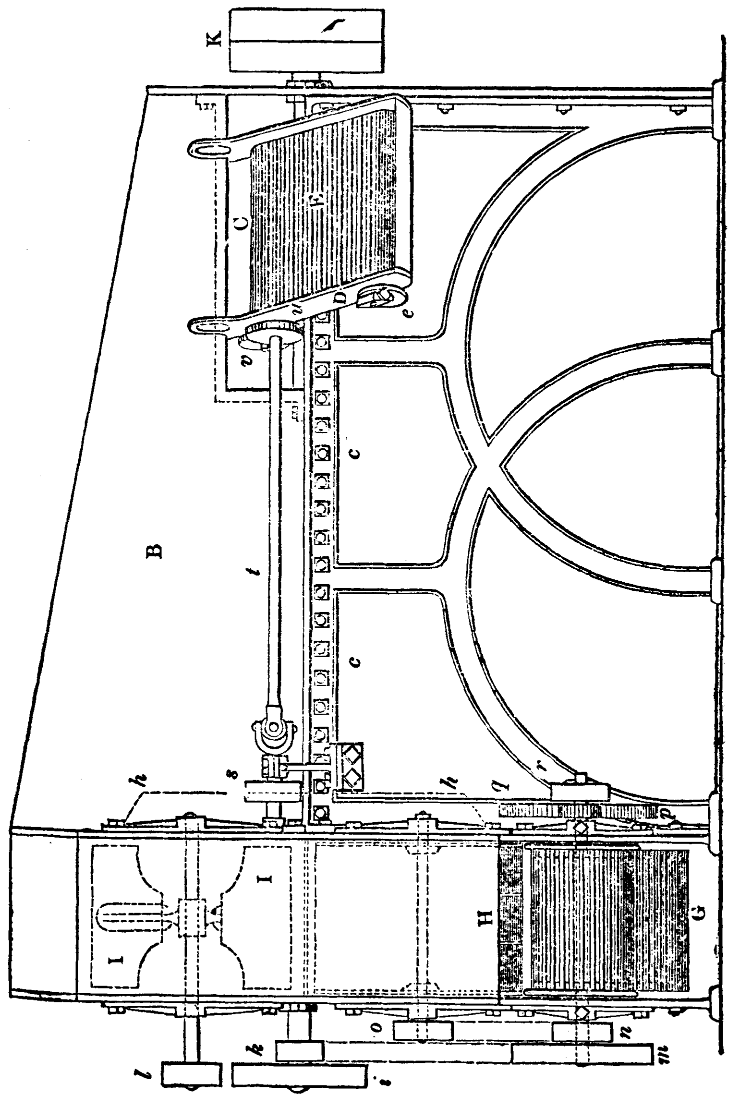


Fig. 25.—Conical Self-acting Willow. Longitudinal View. Scale, half an inch to the foot.

upon a moving apron, or delivering-cloth, which turns it gently out upon the floor of the apartment.

Fig. 26 is a longitudinal view of that side of the conical willow which receives and discharges the

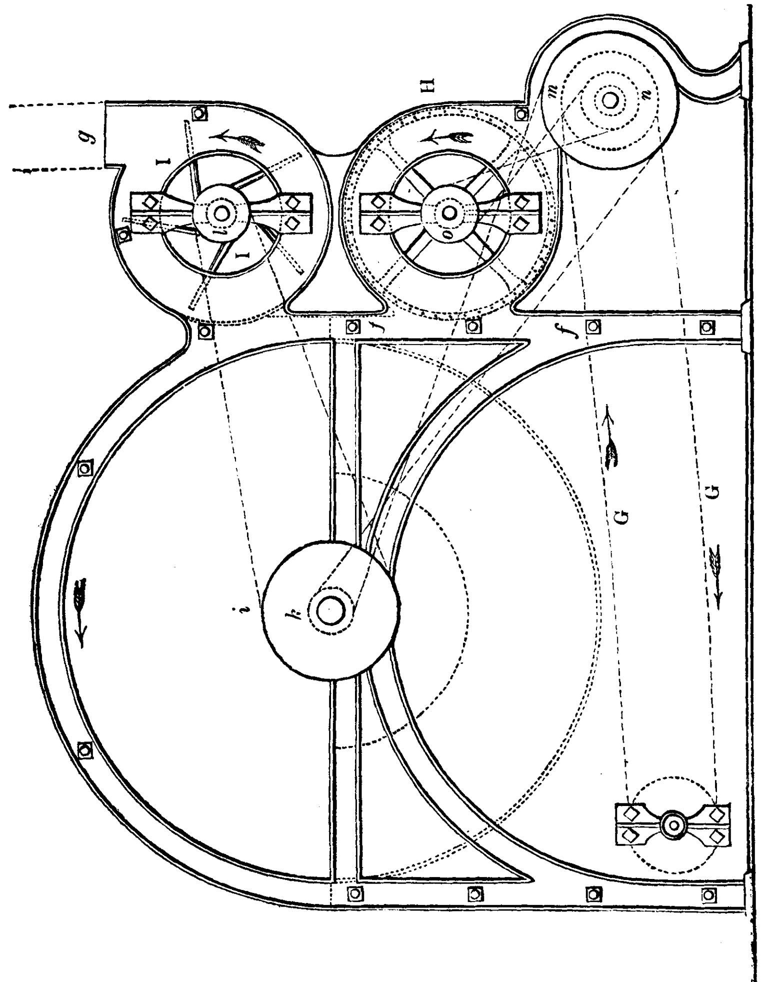


Fig. 26.—Conical Self-acting Willow. End View.
Scale, half an inch to the foot.

cotton; fig. 26 is an end view; fig. 27 is a top view, with part of the casing and frame-work removed to show the interior structure; fig. 28 shows a part of the perforated iron plate, or grid, which forms the

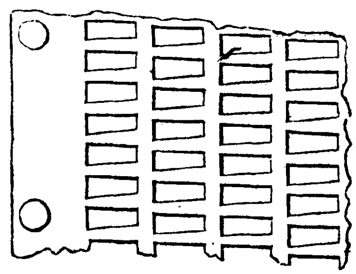


Fig. 28,—Bottom Grid of Conical Willow.

bottom casing round the cone. A parallel wire-grating, such as exists in the common willow, has been also employed. The cone, A, consists of a strong shaft, *a, a,* mounted with three cast-iron rings—one being at each end, and one in the middle—for the purpose of supporting the sheet-iron mantle which forms the surface of the cone. Along this surface, four equidistant iron bars are riveted parallel to the axis, into which four lines of strong iron pins or pegs, *b, b,* are screwed by means of nuts. Corresponding to the intervals of these pins, one line of pins, *d, d,* is fixed by other nuts, *c, c,* fig. 25, upon each side of the easing-frame interiorly. The top of the cone is covered with a concentric case, B, fig. 25, while the bottom casing consists of the grid, or screening-plate. In the top casing, near the narrow end, there is an oblong aperture, C, to which a frame, D, is attached, that carries an endless apron, E. Upon this apron-frame the cotton flocks from the bing are spread by hand. The apron consists of parallel slips of thin sheet iron, three-quarters of an inch broad, placed at intervals of half an inch asunder, riveted at their ends

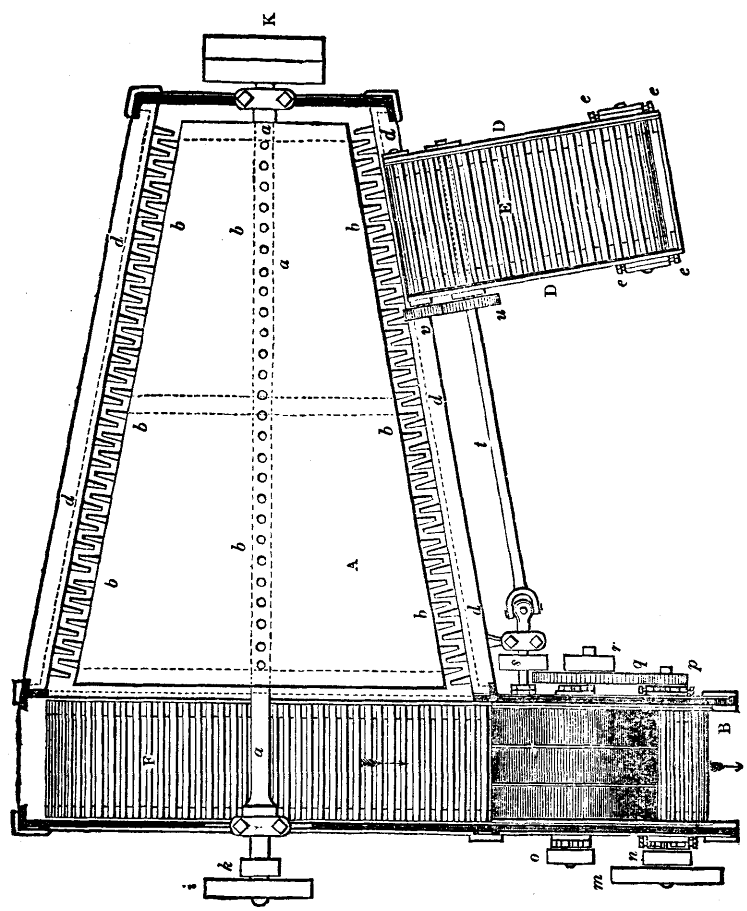


Fig. 27.—Conical Willow. Top View.
Scale, half an inch to the foot.

to two endless leather straps, which travel upon pulleys fixed to two shafts parallel to the sheet-iron slips, one of which shafts is moved by wheel-work, and the other is adjustable by set screws, which act upon the bearings of the shaft, so as to tighten the strap at pleasure.

At the wider end of the machine there is a chamber, F, fig. 26, into which the cotton is whisked out of the cone, after having been whirled onwards from its narrow end, and is received upon a moving apron, like the former, which is seen at fig. 27, and at the dotted lines, G, G, fig. 26. About an inch above the surface of this apron, a cylindrical wire cage, H, revolves upon an axis parallel to the apron. This cage is shown at fig. 27, and by dotted lines in fig. 25 and 26. It is enclosed in a case of sheet-iron, which communicates at its side, *f*, *f*, fig. 26, with the chamber, F. Over this cage, between the frame-work of the machine, a fan, I, enclosed in a similar case, is placed, which sucks out the dust of the cotton wool through the wire cage from the chamber, F, beneath it, and blows it out through a large pipe in connexion with the orifice, *g*, fig. 26. This cage not only prevents the cotton fibres from being wafted away with the dust, but lays them down by its rotation upon the travelling apron.

The wire cage and the fan are placed in communication by a flat tin-plate cover, or lid, which embraces at once both the orifices at the ends of the two axes of these cylinders, and is shown by interrupted lines at *h*, fig. 25. The other ends of the fan and cage, seen in fig. 26, are left open, in order to draw out the dust, and to ventilate the air of the apartment.

The motions of this elegant automatic machine are given as follows: Upon the shaft, *a*, of the cone, A fig. 27, the usual fast and loose pulleys, K, K′, are fixed, by which the cone may be put in or out of gear at pleasure. Upon the other end of the same shaft two other pulleys, *i* and *k*, are fixed, the first of which gives motion to the fan, I, by a strap moving the little pulley, *l*; the second pulley, *k*, gives motion to the apron, G, G, by driving the pulley, *m*, made fast to one shaft of the apron. Upon the same shaft there is a smaller pulley, *n*, which, by means of a strap and pulley, *o*, drives the wire cage, H. At the other end of the last shaft, there is a pinion, *p*, which drives the the wheel, *q*, and its attached pulley, *r*. From this pulley, *r*, a strap goes up to the pulley, *s*, which turns a shaft, *t*, furnished with a Hook's universal joint, for the purpose of converting the motion parallel to the axis of the cone, into a motion parallel to its side, as is clearly shown in fig. 27. This shaft, with the universal joint, is supported at its other end in the frame, D, and it carries a toothed wheel, *u*, which drives the wheel, *v*, upon the apron-shaft; and thus the feeding apparatus is moved.

The velocity of the cone may be from 400 to 600 revolutions per minute.

The mode of action of this willow is obvious, from the preceding detail of its structure. The cotton slowly introduced by the creeping-apron, E, is teazed out by the spikes of the cone revolving in the direction of the arrow, fig. 26, and thus is made to discharge its heavier impurities, twigs and stones, through the grid-work bottom. On advancing to the other end by the centrifugal force, its lighter dust is wafted out by the fan through the squirrel-cage sieve, and blown away through square pipes into an adjoining closet. The filaments thus cleaned are discharged from the apron, *w*, fig. 27, in the direction of the arrow.

The above machine belongs to the class formerly called the Devil, or Wolf.

Batting, or Scutching, and Blowing Machines.

The next process to which cotton is subjected in a spinning factory, is that of batting (beating) and blowing, by a machine called sometimes by the one name and sometimes by the other. Its object is to loosen thoroughly the filaments of the cotton already partially cleaned by the hand or the willow, and to carry off, through fan-sieves, the remainder of the dust. The beating action is produced by flat bars carried rapidly round, which strike with their faces the cotton fibres as they are slowly introduced from the feeding rollers, connected with the feeding apron-cloth. In each machine there is usually a double set of the beating or scutching apparatus, from the last of which the cotton is frequently discharged upon the floor of the apartment, whence it is removed to the next machine, in order to be scutched again, and lapped into a cylindrical roll. But a much more improved, and far preferable plan, is that represented in Plate III, where the batting machine turns out the cotton in the form of a cylindrical lap, without the labour of gathering and spreading, and ready to be applied to the next machine, where the different sorts are occasionally mixed, before being finally made into a lap for the carding operation.

In many fine spinning-mills, where the best Sea-island cotton is used, batting machines are dispensed with, and the hand-picked and beat cotton is at once evenly spread upon the feed-cloth of the cards. Plate III, and wood-cuts 29, 30, 31, represent a con-

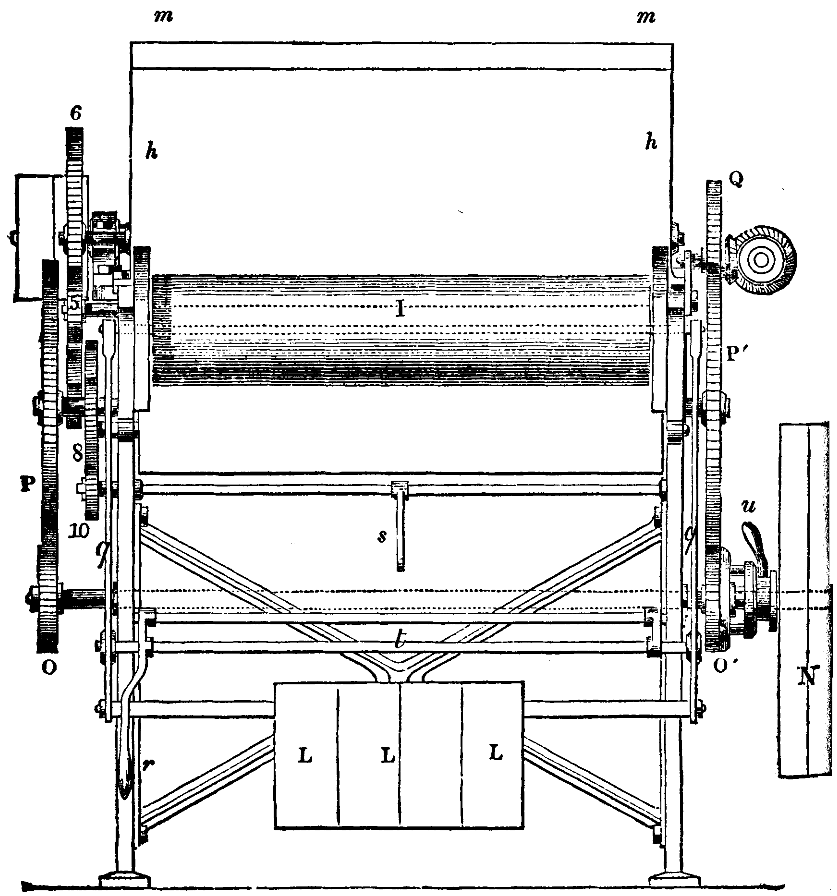


Fig. 30.—Front View of the Lap Machine.

nected system of apparatus, embracing the batting and the lapping machines. Plate III is a longitudinal section of a double batting or blowing machine, with the lap mechanism attached to it. The feed-apron is about eight feet long: part of it is shown at A, where the one end passes over a roller, *a*, as its further end does over the fellow roller, beyond the limits of our figure. Fig. 29 is a longitudinal section of the proper lap machine. Fig. 30 is a front view of the lapping mechanism, representing, in fact, the delivering end of both the preceding machines. Fig. 31 is a longitudinal view of the outside of the lapping apparatus, to show the working parts common to both engines. The same letters of reference denote the corresponding parts in the four figures.

The willowed cotton is spread by hand about two inches thick upon the apron-cloth, A, plate III., and is carried forward by it at the rate of about three feet per minute, to the feed-rollers, *b*, *b*, which are pressed together by a weight acting through the lever, *c*, upon the brass bearings of the top rollers. A wooden roller, *d*, serves to keep the cotton close to the apron, and to facilitate its introduction between the feed-rollers, which consist here, as in the carding-engines generally, of small iron cylinders coarsely fluted parallel to their axes. B is the first beater, consisting of two flat bars, *e*, *e*, fixed at right angles upon the arms of the revolving shaft, so as to strike upon the cotton filaments as they issue from between the feed-rollers. This, the scutching shaft, is made to revolve with a velocity of 2,000 turns per minute, by means of a strap proceeding from a pulley upon the mill shaft near the ceiling, as has been explained in Chap. I., Book III. C is the harp, a grating or grid, in the form of the quadrant of a cylinder, composed of long flat bars, against whose edges the cotton is scutched by the beaters, and thereby thoroughly opened, after which it is wafted upon the endless apron D. This apron consists of thin spars of wood about three-quarters of an inch broad, and half an inch apart, fixed at their ends to two endless leather straps, which turn round the rollers, *f* and *g*, the latter being driven by the outside wheel-work.

Near the end of the apron there is a revolving cage-cylinder, E, enclosed under the general cover, *h*, *h*, *h*, through the top of which there is a pipe, *i*, in communication with a rotatory fan, placed in any convenient part of the room. This cylindric cage permits the dust to be sucked through it, and also serves to spread smoothly upon the apron the loose cotton filaments into a level fleece, which passes off under the wooden roller *h*, and is thence drawn in by the second pair of feed-rollers, *l*, *l*, in order to be exposed to a second scutching by the beater-bars at F, the axis of which revolves 2,200 times per minute. This increased velocity does no harm to the flocks of cotton in their loosened state. The second beater delivers the filaments upon a second apron, G, similar to the first. Here it is exposed to the sucking action of a second sieve-cylinder, in communication by the orifice, *m*, with the general fan ventilator.

The cotton, once more formed into a fleecy nap, is brought out by the rotation of the roller, *n*, and now, instead of being thrown upon the floor, as formerly, it is carried through between the two pairs of iron rollers, o', o' and *p*, *p*, the upper ones being weighted (loaded) as shown in the engraving. These rollers deliver the compressed fleece to the wooden lap-cylinder I, whose axis is loaded with weights, L, L, L, so as to bear down between the two rollers, K, K, which, revolving both in one direction, as shown by the arrow,

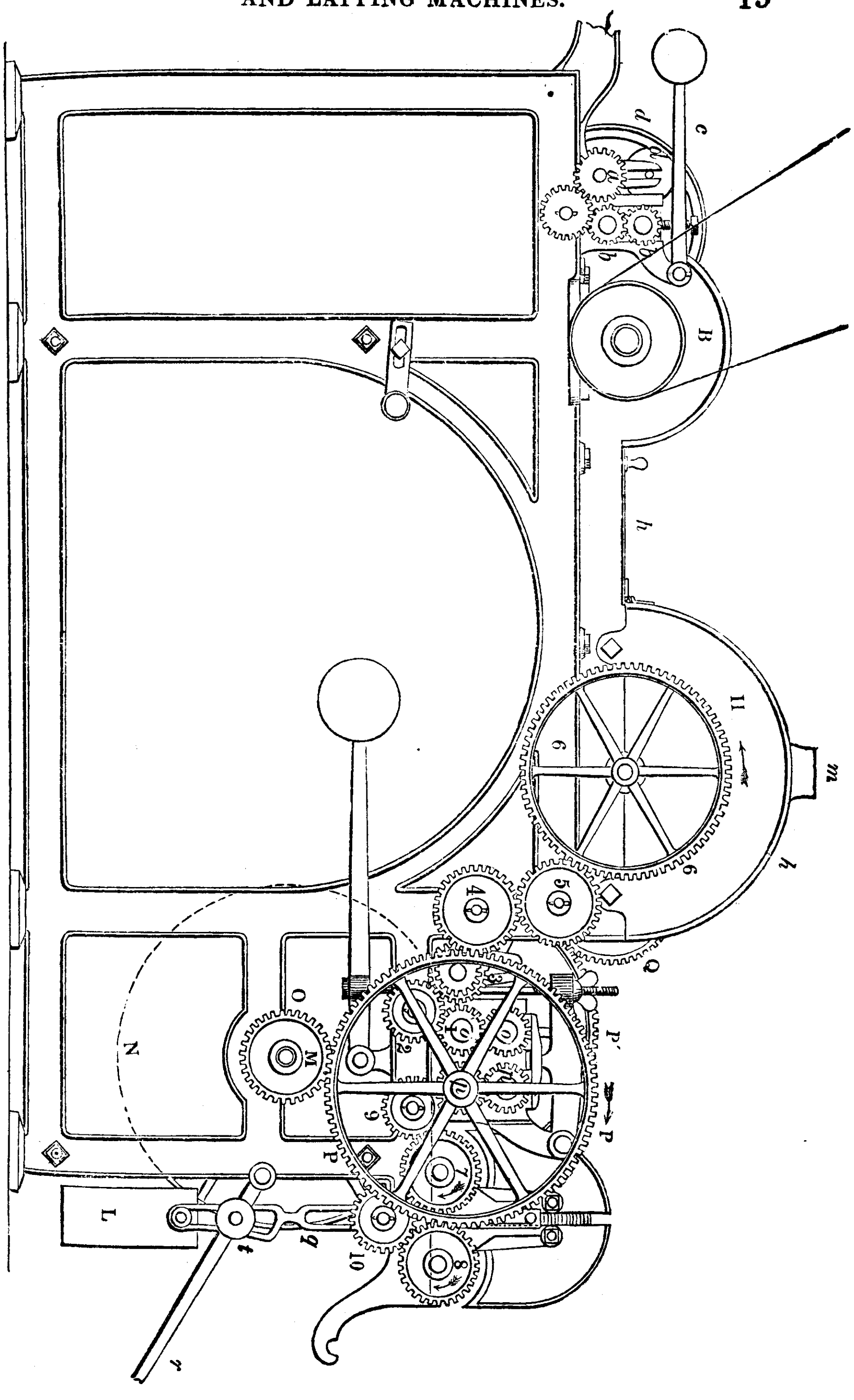


Fig. 31.—A Longitudinal View of the outside of the Lap Machine to show the moving mechanism.

carry round with them by friction alone the lap-cylinder. As this cylinder increases in diameter, the links, *q*, *q*, progressively rise up with their weights, L, L, so that the pressure continues always uniform. Whenever the coil of lap has acquired the proper size, the twin rollers, *o′*, *o′*, with the aprons, cages, and feed rollers, throw themselves out of gear, whilst the twin rollers, *p*, *p*, and the lap-cylinders continue to revolve, whereby the fleece is torn or cut across in the middle line between the two pairs of twin rollers. The attendant now lifts the lever, *r*, which raises the links, *g*, *g*, and suspends the weights, L, L, by the hook, *s*. Thus he relieves the axis of the lap-cylinder, removes it, and puts an empty one in its place. He now throws the machinery once more into gear, disengages the connecting rod, *t*, from the suspending hook, *s*, and restores the action of the weight, at the same time that he guides the beginning of the fleece round the empty roller, *see* fig. 30.

The beaters, B and F, derive their motions from the mill shaft, independently of the rest of the machine, by means of pulleys shown by dotted lines in the engraving. Near the finishing or discharge end of the blower, there is a cross shaft, M, upon whose end there is a pulley, N, which revolves 36 times in the minute. Upon each end of the same shaft there is also a toothed pinion, O, O′, which drives the wheels, P and P′; the first of them being made fast to the end of the under roller, *p*, and the second to the end of the next roller, *o′*. By disengaging the pinion, by means of the lever, *u*, fig. 30, from the shaft, M, the wheel, P, will be set at rest, as well as the other parts driven by this wheel.

It is obvious, therefore, that by this arrangement the fleece may be cut across between the rollers, *o, o*, and *p, p*, as formerly stated; in consequence of the first pair of rollers being stopped, while the second pair continues moving.

A wheel, Q, as shown particularly in fig. 31, and by dotted lines in plate 3, transmits motion to the feed-rollers, *l, l*, and *b, b*, to the cylindrical cage, E, and to the apron, D, from the wheel, P, by means of bevel wheels and a horizontal shaft, as shown by dotted lines in plate 3. Upon the other end of the roller, *o*, is a wheel that gives motion to the apron, G, and to the cage, H, as is shown in fig. 31, where the carrier wheel 2 drives the wheel 3 of the apron roller, *n*. Upon the axis of wheel 3 is a pinion which drives the carrier wheels 4 and 5, and thereby the wheel 6 upon the shaft of the cylindric cage, H. The roller, *p*, driven by the large wheel, P, has upon the same end of the axis a pinion which drives the rollers, K, K, of the lapping apparatus, by means of wheels 7 and 8, and the carrier wheels 9 and 10, as shown in fig. 31.

The preceding explanation applies fully to the lap-machine, as represented in figs. 29, 30, 31; the only difference being in the mode of feeding, which, in fig. 29, consists in an endless apron moving between a frame, upon which there are slot bearings, R, for receiving the ends of the wooden pin that is thrust through the central hole of the lap, after the withdrawal of its roller. Upon this frame as many pairs of slot bearings are affixed as there are different sorts or laps of cotton to be mixed.

By the movement of the apron the fleece is unwound from each lap, and carried forwards in parallel layers, lying over each other, by the traction of the feed-rollers. In the excellent machine, of which the preceding figures are a faithful delineation and analysis, there were five slot bearings, two of which carried laps of New Orleans cotton wool, and three, laps of Bahia. Many of the mechanical contrivances above described are new, and the whole execution and performance of the engines are highly creditable to their constructor, Mr. Crighton, of Manchester. The beaters of such machines make from 1,800 to 2,200 revolutions per minute.

The scutching machine was originally invented by Mr. Snodgrass, of Johnston, in Renfrewshire, and afterwards improved by Mr. Peter Cooper, of the same place. The lap-apparatus is sometimes called a spreading machine.

Different staples of cotton require different degrees of scutching; the short and soft staples admitting of less powerful and rapid beating than the firm and long staples. For the last, the beating-bars should be adjusted at a greater distance from the feed-rollers, to prevent the filaments from being torn. For accurate work, the cotton wool should be laid upon the feed-cloth in weighed quantities, and very evenly spread or distributed.

These mechanisms require to be frequently cleaned, and to be lubricated at the moving parts, both on account of their extreme velocity, and of the dusty and downy particles, which are apt to clog the axes and bushes by inspissating the oil. When in good order, they will put through 5,000 pounds of cotton wool in a week of 69 hours, and supply 21 cards (breakers and finishers), with a sufficient lap, in a mill spinning from 35'*s*. to 40'*s*. The great speed of the beaters produces a current of air which carries the filaments onwards in the machine; but to remove the dust entirely an independent ventilator is employed, as already stated, which, like the scutching and spreading engine, takes about a horse power to drive it at a proper speed.

We shall introduce here the description of the ventilator employed in modern mills, as constructed by Messrs. Fairbairn and Lillie.

Figs. 32 and 33 represent a side and front view of

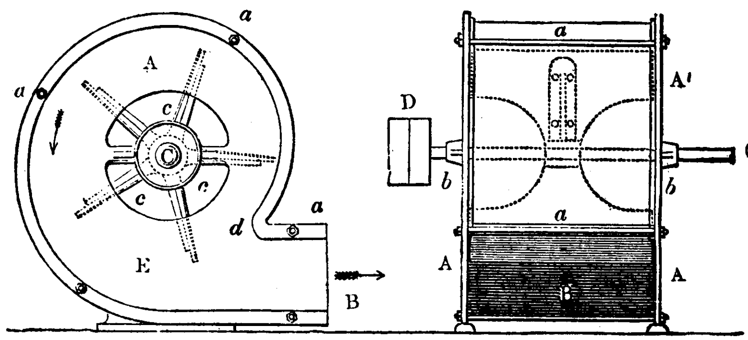


Fig. 32. Fig. 33.
Centrifugal eccentric Fan. Scale, three-fourths of an inch to the foot.

this simple but effective engine for creating a current of air, equally applicable to general ventilation of buildings for the health of their inmates, as it is to the conical willow, the scutching, and spreading machines. It consists of two cast-iron end plates, A, A′, provided with a central circular opening, *c, c, c,* from whose circumference the outer edge of each plate enlarges in a spiral line; the point of it nearest the centre being at *d,* and the one farthest from the centre being at the base under E, fig. 32. This pair of parallel plates is connected by bolts *a, a, a,* a mantle or case of sheet-iron having been previously fitted into grooves cast in the edges of the said plates. By this means a cavity or chest is formed, which has an elongated aperture at B, to which a pipe may be attached for conducting the discharged air in any direction. Within this cavity a shaft, C, is made to revolve in bearings, *b*, *b*, placed centrally in the plates, A, A, and cast in the same piece. Upon the shaft a boss is made fast by wedges, which carries five flat arms, seen in section fig. 32, at the sides of *c*, *c*, *c*, to which five flat plates are riveted. These vanes or wings have each the form represented in the front view between *a*, *a*, being rectangular plates of iron, with a semi-circular segment cut out of their edge upon each side, whose diameter is equal to that of the end opening in the case. Upon one end of the shaft, C, exterior to the bearing, *b*, the fast and loose pulleys are fitted for receiving the driving strap, and for turning the vanes in the direction indicated by the arrow in the side view, whereby the air is expelled before them out of the end orifice at B, while it is allowed to enter freely by the side openings at *c*, *c*, *c*. By the centrifugal force of these revolving vanes, the air is condensed towards their extremities, makes its escape from the pressure through B, and is continually forced in at the sides, in virtue of the atmospheric equilibration.

Some ventilators have their hoods or mantles made concentric with the revolving vanes, and though they do good work when turned with great velocity, they are not well adapted to produce pressure by condensation of the air; for the wind at the outlet B consists partly of the air compressed by the extremities of the wings, and of the air rarefied on its entrance near their roots. In the fan here represented, called the eccentric, the air which is driven out from B, has been subjected to compression during its whole course through the spiral space before the revolving wings, and is equal in density to that compressed at their extremities by the centrifugal force. This engine discharges therefore a considerably greater body of air than the fan with a concentric mantle, because each wing, in passing the point *d*, acts as a valve to intercept the ingress of the uncondensed quiescent air, which would cause an eddy, and retard the rapid current by the inertia of its particles. The wings are usually made to revolve with such speed as to pass through a space of from 80 to 100 feet in a second.

When the fan is employed to draw air out of the willow, the batting machine, or chambers of any kind, the circular openings in its sides must be enclosed within caps, which are then connected with pipes placed in communication with the cavities or spaces to be acted upon. Slide valves or throstle-valves may be introduced into these exhausting pipes, or into the condensing pipe connected with B, in order to modify the rarefying or blowing force. The last arrangement is adopted with signal advantage for applying a regulated blast to forge fires.

I have found experimentally that a fan like the above, 18 inches in diameter, and 12 inches in width, moving its wings at the rate of 120 feet in the second, supports by aspiration, in a syphon, a column of water two inches high, and when it moves at the rate of 180 feet, it supports a column three inches. The chimney of an excellent drawing air-furnace does not support, by aspiration, more than one-seventh of an inch.

SECTION II.

Carding Engines, or Cards.

The objects of the carding operation are to separate the fibres which, in their imported state, are entangled in small tufts and knots, and which have been but imperfectly opened in the blowing machine, so as to draw them out into somewhat parallel directions, and to remove completely all the residuary impurities. The carding principle consists in the reciprocal action of two surfaces, which are mounted with hook-shaped elastic wire points. These little hooks, made of hard-drawn iron wire, are represented in fig. 34. The wire

Figure 34.

Fig. 1. Fig. 2.

must be first bent at right angles, as at *a* and *b*, fig. 1; then each branch must receive a second bend, as at *c* and *d*, fig. 2, at a determinate obtuse angle, which must be invariable for the same set of cards. It is indispensable that these two obtuse angles, *a, c, e, b, d, f,* be mathematically equal, not only for the two conjoined points, but for the whole series of teeth; for if one of them slope more or less than its fellow, it will lay hold of more or less cotton wool, and cause the carding to be irregular.

The leather must be pierced by a fork, with two holes for each double tooth, at the distance *a, b,* but in such a way that the inclination of these holes, in reference to the plane surface of the leather, be invariably the same; otherwise the length of the teeth would vary with the angle of inclination, and spoil the card. Another condition in making good card cloth, or *garniture*, is to have the leather of uniform thickness. This is effected by a species of planing machine, which strips the surface smooth, and renders the thickness equable. A riband or sheet of leather thus furnished, being made fast to either a flat or cylindrical surface of wood, will constitute a flat, or a cylinder card. Suppose *a*, fig. 35,

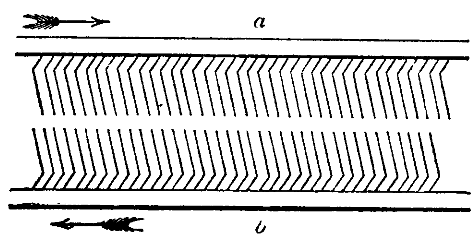


Fig. 35.—Card Teeth.

to be one such card, and *b* to be another, whose teeth are set in opposite directions, the two wire surfaces being parallel, and very near each other, with a tuft of cotton wool betwixt them. Let *a* be now moved in the direction of the arrow, the points of the opposite sets of teeth being in contact, while *b* remains stationary, or is moved in the opposite direction; it is obvious that every small flock of the wool, placed in such a predicament, must experience the traction of both sets of teeth. The teeth of *a* will endeavour to pull the filaments away with them, while those of *b* will keep hold of them, or pull them in the contrary direction. Each of the teeth will, in fact, appropriate to itself a portion of these filaments, and will thereby disentangle the tuft of cotton, thus drawing out the fibres, and placing them lengthwise, agreeably to the line of traction. If this operation be often enough repeated, it must eventually arrange all the filaments in a direction truly parallel, and thus accomplish the end in view. Suppose, now, the whole filaments to be hooked upon the card *a,* a single cross stroke of the two will transfer to *b* a portion of those upon *a,* should the teeth of *b* be moved in the same direction with those of *a,* but more slowly. If the cards be so placed that the sloping points of their teeth look the same way, as in fig. 36,—and if *a* be moved in the

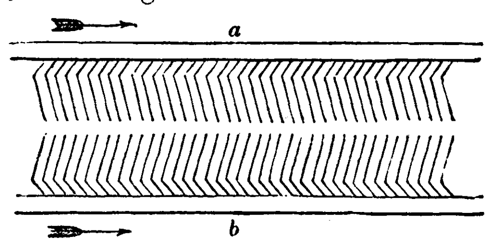


Fig. 36—Card Teeth.

direction of the arrow, while *b* is stationary, or is moved more slowly in the same direction,—*a* will comb all the wool out of the teeth of *b,* since the hooks have in this position no tendency to retain the filaments. The consideration of these different results, according to the different circumstances now stated, will enable any one to comprehend clearly the action of the carding engine.

For carding long-stapled fine cotton, one operation is not sufficient to clean the fibres completely, and to lay them in parallel positions, ready for the next process of a spinning-mill. Two cardings are had recourse to in this case; the first, by what is called the breaker cards, and the second by the finisher cards. The two operations do not, however, essentially differ from each other.

The cylinder cards, invented by Lewis Paul, and patented in 1748, were covered parallelly to the axis with fillets of leather thus mounted, having intervening stripes free from points. A concave card of the same curvature as the cylinder was applied to its under surface. Hence, on turning the cylinder by the handle at its end, the two bristling surfaces worked against each other, and performed the carding operation. When the filaments were thought to be sufficiently carded, the stationary concave part was let down, and the cylinder was then stripped of its wool by means of a comb made of a bar of wood, bearing a row of needles. These card-ends of the length of the cylinder were joined together by a particular contrivance which it is unnecessary now to describe.

When the concern of Lewis Paul, at Northampton, came to be dismantled by the failure of his operations, the carding cylinders were purchased by a hat manufacturer from Leominster, and applied by him to the carding of sheeps' wool for hats; and about the year 1760 they were introduced into Lancashire, and re-applied to the carding of cotton, by a gentleman of the name of Morris, in the neighbourhood of Wigan.*

Mr. Peel was one of the first Lancashire manufacturers who adopted this mode of carding, being assisted in carrying it into operation by James Hargreaves, the ingenious author of the Jenny. His machine was composed of two or three cylinders, covered with the card-fillets; and the carded cotton was taken from the cylinders by hand-cards applied by women. This process answered so indifferently, that Mr. Peel laid it

* John Kennedy, Esq., in Memoirs of Manchester Society, vol. v., second series.

aside. Then Arkwright took the cylinder-card in hand, and made it a practicable machine, about the year 1770, or 1771.* The feed-apron, as applied to cylinder-carding, has been claimed as an invention of John Lees, a quaker, of Manchester, in 1772; but there is no doubt that Arkwright had previously used the same contrivance, along with the crank and comb, at Cromford; for continuity in the discharging riband, at one side of the cards, obviously implies continuity in the feeding fleece, at the other side. In fact, the crank and comb, with its incessant stripping action, would have been a preposterous apparatus, without a corresponding punctuality of supply. Arkwright, indeed, refined upon the feed-apron, by rolling it up into a coil, after having spread the cotton evenly along it in an extended state, and thus fed the cards by the gradual unrolling of the apron-cloth. There can be no reasonable doubt in the mind of any man, acquainted, however slightly, with the carding process, that Arkwright had also used doffer cylinders, covered all over with spiral fillets, along with the crank and comb, in 1771 or 1772; for had his doffer been covered with pieces of card-cloth parallel to its axis, like the card-drum, with intervening bare spaces, the machine could not have turned off continuous ribands, as it did. It is preposterous to ascribe to Wood and Pilkington, about the year 1774, what Arkwright must have done two or three years before, though he did not specify it in a patent till 1775, on bringing his whole system to maturity. Then, indeed, all the schemers

* I was informed by Mr. Strutt, that Mr. Arkwright says he remembers of his father, Sir Richard, getting cylinder-cards from Northampton.

who had perchance imagined something similar to some of its parts, though never able to make them operate productively, began to put in their claims, and they were well encouraged by the many sordid and invidious rivals of the Cromford Company. In fact, it was impossible for Arkwright to keep any invention secret in his mill, when almost every one of his workmen was bribed to act as a spy, and report the progress of his improvements.

Carding-engines may be defined to be brushes of bent iron wire fixed in leather, and thereby applied to a set of cylindrical and a set of plane surfaces, the former being made to revolve so as to sweep over the surfaces of the latter at rest. Sometimes large cylindrical cards work against the surfaces of smaller cylindrical cards, moving at a less velocity; and occasionally both plans are combined in the same engine, as the following figures will show. The tufts are held fast by the stationary or slow-moving cards, while the quick-moving cards teaze out the fibres, and gradually disentangle them. Hence we can understand how fixed cards, in which the tufts are exposed to an uninterrupted course of teazing, disentangle the long-stapled cotton better than the squirrel or secondary revolving cards, which bring the tufts under the action of the great drum-card only once in each one of their revolutions. They exercise a greater tearing force, and are therefore used for coarser and shorter stapled cottons, with which rapidity of work is an object of importance. In fact, much more cotton can be passed through in the same time when both the main card and the counter cards revolve; and as the latter require less frequent cleaning than what are called the flat-top cards, this system is generally used in preparation for the lower counts of spinning; and occasionally in combination with fixed tops in that of the middling fine yarns.

Figs. 37, 38, 39, represent a carding-engine, in which both systems are combined, and constructed upon the best principles. Fig. 37 is a longitudinal section, fig. 38 the front view, where the carded cotton is seen to be delivered, and fig. 39 is a longitudinal view of the side of the engine, where the principal wheel-work lies.

In fig. 37, A is the main carding cylinder, constructed of parallel segments of mahogany, *a, a,* screwed upon three or four cast-iron rings fixed to the central shaft. Upon each of these segments a card-leather (card-cloth) is nailed in a length equal to the width of the main cylinder or drum. The inclination of the card-teeth is visible in the figure. B, B, *f,* are parallel segments of mahogany, called card-tops, which rest with their ends upon heads of screws, *b, b,* fig. 39, projecting from the side-framing, *c,* of the engine, and they are held in their places upon the frame by pins, which pass through their ends. The interior curvature of these segments is covered with a narrow fillet of card-leather. This surface may be placed nearer to, or farther from, the card-drum, A, by adjusting the screw-props at the end of each segment. This structure is clearly seen at *b, b,* in fig. 39. D, E, F, G are rollers covered with card fillets wound spirally round them from one end to the other. These small cylinders, called urchins or squirrels, revolve by their necks in the bearings, *d, e, f, g,* fig. 39, which may be moved nearer to or farther from the drum, and from each other, by adjusting screws, as shown in the wood-engraving.

H, fig. 37, is a pair of fluted iron feeding-rollers, like those described for the blowing machine, which are pressed together by means of a screw, *c*; *h* is a feed-board, along the surface of which the fleece unwound from the lap-roll I, by the acting roller K, advances to the feed-rollers H. The first roller-card D, turning with much less velocity than the drum-card, draws in single filaments from the feed-roller, and is thence sometimes called the licker-in. These filaments are immediately stripped from it by the large cylinder, A, to be again teazed out by the teeth of the second roller or squirrel, E, moving still more slowly than D, and thereby serving to pick off the knots from the drum. These knots being carried round by the roller, are again presented to the cylinder D, as it revolves nearly in contact with E. The roller, D, next transfers the teazed-out filaments to the drum, blending them with fresh ones supplied by the feed-rollers. The tufts or knots which elude the action of the first two rollers, D and E, are pretty sure to be laid hold of by the fourth roller, G, because it is placed closer to the drum, and moves with the same speed as the roller E. The knots caught by G are teazed out by the roller F, which is nearly in contact with it, but revolves at a quicker rate, yet not so fast as the surface of the drum, F. The loosened fibres are thus seized by F, and once more transferred to the drum, whence they proceed and receive a second teazing from the roller, G. Should any knots still remain they will be arrested by the first flat top cards, and held there till they are disentangled by the rotation of the drum. On this account the first flats require more frequent cleaning than the subsequent ones.

The filaments, after emerging from the flats, lie in nearly parallel lines among the card-teeth of the drum, whence they are removed by a smaller drum-

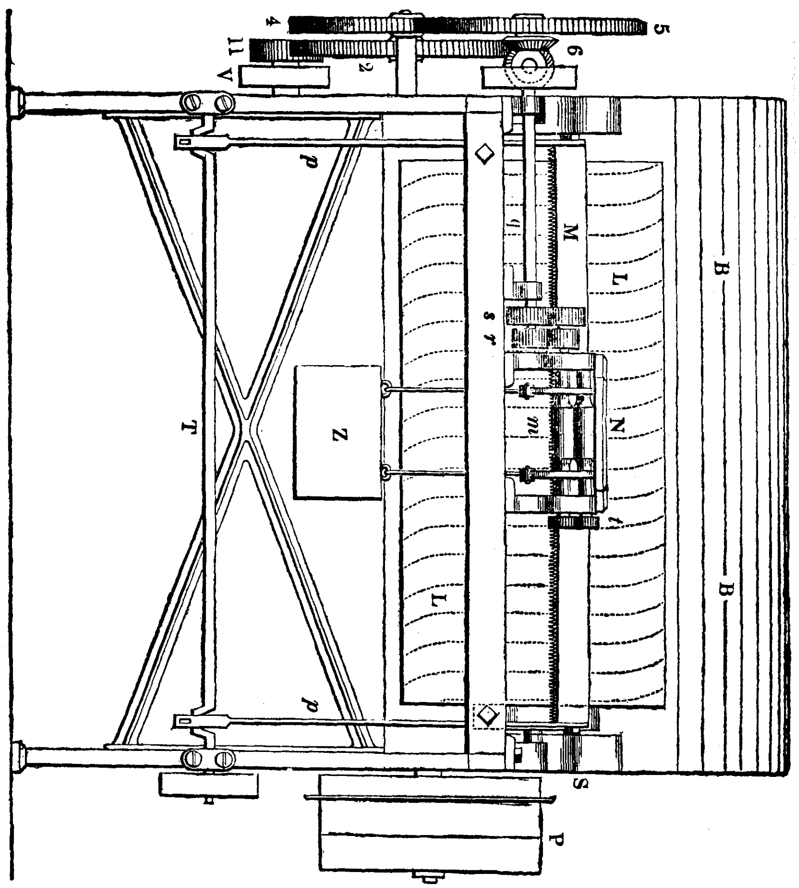


Fig. 38.—Carding Engine. Front view. Scale, three-fourths of an inch to the foot.

card, which turns in contact with it, called the *doffer*, (stripper), or doffing cylinder, L, and is covered spirally with fillet cards. By its slow rotation in an opposite direction it strips the loosened filaments from the drum, and thus clothes itself uniformly with a fine fleece of cotton, which is shorn or combed off from the opposite side of the cylinder by the vibratory action of the doffing-knife, M. This mechanism consists of a blade of steel, toothed at its edge like a fine comb, and it is made to strike down, with a rapid shaving motion, tangentially over the points of the cards. This is the crank and comb contrivance so unjustly claimed for Hargreaves in the law-suit against Sir R. Arkwright. This elegant instrument takes off the cotton in a fine transparent fleece, like the aerial web or woven wind of Aurungzebe's daughter. Its breadth is equal to the length of the card on the doffer, but it is formed into a narrow riband, by being gradually hemmed in by passing through the funnel, *i*. This riband is called a card end (sometimes a sliver), and is drawn forwards by the first pair of rollers, *k*, in that part of the engine marked N. This apparatus consists of three pairs of iron rollers, *k, l, m*; the bottom rollers of *k* and *l* are finely fluted or channelled, and their top ones are covered with two coats, the inner being flannel and the outer being leather. These top rollers are pressed firmly upon the under ones by weights hung upon their axes. The pair of rollers *l*, by moving faster than the pair *k*, has the effect of drawing and straightening the filaments. The card end, after being spread by the rollers into a flat riband, is again gathered into an elliptical sliver, by being passed through the vertical slit in the plate *n*, and being drawn through between the two smooth rollers *m*, which are but slightly pressed together. This card-end is of a very spongy texture, and very slightly coherent. It is allowed to fall down into a tin can, O, as it escapes from the front delivering roller. In some factories the finished card-ends of several engines are wound, as they are delivered, upon large wooden bobbins, with tin-plate ends, in parallel layers, so as to form a series of ribands easy of application to the next machine—the drawing-frame. In other factories the whole of the card-ends pass into a covered square conduit of wood on the floor of the apartment, which is furnished with a series of friction rollers, in correspondence with the respective card-engines. The whole card-ends are finally conducted upon a large bobbin, and wound into a fleece of parallel ribands, ready, like the above, to be presented most conveniently to the drawing heads.

The motions of the carding-engine are produced as follows:—To the shaft of the main cylinder, exterior to the frame-work, the usual fast and loose pulleys P, are attached. Upon the same shaft, between each end of the drum and the frame, is one pulley Q, fig. 39, and another R, in dotted lines, fig. 37. The latter of these pulleys drives the card roller (the licker-in) D, and the former drives the card-roller or squirrel F. Upon the shaft of the main cylinder, A, there is another pulley, S, alongside of the steam-pulley, P, from which motion is given by a strap to a slender shaft, T, fig. 37, 38, carrying upon its ends two small cranks, which are connected by rods, *p*, with the doffer-knife. These rods are guided by two arms, *o*, which keep the knife close to the doffing cylinder, L, while the cranks make it vibrate most rapidly up and down. The shaft of the main cylinder bears upon the end opposite to its steam-pulley end, a pinion, 1, fig. 39, which works into a wheel, 2, on whose axis there is another pinion, 3, working in a wheel, 4, so as to produce a slow motion. The last wheel drives the doffing cylinder, L, by means of the wheel 5. From the shaft of this cylinder motion is given to the squirrel cards, E and G, by means of a strap going round pulleys, between the squirrel-cylinders and the frame, as is shown by dotted lines in fig. 37. Outside of the frame, upon the other end of the shaft of the doffing cylinder, is a bevel wheel, 6, which drives the hanging or inclined shaft, U, as also, by means of the bevel wheels, 7 and 8, the inferior feeding-roller, H. From this roller, motion is given, by a carrier wheel, 9, to a wheel, 10, upon the roller, K, which serves to wind off the fleece from the lap-roll. The wheel 2, formerly mentioned, drives another wheel, 11, below it and of course the pulley on its axis, whence motion is communicated to the drawing apparatus, N, as shown in figs. 38 and 39.

The shaft *q*, fig. 38, bears upon its end two wheels, of which one, *r*, gives motion to two small wheels fixed upon the ends of the two under rollers of the pairs *l* and *m*. The other wheel, *s*, drives a larger wheel upon the end of the under roller, *k*, so as to give a slower motion to this pair of rollers than to the two former pairs, both of which have nearly the same velocity, as *m* is but slightly larger than *l*, and therefore has a surface motion little greater. To prevent the two rollers at *m*, from sliding upon each other, little toothed-wheels, *t*, fig. 38, are fixed to their ends, so as to work into each other.

In many factories the cylinders are not constructed of wood, with iron framing, but are made entirely of cast-iron, and are coated with a cement composed of chalk and glue, which is somewhat harder than Paris plaster. Into holes drilled in the iron cylinders, wooden pegs are fixed for receiving the nails or pins which are used to fasten on the sheet or fillet-card leathers.

We have already mentioned that, in many of the coarse-spinning, and in all the fine-spinning factories, two sets of card-engines are employed, called the breakers and the finishers, which do not differ in any essential respect, except in the fineness of the card-teeth. The breaker delivers or winds its thin continuous fleece of cotton as it is combed off from the doffer, without narrowing it, upon the periphery of a revolving wooden roller. When this has received such a number of layers as constitutes a pretty thick coat, the fleece is torn asunder at the doffer, and the clothed roller is removed to the feed roller of the finisher card. When the ends from several cards are to be wound together on a large bobbin, their course is frequently guided by a series of smooth pins, or spiral channels; and then coiled round a roller in parallel ribands. The movable tin-plate ends of these bobbins being taken off, and a round wooden pin being substituted for the bobbin itself, the lap of parallel card-ends is ready to be presented to the feed-roller or licker-in of the finisher-card. In other cases, the card-ends of the breaker-cards are introduced directly from the cans in which they were received in parallel lines to the finisher-cards to save the winding-on process.

Fig. 40, the old carding-engine, surrounded with urchin-cards.

A, the drum; *a*, the feed-apron; *b*, *b*, moving rollers of the apron; *c*, *c*, feed-rollers; B, first urchin which takes the cotton off, and returns it to the drum; C, C, working urchins; D, D, cleaning urchins. By repeated transfers from one of these card-cylinders to another, and by a continual drawing out between the teeth of the different orders of cards, the cotton filaments, (for low counts,) become separated and expanded. E is the doffer cylinder which strips the cotton from the drum; F, the steel comb or knife for taking the fleece off the doffer in a semi-transparent web. G represents a fluted cylinder, which is not employed in the cotton, but only in the woollen manuture, for making the card-rolls.

Here we have a carding-engine, with the drum surmounted with urchin or squirrel cards instead of

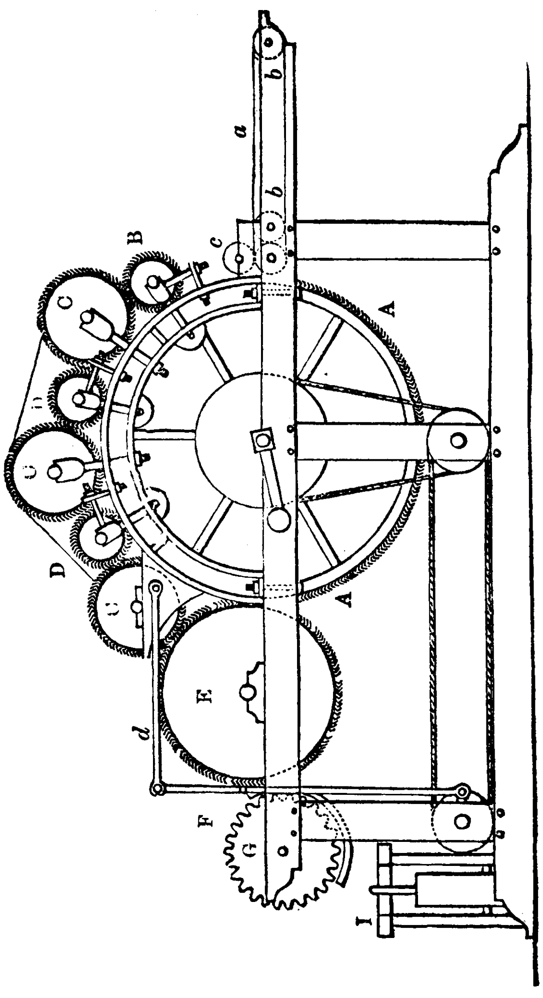


Fig. 40.—Carding Engine, surmounted with Urchin, or Squirel Cards.

tops, such as are used in the preparation of inferior cotton wools for spinning coarse yarns. The principles of its mechanism are similar to those above described.

The speed communicated by the driving shaft to the main drum is not the same for every different staple of cotton. As carding is intended to open up the filaments, to undo their knots, and to shake out the dust, it would not answer its purpose perfectly were it performed with either too great or too small a velocity. It is the duty of the overlooker of the preparation-room to study the cotton wool in hand. It is obvious that tufts should not be disentangled too forcibly on the one hand, and, on the other, the filth adhering to the staple cannot be shaken off by too slight a degree of motion. The main drum must therefore be made to revolve, according to circumstances, from 120 to 150 times in a minute. Nor are the velocities of the other cylinders relatively to the principal one to be invariable; they require also to be modified. Supposing for example, that the latter has a speed of 130 in the minute, the different movements both of the axes and of the surface of the cylinders, which is the point to be considered, may be regulated as follows:—

While the drum card makes that number of turns, the feed-rollers should make only two-thirds of a revolution, so that the doffer shall deliver about sixteen feet of lap;—the first pair of drawing rollers should draw it about 26 inches, being the difference between 232 inches and 206 inches;—between the first and the delivering pair of drawing rollers, the card-end should suffer an elongation of 210 inches, being the difference between 442, the surface-speed of the last pair, and 232, the surface-speed of the first pair;—the last smooth roller should draw it 11 inches more; and, finally, the ratio of the speed at the circumference of the feed-rollers, to that of the smooth delivering roller, should be as 26 inches are to 442, or as 1 to 17.

The card-engine being charged with a lap roll of perhaps 32 feet in length, weighing about 5 pounds, must be passed entirely through in 15 minutes; and the 32 feet of lap will form a card-end at the smooth roller of nearly 540 feet, of which one-fifth part, or one pound, will measure 108 feet; about three per cent. may be allowed for waste.

Long-stapled cottons require more carding than the short, on which account the drum is made to turn more rapidly, while that of the other cylinders is left unchanged, or even made to revolve more slowly. Such changes, however, are introduced only between the feed-rollers and the main-drum, or between the great drum and the doffer, whence a variation is produced in the grist of the card-end, the count of which must always be attended to.

Card sheets are distinguished by the number of wires in each breadth of three inches and a half for the drum, and two inches for the top cards; hence, in the former there will be 70 wires in all, or 20 per inch. The numbers of wires per inch, counted in the length of the sheet-leather, are called crowns. For the preparation of yarns below 36 hanks in the pound, the cards have 80 wires per sheet for the drum; the first, second, and third tops 20; the middle tops 26; and the last 28. For the preparation of yarns of 100 and above, the cards have from 90 to 100 wires per sheet for the drum, and so on in proportion.

The drum revolves with a surface velocity of from 20 to 30 times quicker than the doffer, according to the nature of the cotton. By measuring the parts of figures 37, 38, 39, which are most exactly delineated, to a scale of three-quarters of an inch to a foot, the relative magnitudes and velocities of every part of the carding-engine may be readily determined.

The tops of cards should, after cleaning, be laid down in their places with a delicate hand, and tested by a gentle pressure, to ascertain that they barely touch without catching the teeth of the revolving drum. I was told by a skilful spinner that a fluted feed-roller is not nearly so good as a pair of cylinder cards from two to three inches in diameter, with their teeth set inwards, so as to operate as lickers-in. They should be surmounted by a cylindrical card of larger dimensions, as shown in the figure, for taking off the cotton fibres and transferring them to the drum.

A patent was taken out a few years ago for travelling card tops, with a self-cleaning apparatus, but it was considered by the above gentleman to be a hazardous expedient. Double cards are now made 42 inches in the diameter of the drum, and 36 inches in length; single cards are half that length, or about 20 inches. I have seen many card-ends wound up continuously upon one large bobbin or roller 12 inches long, in parallel ribands, to form a lap for the drawing-frame.

In a *fine* spinning-mill at Manchester, seven finisher cards turn off 150 pounds of cotton (Sea-island) in 69 hours, or one week. Three yards of the lap presented to these cards weigh only four ounces. These seven finishers correspond to six breaker-cards; for a preparation as it is called (one set), 12 card-ends go to form the first drawing. In the breaker-cards, 1,600 grains' weight of cotton are spread out upon seven feet of the apron-cloth, to form one lap.

In such an establishment, 150 pounds constitute as we have said, a preparation, which is confined to its peculiar set of cards, of drawing and roving frames. One man superintends four such preparations. The total wages for the preparation work of these 600 pounds of cotton wool is £11. 11*s*.

In a mill at Manchester, where fustian yarns are chiefly spun of No. 30 weft and No. 40 warp, the carding-engines are surmounted with urchin-cards, and do each to the amount of 1,000 pounds per week. The drum makes 180 revolutions per minute. Each card supplies 15 tubes of Dyer's roving-frame, equivalent to 800 throstle spindles.

For coarse spinning, where the card-ends are not received in cans (to save hand-labour), the card delivers its end on a roller, which rests on a horizontal carrier wooden drum. One bobbin roller usually takes on two ends together, through a guide funnel, which is carried at the extremity of a traversing arm, moved by a pinion, which works in a horizontal gridiron rack, alternately to the right hand and the left, upon the upper and under surface of the rack; whereby the double card-ends are wound in parallel rows, without crossing each other. Four of these large bobbins, thus filled with card-ends, are laid in horizontal frames, from which they deliver their ends to one drawing head, wherein eight ends are again combined through one guide funnel, and, after drawing, are wound upon another large bobbin, also revolving in a horizontal plane by the friction of a carrier drum. By such artifices cans are now entirely superseded in the carding and drawing departments of several coarse spinning-mills, as in the progress of machinery they may probably come to be also in fine spinning-mills. The wooden cylinder of the last-mentioned bobbin is two inches in diameter, and has a steel axis driven hard into each end, which is enclosed by a saucer-shaped tin platter. This is removable at pleasure.

When the card-fleece from the comb exhibits inequalities, it is a proof of bad carding, denoting ill-adjusted motions in the several cylinders, or want of truth in the play of the main-drum and the tops. This defective state must be corrected immediately, for good yarn could not be spun from card-ends of that texture.

The card-overlooker is called a stripper when he cleans the card-teeth from the entangled filaments. He should clean the drum four or five times a-day, taking care that his stripping is made upon the seven or eight cards, constituting a preparation, in succession, and at regular intervals, whenever the lap allowance is passed through. He strips, in like manner, the tops, going over the first, the fourth, the seventh, and the tenth of one carding-engine, and then the same tops of a second engine, of a third, and thus to the last in the series. Returning to the first engine, he strips the second top, the fifth, the eighth, and the eleventh, throughout the set; lastly, he strips the third, sixth, ninth, and twelfth. If there be fifteen tops, however, he makes an analogous distribution, whereby he secures uniformity of work.

With regard to the main drum, and the doffer cylinder, he contents himself with removing the light down which is whisked upon them, without stopping the engine. The urchins which move with the greatest velocity, can be stripped only when the carding operation is suspended.

The whole parts of the machine should be cleaned carefully twice daily; namely, at the dinner hour, and when the business of the day is over. The moving parts must be lubricated in the morning, and at mid-day; and the drum every time the machine is stopped for the purpose of stripping.

The grinding of cards was formerly executed always, and still is in some small mills, by means of a flat, smooth bar of wood, on which coarse-grained emery is fixed by glue, which forms a kind of hone or grindstone. This is placed in the position of one of the flat tops for sharpening the teeth of the main drum and over the other card-cylinders, by means of iron props, which allow it to be pressed more closely down as the teeth points are ground away.

This hand-method was tedious and incorrect. Two very ingenious machines are now substituted instead of it; one of them for grinding the tops, and another the cylinder cards; but they are not of sufficient importance to merit the detail of engravings and descriptions necessary to make them intelligible to the general reader.

SECTION III.

The Drawing Frame.

THE principle and object of the next operations in a cotton-mill are entirely different from the preceding. They are intended to draw out and elongate the spongy slivers or ribands, but particularly to straighten the filaments, and lay them as parallel to each other as possible. This effect is produced by the action of revolving rollers; and it can be clearly understood only by an attentive and minute consideration of the operation of such mechanisms upon textile fibres. Sir Richard Arkwright, who was the undoubted inventor and first constructor of the drawing-frame, was so impressed with its importance in automatic spinning, that when any bad work was turned out, he immediately desired his people to "*mind their drawings.*" The drawing-frame likewise serves to equalize the constitution of the cotton wool, by uniting many slivers into one, so as mutually to correct each other's defects, and also to attenuate the sliver preparatory to the next process. The cards, no doubt, tend to straighten many of the filaments, but they also double not a few by catching them by the middle. The drawing undoes all these foldings of the fibres when it is well conducted, and is, therefore, the most curious process in a philosophical point of view, which factory genius displays. It constitutes, in my opinion, an irresistible proof of the scientific acumen of Arkwright. It is the transcendental problem of the cotton-mill, and illustrates, best of all, the great principle of roller-spinning devised by that artist. The machine consists of upper and under rollers, the former being smooth, and covered with an elastic leather coat, the latter being fluted longitudinally, in order to seize and pull along the slenderest filaments. Of such twin rollers there are usually three pairs in one line of traction and one parallel plane, whereof the under ones are driven by wheel-work, with successive degrees of velocity, and carry round, by the mere friction of the sharp-edged flutings, the upper ones which are pressed upon them by a considerable weight.

Fig. 41, 42, 43, 44, represent the Drawing Frame in its most perfect form. Fig. 41, is an end view;

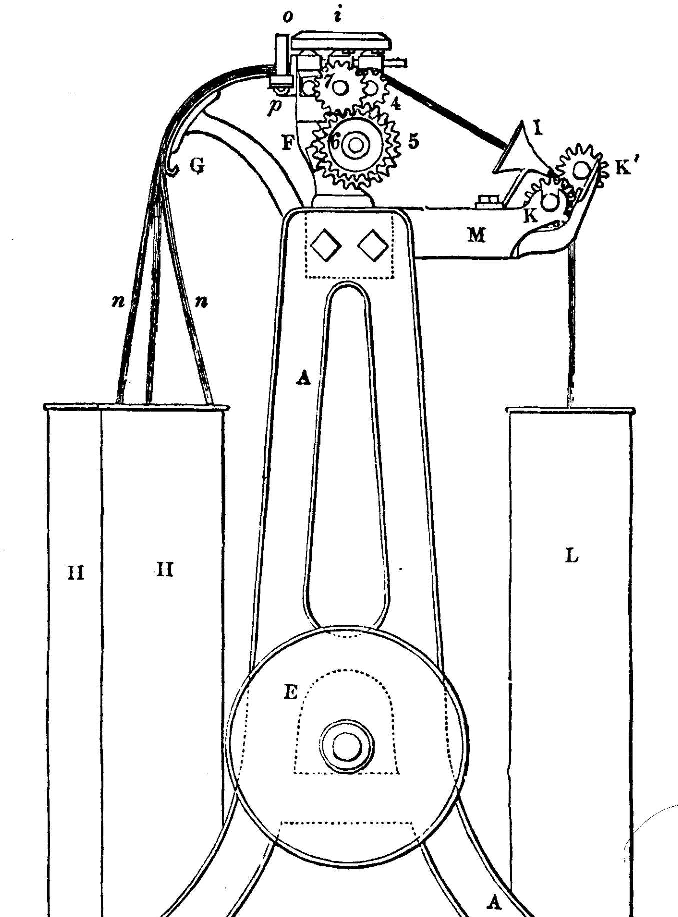


Fig. 41.—End view of the Drawing Frame. Scale one inch to the foot.

fig. 42 is a front view of one head of the machine; fig. 43 shows a section of the working parts drawn to a double size; and fig. 44 illustrates the manner in which the top rollers are made to press upon the under ones.

A is the frame which bears at its top the strong roller-beam B, upon which several drawing heads are fixed; one only of these heads being shown in fig. 42.

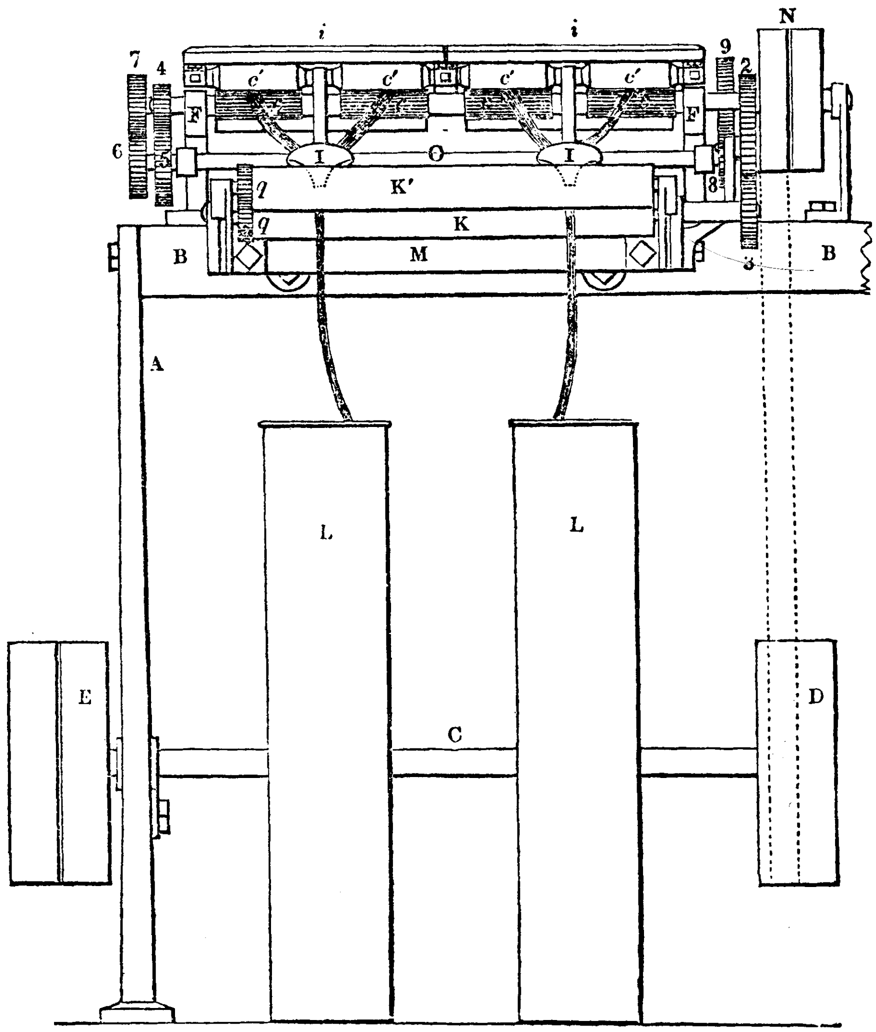


Fig. 42.—Drawing Frame. Front View of one head. Scale, one inch to the foot.

C is a horizontal shaft running the whole length of the machine, furnished with several pulleys D, which give motion to the several drawing heads; the fast and loose pulleys E deriving, as usual, their motion from the mill shaft near the ceiling by a strap. See Chap. II. Book III.

In fig. 43 *a, b, c,* show the under rollers, and *a', b',*

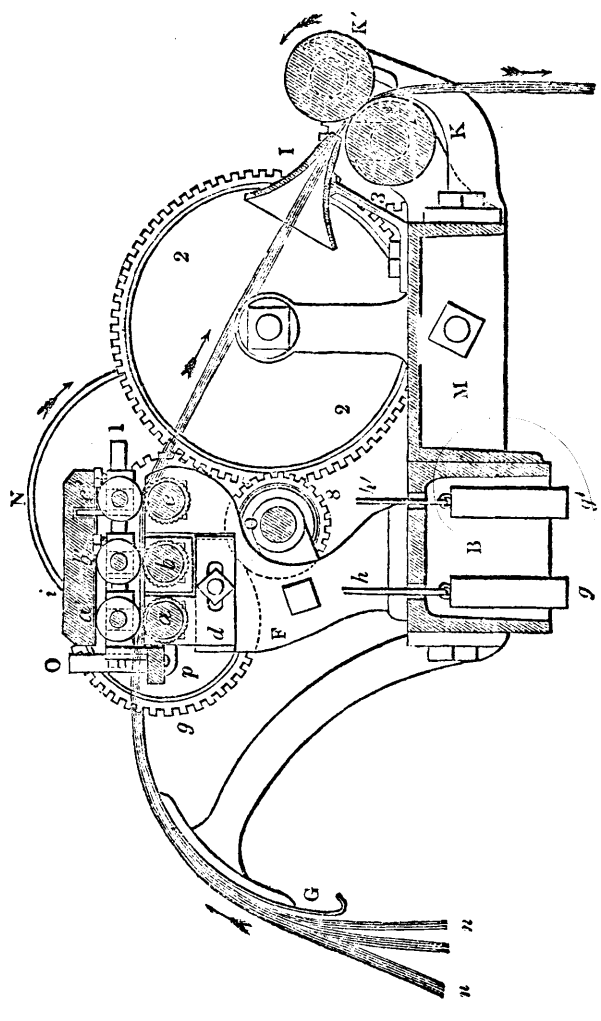


Fig. 43.—Drawing Frame; Section of the working parts. Scale two inches to one foot.

c', their respective top rollers; the former turn in brass bushes fixed upon iron bearings *d*. The front roller-beam F is fixed, but the bearings of the two other rollers may be shifted in grooves, so as to make these rollers approach to, or recede from, each other, and from the front roller, till the adjustment of their mutual distances suitable to the length or the staple of the particular cotton-wool be attained; when the bearings are made fast in that situation by the screw-nut *d* acting upon the edges of the slots in the slide-bearers. This adjustment constitutes an important improvement in the construction of the machine; because, not long ago, these two bearings were so connected as to move together at an invariable distance, and to be thus jointly adjustable only to the front roller. But in the machine here represented, the intervals between each two of the three rollers may be varied within proper limits at pleasure. The slot piece *d* adjusts the roller *a*, and a similar slot piece at the other side of the head adjusts the roller *b*.

The length of the top rollers is equal to that of two fluted portions of the under rollers, as plainly seen in fig. 42; and the top rollers turn with their necks in bearings, which are adjustable in a similar way to the bearings of the under rollers, as shown also in fig. 42. In the middle of each top roller, a', b', c', fig. 44, there

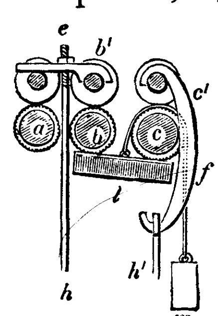


Fig. 44.—Pressure of Top Rollers.

is a smooth neck, upon which the brass bushes *e, f*, rest, suspending weights *g g'*, fig. 43, by wires *h h'*, fig. 43, 44. In general, the two back rollers, which turn most slowly, are pressed down by one common weight, while the front roller is pressed by a separate one. The three top rollers are covered with a mahogany bar *i*, faced below with flannel cloth for the purpose of wiping off any stray filaments which may tend to adhere to the top rollers. A corresponding bar *l*, also about an inch thick, faced with flannel above, and as long as one head, fig. 42, is made to bear by a light weight, *m*, fig. 44, upwards against the two front rollers *b* and *c*, to wipe them also from stray filaments. The cord or wire from *m* is seen going over the neck of the roller *c*, and down again to suspend the wiper-bar of mahogany *l*.

In figs. 41 and 43 G represents a smooth curved brass or tin plate, seen separate in plan in fig. 45,

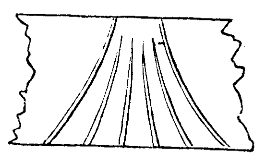


Fig. 45.—Drawing Frame; curved guide plate of the drawings.

along the channelled surface of which the slivers (porous ribands) *n, n*, fig. 43, from the respective cans H, H, standing at the back of the machine, are introduced to the rollers, and are kept apart by the pins *o*, fixed upon a brass bar *p*, figs. 41 and 43. In this way from three to six slivers may be brought together and united upon one fluted portion of the under rollers. In fig. 45 the same end is seen to be effected by a plate having converging channels, separated by ridges, to guide several slivers in upon one fluting.

This compound or sextupled sliver, in passing between the roller series, is drawn out most particularly by the front roller into a uniform, somewhat attenuated, and much elongated sliver. Of such slivers, usually two are again brought together in a funnel I, and delivered by the two smooth rollers K K′, into a can L, standing in front of the machine. Occasionally one of the slivers, just after its delivery, is turned back over the smooth roller K′, and united with the slivers entering the funnel of the adjoining drawing. The smooth roller K turns in bearings of the frame M, which is attached to the roller-beam B, and supports the funnels I. The top roller K′ presses upon the other by its own weight, and is turned from the under roller by wheels *q q*, fig. 42, fixed upon their ends. The purpose of this funnel and long pair of smooth rollers is to collect, into a compact riband, the cotton filaments which were previously spread broad and thin between the drawing rollers *a, b, c*. Hence those rollers must have a surface velocity equal to that of the front fluted roller *c*. The motions of the machine are produced in the following way:—N represents the usual fast and loose pulley in the prolongation of the front roller shaft. The steam-pulley receives motion by a strap from the pulley D, upon the horizontal shaft C. Upon the same front roller-shaft is also fixed the pinion 1, fig. 43, driving, by the carrier (intermediate) wheel 2, the wheel 3, on the end of the smooth roller K. Upon the other end of the shaft of the front fluted roller *c* is a pinion, (figs. 41, 42,) driving the shaft O, (figs. 42, 43,) by means of the wheel 5. Close to the last wheel, and upon the same shaft, is another smaller wheel 6, which drives a larger wheel 7, made fast to the prolongated middle roller *b*. Upon the other end of the shaft O is a wheel 8, driving the wheel 9, which is attached to the back under roller *a*.

A convenient and common mode of increasing the speed of the front roller *c*, without being obliged to use wheels too much differing in diameter, is to make that roller somewhat thicker than the others; so that it may be one inch and one quarter, or one inch and three-eighths, while the others may be from seven-eighths of an inch to one inch. The ratio of the sur face speed of the front roller *c*, to that of the back roller *a*, varies from 4 or 6 to 1; and that ratio may be modified by changing the wheels according to the size of the sliver that is desired. The difference between the speed of the two back rollers *a* and *b* is inconsiderable, being no more than one-tenth part, or thereby; the middle one serving rather as a guide in leading the filaments to the front roller.

The drawing tenter must be very careful to mend the feeding sliver-ends whenever any one of them breaks, and to stop the machine by sliding the strap upon the loose pulley at N, in case the delivering roller be in fault.

The drawing rollers above mentioned are cylindrical rods, subdivided into fluted portions, to each of which one sliver is assigned, as shown in fig. 42. Two such portions are covered with a top roller, having a narrow neck in its middle part, and resting at its ends or journals, in slot-bearings which lie between the fluted portions of the under rollers, as plainly seen over I I, in fig. 42. Upon each neck of the front top roller is a brass hook, *c′*, fig. 44, to which a weight, *h′*, is hung, whilst another weight, at *h*, acts upon the centre of a brass plate (under *e*) resting upon the necks of the two upper back rollers, *a′*, *b′*. The slot-bearings of the top rollers are attached to a bar, *p*, at the back of the rollers, which is fixed with its axis in the drawing heads, F (figs. 41 and 43), which the under rollers rest upon, in order to turn them round, if the latter are to be taken out.

The scale of figs. 41 and 42 is 1 inch to the foot; that of 43 and 44 is 2 inches to the foot.

Having explained the structure and general action of the drawing frame, it may be worth while to examine the changes it produces on the cotton staple a little more minutely.

Were the surface velocities of the three rollers, *a*, *b*, *c*, fig. 43, equal, the card ends, *n*, *n*, after gliding over G, would pass through to the funnel *i* unchanged. But the velocity of *b* and *c* being greater than that of *a*, the former will deliver a greater length of riband than they receive from the first, or than this receives from the cans, H, H. Under these circumstances the only result must be a proportional extension of the riband or sliver, in the intermediate space between *a*, *b*, and *c*, and an approximation of the filaments to rectilinear parallel directions, during this stretching process. The rollers are so adjusted, as we have seen, that the drawing takes place chiefly between the first and the third pair: in fact, the middle pair can have no influence in the drawing power beyond the difference of the first and third. The intervals between *a*, *b*, and *c*, or between their lines of contact with the upper rollers, should be in all cases calculated so that they may exceed the average length of the cotton filaments; and so that these filaments may not be placed in danger of being torn by the third pair pulling, while the second pair has a firm hold of their other ends. Between these two pairs of rollers, however, where the principal drawing occurs, the distance should be no greater than is absolutely necessary to render the drawing out of the fibres alongside of each other practicable without their disruption; this adjustment being requisite to the uniformity of the drawing operation. Were that interval too great, it is obvious that a sliver in running through the rollers would become attenuated in the middle point between them, or might possibly break asunder; hence the drawing will be the more regular, the more nicely the interstitial space between the rollers is adapted to the length of the staple of the cotton. When one end of a filament, after being ushered in by the back rollers, is laid hold of by the second or middle pair, it is twitched suddenly forwards in a very gentle manner, so as to stretch it very slightly; but when advancing, it is seized by the front pair, and is more forcibly pulled at one end, while it is held at the other by the friction of its fellow filaments detained by the slower rollers; the distances of the different rollers being previously adjusted exactly to the average length of the staple. The sliver thus drawn, with multiplied doublings, acquires a regularity of texture which, if not impaired in the subsequent processes, ensures a level yarn to the cotton-spinner.

Were the drawing of a single sliver attempted to be continued until the suitable parallelism of its filaments were effected, it would ere long become an impossible operation, on account of the excessive attenuation of the riband. This inconvenience is obviated by the very simple method of associating at each repeated drawing several of the formerly-drawn slivers together into one riband: this is the process called doubling. It is an accurate imitation of what happens when we take a little cotton wool between the fingers and thumb of one hand, and draw it out with those of the other, at each turn laying the two parcels parallel again. The doubling secures the great advantage of causing the unequal parts of slivers to correct one another, and to produce finally a very uniform riband.

In the preparation department for spinning the mean counts of 36's or 40's, three drawing heads are appropriated to each card, and the doubling upon these heads is as follows: $\frac{6}{1}$; $\frac{6}{1}$; $\frac{9}{1}$, constituting one multiple sliver after 324 doublings.

In other good factories, four drawing heads go to one card, and these supply slivers to one coarse-bobbin and-fly frame, and to three fine frames.

Some manufacturers have lately introduced a double roller beam, and a double draught at the same doubling, into their drawing-frames. I have seen this contrivance working satisfactorily in mills where low numbers were spun, and where the tube-roving frame was employed; but I was informed, by competent judges, that it was not advisable where a superior fabric of calicoes for printing was manufactured.

In another factory, I found that 2,000 pounds of Bowed Georgian cottons were put through seven cards (breakers and finishers) weekly, which supplied work to three drawing heads; and to one coarse, and two fine bobbin-and-fly frames. The numbers spun were 20's.

In the finest spinning mills, the doublings at the drawing frame are far more numerous, of which the following numbers form a good example:—

$$\frac{8}{1}; \frac{4}{1}; \frac{7}{1}; \frac{6}{1}; \frac{6}{1}; \frac{6}{1}.$$

If these numerators, which indicate the number of slivers united at each successive drawing, be multiplied together, they will give the product 48,384; to which may be added another doubling at the coarse bobbin-and-fly frame, or the stretcher mule, constituting in all nearly 100,000 times that the fibres are repeatedly placed parallel to each other before a thread is attempted to be spun. Such is the mechanical refinement, of which the conception is originally due to the genius of Arkwright. It gives mathematical equality to the most irregular, and, at first sight, evanescent filament. In such a fine mill, the first head furnishes drawings for the next two heads; the second and third heads supply the fourth and fifth heads. There are indeed sometimes seven successive drawing and doubling operations.

Suppose that in a drawing-frame of four heads the extension or draught operated upon the sliver in each is as the number 4.65 to 1, we shall have the following ratio:—

$$\frac{6}{4.65} \times \frac{6}{4.65} \times \frac{6}{4.65} \times \frac{5}{4.65} = \frac{1080}{446.16} = 2.31$$

Hence, with 1,080 doublings, the card-end has become 2.31 times heavier or stronger. It had originally a weight corresponding to number 28 upon our scale of counts; and it has become $\frac{28}{2.31} = 12.1$, showing that many more filaments are now arranged in nearly the same-sized riband, in consequence of their condensation, from being straightened and laid closely parallel. In the drawing operation there is no sensible waste of the cotton wool.

Nothing is easier than to change the relative velocities of the drawing machinery, by substituting, for the existing toothed wheels, others of a different count, either to increase or to diminish the number of the sliver. Drawing-frames are usually furnished by their constructors with these change wheels, which, by means of the shot and screw mode of fixture, are easily substituted for the others.

The mean velocity of the delivering-fluted roller is about 160 turns per minute, which, if it be $1\frac{1}{4}$ inch in diameter, or 3·95 inches in circumference, will give out nearly 53 feet per minute. Many of them discharge 60 feet per minute, or 1 foot per second.

SECTION IV.—Roving Frames.

AFTER the process of drawing as just described, the next operation of a cotton-mill is the making a roving, or thin sliver, which is very tenderly twisted, at least in the course of its attenuation. In the tube-roving frame the twist is merely momentary. In this stage of the cotton manufacture, the utmost delicacy is required to preserve the evenness of the spongy cord, upon which the final levelness of the yarn depends. An incredible number of machines has been contrived, since the first elegant can-roving frame of Arkwright, for the purpose of performing this process with precision and speed. By means of that frame (see figs.

46 and 47) the slivers, after passing through the usual drawing rollers, where they were considerably elongated, received a slight twist from the revolution of the tin cans into which the rovings fell, and were distributed round its interior surface in regular coils by the centrifugal force. It is in fact the drawing-frame, fig. 41, with the receiving cans set in rotation upon a central pivot.

A, A, are the tin cans containing two sets of drawings in fig. 46, and several card-ends in fig. 47; *d, c,*

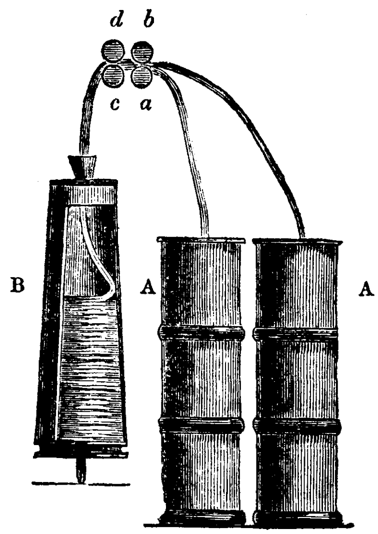


Fig. 46.—Can-Roving Frame of Arkwright.

are the front pair of drawing rollers; *b, a,* the back pair (the middle being suppressed, for the sake of simplifying the illustration); *f, e,* in fig. 47, are the delivering smooth rollers; *g* is the funnel for contracting and rounding the sliver a little before it passes through the delivering rollers; B is the receiving can, where, in fig. 46, the coils of roving are exhibited. The can B has a door (left open in that figure) for

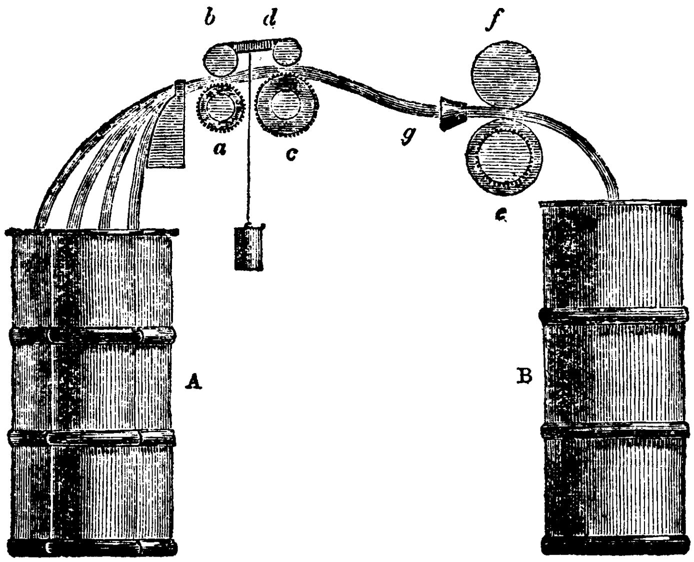


Fig. 47.—Common Roving Frame.

removing the rovings, when it was filled. They were then taken by girls and wound upon bobbins, with the aid of a simple machine, called a winding-block, also the invention of Arkwright. Sometimes the cans were made of what was called the skeleton kind, so that the interior cage-frame could be taken out full of roving, and carried to the winding-block. This was an improvement, as it saved the risk of injuring the tender rovings by handling them. At other times, these skeleton frames were transported at once, and placed in connection with the next machine, in the factory series at the time, which drew out the contents slowly, as wanted, at the top orifice.

Very good yarn was made by Messrs. Arkwright and Messrs. Strutt with the aid of this roving apparatus, but in ordinary hands it was found to have many defects. The torsion was not equally diffused over the whole length of the roving; and the subsequent winding or drawing out of the cans injured the rovings, if they were equally twisted. Considerable expense was also incurred in the winding process.

To obviate these evils, the Jack-frame, or *Jack-in-a-Box,* was contrived—a very ingenious, but rather complex mechanism, and therefore liable to frequent derangement. Fig. 48 exhibits an outline of its con-

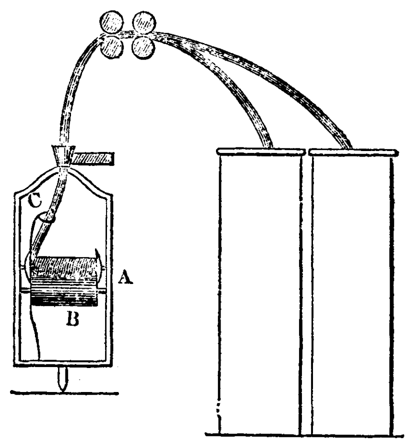


Fig. 48.—Jack-Roving Frame, or Jack-in-a-Box.

struction. B is the carrier cylinder, made to revolve by wheel-work (not shown here) at such a rate, that its surface velocity is the same with that of the front drawing roller; A is the bobbin lying upon it; C the guide-wire, with an eye at its end, which was made to traverse from right to left and left to right alternately, thus equalizing the distribution of the roving upon the bobbin. The vertical rotatory motion of the jack-frame upon its pivot, like that of the revolving can, gave the twist.

The jack-in-the-box was after some time superseded by the bobbin-and-fly frame—a contrivance upon the same principle as the flax or Saxon hand-wheel (fig. 16), already described, and which Arkwright, with singular sagacity, sought to apply at the earliest period to cotton-roving; though he found the state of mechanical refinement then inadequate to realize this happy conception. But, in fact, this beautiful machine has arrived at its present state of perfection through more numerous efforts of ingenuity, and by the co-operative agency of a greater variety of individuals, than any other mechanism known in the cotton trade. The chief difficulty in these machines proceeded from the soft delicate nature of the roving, and the nicety required to wind it on at neither a faster nor a slower rate than the front-roller pair sent it forth. This nicety was increased by the ever-varying circumference of the bobbin within the flyer, as well as by the changes occasionally required in the degree of twist to be given to the roving for particular purposes. To accomplish these several objects, with precision and facility, was for many years a desideratum in cotton manufactories.

The peculiar functions of this class of machines may be arranged under two heads: 1, the twisting action; 2, the winding-on motion.

The twisting is effected by the revolution of the spindle (see fig. 49) F, to which the fly-fork is attached, while the sliver A, in its passage from the roller to the bobbin, proceeds along the hollow arm, H H, of the flyer, which, being of one piece with the spindle, revolves with it; the quantity of twist given to the roving depends upon the ratio between the surface speed of the front roller and the revolutions of the spindle. The winding-on was accomplished in jack-frames by a uniform motion applied by a carrier roller to the *surface* of the roving on the bobbin, which was made to correspond exactly with the surface speed of the front roller; but in the bobbin-and-fly frame it is

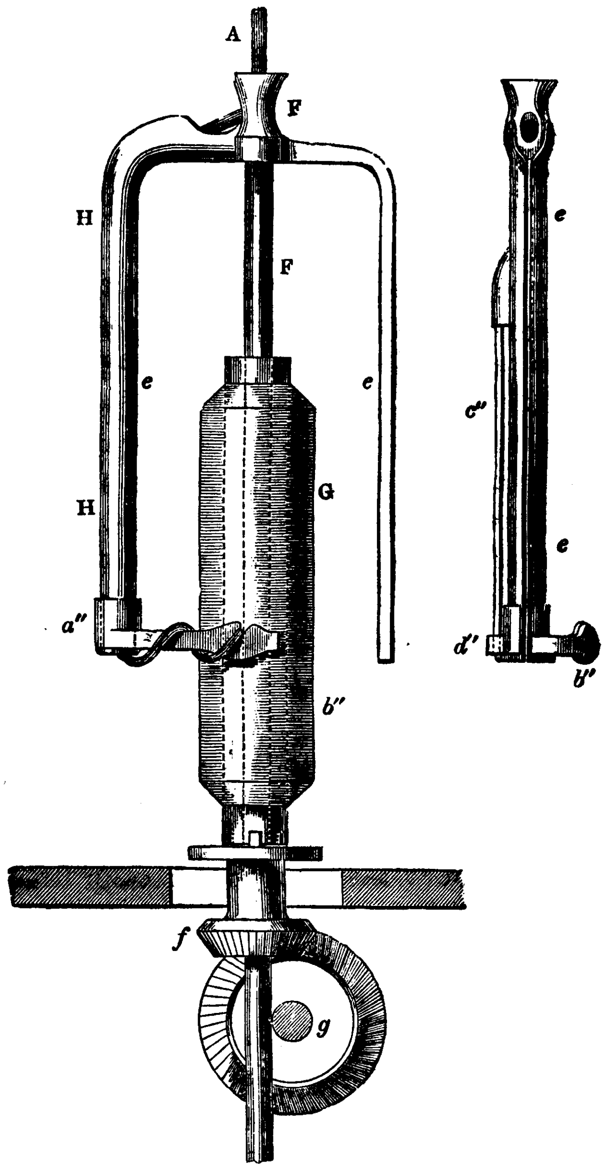


Fig. 49.—Spindle of Bobbin-and-Fly Frame, with Spring Presser. Scale three inches to the foot.

accomplished by giving to the bobbin such a velocity that the difference between the motion of the surface of the bobbin, and the motion of the delivering end at the arm of the flyer, shall equal the surface motion of the roller, or the supply of sliver. This distinction between the action of the jack-frame (to which, in the winding-on, the tube-frame may be assimilated), and the bobbin-and-fly frame, must be constantly kept in view.

In the bobbin-and-fly frame the bobbin revolves round the spindle, and not at right angles to it, as in the jack-frame, which circumstance removes many of the objections justly urged against the latter contrivance. The first bobbin-and-fly frames were of a very complicated kind, containing three or four conical drums for producing the several variable motions. These were gradually diminished, and the whole was simplified, and reduced to the state in which we find it, first by the indefatigable labours of Messrs. Cocker and Higgins, the eminent engineering-mechanicians, and partly by the inventive ingenuity of Henry Houldsworth, jun., Esq., formerly of Glasgow, now of Manchester.

From the position of the bobbin upon the axis of the spindle, it is obvious that every revolution of the spindle or delivering arm of the flyer round the bobbin supposed at rest, or ahead of it supposed in motion, will wind up a length of roving equal to the determinate periphery of the bobbin, the end of the roving being previously attached to it. But as the number of revolutions of the spindle requisite to give the desired degree of twist has no necessary connection with, but, in fact, greatly exceeds the number of turns required to wind up the length of roving delivered by the front rollers, it follows that, unless some scheme be contrived for lessening progressively the number of revolutions of the flyer round the bobbin, the roving will be coiled up too fast, and will be infallibly stretched and broken. This scheme cannot consist in reducing the number of revolutions of the flyer (for these must be proportional to the desired degree of torsion), but in making the bobbin revolve in the same direction with the spindle, but at a speed so much less than it as to cause the circumference of the bobbin to fall behind the delivering arm of the flyer, so that the difference of their velocities shall equal the rate at which the roving issues from the front roller. Thus, if a given length of roving, equal, for instance, to the periphery of the front roller, or four inches, be equal also to one circumference of the bobbin at a certain stage of its increase, then, to wind up this length, the arm of the flyer must revolve several times about the bobbin till it has got ahead of its surface rotation by four inches; and this may be effected either by making the spindle turn once round while the bobbin stands still, or by making the bobbin revolve one turn less than the spindle, whatever may be the speed of the spindle. If the spindle, for example, makes ten turns while the above four inches are given out by the rollers, then the bobbin will require to make nine turns; or, if the spindle makes twenty turns, the bobbin will require to make nineteen. The same result will be produced whatever be the speed of the spindle, provided the difference between the circular space, percurred by the spindle and the bobbin in the given time, remains four inches. This difference, which represents exactly the requisite winding-on motion, is, therefore, dependent jointly upon the speed of the front roller, or the delivering motion, and upon the size of the circumference of the bobbin at the particular stage of the winding-on, and is quite independent of the twist or the velocity of the spindle.

From the manner in which the first bobbin-and-fly frames were constructed, every change in the twist required a corresponding change in the speed of the bobbin—a change not proportional to that of the twist, but such as would preserve the difference between the motion of the spindle and bobbin as it was, relatively to the roller. Thus if the spindle, turning ten times while the bobbin turned nine times, gave the proper difference of motion = 1, for winding-on, then if the twist was doubled, the speed of the bobbin would require to be more than doubled, for, as the spindle would then turn 20 times, the bobbin ought to turn not 18, but 19 times, in order to maintain the same difference of motion = 1, as at first.

The object of the recent improvements of this important machine, for most of which the world is indebted to Mr. Houldsworth, has been to get rid of the difficulty of making these perpetually recurring and very intricate adjustments of the speed of the bobbin, which were found in practice to be beyond the capacity of most overlookers of the preparation-rooms of cotton-mills, who seldom arrived at the correct difference till after an expensive and wasteful series of errors and alterations, whereby the quality of the work was more or less damaged for several weeks at each change of the twist or of the cotton staple. It is only since these improvements of Mr. Houldsworth were introduced, about eight or nine years ago, that excellent yarn has been turned off with increased uniformity and speed, so as to extend the trade by lowering the cost of producing a superior article. The good yarn formerly made, required prodigious pains in the first adjustment of the machine; and its quality could not be altered to suit a new market without extraordinary exertions on the part of the mechanics as well as the spinners of a factory.

Green, a tinman in Mansfield, who had been occasionally employed in a cotton-mill in the neighbourhood of that town, became acquainted with the difficulty now stated, and, being of a scheming turn of mind, hit upon the novel idea of connecting the spindle and bobbin together in such a manner as to be able to modify the speed of the bobbin, or to make it differ from that of the spindle, by a train of mechanism acted upon by the front roller, upon which, as already stated, the quantity of the winding-on motion depends. By this mechanism he was able at pleasure to regulate the difference of speed between the spindle and the bobbin, without reference to the velocity of the spindle; so that alterations of the twist did not, as formerly, require any altered adjustment of the bobbin motion.

The difference between all the old constructions and this new one may be illustrated popularly as follows: —Suppose two ships, sailing in the same direction, one after the other, and that the pilot of the sternmost is desired to follow his leader at such a rate as to fall behind one mile every hour, whatever be the speed of the first ship. There are two ways in which the pilot may execute his orders: first, he may measure the speed of the leading ship, and regulate his rate of sailing accordingly, but this would be a very difficult if not impracticable undertaking; secondly, he may attach a line to his leader, and let it out at the rate of a mile per hour. Thus he would make sure work; but, if he adopted the first plan, he would require to note incessantly the changed velocity of his leader, and study to slacken his own rate accordingly, so as always to recede a mile in the hour. By the second plan, all the concern and uncertainty of looking after the first ship would be superseded, and he might perform his task with equal certainty by night as by day.

This illustration will enable any one thoroughly to apprehend the difference between the old bobbin-and-fly frame movements, and those of Green; for if we consider the spindle in the old construction to be the leader, the bobbin the follower, and the mile an hour of retardation (the required difference of speed between the spindle and bobbin, in order to wind up the roving as it is delivered by the front rollers), then, by the first mode of piloting the second ship, we see exemplified the difficulty imposed upon the workman with the former machines, when changes in the twist, that is, in the relation between the speed of the spindle and the rollers, were required; but, on the second plan of sailing, we see the value of Green's idea of connecting the spindle and bobbin in such a manner that the required difference of motion shall be regulated and measured by the front roller, just as the rope connecting the two ships could be let out at a uniform rate, whatever changes were made in the speed of the leader, and of course of the follower. Mr. Green obtained a patent for his invention upon the 26th of June, 1823, and states in the specification that the object of his improvement in roving, spinning, &c., "is to retard in a small degree the revolution of the bobbin, by which it shall revolve in the proportion of about nine times to ten of the spindle, and hence in every ten revolutions of the spindle the thread will be laid once round the bobbin." * I need not transcribe his description of the apparatus, as it could not be successfully brought into practice; not from any error in the general principle, which was sound, but from his manner of applying it. The great objections to its use were, first, that the complex regulating mechanism was applied to every spindle; and, second, that upon the stem of each spindle, below the bobbin, there were two tubes subjected to quick reciprocating motions, and thence very liable to become deranged, or to derange the bobbin and fly. A skilful mechanician, who gave the scheme a full trial, assured me that he was compelled to relinquish it in consequence of the accidents which perpetually happened to the studs that projected from the stem of the spindle, and worked in a spiral groove cut in the tube round the spindle-stem which carried the bobbins. These studs struck upon the tops and bottoms of this spiral groove, at every change of direction, with such violence, during the rotation of the spindles, as to break everything in pieces. In fact, any one may conceive that quick reciprocations of movement, with a spindle revolving many hundred times in the minute, must be inconsistent with mechanical stability.

The idea was not, however, lost to the world, for Mr. H. Houldsworth took it up, and invented in 1824 a method of communicating motion to the bobbins by smooth rotatory means, which removed completely the difficulties encountered by Mr. Green, and reduced

* Newton's Journal of Science, vol. viii., p. 284.

the bobbin-and-fly frame in this important particular to a simplicity and precision of adjustment accommodated to the capacity of any intelligent workman. Mr. Houldsworth obtained a patent for his admirable invention in January, 1826.

Before entering into a detailed description of this mechanism, which affords perhaps the most refined specimen of the automatic equating principle to be found in the whole compass of science and art, I shall advert to a point not sufficiently brought out in the preliminary elucidation. While the circumference of the bobbin is equal to that of the front roller, during the time of every turn of the latter the bobbin must make one turn less than the spindle, in order that it may take up the roving which has been simultaneously given out. Thus, if the spindle makes six turns for one turn of the roller, the bobbin must, in the same time, make five turns. But we must remember that the bobbin is perpetually increasing in size, so that, by every successive layer of the tender spongy cord, its motion requires to be quickened (otherwise it would take up too fast by its enlarged surface), so that the difference between its rotatory motion, and that of the spindle, shall become less. When the bobbin, for instance, is twice the diameter of the roller, its speed would require to be five and a half (instead of six, as at first), while the spindle still makes six turns, because one-half the circumference of the bobbin *now* is equal to the whole of it when empty, and to the whole surface motion of the front roller. Hence the speed of the bobbin, when empty, is to the speed of the bobbin, when so filled, as five to five and a half—a retardation which is effected by causing the driving-strap to slide along the surface of a conical drum. This proportion does not, however, remain constant when a change of twist is to be made, and hence the cone motion was inadequate to remedy the defect, till Mr. Houldsworth's differential system was introduced along with it.

Description of the Bobbin-and-Fly Frame.

This beautiful machine, as constructed by Messrs. Cocker and Higgins, with these modern patent improvements, is represented in plate IV., and in figs. 49, 50, 51, and 52, and deserves the peculiar study of the philosopher, on account of its exquisite mechanical combinations. It consists of several organic structures, which may be separately considered. There is a roller-beam similar to that described under the drawing-frame, and there are vertical revolving rods of steel, called spindles, bearing on their summits a bifurcated piece, called a flyer, of which one leg is tubular, and serves to conduct the soft roving from the nose of the spindle to the bobbin (see fig. 49). By the revolution of the spindle and flyer the cotton slab receives its twist, and by the difference of the rotation of the flyer and bobbin it is wound upon the latter exactly in proportion as it is given off by the rollers. The winding-on takes place in a ratio compounded of the difference of the speed of the bobbin and flyer, and of the circumference of the bobbin. Were the winding-on to be a constant quantity, like the motion of the delivering rollers, the product of the two numbers would remain the same; but when one of them alters, as happens to the diameter of the bobbin, which is constantly increasing, the other quantity, namely, the difference between the number of revolutions of the bobbin and the flyer, must be decreased; a change produced by increasing the speed of the bobbins, while the flyers revolve uniformly, in order to give a uniform degree of torsion to a definite length of the delivered slab. As, therefore, the up-and-down motion of the bobbin, in the distribution of the roving over its surface, must be decreased in a constant progression according to the grist of the roving, so the rotation of the bobbin is increased by a motion compounded of the regular speed of the driving-shaft of the machine, and the decreased speed of the other parts.

Till lately the bobbins were formed of wooden tubes, with flat circular ends or discs, which confined the roving; but these discs are now discontinued, as they were found to injure the roving in various ways for the best work. In the most-recently made fly-frames the bobbins are simple wooden tubes, upon which the roving is wound, so as to produce conical ends, by shortening, after a certain period in the winding-on, the extent of the traverse, or up-and-down motion of the bobbin.

Fig. 50 exhibits that end of the machine where the motions are communicated. Fig. 51 is a cross section, taken parallel with the former view. Plate IV. is a part of the longitudinal back view, containing all the working gear. The other parts (not shown here) are merely a series of spindles to suit the length of the space destined to accommodate the machine.

Two sets of bobbin-and-fly frames are generally used in the best factories, called the coarse and fine, or the first and second roving-frames; they are both the same essentially, but the first is generally constructed in larger dimensions, but with fewer spindles, and is fed with slivers from cans or large bobbins filled at the drawing frame, placed at the back of the machine. The second roving-frame is fed from the bobbins filled at the first frame, which are arranged on upright skewers in a shelf, called the *creel*, placed behind the roller-beam. This creel is shown in figs. 50 and 51; but it is left out in plate IV., to prevent confusion.

A is the fast and loose pulley which is connected by a strap with the mill shaft, as shown at *h*, in the transverse section of the mill, plate II.

B is a small fly-wheel to equalize the motion of the machine.

C is a horizontal shaft going nearly the whole length of the frame, as seen in plate IV., and producing all its internal motions.

D is a set of drawing rollers mounted upon a beam E, fig. 51, of exactly the same construction as that used in the drawing frame already described. The rollers are not, however, like them, divided between several independent heads, but are equally distributed along the length of the machine, from the one end to the other, and are supported at several places by bearings, similar to those seen at the right end of the figure, upon which they rest in collars.

F, F′, are the spindles arranged in two rows, through the whole length of the frame, in such a way that those of one line stand in the intervals of the other. These spindles are carried in the bearings *a, a,* fig. 51, and revolve upon the steps *b, b.* At their lower ends there are small bevel wheels *c, c,* which are driven by others *d, d,* fixed upon shafts which go from one end

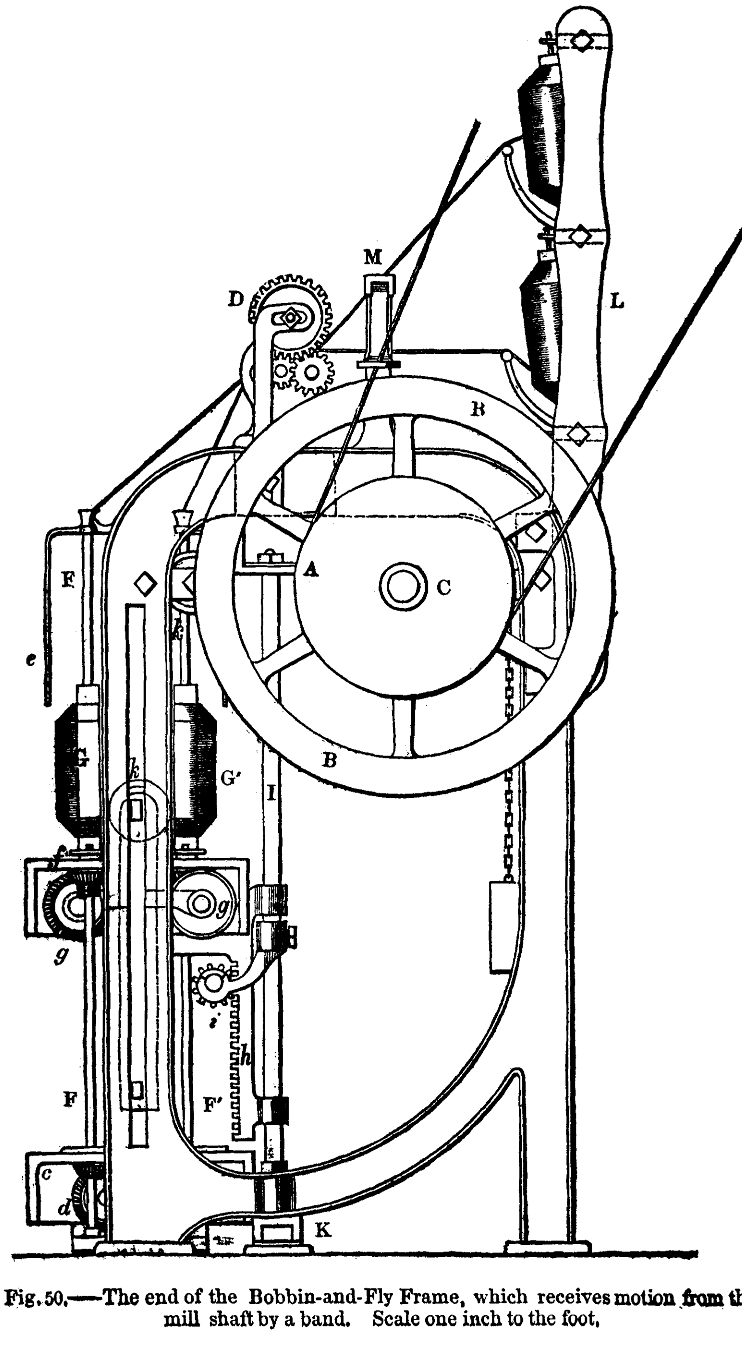


Fig. 50.—The end of the Bobbin-and-Fly Frame, which receives motion from the mill shaft by a band. Scale one inch to the foot.

of the machine to the other. In order to allow these shafts to run along side of the spindles, the teeth of these bevel wheels *c, c,* and *d, d,* are not cut in a line leading to the axis of their motion, but are cut as tangents to a circle, whose radius is equal to the distance between the centre of the horizontal shafts, and the centre of the spindle.

e, e, is the flyer, one arm of which is a tube with a slot to introduce the slab or roving, but the other is a mere rod to counterbalance the former, and to prevent its flying off or getting loose upon the spindle, upon the conical summit of which it is pressed after the full bobbins have been changed for empty ones. G, fig. 50, is the bobbin resting upon a plate connected with a small bevel wheel *f, f,* similar to the wheels *c, c,* upon the spindles, as above described. They are driven independently of the revolving spindles by other wheels *g, g,* fixed upon shafts which run through the whole length of the machine, and are moved by a mechanism afterwards to be described. The bearings of the shaft of *g, g,* and the upper bearings of the spindles, are fixed to a strong beam H, plate IV., which slides slowly up and down, carrying with it the shafts and wheels, which give motion to the bobbins. In this up-and-down motion the beam is guided by several rods I, I, which connect the roller-beam E with an iron beam K resting with feet upon the floor, and made fast to the frame work of the ends of the machine. It is raised by several racks *h,* fig. 50, in which pinions *i* work, on a shaft also running the length of the machine, and which get by turns a motion to the right and the left. The copping-beam H, which is covered with a casing of wood, which encloses also the shafts and wheels, is

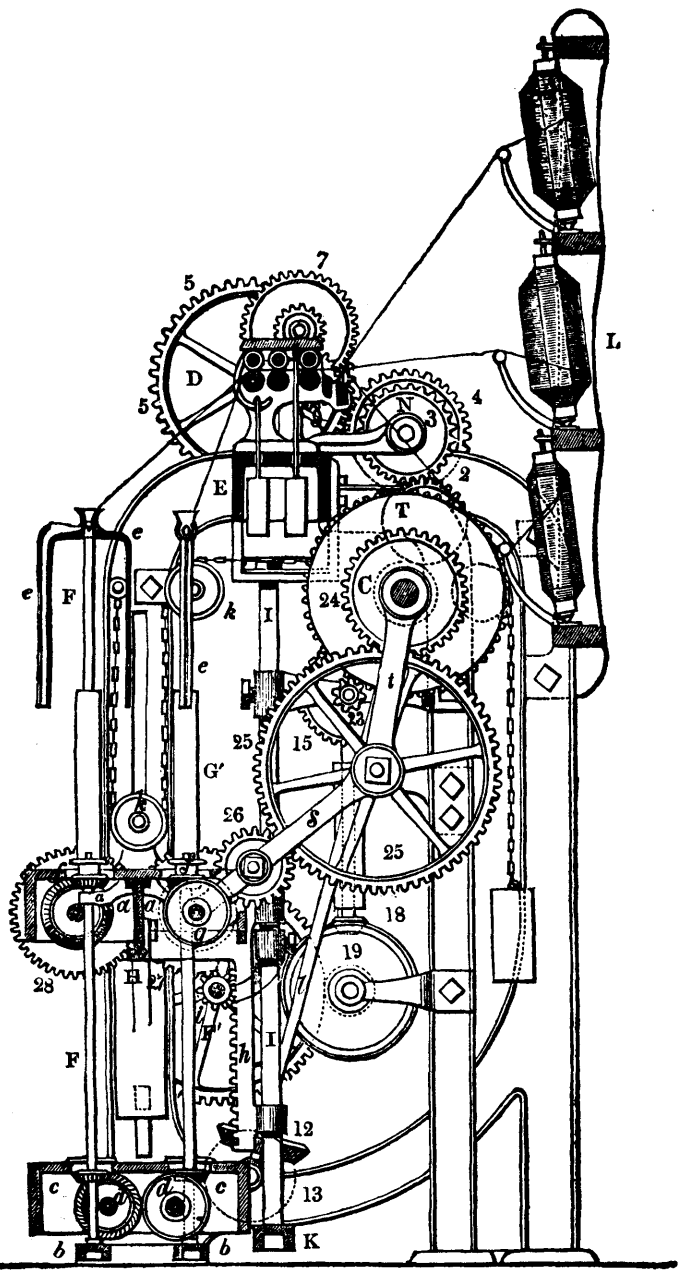


Fig. 51.—Cross Section of Bobbin-and-Fly Frame, parallel with the view in fig. 50. Scale one inch to the foot.

counterpoised by weights suspended to chains going over the pulley *k, k,* fig. 51 and plate IV.

The sliver before entering between the back pair of drawing-rollers, is led through between two guides fixed upon a wooden bar, which has a very slow lateral traverse motion, so as to shift the sliver alternately to the right and left, about three-quarters of an inch, in order to prevent the leather covering of the top rollers from being indented or grooved by the slivers passing constantly over the same line of their surface. The motion is given to this bar, in this machine as well as in all the roller spinning-machines, by a little excentric, or a crank, fixed upon a toothed-wheel, which is moved by a snail-screw on the end of the axis of the back roller. See description of the throstle.

L is the creel, which serves in the fine bobbin-and-fly frame to carry the bobbins filled with the rovings made at the coarse frame. From the section fig. 51, it will be seen that this roving passes through wire-eyes, which extend the whole length of the machine, to protect it from being torn obliquely from the bobbins.

In the coarse roving-frame, the top of the machine behind the rollers is covered with a smooth plate, upon which the slivers glide towards the rollers. M is a rod stretching along over the machine, having at its extremity a guide for pulling the strap which drives the steam-pulley: this rod therefore serves, when slid to right or left, to put the machine into, or to throw it out of geer, as the *tenter* requires in the course of his work, at whatever part of the frame he may happen to be employed at the time. See plate IV.

In order to explain the manner in which this curious mechanism acts, we must first turn our attention to the principal shaft C, C, a portion of which is seen in plate IV.

The two motions, which do not vary during the action of the machine, are those of the drawing-rollers, and the spindles; the first giving off a certain length of sliver, and the other revolving with a constant velocity to give a definite degree of twist to the definite length of roving.

Upon the end of shaft C is fixed a wheel 1, which by means of the carrier-wheel 2, and the wheel 3, drives the shaft N, upon whose other end, and exterior to the right-hand framing, there is another wheel 4, which drives a wheel 5, fixed on the prolonged end of the front roller; a pinion 6, on the shaft of the same roller, drives by the carrier-wheels 7 and 8, a wheel 9, upon the back roller-shaft. From this shaft, motion is given to the middle roller by means of a carrier-wheel, and two wheels, of nearly the same diameter, upon the other ends of the roller-shaft, which end is broken off in the engraving, plate IV., but is seen in the end view, fig. 50.

10 is a bevel wheel fixed upon the shaft C, which by means of wheel 11, drives the upright shaft *l*, *l*, and by the bevel wheels 12 and 13, the short shaft *m*, near the floor. From this shaft, motion is transferred by spur-wheels to the first horizontal shaft, in order to drive one line or row of spindles, whilst itself moves the second shaft by means of two spur-wheels attached to them, and working one another. See plate IV.

To produce the up-and-down motion of the bobbins, there is a pulley O, movable along the shaft N. A key or wedge, sliding in a groove of the latter, attaches it to the shaft, and makes it revolve with it. This pulley O, by means of a strap, turns the cone P, which receives a diminishing rate of motion, as the strap advances from the smaller to the wider end. *n* is a pulley, pressed by a weight against the strap to keep it tight, and which advances with the other pulley O. The cone drives the shaft Q by the wheels 14 and 15; and from these, by the wheels 16 and 17, it drives the upright shaft R, which by the intervention of the small bevel wheel 18, drives either of the wheels 19 or 20 on the shaft S. One of them is shifted into geer with it by an apparatus, to be described hereafter. The shaft S is driven by these means to the right or to the left, and therefore turns, also, the pinion 21, at its end. The wheel 22 is made fast to the shaft with the pinions *i, i,* so as to move the latter, either in the one or the other direction. The alternate up-and-down motion, formerly mentioned, is thus communicated to the copping-rail, which carries the bobbins. See I, I, in plate IV.

The shaft Q has at its end a pinion 23, which

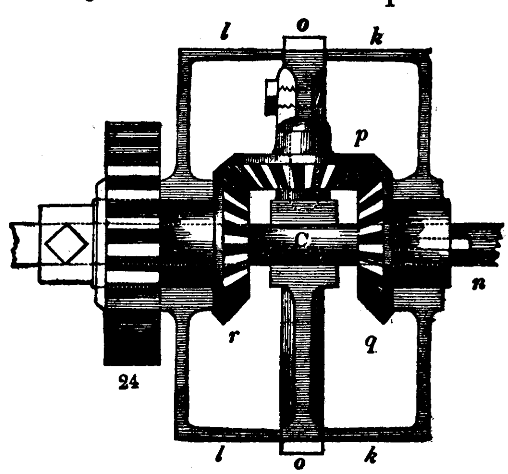


Fig. 52.—Equational Mechanism of Mr. Houldsworth's Differential Box in the Bobbin-and-Fly Frame. Scale two inches to the foot.

works in a toothed part of the apparatus T, called the differential box, being the subject of Mr. Houldsworth's patent. It is represented separately in figs. 52, 53, and 54. O′ is a wheel, plate IV., revolving loosely upon the shaft C, figs. 52, 53, and 54, having

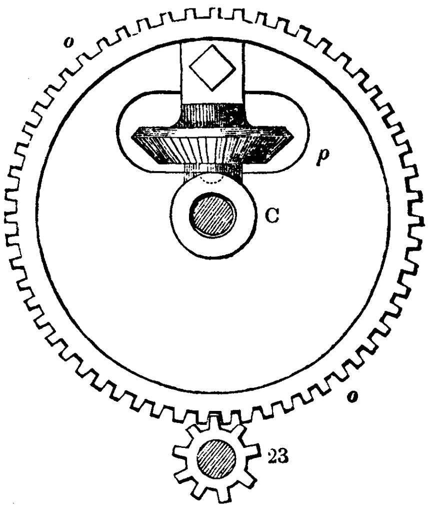


Fig. 53.—Equational Mechanism. Scale two inches to the foot.

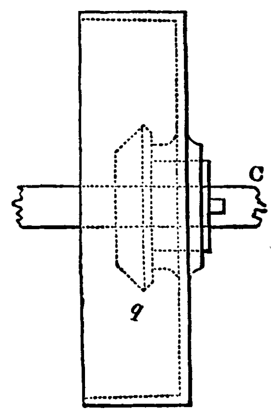


Fig. 54.—One-half of the Equational Box seen outside. Scale two inches to the foot.

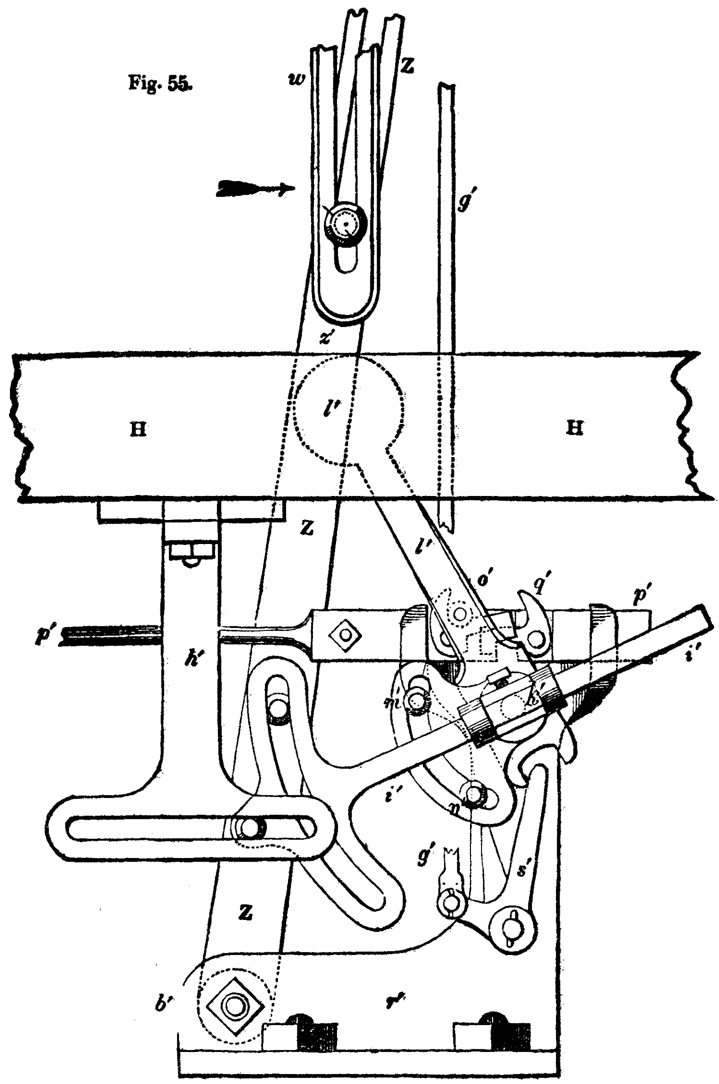
attached over it a bevel wheel *p*, which also revolves loose upon its own axis in a direction perpendicular to C; *q* and *r* are bevel wheels in geer with the bevel wheel *p*, whose axis is in the plane of the wheel *o*, and goes round with it; *q* is fixed upon the shaft C, but *r* revolves loose upon C, and is connected with wheel 24. This apparatus is enclosed within two hollow cylinders, which join together to form one cylindric box; each cylinder has one of the bevel wheels *q* or *r* fixed to it: these boxes joined serve to support the large spur-wheel *o*, which forms the middle part of the cylindric box.

Suppose now that the wheel *o* were stopped, it is obvious that the bevel wheel *q* would drive *r*, by the intervention of *p*, with the same speed, but in a contrary direction; should the wheel *o*, however, also revolve in the same direction with *q*, and with the same velocity, it is manifest that no motion at all would be transmitted to the wheel *r*, which would therefore remain at rest, while encircled, as it were, with motion. But if the wheel *o* turns more slowly than *q*, the wheel *r* will necessarily be made to turn with a velocity equal to the difference between the speeds of *q* and *o*. By gradually decreasing the speed of *o* (in proportion to the fineness of the roving) the wheel 24 will be turned with a velocity equal to the difference between a uniform motion (that of the spindles) and a variable motion (that required for the increasing diameter of the bobbins). From wheel 24, motion is transmitted to regulate that of the bobbin in winding the roving upon it, agreeably to the principles formerly stated. The wheel 24 drives by the two carrier-wheels 25 and 26, a wheel on the first horizontal shaft for driving the bobbins, shown by dotted lines in fig. 51. From the first shaft motion is given to the second by two spur-wheels 27 and 28, fixed upon the ends of the shafts, and working in each other.

While the great copping-beam H, with the shafts attached to it, works up and down, the contact or geering of the wheels 24, 25, 26, is preserved, as well as that of the dotted wheel on the shaft *g*, fig. 51, by means of two arms *s* and *t*, (to the left of the line of wheel-work 24, 25, 26, in plate IV.,) jointed at one of their ends, turning loose at the other end upon the shafts *g* and C, and having fixed upon them the central studs for carrying the wheels 25 and 26 (as is clearly shown in fig. 51, and in plate IV.).

We have now to show how the pulley O, with its tightening pulley *n*, is gradually shifted, or made to slide along the shaft N, in such manner as to communicate a variable motion to the cone P, and to cause it to turn progressively slower as it approaches its apex or summit. *u* is an oblong slot-plate of cast iron, screwed fast against the roller-beam E. On its slot-face another piece *v* is fitted, so as to be susceptible of a sliding motion. The upper and under edges of this piece are notched with ratchet-teeth, in which two clicks *x* and *y* work. A perpendicular arm or branch *w* of that slide-piece can be adapted to it, at any height, by a bolt *a′* with the lever Z, turning on the joint *b′*. To the top *c′* of the lever a long horizontal rod *d′* is attached, which connects it with the guide-groove, in which the pulley O moves upon the shaft N. From the same point a rope proceeds and runs over a pulley *e′*, suspending a weight *f′*, for drawing the lever Z in the direction of the arrow (plate IV.); whence, by lifting one of the clicks *x* and *y*, a tooth of the slide-piece *v* escapes, and the other click catches the next tooth of the rack. The successive lifting of one tooth after another, is performed by an upright rod *g′* being moved a little up and down by the apparatus U, which is delineated separately in plan (see fig. 56), and in a front view (fig. 55). It is shown in a back view, in plate IV., in connexion with the whole machine. H, H, is the copping-rail for moving up and down all the bobbins simultaneously, to which is attached the piece *h′*, which by means of the straight slot above Z, moves the lever *i′*, sliding in a staple-piece, which

Fig. 55.



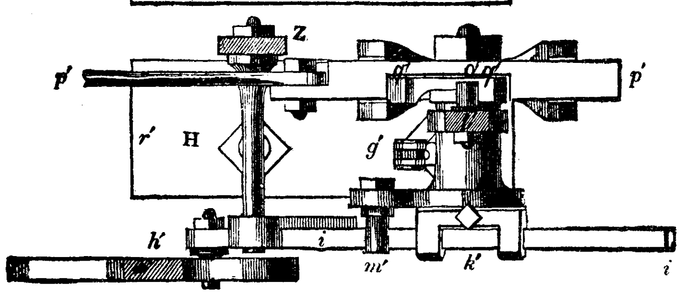


Fig. 56.—Rack-shifting Mechanism of Bobbin-and Fly Frame.
Scale two inches to the foot.

turns loosely upon an axis k'; at the lower end of the lever i' there is a curved slot, in which a stud or pin lies attached to the lever Z; on the centre k' there is a tumbler l', l' furnished with a curved slot-branch, into which are screwed two pins m' and n'. A pin or stud o' screwed into the tumbler l', moves by tumbling (from the right to the left, or from the left to the right,) the rod p', so as to shift one of the bevel wheels 19 or 20, into geer with the wheel 18 (see plate IV.); by which means, as was formerly stated, the up-and-down motion of the copping-rail H is produced. The tumbling of the lever l', loaded with a ball weight at its end, is occasioned by the lever i', which is moved up or down by h', fixed upon the copping-rail H, and presses against one of the pins m' or n'; after having lifted one of them so high that the weight of the lever l' gets into a position beyond its centre of gravity, (or line of direction,) it will tumble suddenly over. The pin o' will thus strike against one of the catches q' attached to the rod p', and lifting it from a projection upon the frame-piece r', will finally move the rod p', either in the one direction or the other.

By the tumbling of the lever l', its other end will also move the upright arm of the bell-crank s'; to the horizontal branch of which the rod g' is joined, which disengages by the jerk of the tumbler, one of the clicks, or detents, x or y' plate IV. This escapement permits the slide-piece v to advance one tooth, and also to move the lever Z a little to the left, or in the direction of the arrow. This movement also makes the lever i', fig. 55, 56, to slide a little backwards through the staple-boss at k', by means of the pin upon the lever z', by which i' is guided in its slot, when moving up and down, in consequence of its connexion with the piece h', and the copping-rail H. The lever i', therefore, after one going up and down (vertical traverse, or ascent and descent) of the bobbins comes to strike every time sooner and sooner against one of the pins m' and n', fixed in the small curved slot of adjustment of the lever l', and thus shortens the extent or range of that motion, while also its velocity is decreased by the sliding of the strap from the smaller to the larger end of the cone, as was formerly explained.

It remains now to show only how the bobbins may be always filled to the same degree at each repetition of the movement, by the machine putting itself out of geer, at the definite period deemed proper for the spinner's purpose. To the rack-piece v is attached a pin t', which, when the rack has arrived at the end of its course, strikes up the catch u', by which the bell-crank lever v', carrying the pulley e', and the suspended weight f', is permitted to obey the action of this weight, and thus move the geering-rod M, so as to throw the driving-strap from the steam-pulley, upon the loose one alongside of it.

The full bobbins being now removed, and replaced by empty ones, the roving-tenter (usually a female) brings back the rack v to its primitive position by the traction of the rope w', which is wound up by a winch-handle upon a small barrel x', whose axis turns in the roller-beam E. Before the tenter works this handle, she raises the end bearing y' of the cone P, by a lever on which it rests, thus permitting the strap of the pulley O to slide easily to the smaller end of the cone, while the rack is pulled back by the rope. The bearing at the thick end of the cone z' turns upon a stud fulcrum, so as to allow the thin end to be readily lifted a little way by the hand of the operative.

In fig. 49, p. 63, one of the roving spindles is represented, along with the bobbin and its driving wheels. The modern mechanism is likewise shown for laying on the roving in a compressed state, which can be used only in the frames adapted to make conical-shaped rovings (such as we have just described). Upon the end of the tube-arm of the flyer there is a brass ring a'', with a brass finger b'', resting upon the roving of the bobbin, and pressing by means of a spring c'', which works or re-acts against the shoulder d'' of the ring. In the flattened point of the finger there is a slit through which the roving passes in its way to the bobbin, meanwhile revolving and gliding up and down under regulated pressure. By giving the roving a turn (as shown in the figure) round the finger, it is prevented from being thrown out and unduly stretched by the centrifugal force generated by the rotation of the flyer.

In plate IV., a few spindles of the back range are shown to complete our explanation of this seemingly complex but perfect automaton. One spindle is left naked, two are exhibited with the bobbins empty, and one with a full bobbin. The spindles of the front range F'' were broken over near the bottom, to keep the drawing neat and perspicuous.

Fig. 57 represents, in a plan, or horizontal section, the copping-rail H, with its two alternate rows of spindles viewed from above; three spindles being shown as mounted with their flyers and bobbins, and three others without them, in order to exhibit the driving shafts and wheels.

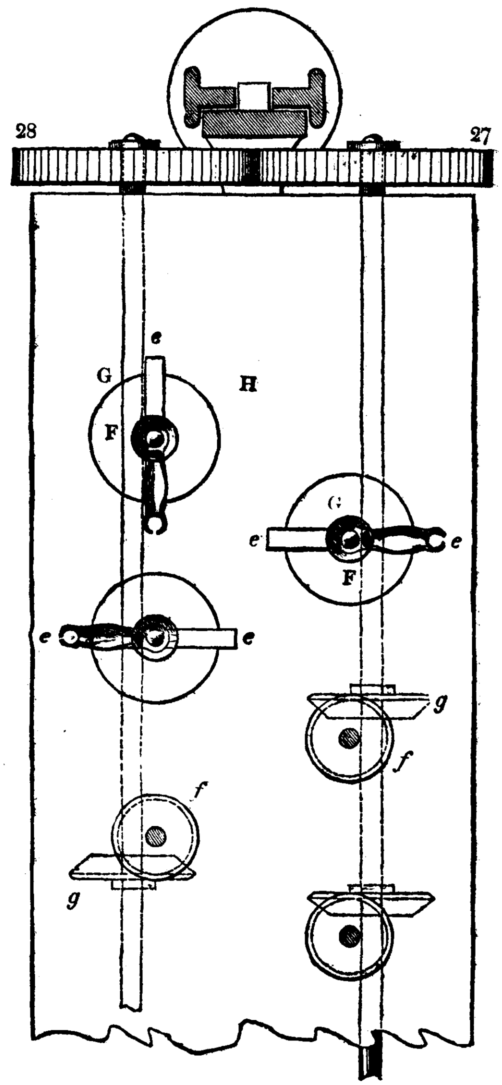


Fig. 57.—Ground Plan of Spindles and their Drawing Wheels, in the Bobbin-and-Fly Frame. Scale two inches to the foot.

Fig. 58 is a back view of one end of the bobbin-and-fly frame of Messrs. Cocker and Higgins, with Mr. Houldsworth's differential box, but without the bevel wheel movements of the spindles and bobbins. Machines of this kind are now doing good work in a great many cotton-mills, and they therefore merit an explanation, were it for nothing else than to illustrate the rapid march of improvement in factory invention. It is adapted to the bobbins with disc ends, which are filled with a soft coil of roving in a cylindrical form. Fig. 59 is a cross section, showing merely some of the principal parts.

This fly-frame differs from the most recent (above described) in the following respects :—1, In wanting the tumbling apparatus U, for reversing the motions of the copping-rail; that motion being here produced by a uniformly revolving motion of the shaft S, working by the pinion 21, upon its end, in the teeth of a mangle-wheel, in which it shifts alternately from the outside to the inside, for reversing the direction of the movements. These, however, continue of equal extent as the roving here is laid on evenly from end to end of the bobbin. In the absence of the apparatus U, the rod g', which raises alternately one of the clicks x and y, is disengaged with a jerk, directly from the copping-rail, the instant it arrives at the top and bottom of its course.

All the other motions and actions are the same in this and in the previously-described bobbin-and-fly frame, except that the flyers are not mounted with spring pressers, as the wooden ends of the bobbins would interfere with their operation. This is certainly a great disadvantage; since a bobbin mounted with a presser can

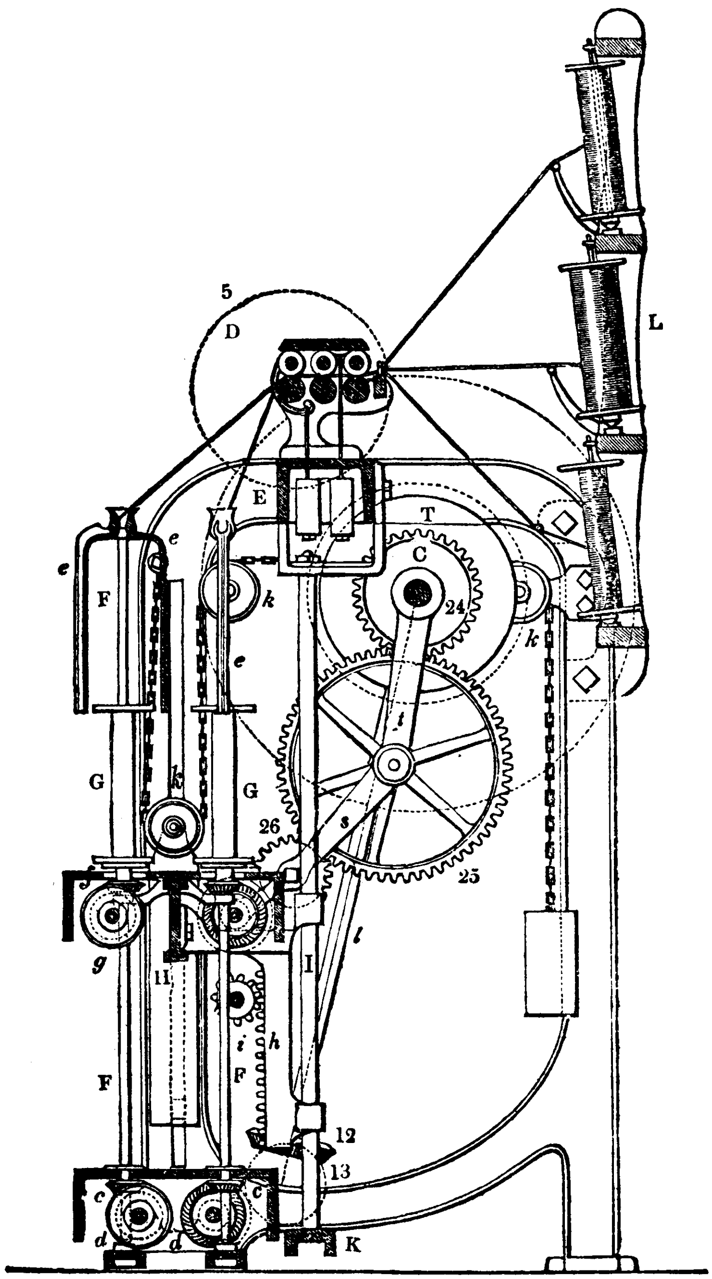


Fig. 59.—Bobbin-and- Frame, with the Mangle-wheel movement. Scale, one inch to the foot.

take on a great deal more roving at a time, and need, therefore, to be far less frequently changed in the creel, either of the fine bobbin-and-fly frame, the mule, or the throstle. I made the following experiments at Mr. Orrell's factory, on uncompressed and compressed bobbins:—

	Ounces.
The large bobbin of the first, or coarse bobbin-and-fly frame, contained of roving applied by the spring presser	14
The same sized bobbin filled with uncompressed rovings, only	$7\frac{1}{2}$
The smaller bobbins of the second, or fine bobbin-and-fly frame, contained of compressed roving	8
The same sized bobbin, uncompressed . .	$2\frac{1}{2}$

These numbers are the means of several weighings.

2,400 inches, or 200 feet, of the fine roving weighed 160 grains. It was perfectly uniform in texture; the motion of the large spindles in his frames being so true and easy, as to be undiscernible by the eye. It was necessary to touch them, in order to ascertain whether they were moving or at rest.

It is a principle universally recognised at the present day, especially for fine spinning, that the less twist rovings receive the better yarn will they, *ceteris paribus*, furnish.

The spindles in the above coarse roving-frame turn 750 times in a minute, for 100 revolutions of the front roller, whose diameter is $1\frac{1}{4}$ inch. As its periphery is therefore very nearly 4 inches, that frame will turn off for each spindle $4 \times 100 = 400$ inches per minute $= 24{,}000$ inches, or $666\frac{3}{4}$ yards per hour.

In the fine bobbin-and-fly frame, the spindles move with the same velocity, but the front roller makes only 80 revolutions in the minute; hence more twisting power is here employed in the proportion of 100 to 80, and the quantity given off in one hour will be about $4 \times 80 \times 60 = 19{,}200$ inches $=$ 1600 feet, or $533\frac{2}{3}$ yards.

A conical bobbin, with compressed roving from the fine bobbin-and-fly frame, will last in a mule five days, and in a throstle six, which is three times longer than the uncompressed bobbins do.

Coarse roving is often called slubbing.

The advantage of the improved bobbin-and-fly frame, as above described, may be judged of from the following fact, which I learned from good authority at Manchester. In an excellent fine spinning-mill, the revolving can-frame was long used, in conjunction with the stretcher mule, to make fine rovings. Of late years, since the first and second bobbin-and-fly frames have been introduced into this factory instead of the can-frame, three bobbin-and-fly frames with one stretcher mule do for 7*l.* what formerly cost 16*l.*

In the coarse bobbin-and-fly frame the sliver is doubled, by setting two cans with drawings in connexion with one portion of the fluted roller. In the fine bobbin-and-fly frame, there is no doubling of the roving. To two sets of drawing-frames, two coarse bobbin-and-fly frames, and four fine ones are usually assigned. Fourteen cards will be equivalent to the whole—to constitute two *preparations*.

In the bobbin-and-fly frame, the sliver is elongated about from four to six times; the principal draught of $4\frac{1}{2}$ being between the front and middle rollers, and the remaining $1\frac{1}{2}$ between the middle and back rollers.

The mangle-wheel, for reversing the motion of the copping-rail, was introduced by Mr. Kennedy many years ago into the bobbin-and-fly frames; but the conical form of the bobbin is found so favourable to fine work, as now to cause a preference to be given to the bevel wheel and tumbler plan of reversing the said motions.

Messrs. Cocker and Higgins informed me, that they contrived and executed the first bobbin-and-fly frames about the year 1815, and introduced into it the differential motions of the cone, and the unequal toothed rack escapement with shifting clicks—an invention which did the greatest honour to their mechanical ingenuity and judgment, and established their reputation as factory machinists all over the world. The teeth of their rack required to be cut by a particular machine, conformably to the segments of a parabolic curve.

Mr. Houldsworth's rack, with *equal* teeth, has superseded all these calculations and adjustments of the old rack. It will suit rovings which differ even 100 per cent. in thickness, that is, from 30 to 60 coils, without changing the rack.

The coarse bobbin-and-fly frame has 30 spindles.
The fine do. do. 60 do.;
but I have seen a double one in Manchester with 120; and Messrs. André Kœchlin and Co., of Mulhouse, have constructed a great many of the same size, with a somewhat modified construction, in which the spindles and bobbins are driven by oblique toothed wheels and snail-work, instead of conical bevel wheels.

For fine spinning, the double-conical rovings are weighed on the bobbins by a quadrant beam, and distributed according to their respective weights into five numbered baskets; such nicety is required for the best quality of work. In some coarse spinning-mills, only one carding, one drawing, and one roving are employed for the manufacture of inferior calicoes at the cheapest rate.

In the coarse bobbin-and-fly frame, it is usual to make the spindle go quicker than the bobbin, and in the fine to make it go slower, by which the winding goes on backwards. Let us state a case in numbers for the sake of illustration. If 45 inches of roving are to be wound upon a bobbin whose barrel is $4\frac{1}{2}$ inches in circumference, 10 turns will be required. Suppose that these 45 inches should receive 30 turns of twist, the spindle, and consequently its attached flyer, must give these 30 turns during the winding on of the roving. If the bobbin therefore is $1\frac{1}{2}$ inch in diameter, it must make 10 turns for the winding on, and 30 turns in following the spindle; in all 40 revolutions.

If the bobbin be 3 inches in diameter, or 9 in circumference, it must make only 5 turns to wind on the 45 inches; these 5 turns added to the 30 turns required for twist, make 35 revolutions; and thus for any other dimensions of the bobbin. It hence results, that the number of turns of the bobbin, *plus* the number of turns of the spindle, is a quantity always inversely as the diameter of the bobbin.

The motion of the bobbin and spindle is simultaneous and in the same direction, with a difference varying more or less according to the variable diameter of the bobbins. But to render the matter still plainer, suppose for a moment the spindle to be stationary; then the bobbin must turn with such a velocity, that it shall wind on the roving just as fast as the front rollers deliver it. This roving comes forward at a uniform rate; but the bobbin growing continually larger in diameter should turn with a velocity uniformly retarded. Let us now restore motion to the spindle: it is evident that when the winding is forwards, as in the fine fly-frame, we must deduct from the rotation of the bobbin, needed for winding on the roving, that of the spindle required for the twist; for the circumference of the bobbin being $4\frac{1}{2}$ inches, 10 turns take up 45 inches. These 10 turns deducted from the 30 made by the spindle, leave only 20 turns for the effective speed of the bobbin; or, if the circumference be 9 inches, 5 turns will take up the 45 inches, if the spindle be at rest; but if the spindle makes 30 turns for twist, the effective speed of the bobbin will be $30 - 5 = 25$ turns. Hence for the fine bobbin-and-fly frame we find that the number of turns of the spindle, *minus* the number of turns made by the bobbin in the same time, is a quantity inversely as the diameter of the bobbin.

In the coarse frame, the bobbin should move faster than the spindle, and its speed should go on diminishing; while in the fine frame, the speed of the bobbin is less than that of the spindle, and it goes on progressively increasing. For this reason the cones of these two machines are set in opposite directions. This arrangement is not, however, indispensable, for the cone might be placed similarly in each; but as the fine frame has a good deal of twisting to perform, the bobbin would need to turn still more rapidly than in the coarse frame, which would consume more moving force, for which reason it has been found more advantageous to make it revolve in the opposite direction.

It has been stated that the twist of the roving in the fine fly-frame takes place in an opposite direction to that in the coarse one; this is a practice with spinners of which it would be difficult to ascertain the origin or to assign the cause. To do and undo is no part of the economy of manufactures.

It may probably be agreeable to some of my readers, and may help their comprehension of Mr. H. Houldsworth's invention, to be presented with an abstract of its description, as given in the specification of his patent.

The main shaft of the machine C (see fig. 52, and plate IV.), turned by a band and rigger (strap and pulley) as usual, communicates motion by a train of wheels through a shaft to the drawing-rollers at the reverse end of the machine, and causes them to deliver the filaments to be twisted. Upon this main shaft C, is mounted a cylindrical hollow box or drum-pulley, from whence one cord passes to drive the whirls and spindles, and another to drive the bobbins (this is now done by wheel-work).

This cylindrical box-pulley (figs. 52, 53, 54) is made in two parts, *k* and *l*, and slipped on to the axle with a toothed-wheel *o*, intervening between them. That portion of the box with its pulley marked *l*, fig. 52, is fixed to the shaft C; but the other part of the box and its pulley *k*, and the toothed-wheel *o*, slide loosely round upon the shaft C; and when brought in contact and confined by a fixed collar or keyedwedge *n*, they constitute two distinct pulleys, one being intended to actuate the spindles, and the other the bobbins.

In the web (plane) of the wheel *o*, a small bevel pinion *p* is mounted upon an axle, standing at right angles to the shaft C, which pinion is intended to take into the two bevel pinions *q* and *r*, respectively fixed upon bosses, embracing the shaft in the interior of the boxes *k* and *l*. Now, it being remembered that the pinion *r* and its box *l* are fixed to the shaft C, and turn with it, if the loose wheel *o* be independently turned upon the shaft with a different velocity, its pinion *p* taking into *r* will be made to revolve upon its axle, and to drive the pinion *r*, and pulley-box *k*, in the same direction as the wheel *o*; and this rotatory movement of the box *k* and wheel *o* may be faster or slower than the shaft C and box *l*, according to the velocity with which the wheel *o* is turned.

Having explained the construction of the box-pulleys *k* and *l*, which are the particular features of novelty claimed under this patent, their office and advantage will be seen by describing the general movements of the machine.

The main shaft C being turned by the band and rigger as above said, the train of wheels *m* (1, 2, 3, plate IV.) connected to it actuates the whole series of drawing-rollers. Upon the shaft N, there is a sliding pulley *o*, carrying a band which passes to a tension pulley *n*, and is kept distended by a weight. This band in its descent comes in contact with the surface of the cone P, and causes the cone to revolve by the friction of the band running against it. The pulley *o* is progressively slidden along the shaft N, by means of the rack and weight, which movement of the pulley is for the purpose of shifting the band progressively from the smaller to the larger diameter of the cone, in order that the speed of its rotation may gradually diminish as the bobbins fill by the winding on of the yarns (rovings).

Connected with the axle of the cone P, a small pinion, 23, is fixed, which takes into the teeth of the loose wheel *o*, and as the cone turns, drives the wheel *o* round upon the shaft C, with a speed dependent always upon the rapidity of the rotation of the cone. Now the box-pulley *k*, (fig. 52) being fixed to the main shaft C, turns with one uniform speed, and, by wheel-work connecting it with the whirls, it drives all the spindles and flyers, which twist the yarn with one continued uniform velocity; but the box-pulley *l*, being loose upon the shaft, and actuated by the bevel pinions within, as described, is made to revolve by the rotation of the wheel *o*, independently of the shaft, and with a different speed from the pulley-box, *k*; and wheels connecting this pulley-box *l* with the bobbins communicate the motion, whatever it may be, of the pulley-box *l* to the bobbins, and cause them to turn, and to take up or wind the yarn with a speed derived from this source, independent of, and differing from, the speed of the spindles and flyers which twist the yarn.

It will be now perceived that these parts being all adjusted to accommodate the taking up movements to the twisting or spinning of any particular quality of yarn intended to be produced, any variations between the velocities of the spinning and taking up, which another quality of yarn may require, may easily be effected, by merely changing the pinion 23, fig. 58, for one with a different number of teeth, which will cause the wheel *o* and the pulley-box *l* to drive the bobbins faster or slower, as would be required in winding on fine or coarse yarn, the speed of the twisting or spinning being the same.

This desirable object is effected in its most simple way by the mechanism above described, and which is extremely simple when considered abstractedly from the ordinary movements of the spinning machine.

There are, however, other modes of effecting the object upon the same principles.

*Popular Explanation of the Mechanism of the Bobbin-and-Fly, (plate IV.) by H. Houldsworth, jun., Esq.**

Upon a shaft N, which lies behind the roller-beam, and is connected by wheel-work with the front roller, there is a sliding fork. This fork has between its prongs a pulley O, which slides with it along the shaft, but the shaft has a groove cut in it lengthwise, and a key or feathered edge in the pulley takes into this groove, so that the shaft cannot turn round without taking the pulley with it. The weight *f′* tends to draw the pulley towards it; the rod *d′* is connected with a rack-scapement, which allows the pulley to slide one tooth for each layer wound upon the bobbin. The pulley O drives the cone, and the tightening pulley *n* lies with its weight upon the strap so as to take up its slack when the strap is working upon the small end of the cone. X is an arm joined to the slide at the one end for carrying at the other the stud on which the pulley *n* revolves.

The guide-rod slot-plate *u u* is fixed to the back of the roller-beam, leaving a space of about one inch:

* A written communication.

v is a plate, which slides along the guide-plate. The tail *w*, of this slide-plate has a slit or slot in it to receive the stud *a'*, which takes into a hole in the lever Z, which works upon the centre *b'*, and has a rod *d'*, at its top end connected with the sliding fork, X O, already described. The vertical bar *g'* has two pins upon its upper end to lift the catches or detents; the lower part of it is a round rod with two set collars upon it, where it passes through an arm or branch *m' n'*, of the copping-rail.

The action is as follows:—at starting, the sliding-fork X, and pulley, with the rack and lever, are all moved by sliding to the right-hand end of the frame. The weight *f'*, at the left-hand extremity of the frame, tends to pull the whole of the said sliding apparatus towards itself by the traction it impresses on the rod, *d'*; but it is obstructed by one or other of the catches or detents *x*, *y*. When the copping-rail reaches the top of its course, the arm *m' n'* comes against the top set-collar of the upright bar *g'*, raises it, by which the top catch *x*, is lifted, and the rack, lever, sliding-fork, pulley, and strap, all shift towards the weight, till the under catch stops the motion by falling into the next tooth of the under rack. When the copping-rail reaches the bottom of its course, its branch comes into contact with the lower set-collar, and makes the bar *g'* descend so as to pull down the lower catch *y*, whereby the rack apparatus is allowed to shift another step to the left, till arrested by the upper catch *x* falling into another tooth of the upper rack, and thus, step by step, the above train of apparatus hitches on towards the left end of the machine. The long bar-lever Z, has the following use: the cone-strap always traverses the same distance in filling a bobbin, because the diameters of the empty and full bobbins have a constant difference; as, for instance, 1 or $1\frac{1}{4}$ inches when empty, and 3 when full, whatever be the fineness of the roving wound upon them. The finer the roving, however, the more coils or layers of it will be required to fill the bobbin, consequently more traverses of the copping-rail, and more escapement motions in the rack; hence a change of rack would apparently be needed for every change of fineness in the roving, but this change is superseded by the intervention of the lever-bar Z. The lever, being attached at c' to the rod d', is thus enabled to act upon it, and thereby to move the sliding-fork upon N. The quantity of this motion is regulated according to the place of the stud a' in the slot branch w. The higher the stud a' is placed in the said slot, the more teeth of the rack will be required to give to the top end of the lever Z the same quantity of strap-traverse motion upon the cone. Suppose, for the sake of illustration, every tooth of the rack to be half an inch; then if the stud is in the middle of the lever-bar Z, the upper end will move one inch for each tooth. The rack has, of course, more teeth than it is ever likely to require for any extent of adjustment, so that by raising the stud, the number of escapements required to cause the conestrap to traverse, may be reduced in any desired degree.*

* The bar Z is a lever of the third kind, in which the fulcrum is at the under end b', the weight to be overcome is at the other end c', and the power or impulse of the arm w, is between them. The motion of that arm is as the size of the teeth of the rack, being one tooth at a time, and it will give more motion to the end c', the nearer the power a' is to the fulcrum or centre of motion b': when applied in

Description of the Tube roving-Frame.

The next machine, in point of importance and mechanical ingenuity, in a cotton-mill, is Danforth's tube-roving frame, which commonly goes by the name of Dyer's, because this gentleman became proprietor of the patent for this invention soon after it was imported from the United States, and has had the merit of bringing it into complete practical operation in the factories of England, and of other countries.

The condensation of the roving delivered by the front rollers is, in this apparatus, elegantly performed by revolving tubes, through which it is made to pass in its way to the bobbins or spools. It is wound upon bobbins which consist of mere wooden tubes, without ends, put upon iron axes, which revolve by the friction of horizontal iron drums or rollers on which the bobbins bear by their own weight, whilst the feeding tube has a traverse movement to distribute the roving along the surface of the bobbin. This traverse movement is progressively shortened, as the diameter of the bobbin is enlarged, in order to generate conical ends, as in the newest bobbin-and-fly frame. The tube-frame contains a drawing-roller beam of the same construction and use as that described in the two preceding machines.

Fig. 60 shows the one end, and fig. 61 the other. In the latter figure, the three pairs of rollers A have been represented in section, and in the other the front one B is shown in an outside view, in order to exhibit their arrangement upon the same roller-beam C, and

the middle of the lever, the range of motion at the end *c'* will, of course, be doubled; if *a'* advance one half-inch, *c'* will describe an arc of one inch.

the same head. With this intent, also, the usual fast and loose pulleys attached to the main-shaft of the frame *a* are merely indicated by dotted lines *b*; the larger pulley *c*, by which the motion is communicated to the revolving tubes, is shown also by dotted lines.

Fig. 62 is a portion of the front view of the machine to explain the working geer, and the manner in which the bobbins are filled.

Fig. 63 is a representation of the essential spinning

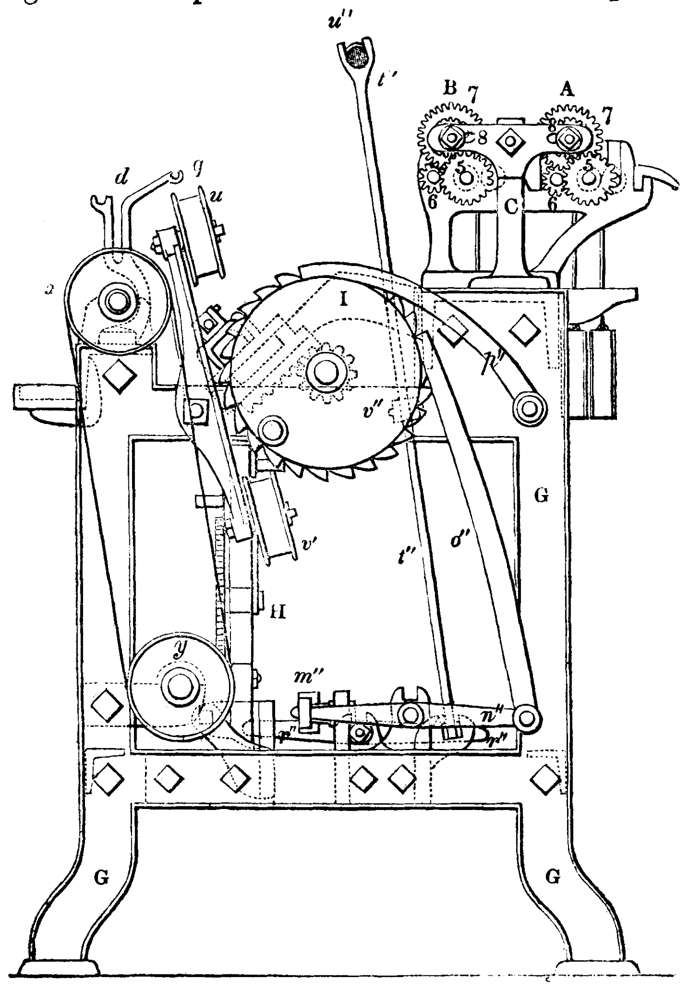


Fig. 60.—Tube Roving Frame. View of the one end. Scale, one inch to the foot.

parts of the machine in a section upon a larger scale; and fig. 64 shows the details of some parts subservient to the traverse motion of the tubes.

A and B are, as above stated, two sets of drawing-rollers, into the first of which the slivers are introduced from the cans stationed behind the machine. The roving, after leaving the front rollers of the first set, enters between the back pair of rollers of the second, both sets revolving with the same speed. It is then delivered by the front roller in slender slubbings, which pass across the frame towards the bobbins, ranged in a line in front, and resting upon a number of grooved cylinders D, D, transfixed by a shaft which extends the whole length of the frame. The flutings are cut upon the cylinders in order to create friction against the cotton-covered barrels of the bobbins. E is one of the bobbins filled with roving, lying in its place, with its axis resting between two slots *d, d,* fixed to an iron beam F, made fast like the roller-beam C, between the frame-work, G, of the machine. *See* fig. 62.

e, e, fig. 61, are several arms screwed fast to the roller-beam C, upon the slanting surface of which the bearings *f* may be shifted up and down by pinions *g, g,* working in the racks *h, h.* In these several bearings, the part *f* is for the purpose of sliding a slender iron frame *i,* which is best seen in section (fig. 63). Upon its surface the bearings *l, l,* are fixed, in which the carriers *k, k,* of the revolving tubes may vibrate, or swing upon an axis, as is shown at one point in fig. 62.

m, m, fig. 63, are the tubes revolving with their ends in bushes or holes of their carriers *k.*

n is a guide plate for conducting the roving after it leaves the tube, in passing through which it gets a transient twist.

o is a catch, made fast to the carrier *k*, to suspend it at a rod of iron, which extends the whole length of the machine, when the bobbins are to be changed, whilst at other times it presses with the plate *n*, upon the roving of the bobbin E, as shown by dotted lines in fig. 63.

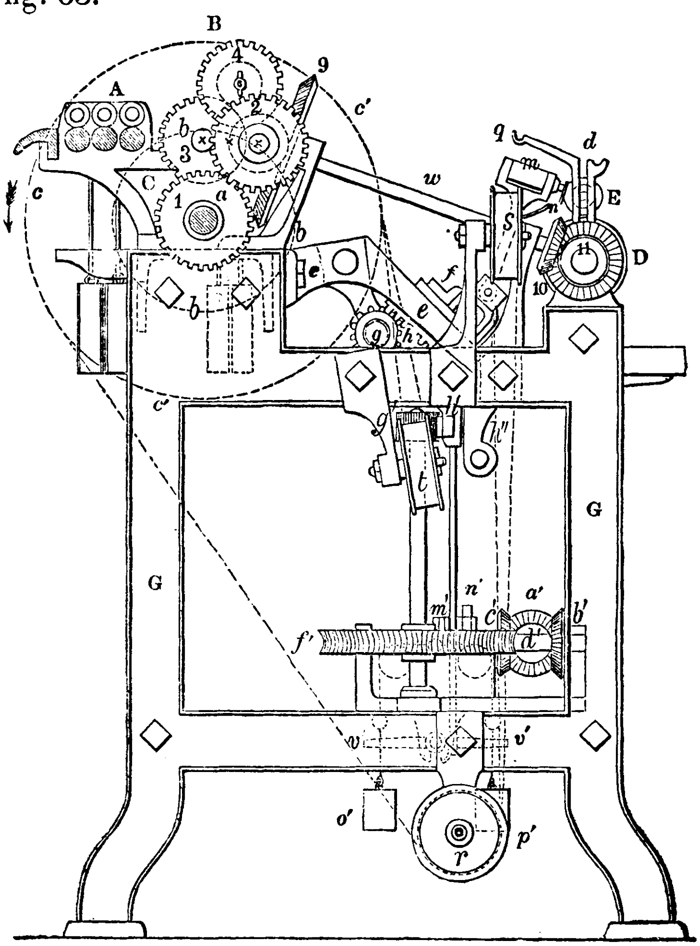


Fig. 61.—Tube-Roving Frame. The other end view. Scale, one inch to the foot.

Whilst the bobbin is filling, the beam *i*, with all the carriers, *k*, *k*, figs. 62, 63, is gradually shifted upwards by the pinions, *g*, working the racks *h*, *h*, of the bearings, *f*, *f*; thus producing, in the same direction, a constant pressure of the delivering ends of the tubes *m*, *m*, against the bobbins E, which being turned by the carrier-rollers D, wind-on the roving as it comes through the hole of the plate *n*. At the same time the beam *i* is sliding or vibrating to and fro, in a line parallel with the ends of the bobbins, so as to distribute the roving properly over their barrels. The extent of this traverse motion is shortened a little at each circuit, in order to form the ends into a conical shape, as with the most improved fly-frame.

When the bobbins are sufficiently filled, the machine is so adjusted as to stop itself, by throwing its driving strap upon the loose pulley. The tube-carriers *k*, *k*, being suspended at the slender rod *p*, the filled bobbins are lifted from the slots *d*, and laid in the notches *q*, for the sake of dispatch, whilst empty bobbins, previously put on their axes, are laid in their places. The same series of operations are once more renewed.

The motions of the tube-roving frame are produced as follows:—

The dotted lines *b*, *b*, (fig. 61) represent, as was said, the steam pulleys in front of that view. The dotted lines *c*, *c*, show another larger pulley upon the same shaft *a*, from which a strap is led over the pulleys *r*, *s*, and *t*, fig. 61, as shown by dotted lines. The strap then passes through the whole length of the machine and over the pulleys *u* and *v* at its other end (see figs. 60 and 62). The strap, in going from the pulley *s* to *u*, passes round the tubes *m*, *m*, in such

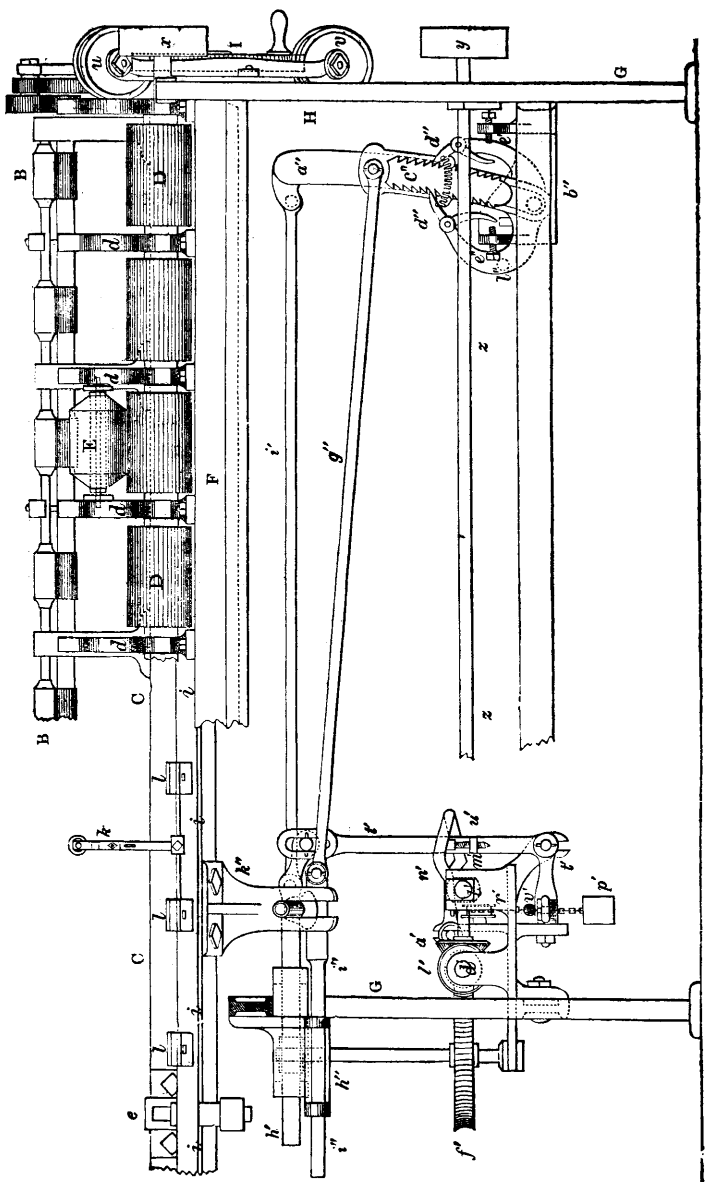


Fig. 62.—Tube-Roving Frame. Front View. Scale one inch to the foot.

a manner as to go in one of the carriers k, fig. 61, over, and in the next under the tubes, which are thus made to revolve by the friction of the strap, without obstructing their traverse motion along with the beam i.

Upon the shaft a is a wheel 1, which drives the front roller of the roller-beam set B by a wheel 2; from that roller, motion is given to the wheel 3 upon the back roller by a small wheel upon the front roller, and two carrier wheels 4. From this back roller, the front roller of the other set A is moved with equal speed by a driving and a carrier wheel (not represented), and which give motion also to the back roller of the set A, in the same manner as explained for the set B. The middle rollers of both sets get their motion at the other end of the frame, fig. 60, by wheels 5 and 6 attached to them and to their respective front rollers, with the aid of two carrier wheels 7 and 8.

Upon the front roller shaft of the set B is a third wheel, a bevel one, behind the wheel 2, fig. 61, which drives the large bevel-wheel 9, and the inclined shaft w, which transmits the motion by two bevel wheels, 10 and 11, to the bobbin roller shaft D.

Upon the other end of this shaft there is a pulley x, whence motion is given by a strap to the pulley y upon the shaft z. This shaft is represented in plan (fig. 64), and works, as there shown, by a bevel wheel a', into either of the two bevel wheels b' and c', giving a motion in a different direction to the shaft d', according as it happens to be shifted into geer with b' or c'. This shifting is effected by moving the bar l' (in which is the and bearing of the shaft z) a little the one way or the other, and keeping it in that position by either of the catches m' or n' falling into notches of the said bar l'. The bar is moved by one of the two weights o' and p', fig. 61, working with a chain over the pulleys, q' and r', upon a pin or stud s' fixed to the frame, whilst the other weight is suspended. *See* also *fig.* 64.

The two chains of the said weights pass through holes in the end of a balance-beam v', over each of

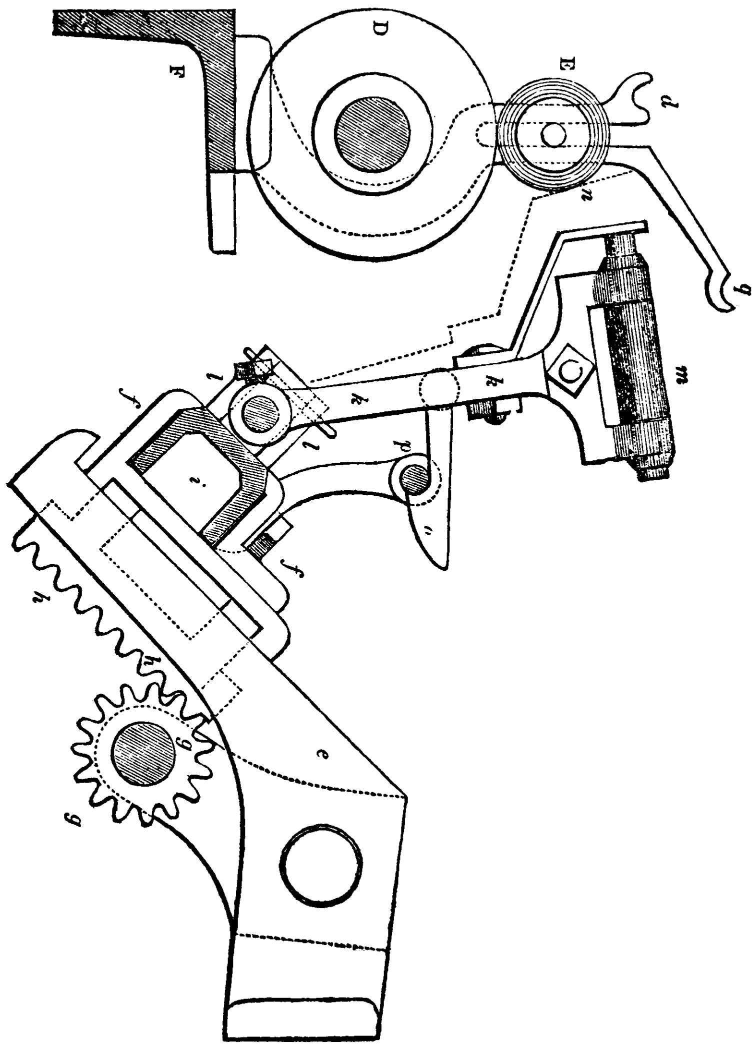


Fig. 63.—Tube-Roving Frame. Working parts in section. Scale three inches to the foot.

which holes there is a little ball upon the chain, against one of which the balance-beam is alternately pressed, in order to suspend that particular weight, whilst one of the catches, m' and n', is lifted from the notch in the bar l', letting the bar be drawn by the other weight in the opposite direction, so as to bring the bevel wheel a' into geer with the other of the two bevel wheels b' and c'.

Upon the shaft d' there is a worm e', which works in a horizontal wheel f', and drives by means of a little pinion g', and a rack h', figs. 61, 62, and 64. This rack is connected by a rod i' with the apparatus H, for shortening the traverse motion of the beam i. The rack h' is moreover connected with the bell-crank lever t', which has at the sides of its upright branch two screws for lifting alternately the catches m' and n', whenever the lever t' arrives at one end of its traverse motion.

In fig. 62 may be seen the shape of the catches which enable them to produce this effect. The other end of the bell-crank lever t', raises or depresses one end of the balance-beam v', at the end of each traverse motion, thus stopping the action of one of the weights o' and p', whilst the other is drawing the bar l', so that the catch, m' or n', which was not previously lifted by the screw w', falls now into its notch, keeping the wheel a' in geer, till the crank-lever t', at the other end of its traverse motion, lifts this catch and suspends the other weight. We can thus perceive how the rod i' is regularly moved to the right hand and to the left, and we have only now to show how this motion is constantly shortened and communicated to the beam i. Fig. 65, a'' is a curved arm swinging round a centre, b'', its other end being attached to the rod i', fig. 62. On the arm a'', a serrated plate, or rack c'', slides downwards during the working of the machine. In the teeth of that rack, on each side, a click works, kept in the teeth by a spiral spring, which connects both clicks, d'', d''. When the arm a'', drawn by the rod i', has reached the end of its traverse motion, it presses one of the clicks, d'', d'', against the point of one of the set screws e'', e'', which pushes the click out of

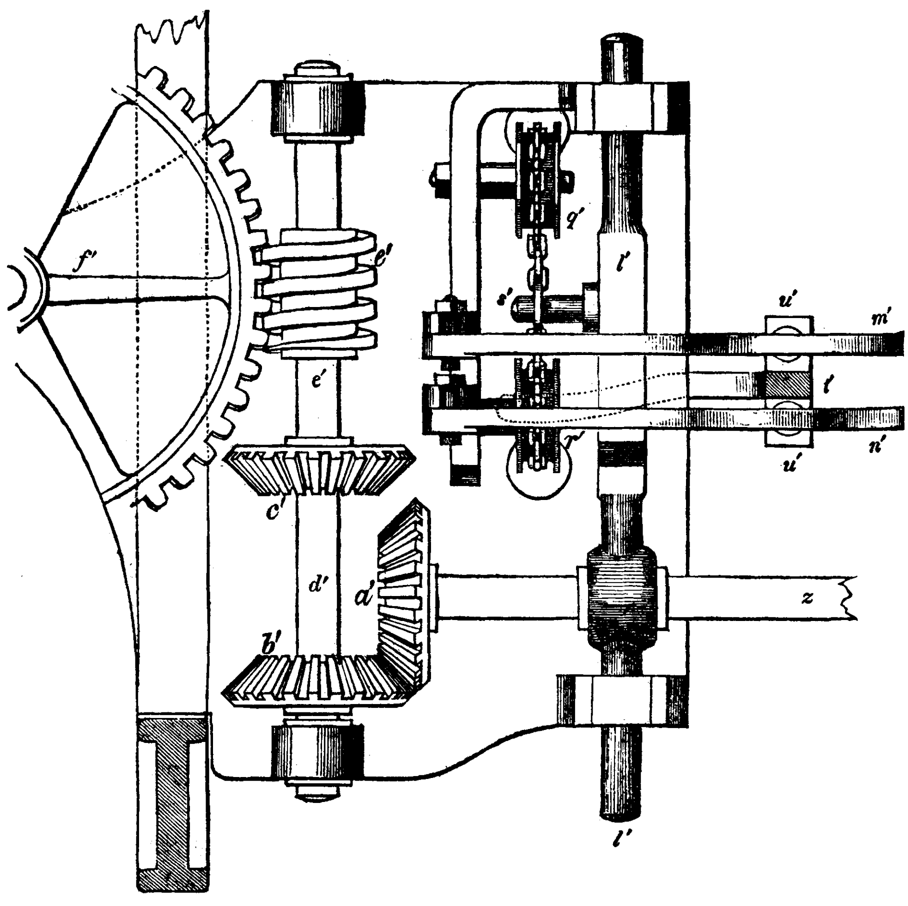


Fig. 64.—Tube-Roving-Frame. Details of the Traverse Motion, shown in plan. Scale, three inches to the foot.

the tooth of the sliding-piece, c'', thus permitting it to fall through the depth of half a tooth, the other click d'' immediately catching it. Whilst, therefore, the point l'' approaches continually to the swinging joint b'', the traverse motion given from that point l'', by a rod g'', to the beam i, must become shorter; the arm a'' swinging through equal spaces. The teeth are cut at alternate intervals on either side of the sliding rack c'', so that the motion at each time is limited to half a tooth. h'' is a staple-guide screwed to one of the middle frames, G$'$, of the machine, to conduct a rod i'', connected with the rod g', and which is joined (fig. 62,) to a slot arm k'', fixed to the beam i, on which the tube carriers stand, as previously described. At each traverse of the rack-guide a'', a pin l'', figs. 62 and 76, projecting from the curved piece near the bottom of the said rack-guide, strikes against a lever m'', seen with its end in fig. 60, and by moving the lever n'', moves the ratchet wheel I, fixed upon the same shaft with the pinion g, through one tooth by means of the click o'', whilst another click p'' prevents the ratchet wheel from running back in consequence of the weight of the beam i'', which gradually rises as the bobbins grow larger. When the rack c'' has descended to its lowest point, a projection q'' comes to press upon the end of a lever m'', which at its other end disengages a catch seen in dotted lines s'' (figs. 60 and 65), and which makes the upright lever t'' move the horizontal rod u'' (which extends the whole length of the machine) bearing upon its other end the fork for throwing the strap from the fixed to the loose pulley. The lever t'' is acted upon by a slight weight which tends to move it round upon its fulcrum r'', and to push the rod u''

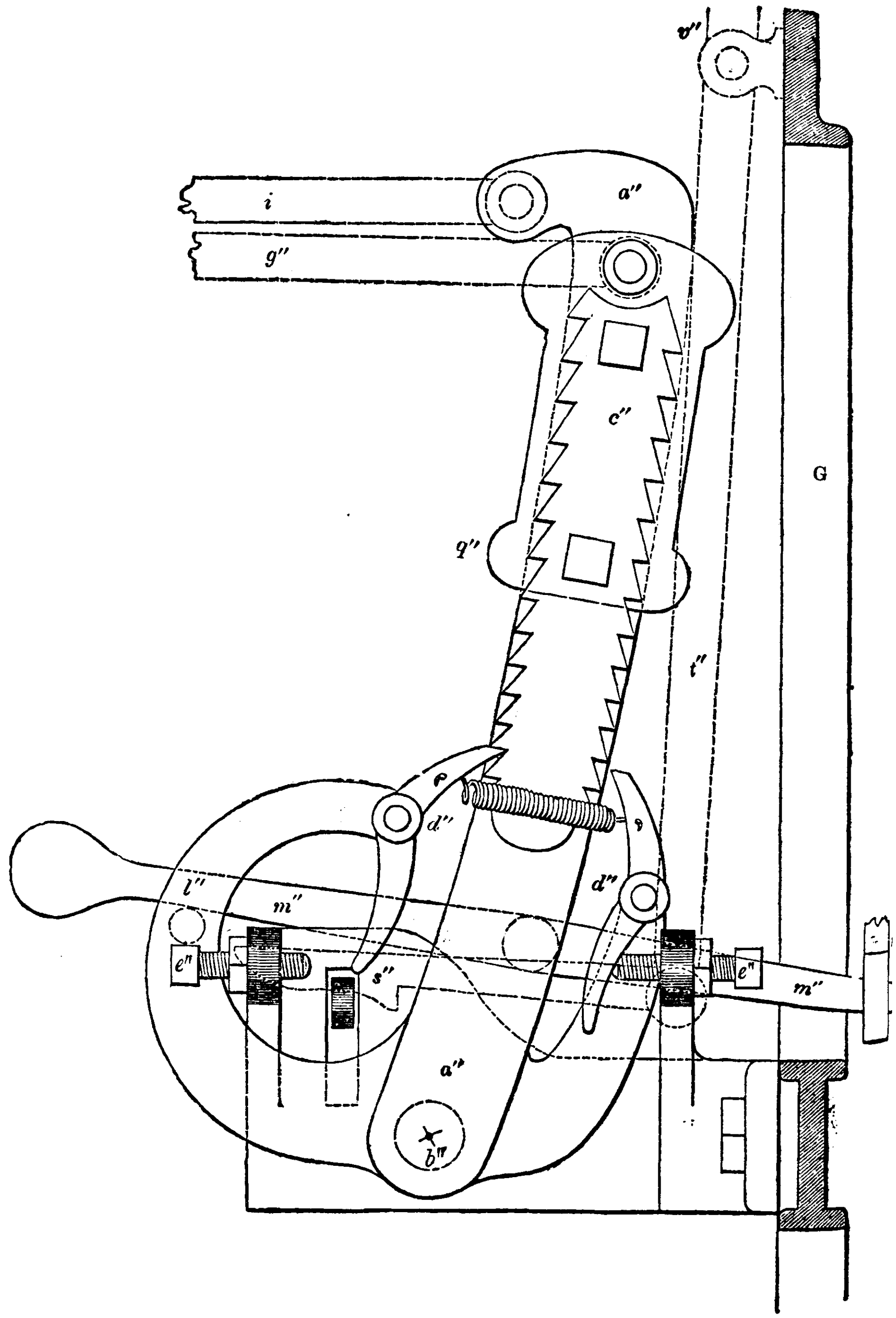


Fig. 65.—Tube-Roving Frame. Details of the Traverse Motion of the Tubes
Scale, three inches to the foot.

horizontally. This rod serves also to enable the attendant to throw the machine in or out of geer, at whatever end he may happen to be, by seizing it in his hand, and sliding it along.

The tube-roving frame is a most expeditious machine, and is employed with great advantage in many coarse spinning-mills for numbers under 30's.; but it is still a subject of considerable debate between respectable spinners whether it can be profitably employed for preparing the rovings of finer yarns.

Its front rollers move from three to four times faster than those of the bobbin-and-fly frame; hence 16 tubes of the former frame will turn off quite as much slab as 60 spindles of the latter, and are reckoned equivalent to them in their first cost, bulk, and power of working.

At one cotton mill in Manchester where the tube-frame is a favourite with the manager, each bobbin or spool takes on two hanks, weighing from six to seven ounces, in obedience to the pressure plan. The roving has five hanks to the pound, which is pretty fine. At this establishment the front rollers turn 450 times in the minute; in another which I visited, 470 times.

A skilful cotton spinner assured me that in his hands he found the tube-machine liable to many accidents, for if a particle of dirt or seed remains in the cotton after the carding and drawing, it will prevent the delivery of the roving upon the bobbin in the untwisted state peculiar to this machine, and will leave points of torsion which create incorrigible defects in the yarn spun from it; hence, said he, it cannot be used for fustian yarns, which must be very level. It is very suitable, however, he added, for a factory of low-priced calicoes. The capricious nature of cotton-spinning is shown by nothing more strikingly than by the fact of this gentleman having tried in vain to work rovings for 20's. with the tube-frame, though his brother and partner, with similar cotton, similarly treated, succeeded perfectly well in producing good yarns of that count by means of this roving frame.

Another manufacturer, who has a high character for skill in spinning, assured me that yarns spun with the aid of the tube frame were too unequal for weaving into cloth for good calico-printing. There can be no doubt, however, from what I saw in many well-conducted mills, that under proper management the tube roving frame is a very excellent and profitable machine.

The first patent for this apparatus was obtained in this country by Joseph Cheeseborough Dyer, Esq., of Manchester, in July, 1825, as an invention communicated to him by a foreigner residing abroad. The following extract from his specification will serve to complete our account of this interesting machine:—

By the rapid rotation of the spindles (tubes), the rovings are twisted from the spindles backwards as far as the delivering drawing-rollers, which twisting is for the purpose of giving strength to the rovings, that is, tenacity to the fibres of the cotton, but as soon as the rovings have passed the eccentric part of the tube, the twist will be immediately discharged, and the rovings wound upon the spools or bobbins in an untwisted state.

The rotation of the drawing rollers which deliver the rovings being uniform, it is necessary to regulate the speed of the taking up or winding of the rovings on to the bobbins or spools, according to their increased diameters. This regulation of the speed, the machine effects without assistance, the bobbins being turned by the friction of contact between their surfaces and those of the carrier cylinders, by which it will be perceived that however much the diameter of the bobbin may increase by the repeated thicknesses of roving wound upon it, only a given extent of its surface will be carried round at every revolution of the carrier-cylinder, and hence the quantity of roving taken up in any given space of time, will be uniform throughout the winding.

Mr. Dyer has made many important improvements upon his machine since the above date, for which he has likewise obtained patents. The engravings here given are taken from drawings most carefully executed under my inspection from a machine newly constructed, and in the very act of being set to work, in a mill at Manchester.

The rovings of the tube-frame are entirely destitute of twist, the twist communicated by the rotation of the tubes being only momentary, for the purpose of giving cohesion to the filaments in their way to be wound upon the bobbins. As the sliver is pinched at the one end between the delivering rollers, and at the other by the nozzle of the tube pressing upon the bobbins, it is obvious that the middle portion of it can receive no permanent twist; what it receives *in transitu* is undone in the act of winding-on.

CHAP. IV.

Finishing Processes of a Cotton-Mill.

SECTION I.—Stretching Mule.

AFTER passing the cotton through one or two bobbin-and-fly frames, or the tube frame, according to the quality of yarn intended to be produced, the rovings are pieced up to the mule or throstle, and spun into yarn. In the finer branches of the trade, however, there is an intermediate process called stretching, in which the rovings are made finer or more attenuated than can be done advantageously on the bobbin-and-fly frames. The machine employed for this purpose is called a stretching frame, and differs essentially from the bobbin-and-fly frame in the mode of twisting and winding on. In the latter, the roving is made and wound up simultaneously, but in the stretching-frame a length of roving is first spun, generally fifty-four inches long, and then the motions of the rollers and spindles are suspended while the winding-up is effected. The stretching-frame is, in fact, a mule-jenny, without the second draught and second speed. The action of the machine may be briefly described as follows—reserving the complete description of the mule for Section III. The bobbins filled at the previous operation being placed upon skewers in the creel, the loose ends of the rovings are introduced between the top and bottom back roller, and are passed forward through the other two rollers, so as to be delivered in front in an elongated and consequently attenuated state, proportional to the draught—that is, to the relative speed of the back and front rollers. The ends of the rovings, being thus elongated, are severally attached to a spindle fixed in the carriage. When the machine starts, the roving is given out by the front rollers, and the carriage is made to recede from them at a speed equal to the rate at which the roving is given out, by which means the roving, as it issues from the front rollers, is kept extended between the spindles and rollers. While the carriage is coming out, the rovings are twisted by the revolution of the spindles, and when it has advanced about fifty-four inches, it stops, as well as the rollers. The twist is produced without the aid of the flyer (of the fly-frame) by the rovings being coiled diagonally up to the point of the spindle, where, from the inclined position of the latter towards the rollers, the one end of the roving remains during the revolution of the spindle, and twists with its twirling. When the carriage stops, the spindle stops also. It is then the business of the attendant to wind up the fifty-four inches of roving thus made, which she does by depressing the faller wire with her left hand, so as to bring the rovings at right angles to their respective spindles. She then turns the spindles round by means of the handle, with her right hand, while she pushes the carriage in towards the roller beam at the exact velocity with which the thread is to be wound up —a task of great delicacy, owing to the very soft state of the fine slab. As the carriage gets near the roller-beam, she slowly raises the faller wire during the last turn of the spindle, and then the roving, from the relative position of the spindle and roller, again coils itself diagonally up to the point of the spindle, ready to recommence the twisting of another length of elongated roving. This immediately takes place by the simultaneous movement of the rollers, the spindle, and the carriage, as above described. The roving is wound on to the spindle in an ovoid cop, somewhat truncated at the base, and tapering at the top. When the cop has become of sufficient size, it is slid off the spindle, and is then ready to be skewered and placed in the creel of the spinning machine.

Certain manufacturers in Lancashire employ the stretching-mule with extraordinary advantage. They use for roving only the coarse bobbin-and-fly frame; after which, they subject these rovings to the stretching-mule, whereby they complete their preparation for No. 40's. With this yarn they make an excellent power-loom cloth, of an equally good appearance with that of their neighbours, though they put into the piece of 24 or 28 yards long four ounces less weight of cotton wool.

The produce of the stretching-mule or frame is a very soft roving, which must be very tenderly handled, for fear of injuring the yarn to be spun from it. By means of this frame, rovings may be equalized, and thereby certain errors of the previous machines corrected. The sets of roving turned off at regular periods by the stretcher being weighed will, in a great measure, show any variation in the grist of the cotton, and enable it to be modified by changing the pinions of the drawing-rollers. Rovings are also equalized by means of the doubling which they frequently receive at the stretching-mule; and as they are here built into a narrow conical cop, they take less room in the creel of a fine spinning mule than the bobbins of the fly-frame.

We have already stated that the rovings, whether produced upon bobbins by the bobbin-and-fly-frame, or by Dyer's frame, or in the form of a roving-cop by the stretcher-frame, are spun into yarn on throstles or mules—two machines, which differ in the mode of winding on, exactly as the bobbin-and-fly differs from the stretching frame. The mule makes a definite length of yarn, after which it winds it up, while the operation of spinning is suspended, whereas the throstle makes the yarn and winds it up simultaneously. The mule is used generally for all numbers above 30's, throstles being now seldom used to spin so high as 40's. The quality of the yarn produced by the two machines is quite different. The throstle yarn, known under the name of water twist, from having been first produced by the machine called a *water frame*, is smooth and wiry, while the mule yarn is of a soft and downy nature. The former is usually employed for warps in heavy goods, such as fustians, cords, or for making sewing-thread, and the latter for the weft in coarse goods—as also for both warp and weft in finer fabrics. We shall first describe the throstle, which, upon the principle of Arkwright's water frame, was coincident with the use of twin rollers. The old water frame differed from the throstle, in having subdivisions in each machine, whereby one or two lengths of rollers and their corresponding spindles might be stopped or set in motion independently of the other rollers and spindles in the same machine. In the infancy of the trade, when the number of threads which broke in the process of spinning was considerable, such a convenience was desirable; but now, since practice has perfected the manufacture, it is no longer necessary, and we see throstles with two hundred spindles and upwards, spinning for days without needing to be stopped, except for the purpose of removing the full bobbins, and putting empty ones in their places.

SECTION II.

Water-twist and Throstle-spinning.

The water-twist frame has been already described at sufficient length in the preceding volume, at page 260. It has been superseded in modern mills by the apparatus called a throstle.

The THROSTLE is a machine so simple in its construction, and seemingly so perfectly adapted to its purpose, that for many years after its introduction few persons thought of altering or improving it in any respect till about the year 1829, an invention appeared in the United States of a very singular kind. Mr. Danforth was its author, and it bears his name in the factories, though the patent was obtained in this country by John Hutchison, Esq., of Liverpool, "for certain improvements in machinery for spinning cotton, woollen, &c., as having been communicated to him by a foreigner residing abroad." The flyer, which had been hitherto deemed an essential of the water-twist system, was in Danforth's contrivance entirely laid aside. This machine, which will be afterwards described, possesses undoubtedly certain advantages over the ordinary throstle, and in particular is calculated to produce a quality of yarn less wiry than common water-twist, and well adapted, as experience has shown, for economizing cotton in the weaving of certain styles of goods. The invention has been not more remarkable for its own success, than for the excitement it has occasioned among schemers, and the number of new throstle devices to which it has given rise. Yet no new principle of spinning has been struck out; so that the original throstle is not superseded to any considerable extent. The only advantage of the new modifications is to permit the spindles to be whirled at a greater velocity, and thereby to turn off more work from a machine of the same size; but this advantage has been in some measure counterbalanced by the increased wear of the machinery and waste of the cotton.

Before proceeding to the description of the *Throstle*, I may remind the reader, that in the preparatory machine—the bobbin-and-fly frame, the quantity of twist given to the roving should not be more than is merely sufficient to enable the rovings to unwind, without impairing their uniformity, from the bobbins upon which they were coiled; for if they be more twisted, the rovings would resist the drawing or elongating action of the fluted rollers in the subsequent processes. When eventually the substance of the roving is being extended to its utmost length, in the finishing spinning machines, it becomes necessary to increase the torsion to such a degree as to implicate the filaments so firmly together that they will resist any effort to separate them from each other. Different staples of cotton wool, and different qualities and finenesses of cotton yarn require different quantities of twist, but all well-made yarn should receive a degree of torsion sufficient to bind the fibres so intimately, that the thread will rather break across than draw out into downy ends.

In the water twist spinning-frame used by Arkwright, each head had only four or six spindles, and it could be stopped or moved by itself; but in the throstle, the drawing-rollers, instead of being mounted in fours or sixes upon independent heads, are all coupled together in one range upon each side of the frame; and the spindles of both sides are driven in common by means of bands from the long horizontal tin cylinder, which extends the whole length of the machine. The throstle consists of fewer parts, is simpler in its movements, has less friction—takes therefore, less power to drive it, and is not so costly at first as the former water-frame. It must be allowed, however, that Arkwright brought the construction and performance of his machines to a state of great practical excellence, for they turned out No. 80's, excellent yarns for warp, hosiery, and sewing-thread; and that he left little to be done in this department of spinning in comparison of what he himself accomplished. Manufacturers of cotton twist hesitated many years between the water-frame and the throstle, and though they prefer the latter in new erections, they still obtain good results from the former in well-conducted establishments like those of Cromford and Belper.

The object of the throstle is to extend the rovings into slender threads, at the same time that it twists them by the rotation of spindles or flyers, and winds upon bobbins somewhat resembling what has already been described under the bobbin-and-fly frame, but with far simpler mechanism, on account of the cohesive strength of the hard-twisted throstle thread. It consists of two roller-beams, each provided with the usual threefold set of drawing-rollers, which are mounted upon each side of the frame. These rollers are supplied with rovings from bobbins placed upright upon skewers, fixed in shelves in the middle of the frame, which are called *creels* by the workmen. There are seldom fewer than 72 spindles in a line upon each side of the throstle, which are set from 2½ to 3 inches apart. There are, as we have already said, several modifications of the throstle, but they all consist in the form and operation of the spindle, or twisting and winding on mechanism. The oldest and most ordinary spindle is a vertical steel rod, upon whose tapering top the fly or flyer is fixed by a left-handed screw. This fly is a fork of iron or steel, having its tapering points hooked up into little eyes, to serve as guides for conducting the yarn to the bobbin revolving round the spindle-axis in the middle between them. Immediately above the top of the spindle is an eyelet of wire, which serves, like the funnel of the flyer in the fly-frame, as a guide to the thread, which is led once or twice round the arm of the fly, and then passed through one of its hooked extremities. The winding of the yarn upon the bobbin is in consequence of the friction by the bottom disc-plate of the latter upon the copping-rail, which retards its rotation, and makes it be dragged round by the yarn delivered out by the revolving fly; meanwhile the bobbins are moved slowly up and down with the regular ascent and descent of the copping-rail, whereby they receive the yarn evenly distributed along the surface of their barrels.

Fig. 66 is an end view of a common throstle of the best construction, where the manner of communicating the various movements of the mechanism is shown.

Fig. 67 is a view of a portion of the front of a throstle-frame.

Fig. 68 is a section of all the spinning parts for a single thread, drawn upon a scale double the size of the others.

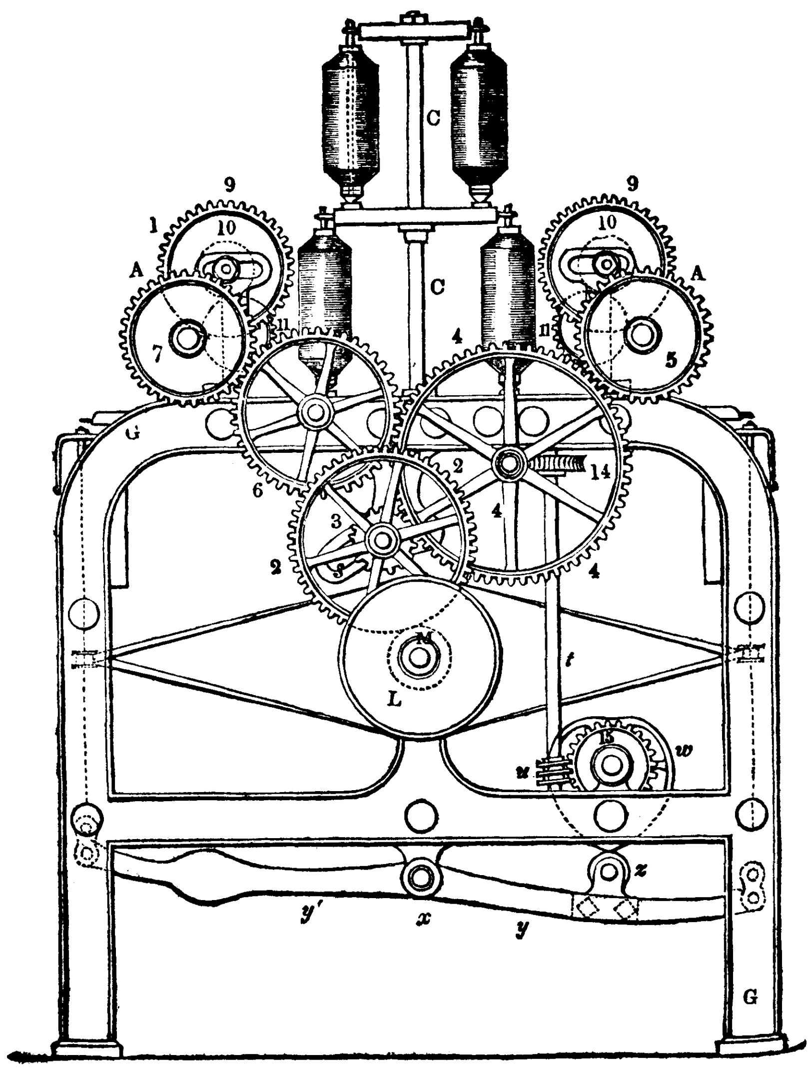


Fig.66.—End View of the Common Throstle. Scale, one inch to the foot.

A and A are the two sets of drawing rollers. These rollers rest upon upright bearings *a, a,* called heads, made fast to the roller-beam B, each head comprehending the fluted portions for six or eight several threads. The two back pairs of fluted rollers are susceptible of being shifted with their bearings *a, a* a little further from or nearer to the front pair, as already explained at sufficient length in describing the drawing-frame. This mechanism of adjustment is shown in fig. 68, which is the common one adopted in throstle-frames. Each of the top rollers, covered as usual with leather, corresponds in length to two fluted portions of the under rollers, and lies with its axis in slots of the top bearings *b;* the middle neck being covered with brasses, which sometimes carry two suspended weights, as in the drawing-frame. In the present figure, the pressure is seen to be produced upon the three corresponding top rollers by one weight C, working lever-wise round its fulcrum *d,* so as to pull down the wire *e.* This wire presses upon a *brass f,* which rests with the one of its ends upon the axis of the front roller, and with the other end upon the middle of the *brass* which covers the two axes of the two back rollers. Behind the back roller the guide bar *g* is seen sliding horizontally in slots, cast upon the heads *a,* which carry the rollers; upon this bar are wire hooks, through which the roving passes to the rollers. This bar gets a very slow traverse (or to and fro motion to the right and left alternately), by the instrumentality of a slender rod *h,* from an eccentric pin *i,* stuck in the axis of the little wheel *k,* and moved by a worm (endless screw) *l,* attached to the end of the back-roller shaft, as shown in a plan of the end of the rollers, fig. 69. The purpose of this mechanism is to cause each thread to traverse a little way along the fluted surface, so as to change the points through which it is drawn, and thereby prevent the leather of each top roller from being channelled or

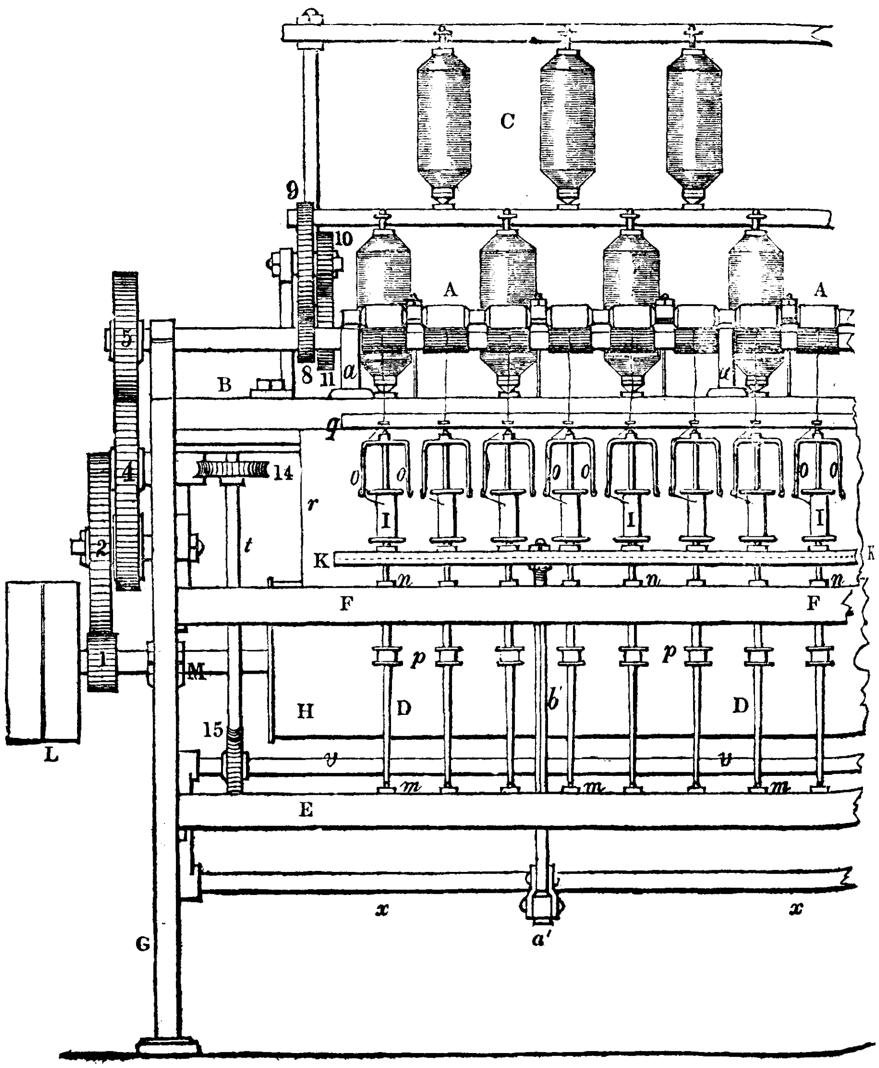


Fig. 67.—Throstle. Front View. Scale, one inch to the foot.

furrowed in one place, which it would be if the thread passed over it invariably in one direction.

C is the creel stocked with bobbins of roving set nearly upright upon skewer wires, in a double row; one for each side of the machine, and in alternate order, as shown in fig. 67.

D, D represent the spindles revolving upon their under ends in the brass steps *m*, *m*, made fast to the iron beam E; while the middle part revolves in the bushes *n*, *n*, made fast to the beam F, as clearly indicated in fig. 68. These two beams extend over the whole length of the throstle, and, as well as the roller-beam, are made fast to the strong frame-work G. In long throstle machines there are sometimes one or more transverse frames at intermediate distances to sustain these beams, and bind the whole more solidly together. *o*, *o* are the flys screwed upon the tops of the spindles; *p*, *p* are the wharves, whorls, or whirls fixed to the spindles, which serve as pulleys to turn them round by the motion of endless cords, bands, or straps proceeding from the long tin-plate drum or cylinder L, which extends through the length of the machine, and actuates the spindle movements upon both sides of the throstle, as shown in the middle of fig. 66.

q, fig. 68, is a wooden bar, to which wire hooks are fixed, to serve as guides to the threads in their way from the front pair of drawing rollers to the spindle-flys; *r* is an upright board at the back of the spindles, which screens them from dust and wind; I, I are the bobbins, consisting of a wooden tube or barrel, with two disc ends, the under end resting upon the copping-rail K. This rail has a series of holes in it for the spindles to pass through. By its ascent and descent, it carries up and down the bobbins, causing them to traverse along the central spindles, and to get equably covered with yarn till they are filled.

The preceding actions and movements are produced as follows: upon the shaft of the tin-plate drum M are the usual fast and loose pulleys L (often called outriggers, from standing out from the frames or steam-pulleys, on account of their immediate connexion with the steam-driven shafts). These pulleys are moved by an endless strap from the mill shaft, *see* Chap. I., Book II., plate II. Upon M the main shaft of the throstle, fig. 67, close to L (outside of the cross end-frame), is a pinion 1 (indicated by dotted lines at M, fig. 66,) which drives the wheel 2; upon the axis of which wheel another pinion 3 is made fast to drive the wheel 4. The last wheel drives wheel 5 of the roller set A, and by means of the carrier (intermediate) wheel 6, fig. 66, the wheel 7 also upon the front roller axis of the set A′. The motion thus received is imparted by the front rollers to their respective back rollers, by means of a pinion 8, which drives a carrier wheel 9, and another carrier wheel upon the same axis drives the wheel 11 upon the back roller shaft. From the back rollers motion is given to the middle rollers upon the other end of the machine, by wheels 12 and 13, attached to their ends, and in gear with a carrier wheel, as seen in fig. 69. When it is desired to change the twist of the yarn, the carrier wheel 2, with its pinion 3, is unscrewed, and a smaller or larger pinion is put on instead of it, and adjusted in its place, so as to be in gear with wheel 4, for which purpose the slot *s* is provided in the plane of 2, which is arched concentric with the shaft M. Thus the wheel 2 remains in gear with the pinion 1, at whatever point of the slot it may be fixed. The up and down motion of

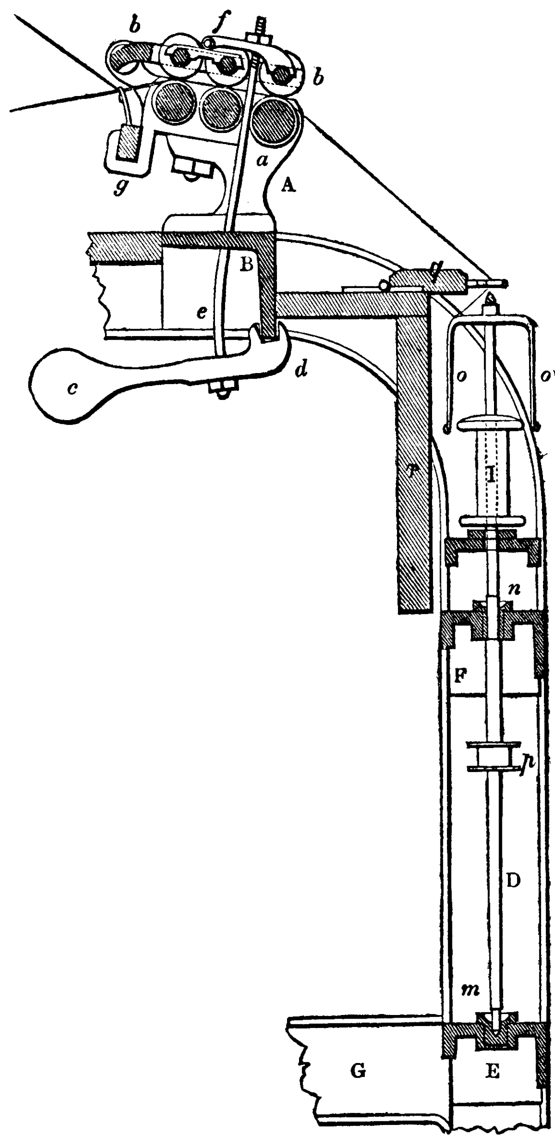


Fig. 68.—Throstle. Section of Spinning Parts. Scale, two inches to the foot.

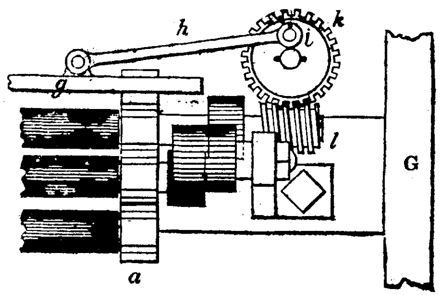


Fig. 69.—Throstle. Mechanism for traversing the Guide-bar.
Scale, two inches to the foot.

the copping-rail K is produced as follows: On the end of the axis of the wheel 4 is a worm, which drives, by the horizontal wheel 14, the upright shaft *t*, at the under end of which there is another worm *u*, driving the wheel 15, fixed upon a shaft *v*, which runs to the middle frame of the machine, where it has fixed to it a heart-wheel *w*, seen in fig. 66: *x* is a shaft running the whole length of the machine, to which are attached, at several points opposite, arms *y* and *y'*, which are connected with links *a'*, and upright rods *b'*, passing through the beams E and F, to the copping-rail K. Thus by turning the shaft *x* a little the one way or the other, one copping-rail is raised and the other is depressed. The middle arm *y* has a roller *z* attached to its top, which is alternately pressed down or suffered to rise by the revolution of the eccentric or heart wheel *w*, while the roller is kept in contact with it by the heavier arms *y'* acting as counter weights.

Upon the upper surface of the rollers (as between *b* and *f*, fig. 68,) in the line A, A, fig. 67, a travelling cone is laid in many factories for the purpose of cleaning the top rollers, or taking off from them any loose filaments of cotton. This cone is made of wood covered with flannel, and is about one foot long, with a base four inches in diameter. It is laid loosely on the rollers, and travels by friction from one end of the roller-beam to the other, in the direction of its summit or taper end, in the course of 1,000 seconds, or about 17 minutes; if the path be 20 feet long, it will move, therefore through one foot in about 50 seconds. It is a very elegant automatic mode of wiping the top rollers, and of thus keeping the whole in good condition. The cone, after completing a journey, is removed, and a clean one substituted for it. The back top roller of the throstle-frame is of iron, large and heavy. It is called a pressing-roller, of which there are 32 in a line of 144 spindles. The cone rests against it.

In a well-mounted factory, such as Mr. Orrell's or Mr. Bailey's, there are lanes of three or four feet between the adjoining throstle-frames, so that the tenters (young women of 17 and upwards), who manage 288 spindles at least, may move about at their ease.

The quantity turned off is about 24 hanks per spindle of 30's twist in 69 hours. The bobbin of compressed roving, laid on with the spring presser already described, will last on the throstle-frame from four to five days. In some factories, with new throstle-frames, fully 30 hanks of 34's or 36's may be turned off.

In spinning 32's, the front rollers of the common throstle make 64 revolutions per minute, and the spindles 4,500. For the spinning of lower numbers, the rollers go quicker; thus, from 28's to 30's, they make from 68 to 70 revolutions. The front roller in the tube roving-frame turns about one-tenth as fast as the spindles above mentioned. In Mr. Orrell's, for 36's, the front rollers make 72 revolutions per minute, and the spindles 4,000.

In the construction of throstle-frames, the less the distance between the front roller and the spindles, the more regularly is each portion of the yarn twisted. When the distance between *b* and *a*, fig 68, is considerable, the thinner parts of the thread become too hard twisted, and the thicker parts receive scarcely any torsion.

Throstle-yarn, for calicoes, is worth 1*s*. 4*d*. the pound, when mule-twist, spun from the same cotton-wool, sells for 1*s*. 3*d*. The greater part of the throstle-twist manufactured in this country is exported.

The common throstle spins the best yarn for the warp of velveteens; the Danforth throstle-yarn is not wiry and smooth enough on the surface for this purpose. The two do not work well together for warp in the same web, because the common throstle-yarn, being the less elastic, is apt to be snapped asunder, while the other gives way a little and remains unbroken.

Throstle spinning costs 1¼*d*. per pound in workwoman's wages.

The average price of a good throstle machine, at Manchester, is 9*s*. 6*d*. per spindle.

At Hyde, where excellent throstle-yarn is spun, 3½ hanks of 36's are the average daily quantity per spindle, or about 21 hanks in 69 hours.

I visited a great factory at Stockport, where the throstle-spindles revolved 5,000 times in the minute;

and the front rollers 90 times, in spinning 36's. These machines were constructed by Mr. Gore, of Manchester. I was informed that Mr. Axton, of Stockport, had contrived a modification of the throstle-spindle, in consequence of which he could give the front rollers a speed of 80 turns in the minute, and the spindles 7,000 turns, in spinning 24's.

The winding-on of the thread in the common throstle is effected upon the following principles: the bobbin is dragged round by the thread, and thus compelled to follow the motion of the flyer and spindle. The thread being firmly pinched by the front pair of rollers at one point, while it is rapidly whirled by the flyer at another, is exposed to continual extension, and is, at the same time, twisted. Putting the tension out of view for a moment, let us consider a certain elongation of the thread, one inch for example, by the action of the drawing-rollers. The weight of the bobbins, and their friction upon the copping-rail, which may be modified at pleasure by putting a bit of leather under their bottom discs, will, upon this supposition, be the cause of the bobbins remaining for that space behind the flyer in a state of rest, till that portion of thread, by the whirling of the flyer, has got wound up, and the former tension is once more renewed. The delivery of the thread from the drawing-roller does not take place, however, by fits, or inch by inch, but unceasingly, at a continuous rate; and hence arises a continuous retrogradation of the bobbins relatively to the spindles, which is such, that the thread given out during the revolution is in the same time wound on. This procedure in the spinning is essentially the same with what has been fully explained in describing the operation of the bobbin-and-fly frame, but it is here simplified, as the retrogradation regulates itself according to the diameter of the bobbin, by means of the tension or drag of the thread. In the fly-frame this dragging action is impossible, on account of the loosely cohesive state of the rovings; and therefore it becomes requisite there to provide the bobbins with an independent mechanism for turning them round.

Nor is the up and down motion of the bobbins upon their central spindles, which is necessary for the equable distribution of the yarn, and which should be nearly of the same extent as the length of the bobbins, effected by the same complex mechanism as in the fly-frame. Strictly considered, this traverse motion should go more slowly in proportion as the bobbins get fuller, as is done in the bobbin-and-fly frame; but on account of the firmness of the throstle-yarn, this variation in the speed of the copping-rail, which would make the machine very complicated, may be neglected without inconvenience. The only consequence is, that the coils of the yarn become progressively more sparse upon the bobbin, as its surface is enlarged.

The chief interruption which occurs in throstle-spinning, takes place during the removal of the full bobbins, and the substitution of empty ones. This task is called *doffing*, and may be estimated to occasion a loss of about half an hour a-day with the common throstle, and three-quarters of an hour with the Danforth, but much depends upon the dexterity of the *doffer*.

The Danforth, or American Throstle.—(Hutchison's Patent.)

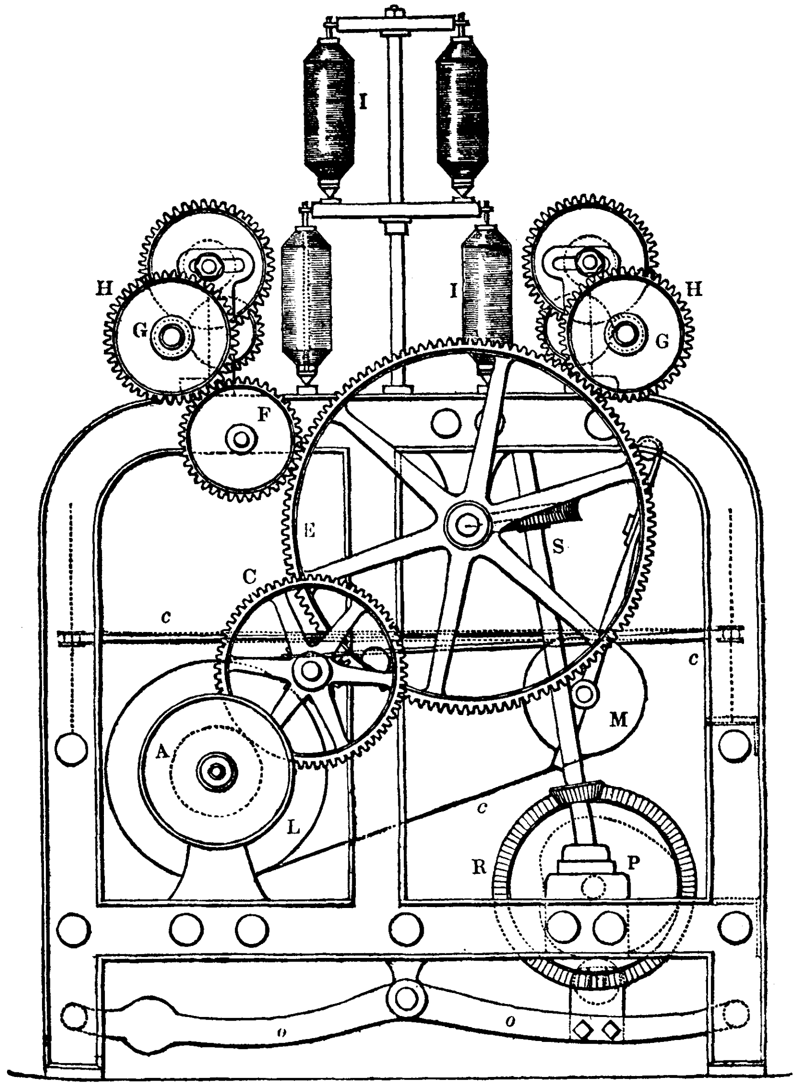


Fig. 70.—Lateral View of the American or Danforth Throstle. Scale, one inch to the foot.

Fig. 71 is part of the front view.

Fig. 72 represents a cross section of one side of the machine displaying the process of spinning.

Fig. 73 is a particular modification of the spindle of this machine, as used for preparing cops for the shuttle, similar to those formed by the mule.

A is the usual fixed and loose pulley, by which the mill-power motion is given to the machine, and is abstracted at pleasure. It makes about 480 revolutions per minute. B is a pinion which drives the wheel C; and a pinion D, on the same shaft with the latter, gives motion to the wheels G, G, by means of the intermediate wheels E and F. The wheels G, G, are connected with two sets of drawing-rollers H, H, on either side of the machine. These drawing-rollers are arranged here as in the other machines for cotton spinning; the bottom ones are of iron and fluted, and the top rollers, being covered with cloth and leather, are pressed upon the former by weights K, fig. 72.

The fluted rollers are put in motion by wheels, and travel with different velocities; the front rollers making about 120 revolutions per minute, (according to the quantity of twist the yarn is to have,) the middle about 17·20, and the back rollers 12·16 revolutions, their speed being regulated by change wheels, according to the quality of the yarn. It may be easily perceived that the roving I, being introduced between those rollers, will be stretched there, and drawn to a thinner thread by the time it leaves the front rollers. This is the first operation of this spinning machine.

The next thing to be done is the twisting. *See* figs. 71, 72.

a is a spindle, fixed in the bar *m*, by a screw; *b* is a small pulley, with a tube connected to it, turning freely round the spindle *a*.

This pulley is put in motion by an endless band *c*, from the drum L, which band passes first round two spindles on one side of the machine, then round two on the other side, and, lastly, over the tightening pulley M, back to the drum. By these means four pulleys *b*, are turned, and four threads twisted by the same band. Upon the pulley *b*, and over the said

Fig. 2.

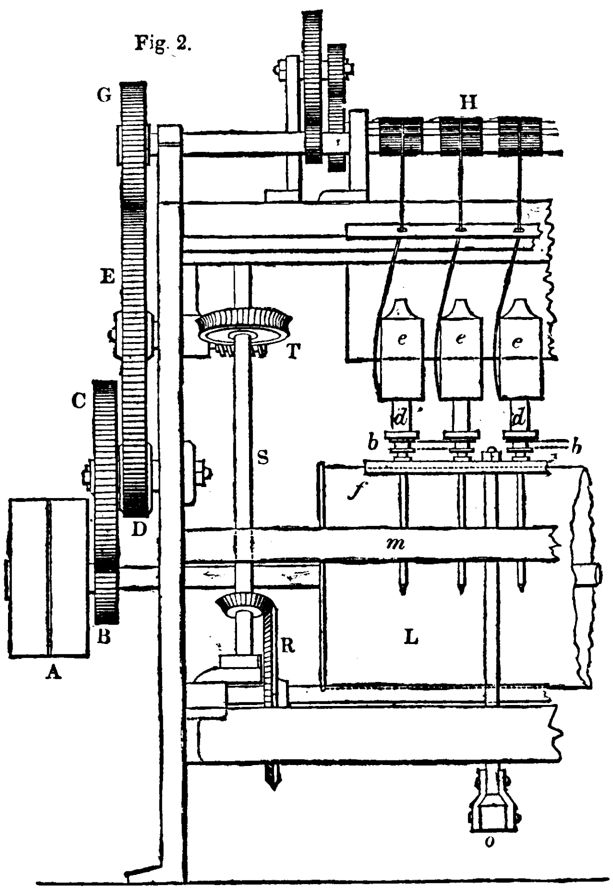


Fig. 71.—Danforth Throstle. Front View. Scale, one inch to the foot.

tube, is put the bobbin, on which the thread is to be wound after it has been twisted by the revolving pulley *b*.

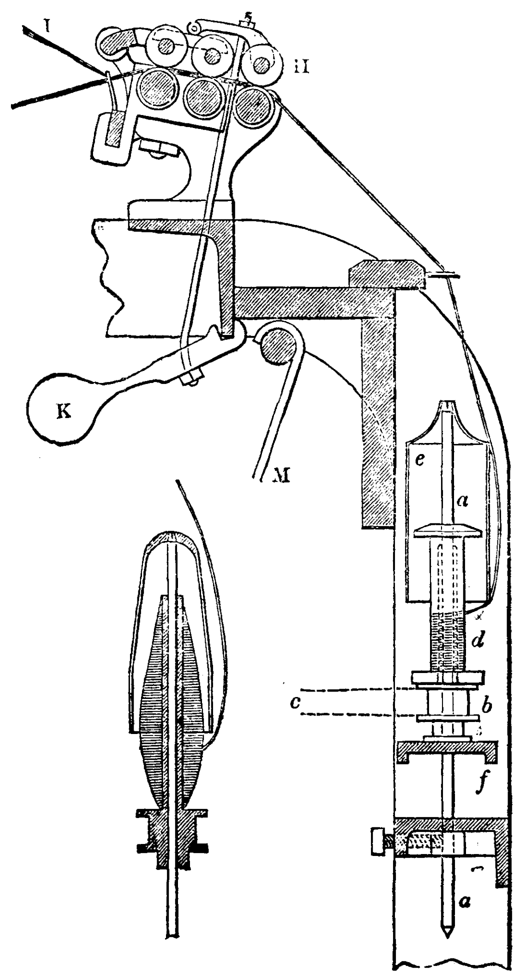
To wind up the thread as it is constantly delivered from the rollers, forms the third operation. For that purpose the thread must be guided perpendicularly upon the axis of the bobbin, which is done in common throstles, as we have explained by the fly of the spindle.

In the present instance it is performed by a hollow cylinder, fixed on the immovable spindle, which causes the thread to pass round its under edge to the bobbin, which has, by the friction on the pulley *b*, a tendency constantly to revolve, and so to wind up the thread as it is delivered. This winding up would be, however, very imperfect if either the bobbin, or the guide, that is the cylinder, did not make an up and down motion in order to fill the whole bobbin uniformly with twist. It has been found the preferable way to give this traverse motion to the bobbin. The small whorls or pulleys which support the bobbins, and easily slide along the spindles, rest upon a plate *f*, which is moved up and down by the levers *o*, *o*, fig. 70. The levers get this motion by a heart-shaped plate P, fig. 70, working on a small roller, and fitted on the same shaft with the wheel R, which is driven by means of the shaft S, by a worm T, on the shaft of the wheel E, fig. 71.

The pulleys or whorls *b*, *b*, make about 6,000 revolutions per minute. To prevent the threads from running against each other at this enormous speed, in some machines the space for each bobbin is separated from the others by semi-cylindrical partitions of tin-plate, made fast to a board behind them.

To be able to spin on the tube of the whorl, a cop like fig. 73, (without a bobbin,) an eccentric apparatus, must be added to the throstle, which regulates the going up and down of the pulley, according to the desired shape of the cop.

The patentee, in his specification, describes his improvements to consist "in the employment of a cir-



Figs. 72.—Cross Section of the Spinning Parts. Fig. 73. A peculiar Spindle for winding on cops. Scale, two inches to the foot.

cular rim adapted to the spindle, for the purpose of guiding the spun thread on to the taking-on bobbin, in place of the ordinary flyer. Upon the spindle a sliding roller is placed, which being connected to a movable bar, like a traversing copping-rail, ascends and descends upon the fixed spindle by the usual lever and heart movement. The whorl, whirl or pulley, turns loosely upon the spindle, its barrel bearing upon the top of the pulley, to which it is locked, when in operation, by a pin passing through the side of the bobbin, and catching against an elevated part of the whorl barrel; hence it will be perceived, that the whorl and bobbin move together: the hollow conical cap placed on the top of the spindle, where it remains stationary, is made sufficiently large to admit of the bobbin, when empty, to pass up within it.

Let it now be supposed that the end of the roving of yarn delivered from the front drawing-rollers is brought down upon the outside of the cone and attached to the lower part of the barrel of the bobbin. The pulley or whorl being then put in motion, the bobbin revolves with it, and spins the yarn as it descends into a tight thread, which flies round the cone, turning under its lower edge or rim, when, from the resistance of the atmosphere, and the light friction of the thread against that lower rim, the effect will be to twist the thread, and to cause it to wind upon the bobbin, beginning at the bottom of the barrel of the bobbin, and progressively winding up round the barrel as the bobbin descends out of the conical cap.

When the bobbin has become filled with the yarn, the conical cap must be lifted off the spindle, the full bobbin be removed, and an empty one put in its place.

In an excellent cotton-mill at Hyde, where the common throstle-spindles turn off $3\frac{1}{2}$ hanks of No. 30's warp each, int he day, the Danforth (with bobbins upon the spindles) turn off $5\frac{1}{2}$. The latter yarn covers better in the web, and is therefore more economical in the manufacture of certain kinds of calico-cloth.

The Danforth frame, with small conical caps, such as are represented in fig. 73, is driven with such velocity as to yield the astonishing quantity, per spindle, of $7\frac{1}{4}$ hanks per diem of $11\frac{1}{2}$ hours. There are 216 spindles in each of these machines. Such soft spongy yarns are estimated to go 40 per cent. further in the warp of a loom, than the wiry polished thread of the common throstle.

The thread in the Danforth throstle is whirled so rapidly round the conical cap, as to project in space the appearance of a continuous conical fleecy surface, intersected by four vertical lines, coincident with the centre and the two lateral edges of the cone. It is impossible for a stranger visitant to resist this visual illusion.

It is the friction of the yarn against the rims of the caps which permits the bobbins to revolve faster than the thread is delivered, and causes the winding of it on. The front rollers are usually one inch in diameter.

The operation of this productive machine is liable to certain objections. The bobbins of yarn it affords are necessarily small, softly wound, and are subject to considerable waste in the reeling upon bobbins for the warping-mill. Yet, as 40 hanks of yarn may be spun weekly upon this throstle, while only 30 of the same number could be spun upon the common one, and as the elasticity of the former kind fits it peculiarly for weaving certain calicoes, the Danforth has many zealous partizans in Lancashire.

Gore's Patent Throstle-Spindle.

Mr. Henry Gore, the eminent machine maker of Manchester, obtained, in December 1831, a patent for a peculiar throstle-spindle, which is much esteemed by several skilful manufacturers. His improvement relates to those parts which are called the collars, for the upper bearings of spindles, retaining them in vertical positions as they revolve. For the ordinary collar, Mr. Gore substitutes a tube made fast at its lower end to the spindle-rail, in the same manner as the ordinary collar would be fixed in it; but the tube stands in a vertical position above the spindle-rail, and is interiorly larger in diameter than the spindle which passes through it, except at its upper end, which rises into the hollow within the barrel part of the wooden bobbin. The bore of the tube at that upper end is made to fit the spindle exactly, so as to form the upper bearing for the spindle, and to keep it truly vertical in its rotation.

In fig. 74, two inch spindles are represented in section. In (1) *a* is the upper end of the spindle, and *b* the lower end or toe, which revolves in the step or cup, supported by the lower spindle-rail; *c* is the wharve or whirl; *d* is the flyer screwed upon the top of the spindle; and *e*, the wooden bobbin; *f* is the tubular collar; the lower part *g* of the collar is fitted into a hole in the upper spindle-rail, and is made fast by a nut, screwed on beneath, which draws it close down to the shoulder. The tube *f* rises and falls upon the spindle.

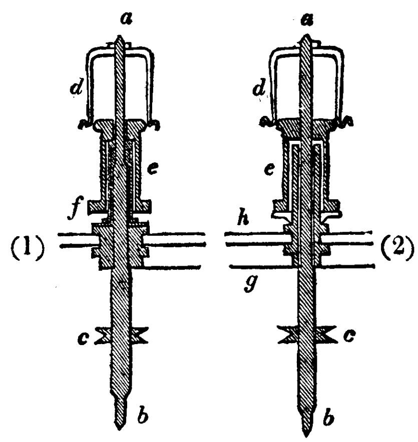


Fig. 74.—Gore's patent Throstle-Spindle.

The bore of that tube is so much larger than the spindle as to give it perfect freedom of revolution; but a brass bush is driven in tight into this wide tube near its upper end, which fits the spindle exactly, and forms its collar or upper bearing.

The upper bush of the wooden bobbin *e* is fitted upon the part of the spindle as ordinary but the lower bush is bored out larger than usual, to fit the outside of the fixed tube *f*. There is a metal washer *h*, fitted loosely upon the outside of the tube *f*, so as to slide freely up and down upon it. The flat flange of the metal washer rests upon the flat surface of the copping-rail, and the usual circular washer of woollen cloth is interposed between the base of the wood bobbin, and the top surface of the flange of the washer.

The metal washer *h* is left quite at liberty either to go round with the bobbin, or to stand still; and another cloth washer may be placed beneath it upon the copping-rail if required. The tube *f* round which the bobbin runs being immovable, the friction which takes place between the lower bush of the wood bobbin and the outside of the tube, tends to augment the drag of the bobbin.

The upper side of the flange at the bottom of the tubular collar, is hollowed out to form a cup for the reception of oil, and every time the washer descends upon the tube, it dips into the oil, and carries up with it as much oil as will keep the outside of the tube *f* sufficiently greased for making the lower bush of the bobbin run light upon the outside of the tube.

The same tube may be fixed in the copping-rail; it will then move up and down the spindle from two to three inches, or the length of the lift, which enables the spindle to wear much longer, and makes it convenient for oiling, and when the bobbin is at the top of the spindle, the top of the tube is nearly there also, which keeps it steady.

The copping-rail must be made of a proper strength, and be fitted up in the best manner.

Fig. (2) represents a similar spindle with the addition of a thin metal tube (seen exterior to *f*,) which is fastened on the spindle just above where it comes through the top of the tubular collar by screwing as usual. This thin tube turns round with the spindle, and the lower bush of the bobbin is fitted to its outside, so as to diminish the drag of the bobbin, since the tube turns in the same direction with the bobbin.

Montgomery's Patent Spindle.

In April 1832, Mr. Robert Montgomery, of the town of Johnstone, in Scotland, obtained a patent for a modification of the throstle, as communicated to him by the American inventor. This contrivance consists in a certain addition to the flyers, which keeps them in the same position, while the spindles are caused to rise and fall, for the purpose of laying the thread regularly on the bobbins; the spindles not being permitted to turn, because they are fixed to the bottom or cross-rail. By this means he supposes the flyers and spindles will be less liable to vibrate than as they are commonly constructed.

In this machine (see *fig.* 75,) the spindle *i*, on which the bobbin is built, does not revolve, because it is made fast to the bottom or cross-rail *f*, and is moved or slidden up and down within the flyer *a*, *a*, so as to carry the bobbin along with it, whereby the yarn may be laid regularly upon the bobbin. This is loose, but bears upon the boss, which is fixed upon the spindle, and is allowed to run on it, in consequence of the friction or drag of the yarn, as shown at the spindle A.

The rail *h*, *h*, into which the spindles are secured, is made to travel up and down in the usual way, as we have already described under the common throstle.

In spinning soft yarns, they may be wound either upon the bobbin, or upon a tube or shell, as shown at the spindle B; which, when full, will be of a proper size and shape to be placed in the shuttle.

At the spindle C, the yarn is represented as laid upon the bare spindle, and in order that the friction should be as much relieved as possible, a small auxiliary spindle is inserted into a hollow part of the fixed spindle, as shown in section at D. The fitting of the auxiliary spindle into the other must be so easy as to allow of its moving round freely by the drag of the yarn. On the common *mule* spindle the cop is built without any auxiliary spindle.

It is to be understood that the spindles *i*, though fixed in the lower rail *f*, yet slide up and down within she flyers *a*, *a*, by the occasional elevation and depression of *k*, called the copping-rail; and that the flyers, though they revolve, are confined between the rails *b* and *k*. The flyers are turned, as usual, by bands or cords going round their wharves or whorls. The lower ends of the flyers, or forks, are connected with the

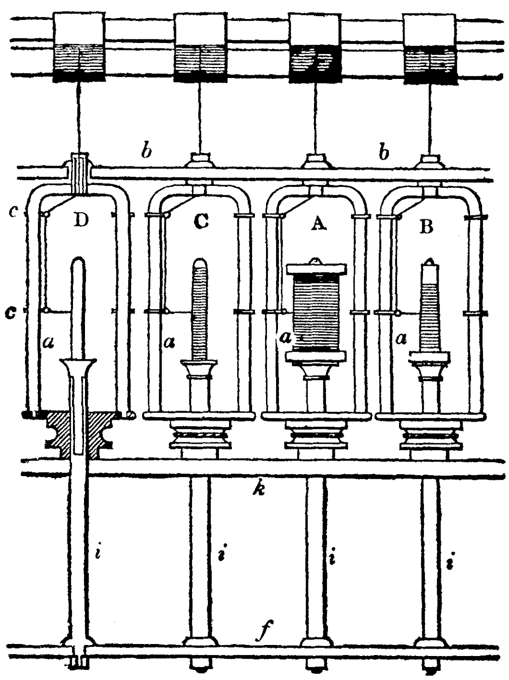


Fig. 75.—Montgomery's Throstle Spindle.

flange or rim upon the top of the wharve, "which forms the main feature of the invention, since it affords the means of building the cop upon the common mule spindle, equally with the inverted spindle, and also of building the bobbin upon the fixed spindle."

b, b, b, are the stay rails, in which the upper parts of the flyers turn; *c, c,* are the side guides for the yarn. A hole is perforated through each flyer in its centre at top, which transmits the thread from the front roller to the side guides *c, c.* The patentee claims merely the connecting the ends of the flyer with the drawing wharve or pulley, whereby he is enabled to keep the flyer in the same position, while the spindle rises and falls, and carries the bobbin or other instrument to receive the yarn up and down with the flyer, for the purpose of laying it on regularly.

Throstle-spinning costs $1\frac{1}{4}d.$ per pound in wages; that of the self-actors costs only three farthings at most, both at No. 36's. In a certain factory five-eighths of a penny is the wages for spinning one pound of 38's. on the self-actors two-thirds of which is weft, and one-third warp or twist.

But there are remarkable differences in the productive power of different respectable factories in and about Manchester, one of them being known to turn off twenty pounds of cotton-yarn, while another turns off only eleven of the same grist, and with the same number of spindles. Of this extraordinary circumstance I was assured by an experienced spinner, who having realized a competency in the trade, had retired.

SECTION II.

The Mule, and Mule Spinning.

THE following introductory remarks, illustrative of the peculiar action of the mule, are intended to give the general reader a clear conception of the philosophical principles of cotton spinning.

Upon a minute examination of thread, it will be found that the twisting is not uniformly distributed throughout the whole of its length, but that it has taken place in different parts, inversely as the square of the diameters of these parts, or at least in nearly that ratio. Hence the thinner portions of the thread take up or appropriate a much larger proportion of the twisting power than the thicker. This peculiarity was noticed at an early period in the art of cotton spinning, though it is uncertain whether Crompton, the inventor of the mule, was acquainted with it; and it gave rise to a peculiar operation in working this machine, called the second draw. This movement is found to be indispensable in the spinning of all the higher or finer numbers, and even in making the best qualities of the middle numbers of yarn. By its means the inequalities which occur, in spite of all the precautions resorted to for equalizing the filaments in the preparation processes, are diminished, and the yarn is rendered more level, and freer from soft or weak points.

The general action of the mule may be stated as follows:—The rovings being passed forwards from their respective bobbins, set upright in the creel, through between the rollers, and their ends being attached to their respective spindles, as already explained in describing the stretching-frame, the rollers, and carriage with its spindles, are all set in motion simultaneously, the carriage being made to recede from the roller-beam at a somewhat quicker rate than the surface-speed of the front rollers, or the delivery of the soft threads, and not, as in the stretching-frame, at the same speed. This excess of velocity is called the " gain " of the carriage, and is intended to render the thread *level* upon the principle above explained, namely, that the greater quantity of twist runs into the slenderer, or weaker parts of the yarn, and obstructs their due extension; whereas, if the quantity of twist be skilfully adapted to the occasion, the thicker portions of the thread will have time to be acted upon by the gain of the carriage, till their substance is reduced somewhat nearer to the average thickness required. When the carriage has moved out about 45 or 50 inches, according to the fineness of the work, a general change takes place in the operation of the mule. The rollers suddenly stop, the spindles begin to revolve with a nearly double velocity, and the carriage slackens its pace to about one-sixth of its previous speed. This stage of the process is called the stretching, or the draw. The extension of the filaments, performed in part by the twin-roller system, is by this action carried on and completed in their softly twisted state. When the carriage, by its advance, has stretched the threads to the full extent they will bear without breaking, the second draw ceases by the stopping of the carriage, while the spindles still continue to revolve till the requisite quantity of twist is communicated, which is regulated by the twist-wheel having completed a certain number of turns. Upon the twist-wheel shaft a finger is usually fixed, which at each revolution disengages a catch, whereby the driving-strap is allowed to pass to the loose pulley, and the whole machinery stands still. The spinner now puts down with his left hand the faller, or guide-wire, to the level requisite for guiding the threads into the proper winding-on position upon the cops of the spindles. In putting down the faller-wire, he at the same time unwinds that portion of the thread which is coiled spirally round the spindle, from its point to the nose of the cop, which he does by causing the spindles to turn the backward way, with his right hand working their main driving pulley. This operation of undoing the spiral coil is called the *backing off*.

Whenever the faller has arrived at the degree of depression suited to the winding-on of the yarn, the spinner now reverses his backward motion, and winds on the yarn by causing the spindles to turn the forward way, while, at the same time, he pushes in the carriage at a rate commensurate with the revolution of the spindles. As the carriage approaches the roller-beam, the spinner gradually raises the *faller-wire*, to allow the last portion of the threads to be coiled again in an open spiral, from the nose of the cop up to their points. One operation being thus completed, another is immediately begun.

By winding successive portions of thread upon the spindle, a conical-shaped coil of yarn is formed, which, when sufficiently large, is slid off the spindle, in which state the article is ready for the market, under the denomination of Cop Yarn. A considerable quantity of it, however,—particularly of that destined to be dyed or